UL 60947-1

STANDARD FOR SAFETY

Low-Voltage Switchgear and Controlgear – Part 1: General Rules

UL Standard for Safety for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1

Sixth Edition, Dated May 31, 2022

Summary of Topics

This sixth edition of ANSI/UL 60947-1 is a IEC-based standard covering general requirements for industrial control equipment. It is based on the edition 5.2 of IEC 60947-1.

Please note that the national difference document incorporates all of the national differences for UL 60947-1.

The requirements are substantially in accordance with Proposal(s) on this subject dated May 8, 2020 and September 10, 2021.

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NMX-J-515-ANCE
Third Edition

CSA Group
CSA C22.2 No. 60947-1:22
Third Edition
(IEC 60947-1:2007+A1:2010+A2:2014, MOD)

Underwriters Laboratories Inc.
UL 60947-1
Sixth Edition

Low-Voltage Switchgear and Controlgear – Part 1: General Rules

May 31, 2022

This standard is based on publication IEC 60947-1, Edition 5.2 (2014).

ANSI/UL 60947-1-2022

Commitment for Amendments

This standard is issued jointly by the Association of Standardization and Certification (ANCE), the Canadian Standards Association (operating as “CSA Group”), and Underwriters Laboratories Inc. (UL). Comments or proposals for revisions on any part of the standard may be submitted to ANCE, CSA Group, or UL at anytime. Revisions to this standard will be made only after processing according to the standards development procedures of ANCE, CSA Group, and UL. CSA Group and UL will issue revisions to this standard by means of a new edition or revised or additional pages bearing their date of issue. ANCE will incorporate the same revisions into a new edition of the standard bearing the same date of issue as the CSA Group and UL pages.

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This Standard is subject to review within five years from the date of publication, and suggestions for its improvement will be referred to the appropriate committee. The technical content of IEC and ISO publications is kept under constant review by IEC and ISO. To submit a proposal for change, please send the following information to inquiries@csagroup.org and include "Proposal for change" in the subject line: Standard designation (number); relevant clause, table, and/or figure number; wording of the proposed change; and rationale for the change.

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This ANSI/UL Standard for Safety consists of the Sixth Edition. The most recent designation of ANSI/UL 60947-1 as an American National Standard (ANSI) occurred on May 31, 2022. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page (front and back), or the Preface. The National Difference Page and IEC Foreword are also excluded from the ANSI approval of IEC-based standards.

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Preface

This is the harmonized ANCE, CSA Group, and UL standard for Low-voltage switchgear and controlgear – Part 1: General rules. It is the third edition of NMX-J-515-ANCE, the third edition of CSA C22.2 No. 60947-1, and the sixth edition of UL 60947-1. This edition of CSA C22.2 No. 60947-1 supersedes the previous edition published in 2013 as CAN/CSA-C22.2 No. 60947-1.

This harmonized standard is based on IEC publication 60947-1, Edition 5.2, Low-voltage switchgear and controlgear – Part 1: General rules, issued September 2014. IEC 60947-1 is copyrighted by the IEC.

This harmonized standard was prepared by the Association of Standardization and Certification (ANCE), CSA Group, and Underwriters Laboratories Inc. (UL). The efforts and support of the Technical Harmonization Committee for Industrial Control Equipment, of the Council on the Harmonization of Electrotechnical Standards of the Nations of the Americas (CANENA), are gratefully acknowledged.

This Standard is considered suitable for use for conformity assessment within the stated scope of the Standard.

This Standard was reviewed by the CSA Integrated Committee on Industrial Control, under the jurisdiction of the CSA Technical Committee on Industrial Products and the CSA Strategic Steering Committee on Requirements for Electrical Safety, and has been formally approved by the CSA Technical Committee. This Standard has been developed in compliance with Standards Council of Canada requirements for National Standards of Canada. It has been published as a National Standard of Canada by CSA Group.

Application of Standard

Where reference is made to a specific number of samples to be tested, the specified number is considered a minimum quantity.

Note: Although the intended primary application of this standard is stated in its scope, it is important to note that it remains the responsibility of the users of the standard to judge its suitability for their particular purpose.

Level of harmonization

This standard adopts the IEC text with national differences.

This standard is published as an equivalent standard for ANCE, CSA Group, and UL.

An equivalent standard is a standard that is substantially the same in technical content, except as follows: Technical national differences are allowed for codes and governmental regulations as well as those recognized as being in accordance with NAFTA Article 905, for example, because of fundamental climatic, geographical, technological, or infrastructural factors, scientific justification, or the level of protection that the country considers appropriate. Presentation is word for word except for editorial changes.

All national differences from the IEC text are included in the ANCE, CSA Group, and UL versions of the standard. While the technical content is the same in each organization's version, the format and presentation may differ

Reasons for differences from IEC

National differences from the IEC are being added in order to address safety and regulatory situations present in the US, Mexico, and Canada.

Interpretations

The interpretation by the standards development organization of an identical or equivalent standard is based on the literal text to determine compliance with the standard in accordance with the procedural rules of the standards development organization. If more than one interpretation of the literal text has been identified, a revision is to be proposed as soon as possible to each of the standards development organizations to more accurately reflect the intent.

IEC Copyright

For ANCE, the text, figures, and tables of International Electrotechnical Commission Publication 60947-1, Standard for Low-voltage switchgear and controlgear – Part 1: General rules, edition 5.2, copyright 2014, are used in this Standard according to the guidelines provided in the ISO/IEC/POCOSA.

For CSA Group, the text, figures, and tables of International Electrotechnical Commission Publication 60947-1, Low-voltage switchgear and controlgear – Part 1: General rules, copyright 2014, are used in this Standard with the consent of the International Electrotechnical Commission. The IEC Foreword is not a part of the requirements of this Standard but is included for information purposes only.

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National Differences

National Differences from the text of International Electrotechnical Commission (IEC) Publication 60947-1, Low-voltage switchgear and controlgear – Part 1: General rules, copyright 2014, are indicated by notations (differences) and are presented in bold text. The national difference type is included in the body.

There are five types of National Differences as noted below. The difference type is noted on the first line of the National Difference in the standard. The standard may not include all types of these National Differences.

DR – These are National Differences based on the **national regulatory requirements**.

D1 – These are National Differences which are based on **basic safety principles and requirements**, elimination of which would compromise safety for consumers and users of products.

D2 – These are National Differences from IEC requirements based on existing **safety practices**. These requirements reflect national safety practices, where empirical substantiation (for the IEC or national requirement) is not available or the text has not been included in the IEC standard.

DC – These are National Differences based on the **component standards** and will not be deleted until a particular component standard is harmonized with the IEC component standard.

DE – These are National Differences based on **editorial comments or corrections**.

Each national difference contains a description of what the national difference entails. Typically one of the following words is used to explain how the text of the national difference is to be applied to the base IEC text:

> ***Addition / Add*** - An addition entails adding a complete new numbered clause, subclause, table, figure, or annex. Addition is not meant to include adding select words to the base IEC text.
>
> ***Modification / Modify*** - A modification is an altering of the existing base IEC text such as the addition, replacement or deletion of certain words or the replacement of an entire clause, subclause, table, figure, or annex of the base IEC text.
>
> ***Deletion / Delete*** - A deletion entails complete deletion of an entire numbered clause, subclause, table, figure, or annex without any replacement text.

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FOREWORD

INTERNATIONAL ELECTROTECHNICAL COMMISSION

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR – Part 1: General rules

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

This Consolidated version of IEC 60947-1 bears the edition number 5.2. It consists of the fifth edition (2007-06) [documents 17B/1550/FDIS and 17B/1563/RVD], its amendment 1 (2010-12) [documents 17B/1710/FDIS and 17B/1721/RVD] and its amendment 2 (2014-09) [documents 121A/15/FDIS and 121A/21/RVD]. The technical content is identical to the base edition and its amendments.

International Standard IEC 60947-1 has been prepared by subcommittee 17B: Low-voltage switchgear and controlgear, of IEC technical committee 17: Switchgear and controlgear.

The main changes with respect to the previous edition are as follows:

– modification and restructuration of 7.1;

– introduction of new figures concerning EMC tests;

– introduction of new Annexes Q, R and S.

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

A list of all the parts in the IEC 60947 series, under the general title *Low-voltage switchgear and controlgear* can be found on the IEC website.

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

• reconfirmed,

• withdrawn,

• replaced by a revised edition, or

• amended.

IMPORTANT – The "colour inside" logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this publication using a colour printer.

DV.1 DE *Modification of the IEC Foreword by adding the following:*

The numbering system in the standard uses a space instead of a comma to indicate thousands and uses a comma instead of a period to indicate a decimal point. For example, 1 000 means 1,000 and 1,01 means 1.01.

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR – Part 1: General rules

1 General

The purpose of this standard is to harmonize as far as practicable all rules and requirements of a general nature applicable to low-voltage switchgear and controlgear in order to obtain uniformity of requirements and tests throughout the corresponding range of equipment and to avoid the need for testing to different standards.

All those parts of the various equipment standards which can be considered as general have therefore been gathered in this standard together with specific subjects of wide interest and application, e.g. temperature-rise, dielectric properties, etc.

For each type of low-voltage switchgear and controlgear, only two main documents are necessary to determine all requirements and tests:

1) this basic standard, referred to as "Part 1" in the specific standards covering the various types of low-voltage switchgear and controlgear;

2) the relevant equipment standard hereinafter referred to as the "relevant product standard" or "product standard".

For a general rule to apply to a specific product standard, it shall be explicitly referred to by the latter, by quoting the relevant clause or subclause number of this standard followed by "IEC 60947-1" e.g. "7.2.3 of IEC 60947-1".

A specific product standard may not require, and hence may omit, a general rule (as being not applicable), or it may add to it (if deemed inadequate in the particular case), but it may not deviate from it, unless there is a substantial technical justification.

NOTE The product standards forming the series of IEC standards covering low-voltage switchgear and controlgear are:

IEC 60947-2: Part 2: Circuit-breakers

IEC 60947-3: Part 3: Switches, disconnectors, switch-disconnectors and fuse combination units

IEC 60947-4: Part 4: Contactors and motor-starters

IEC 60947-5: Part 5: Control-circuit devices and switching elements

IEC 60947-6: Part 6: Multiple function equipment

IEC 60947-7: Part 7: Ancillary equipment

IEC 60947-8: Part 8: Control units for built-in thermal protection (PTC) for rotating electrical machines.

1DV.1 DE *Modification of Clause 1 by adding the following NOTE:*

NOTE 2DV: The Canadian, Mexican, and United States product standards based on the IEC 60947 series are part of the series of standards covering low-voltage switchgear and controlgear. See Annex DVA, Table DVA.2, for the Canadian, Mexican, and U.S. equivalent standards.

1DV.2 DE *Modification of Clause 1 by adding the following:*

1DV.2.1 The user of this standard should note that the term "switchgear" as used in IEC 60947-1 has a different definition than the North American definition. Refer to Clause 2.1.1 of this standard for the definition.

1DV.2.2 In Canada, general requirements applicable to this standard are given in CSA C22.2 No. 0. In Mexico and the United States, this requirement does not apply.

1.1 Scope and object

This standard applies, when required by the relevant product standard, to low-voltage switchgear and controlgear hereinafter referred to as "equipment" or “device” and intended to be connected to circuits, the rated voltage of which does not exceed 1 000 V a.c. or 1 500 V d.c.

This standard states the general rules and common safety requirements for low-voltage switchgear and controlgear, including:

– definitions;

– characteristics;

– information supplied with the equipment;

– normal service, mounting and transport conditions;

– constructional and performance requirements;

– verification of characteristics and performance;

– environmental aspects.

This standard does not apply to low-voltage switchgear and controlgear assemblies which are dealt with in IEC 61439 series, as applicable.

1.1DV.1 D2 *Modification of 1.1 by adding the following*

1.1DV.1.1 This equipment is intended for installation in accordance with CSA C22.1, Canadian Electrical Code (CE Code, Part I); Mexican Official Standard, NOM-001-SEDE; and the US National Electrical Code (NEC), NFPA 70.

1.2 Normative references

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

IEC 60050(151):2001, *International Electrotechnical Vocabulary (IEV) – Chapter 151: Electrical and magnetic devices*

IEC 60050(441):1984, *International Electrotechnical Vocabulary (IEV) – Chapter 441: Switchgear, controlgear and fuses*
Amendment 1 (2000)

IEC 60050(604):1987, *International Electrotechnical Vocabulary (IEV) – Chapter 604: Generation, transmission and distribution of electricity – Operation*
Amendment 1 (1998)

IEC 60050(826):2004, *International Electrotechnical Vocabulary (IEV) – Chapter 826: Electrical installations*

IEC 60060, *High-voltage test techniques*

IEC 60068-1:1988, *Environmental testing − Part 1: General and guidance*
Amendment 1 (1992)

IEC 60068-2-1:1990, *Environmental testing − Part 2-1: Tests − Tests A: Cold*
Amendment 1 (1993)
Amendment 2 (1994)

IEC 60068-2-2:1974, *Environmental testing − Part 2-2: Tests − Tests B: Dry heat*
Amendment 1 (1993)
Amendment 2 (1994)

IEC 60068-2-6:1995, *Environmental testing − Part 2-6: Tests − Test Fc: Vibration (sinusoidal)*

IEC 60068-2-27:1987, *Environmental testing − Part 2-27: Tests − Test Ea and guidance: Shock*

IEC 60068-2-30:2005, *Environmental testing − Part 2-30: Tests − Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60068-2-52:1996, *Environmental testing − Part 2-52: Tests − Test Kb: Salt mist, cyclic (sodium chloride solution)*

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

IEC 60071-1:1993, *Insulation co-ordination – Part 1: Definitions, principles and rules*

IEC 60073:2002, *Basic and safety principles for man-machine interface, marking and identification – Coding principles for indicators and actuators*

IEC 60085:2004, *Electrical insulation – Thermal classification*

IEC 60092-504:2001, *Electrical installations in ships – Part 504: Special features – Control and instrumentation*

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

IEC 60216, *Guide for the determination of thermal endurance properties of electrical insulating materials*

IEC 60228:2004, *Conductors of insulated cables*

IEC 60269-1:1998, *Low-voltage fuses – Part 1: General requirements*
Amendment 1 (2005)

IEC 60269-2:1986, *Low-voltage fuses – Part 2: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application)*
Amendment 1 (1995)
Amendment 2 (2001)

IEC 60300-3-5:2001, *Dependability management – Part 3-5: Application guide – Reliability test conditions and statistical test principles*

IEC 60344:1980, *Guide to the calculation of resistance of plain and coated copper conductors of low-frequency cables and wires*
Amendment 1 (1985)

IEC 60364-4-44:2001, *Electrical installations of buildings – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances*
Amendment 1 (2003)

IEC 60417-DB:2002[1], *Graphical symbols for use on equipment*

[1] "DB" refers to the IEC on-line database.

IEC 60445:1999, *Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals and of terminations of certain designated conductors, including general rules of an alphanumeric system*

IEC 60447:2004, *Basic and safety principles for man-machine interface, marking and identification – Actuating principles*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP code)*
Amendment 1 (1999)

IEC 60617-DB:2001[1], *Graphical symbols for diagrams*

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 60664-5:2007, *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 60695-2-2:1991, *Fire hazard testing – Part 2: Test methods – Section 2: Needle-flame test*
Amendment 1 (1994)

IEC 60695-2-10:2000, *Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedure*

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 60695-2-12, *Fire hazard testing – Part 2-12: Glowing/hot-wire based test methods – Glow-wire flammability test method for materials*

IEC 60695-11-10:1999, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*
Amendment 1 (2003)

IEC 60947-5-1:2003, *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*
Amendment 1 (2009)

IEC 60947-8:2003, *Low-voltage switchgear and controlgear – Part 8: Control units for built-in thermal protection (PTC) for rotating electrical machines*
Amendment 1 (2006)

IEC 60981:2004, *Extra heavy-duty electrical rigid steel conduits*

IEC 60999-1:1999, *Connecting devices – Electrical copper conductors – Safety requirements for screw-type and screwless-type clamping units – Part 1: General requirements and particular requirements for clamping units for conductors from 0,2 mm^2 up to 35 mm^2 (included)*

IEC 60999-2:2003, *Connecting devices – Electrical copper conductors – Safety requirements for screw-type and screwless-type clamping units – Part 2: Particular requirements for clamping units for conductors above 35 mm^2 up to 300 mm^2 (included)*

IEC 61000-3-2:2005, *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)*
Amendment 1 (2008)
Amendment 2 (2009)

IEC 61000-3-3:2013, *Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems for equipment with rated current ≤ 16 A per phase and not subject to conditional connection*

IEC 61000-4-2:2008, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3:2006, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*
Amendment 1 (2007)
Amendment 2 (2010)

IEC 61000-4-4:2012, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-5:2005, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-6:2013, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-8:2009, *Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test*

IEC 61000-4-11:2004, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests*

IEC 61000-4-13:2002, *Electromagnetic compatibility (EMC) – Part 4-13: Testing and measurement techniques – Harmonics and inter-harmonics including mains signalling at a.c. power port, low-frequency immunity tests*
Amendment 1 (2009)

IEC 61000-6-2:2005, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity for industrial environments*

IEC 61131-2:2003, *Programmable controllers – Part 2: Equipment requirements and tests*

IEC 61140:2001, *Protection against electric shock – Common aspects for installation and equipment*
Amendment 1(2004)

IEC 61180 (all parts), *High-voltage test techniques for low voltage equipment*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC 61557-2, *Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. – Equipment for testing, measuring or monitoring of protective measures – Part 2: Insulation resistance*

IEC 61649:2008, *Weibull analysis*

IEC 62061:2005, *Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems*

IEC 62430:2009, *Environmentally conscious design for electrical and electronic products*

IEC 62474:2012, *Material declaration for products of and for the electrotechnical industry*

CISPR 11:2009, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*
Amendment 1 (2010)

ISO 13849-1:2006, *Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design*

1.2DV D2 *Modification of 1.2 by adding the following:*

See Table DVA.2 for normative references and Table DVB.1 for component standards.

2 Definitions

NOTE 1 Most of the definitions listed in this clause are taken unchanged from the IEV (IEC 60050). When this is the case, the IEV reference is given in brackets with the title (the first group of 3 figures indicates the IEV chapter reference).

When an IEV definition is amended, the IEV reference is not indicated with the title, but in an explanatory note.

Alphabetical index of definitions

NOTE 2 The alphabetical list of ratings, characteristics and symbols is given in Clause 4.

Reference

2.1 General terms

2.1.1
switchgear and controlgear
general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equip¬ment with associated interconnections, accessories, enclosures and supporting structures

[441-11-01]

2.1.2
switchgear
general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures, intended in principle for use in connection with generation, transmission, distribution and conversion of electric energy

[441-11-02]

2.1.3
controlgear
general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting struc¬tures, intended in principle for the control of electric energy consuming equipment

[441-11-03]

2.1.4
over-current
current exceeding the rated current

[441-11-06]

2.1.5
short circuit
accidental or intentional conductive path between two or more conductive parts forcing the electric potential differences between these conductive parts to be equal to or close to zero

[151-12-04]

2.1.6
short-circuit current
over-current resulting from a short circuit due to a fault or an incorrect connection in an electric circuit

[441-11-07]

2.1.7
overload
operating conditions in an electrically undamaged circuit which cause an over-current

[441-11-08]

2.1.8
overload current
over-current occurring in an electrically undamaged circuit

2.1.9
ambient air temperature
temperature, determined under prescribed conditions, of the air surrounding the complete switching device or fuse

[441-11-13]

NOTE For switching devices or fuses installed inside an enclosure, it is the temperature of the air outside the enclosure.

2.1.10
conductive part
part which is capable of conducting current although it may not necessarily be used for carrying service current

[441-11-09]

2.1.11
exposed conductive part
conductive part which can readily be touched and which is not normally alive, but which may become alive under fault conditions

[441-11-10]

NOTE Typical exposed conductive parts are walls of enclosures, operating handles, etc.

2.1.12
extraneous conductive part
conductive part not forming part of the electrical installation and liable to introduce a potential, generally the earth potential

[826-03-03]

2.1.13
live part
conductor or conductive part intended to be energized in normal use, including a neutral conductor but, by convention, not a PEN conductor

[826-03-01]

NOTE This term does not necessarily imply a risk of electric shock.

2.1.14
protective conductor (symbol PE)
conductor required by some measures for protection against electric shock for electrically connecting any of the following parts:

– exposed conductive parts,

– extraneous conductive parts,

– main earthing terminal,

– earth electrode,

– earthed point of the source or artificial neutral

[826-04-05]

2.1.14DV DR *Modification of 2.1.14 by adding the following:*

2.1.14DV.1 Segments of the "protective conductor" connecting various parts together are referenced by specific terms which identify their location in the grounding system and specific regulatory requirements for their installation.

2.1.14DV.2 In Mexico and the United States, the defined term "equipment grounding conductor" describes a conductor connecting non-current carrying parts of electrical equipment to the system grounded conductor. In Canada, this conductor is defined as a "bonding conductor".

2.1.14DV.3 In Canada, the defined term "grounding conductor" describes a conductor connecting service equipment or a system circuit conductor to the grounding electrode. In Mexico and the United States, this conductor is defined as a "grounding electrode conductor".

2.1.15
neutral conductor (symbol N)
conductor connected to the neutral point of a system and capable of contributing to the transmission of electrical energy

[826-01-03]

NOTE In some cases, the functions of the neutral conductor and the protective conductor may be combined under specified conditions in one and the same conductor referred to as the PEN conductor (Symbol PEN).

2.1.16
enclosure
part providing a specified degree of protection of equipment against certain external influences and a specified degree of protection against approach to or contact with live parts and moving parts

NOTE This definition is similar to IEV 441-13-01, which applies to assemblies.

2.1.17
integral enclosure
enclosure which forms an integral part of the equipment

2.1.18
utilization category (for a switching device or a fuse)
combination of specified requirements related to the conditions in which the switching device or the fuse fulfils its purpose, selected to represent a characteristic group of practical applications

[441-17-19]

NOTE The specified requirements may concern e.g. the values of making capacities (if applicable), breaking capacities and other characteristics, the associated circuits and the relevant conditions of use and behaviour.

2.1.19
isolation (isolating function)
function intended to cut off the supply from all or a discrete section of the installation by separating the installation or section from every source of electrical energy for reasons of safety

2.1.20
electric shock
pathophysiological effect resulting from an electric current passing through a human or animal body

[826-03-04]

2.1.21
manufacturer
for the purposes of this standard, any person, company or organisation with ultimate responsibility as follows:

− to verify compliance with the appropriate standard or standards

− to provide the product information according to Clause 5

NOTE For instance, in the case of "protected starters" assembled according to the instructions of the component providers, the manufacturer will be the entity that undertook the assembly.

2.1.22
solid insulation
solid insulating material interposed between two conductive parts

2.1.23
insulation coordination barrier
solid insulating material that is not an integral part, provided for the purpose of increasing either creepage distances or clearance distances or both

2.1.24DV D2 *Add the following definition:*

Bonding
A low impedance path obtained by permanently joining all non-current-carrying metal parts to assure electrical continuity and having the capacity to conduct safely any current likely to be imposed on it.

2.1.25DV D2 *Add the following definition:*

Ground
A conducting connection, whether intentional or accidental, between an electric circuit or equipment and the earth or to some conducting body that serves in place of the earth.

2.1.26DV D2 *Add the following definition:*

Grounding
Means to limit the voltage to ground on exposed metal parts of enclosures for electrical conductors and equipment by connection to a permanent or continuous conductive path to the earth.

2.1.27DV D2 *Add the following definition:*

Grounding conductor
A conductor used to connect equipment or the grounded circuit of a wiring system to a grounding electrode or electrodes.

2.1.28DV D2 *Add the following definition:*

Grounding electrode conductor
The conductor used to connect the grounding electrode(s) to the equipment grounding conductor, to the grounded conductor, or to both, at the service, at each building or structure where supplied from a common service, or at the source of a separately derived system.

2.1.29DV D2 ***Add the following definition:***

Insulation system
The classification of insulation materials for the purpose of establishing temperature limits.

2.1.30DV D2 ***Add the following definition:***

Field wiring
Conductors installed for connections to external circuits.

2.2 Switching devices

2.2.1
switching device
device designed to make or break the current in one or more electric circuits

[441-14-01]

NOTE A switching device may perform one or both of these operations.

2.2.2
mechanical switching device
switching device designed to close and open one or more electric circuits by means of separable contacts

[441-14-02]

NOTE Any mechanical switching device may be designated according to the medium in which its contacts open and close, e.g.: air, SF_6, oil.

2.2.3
semiconductor switching device
switching device designed to make and/or break the current in an electric circuit by means of the controlled conductivity of a semiconductor

NOTE This definition differs from IEV 441-14-03 since a semiconductor switching device is also designed for breaking the current.

2.2.4
fuse
device that, by the fusing of one or more of its specifically designed and proportioned components, opens the circuit in which it is inserted by breaking the current when this exceeds a given value for a sufficient time. The fuse comprises all the parts that form the complete device

[441-18-01]

2.2.5
fuse-linkpart of a fuse (including the fuse-element(s)) intended to be replaced after the fuse has operated

[441-18-09]

2.2.6
fuse-element
part of the fuse-link designed to melt under the action of current exceeding some definite value for a definite period of time

[441-18-08]

2.2.7
fuse-combination unit
combination of a mechanical switching device and one or more fuses in a composite unit, assembled by the manufacturer or in accordance with his instructions

[441-14-04]

2.2.8
disconnector
mechanical switching device which, in the open position, complies with the requirements specified for the isolating function

NOTE This definition differs from IEV 441-14-05 because the requirements for the isolating function are not based only on an isolating distance.

2.2.9
switch (mechanical)
mechanical switching device capable of making, carrying and breaking currents under normal circuit conditions which may include specified operating overload conditions and also carrying for a specified time currents under specified abnormal circuit conditions such as those of short circuit

[441-14-10]

NOTE A switch may be capable of making but not breaking short-circuit currents.

2.2.10
switch-disconnector
switch which, in the open position, satisfies the isolating requirements specified for a disconnector

[441-14-12]

2.2.11
circuit-breaker
mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified time and breaking currents under specified abnormal circuit conditions such as those of short circuit

[441-14-20]

2.2.12
contactor (mechanical)
mechanical switching device having only one position of rest, operated otherwise than by hand, capable of making, carrying and breaking currents under normal circuit conditions including operating overload conditions

[441-14-33]

NOTE Contactors may be designated according to the method by which the force for closing the main contacts is provided.

2.2.13
semiconductor contactor (solid-state contactor)
device which performs the function of a contactor by utilizing a semiconductor switching device

NOTE A semiconductor contactor may also contain mechanical switching devices.

2.2.14
contactor relay
contactor used as a control switch

[441-14-35]

2.2.15
starter
combination of all the switching means necessary to start and stop a motor, in combination with suitable overload protection

[441-14-38]

NOTE Starters may be designated according to the method by which the force for closing the main contacts is provided.

2.2.16
control circuit device
electrical device, intended for the controlling, signalling, interlocking, etc. of switchgear and controlgear

NOTE Control circuit devices may include associated devices dealt with in other standards, such as instruments, potentiometers, relays, in so far as such associated devices are used for the purposes specified.

2.2.17
control switch (for control and auxiliary circuits)
mechanical switching device which serves the purpose of controlling the operation of switchgear or controlgear, including signalling, electrical interlocking, etc.

[441-14-46]

NOTE A control switch consists of one or more contact elements with a common actuating system.

2.2.18
pilot switch
non-manual control switch actuated in response to specified conditions of an actuating quantity

[441-14-48]

NOTE The actuating quantity may be pressure, temperature, velocity, liquid level, elapsed time, etc.

2.2.19
push-button
control switch having an actuator intended to be operated by force exerted by a part of the human body, usually the finger or palm of the hand, and having stored energy (spring) return

[441-14-53]

2.2.20
terminal block
insulating part carrying one or more mutually insulated terminal assemblies and intended to be fixed to a support

2.2.21
short-circuit protective device (SCPD)
device intended to protect a circuit or parts of a circuit against short-circuit currents by interrupting them

2.2.22
surge arrester
device designed to protect the electrical apparatus from high transient overvoltages and to limit the duration and frequently the amplitude of the follow-on current

[604-03-51]

2.2.23
individual enclosure
enclosure designed and dimensioned to contain one equipment only

2.3 Parts of switching devices

2.3.1
pole of a switching device
portion of a switching device associated exclusively with one electrically separated conducting path of its main circuit and excluding those portions which provide a means for mounting and operating all poles together

[441-15-01]

NOTE A switching device is called single-pole if it has only one pole. If it has more than one pole, it may be called multipole (two-pole, three-pole, etc.) provided the poles are or can be coupled in such a manner as to operate together.

2.3.2
main circuit (of a switching device)
all the conductive parts of a switching device included in the circuit which it is designed to close or open

[441-15-02]

2.3.3
control circuit (of a switching device)
all the conductive parts (other than the main circuit) of a switching device which are included in a circuit used for the closing operation or opening operation, or both, of the device

[441-15-03]

2.3.4
auxiliary circuit (of a switching device)
all the conductive parts of a switching device which are intended to be included in a circuit other than the main circuit and the control circuits of the device

[441-15-04]

NOTE Some auxiliary circuits fulfil supplementary functions such as signalling, interlocking, etc., and, as such, they may be part of the control circuit of another switching device.

2.3.5
contact (of a mechanical switching device)
conductive parts designed to establish circuit continuity when they touch and which, due to their relative motion during an operation, open or close a circuit or, in the case of hinged or sliding contacts, maintain circuit continuity

[441-15-05]

2.3.6
contact piece
one of the conductive parts forming a contact

[441-15-06]

2.3.7
main contact
contact included in the main circuit of a mechanical switching device, intended to carry, in the closed position, the current of the main circuit

[441-15-07]

2.3.8
arcing contact
arc contact on which the arc is intended to be established

[441-15-08]

NOTE An arcing contact may serve as a main contact; it may be a separate contact so designed that it opens after and closes before another contact which it is intended to protect from deterioration.

2.3.9
control contact
contact included in a control circuit of a mechanical switching device and mechanically operated by this device

[441-15-09]

2.3.10
auxiliary contact
contact included in an auxiliary circuit and mechanically operated by the switching device

[441-15-10]

2.3.11
auxiliary switch (of a mechanical switching device)
switch containing one or more control and/or auxiliary contacts mechanically operated by a switching device

[441-15-11]

2.3.12
"a" contact – make contact
control or auxiliary contact which is closed when the main contacts of the mechanical switching device are closed and open when they are open

[441-15-12]

2.3.13
"b" contact – break contact
control or auxiliary contact which is open when the main contacts of the mechanical switching device are closed and closed when they are open

[441-15-13]

2.3.14
relay (electrical)
device designed to produce sudden, predetermined changes in one or more electrical output circuits when certain conditions are fulfilled in the electrical input circuits controlling the device

[446-11-01]

2.3.15
release (of a mechanical switching device)
device, mechanically connected to a mechanical switching device, which releases the holding means and permits the opening or the closing of the switching device

[441-15-17]

NOTE A release can have instantaneous, time-delay, etc., operation. The various types of releases are defined in 2.4.24 to 2.4.35.

2.3.16
actuating system (of a mechanical switching device)
whole of the operating means of a mechanical switching device which transmit the actuating force to the contact pieces

NOTE The operating means of an actuating system may be mechanical, electromagnetic, hydraulic, pneumatic, thermal, etc.

2.3.17
actuator
part of the actuating system to which an external actuating force is applied

[441-15-22]

NOTE The actuator may take the form of a handle, knob, push-button, roller, plunger, etc.

2.3.18
position indicating device
part of a mechanical switching device which indicates whether it is in the open, closed, or, where appropriate, earthed position

[441-15-25]

2.3.19
indicator light
light signal giving information either by lighting or extinguishing

2.3.20
anti-pumping device
device which prevents reclosing after a close-open operation as long as the device initiating closing is maintained in the position for closing

[441-16-48]

2.3.21
interlocking device
device which makes the operation of a switching device dependent upon the position of operation of one or more other pieces of equipment

[441-16-49]

2.3.22
connecting device
a device for the electrical connection of one (or more) conductor(s), comprising one (or more) terminal(s), either fixed to a base or forming an integral part of the equipment

[IEC 60999-1:1999, 3.3]

2.3.23
terminal
conductive part of one pole of a device for electrical connection to external circuit, composed of one or more clamping unit(s) and insulation if necessary

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

2.3.23DV DE *Modification of 2.3.23 by adding the following:*

The term "field wiring terminal" is equivalent.

2.3.24
screw-type terminal
terminal intended for the connection and disconnection of conductors or for the inter-connection of two or more conductors, the connection being made, directly or indirectly, by means of screws or nuts of any kind

NOTE Examples are given in Annex D.

2.3.25
screwless-type terminal
terminal intended for the connection and disconnection of conductors or for the interconnection on two or more conductors, the connection being made, directly or indirectly, by means of springs, wedges, eccentrics or cones, etc.

NOTE Examples are given in Annex D.

2.3.25.1
universal terminal
terminal for the connection and disconnection of all types of conductors (rigid and flexible)

[IEC 60998-2-2:2002, 3.101.1]

2.3.25.2
non-universal terminal
terminal for the connection and disconnection of a certain kind of conductor only (for example, solid conductors only or rigid [solid and stranded] conductors only)

[IEC 60998-2-2:2002, 3.101.2]

2.3.25.3
push-wire terminal
non-universal terminal in which the connection is made by pushing in rigid (solid or stranded) conductors

[IEC 60998-2-2:2002, 3.101.3]

2.3.26
clamping unit
the part(s) of the terminal necessary for the mechanical clamping and the electrical connection of the conductor(s), including the parts which are necessary to ensure the correct contact pressure

[IEC 60999-1:1999, 3.1]

2.3.26.1
universal clamping unit
clamping unit intended for all types of conductors

2.3.26.2
non-universal clamping unit
clamping unit intended for certain types of conductors only, for example:

– push-wire clamping unit for solid conductors only

– push-wire clamping unit for rigid (solid and stranded) conductors only

NOTE On push-wire clamping unit the connection is made by simple insertion of rigid conductors. (see 7.1.8.1)

2.3.27
unprepared conductor
conductor which has been cut and the insulation of which has been removed for insertion into a terminal

NOTE A conductor the shape of which is arranged for introduction into a terminal or the strands of which are twisted to consolidate the end is considered to be an unprepared conductor.

2.3.28
prepared conductor
conductor, the strands of which are soldered or the end of which is fitted with a cable lug, eyelet, etc.

2.3.29
solid conductor
conductor consisting of a single wire

NOTE 1 The solid conductor may be circular or shaped.

NOTE 2 Solid conductor is defined as class 1 conductor in IEC 60228, or by IEC 60344, or equivalent AWG/kcmil.

[461-01-06, modified]

2.3.30
stranded conductor
conductor consisting of a number of wires, all or some of which are wound in a helix

NOTE Stranded conductor is defined as class 2 conductor in IEC 60228, or by IEC 60344, or equivalent AWG/kcmil.

[151-12-36, modified]

2.3.31
rigid conductor
solid or stranded conductor having wires of such diameters, or so assembled, that the conductor is not suitable for use in a flexible cable

2.3.32
flexible conductor
stranded conductor having wires of diameters small enough and so assembled that the conductor is suitable for use in a flexible cable

NOTE Flexible conductor is defined as class 5 or class 6 conductor in IEC 60228, or by IEC 60344, or equivalent AWG/kcmil.

[461-01-11, modified]

2.3.33
multiple tip contact system
contact system comprising more than one contact gap per pole, which can be switched, in series and/or in parallel

2.3.34
minimum cross-section
value of the smallest connectable conductor cross-section stated by the manufacturer as suitable for the terminal

NOTE The manufacturer may declare several minimum cross-sections depending on the type of conductor, for example rigid, stranded, flexible, with or without ferrule.

2.3.35
maximum cross-section
value of the largest connectable conductor cross-section stated by the manufacturer as suitable for the terminal

NOTE 1 The manufacturer may declare several maximum cross-sections depending on the type of conductor, for example rigid, stranded, flexible, with or without ferrule.

NOTE 2 The term “rated cross-section” used in IEC 60947-7-1 and IEC 60999-2 and the term “rated connecting capacity” of a clamping unit used in IEC 60999-1 are considered equivalent when referring to certain thermal, mechanical and electrical requirements, as stated by the manufacturer and as specified in their relevant product standard.

2.3.36
electronically controlled electromagnet
electromagnet in which the coil is controlled by a circuit with active electronic elements

2.4 Operation of switching devices

2.4.1
operation (of a mechanical switching device)
transfer of the moving contact(s) from one position to an adjacent position

[441-16-01]

NOTE 1 For example, for a circuit-breaker, this may be a closing operation or an opening operation.

NOTE 2 If distinction is necessary, an operation in the electrical sense, e.g., make or break, is referred to as a switching operation, and an operation in the mechanical sense, e.g., close or open, is referred to as a mechanical operation.

2.4.2
operating cycle (of a mechanical switching device)
succession of operations from one position to another and back to the first position through all other positions, if any

[441-16-02]

2.4.3
operating sequence (of a mechanical switching device)
succession of specified operations with specified time intervals

[441-16-03]

2.4.4
manual control
control of an operation by human intervention

[441-16-04]

2.4.5
automatic control
control of an operation without human intervention, in response to the occurrence of predetermined conditions

[441-16-05]

2.4.6
local control
control of an operation at a point on or adjacent to the controlled switching device

[441-16-06]

2.4.7
remote control
control of an operation at a point distant from the controlled switching device

[441-16-07]

2.4.8
closing operation (of a mechanical switching device)
operation by which the device is brought from the open position to the closed position

[441-16-08]

2.4.9
opening operation (of a mechanical switching device)
operation by which the device is brought from the closed position to the open position

[441-16-09]

2.4.10
positive opening operation (of a mechanical switching device)
opening operation which, in accordance with specified requirements, ensures that all the main contacts are in the open position when the actuator is in the position corresponding to the open position of the device

[441-16-11]

2.4.11
positively driven operation
operation which, in accordance with specified requirements, is designed to ensure that auxiliary contacts of a mechanical switching device are in the respective positions corres-ponding to the open or closed position of the main contacts

[441-16-12]

2.4.12
dependent manual operation (of a mechanical switching device)
operation solely by means of directly applied manual energy such that the speed and force of the operation are dependent upon the action of the operator

[441-16-13]

2.4.13
dependent power operation (of a mechanical switching device)
operation by means of energy other than manual, where the completion of the operation is dependent upon the continuity of the power supply (to solenoids, electric or pneumatic motors, etc.)

[441-16-14]

2.4.14
stored energy operation (of a mechanical switching device)
operation by means of energy stored in the mechanism itself prior to the completion of the operation and sufficient to complete it under predetermined conditions

[441-16-15]

NOTE This kind of operation may be subdivided according to:

1 the manner of storing the energy (spring, weight, etc.);

2 the origin of the energy (manual, electric, etc.);

3 the manner of releasing the energy (manual, electric, etc.).

2.4.15
independent manual operation (of a mechanical switching device)
stored energy operation where the energy originates from manual power, stored and released in one continuous operation, such that the speed and force of the operation are independent of the action of the operator

[441-16-16]

2.4.16
independent power operation (of a mechanical switching device)
stored energy operation where the stored energy originates from an external power source and is released in one continuous operation, such that the speed and force of the operation are independent of the action of the operator

2.4.17
actuating force (moment)
force (moment) applied to an actuator necessary to complete the intended operation

[441-16-17]

2.4.18
restoring force (moment)
force (moment) provided to restore an actuator or a contact element to its initial position

[441-16-19]

2.4.19
travel (of a mechanical switching device or a part thereof)
displacement (translation or rotation) of a point on a moving element

[441-16-21]

NOTE Distinction may be made between pre-travel, over-travel, etc.

2.4.20
closed position (of a mechanical switching device)
position in which the predetermined continuity of the main circuit of the device is secured

[441-16-22]

2.4.21
open position (of a mechanical switching device)
position in which the predetermined dielectric withstand voltage requirements are satisfied between open contacts in the main circuit of the device

NOTE This definition differs from IEV 441-16-23 to meet the requirements of dielectric properties.

2.4.22
tripping (operation)
opening operation of a mechanical switching device initiated by a relay or release

2.4.23
trip-free mechanical switching device
mechanical switching device, the moving contacts of which return to and remain in the open position when the opening (i.e. tripping) operation is initiated after the initiation of the closing operation, even if the closing command is maintained

NOTE 1 To ensure proper breaking of the current which may have been established, it may be necessary that the contacts momentarily reach the closed position.

NOTE 2 The wording of IEV 441-16-31 has been completed by adding "(i.e. tripping)" since the opening operation of a trip-free mechanical switching device is automatically controlled.

2.4.24
instantaneous relay or release
relay or release which operates without any intentional time-delay

2.4.25
over-current relay or release
relay or release which causes a mechanical switching device to open with or without time-delay when the current in the relay or release exceeds a predetermined value

NOTE This value can in some cases depend upon the rate-of-rise of current.

2.4.26
definite time-delay over-current relay or release
over-current relay or release which operates with a definite time-delay which may be adjustable, but is independent of the value of the over-current

2.4.27
inverse time-delay over-current relay or release
over-current relay or release which operates after a time-delay inversely dependent upon the value of the over-current

NOTE Such a relay or release may be designed so that the time-delay approaches a definite minimum value for high values of over-current.

2.4.28
direct over-current relay or release
over-current relay or release directly energized by the current in the main circuit of a switching device

2.4.29
indirect over-current relay or release
over-current relay or release energized by the current in the main circuit of a switching device through a current transformer or a shunt

2.4.30
overload relay or release
over-current relay or release intended for protection against overloads

2.4.31
thermal overload relay or release
inverse time-delay overload relay or release depending for its operation (including its time-delay) on the thermal action of the current flowing in the relay or release

2.4.32
magnetic overload relay or release

overload relay or release depending for its operation on the force exerted by the current in the main circuit exciting the coil of an electromagnet

NOTE Such a relay or release usually has an inverse time-delay/current characteristic.

2.4.33
shunt release
release energized by a source of voltage

[441-16-41]

NOTE The source of voltage may be independent of the voltage of the main circuit.

2.4.34
under-voltage relay or release
relay or release which permits a mechanical switching device to open or close, with or without time-delay, when the voltage across the terminals of the relay or release falls below a predetermined value

2.4.35
reverse current relay or release (d.c. only)
relay or release which permits a mechanical switching device to open, with or without time-delay, when the current flows in the reverse direction and exceeds a predetermined value

2.4.36
operating current (of an over-current relay or release)
value of current at and above which the relay or release will operate

2.4.37
current-setting (of an over-current or overload relay or release)
value of current of the main circuit to which the operating characteristics of the relay or release are referred and for which the relay or release is set

NOTE A relay or release may have more than one current setting, provided by an adjustment dial, interchangeable heaters, etc.

2.4.38
current setting range (of an over-current or overload relay or release)
range between the minimum and maximum values over which the current setting of the relay or release can be adjusted

2.5 Characteristic quantities

2.5.1
nominal value
value of a quantity used to designate and identify a component, device, equipment, or system

[151-16-09]

NOTE The nominal value is generally a rounded value.

2.5.2
limiting value
in a specification of a component, device, equipment, or system, the greatest or smallest admissible value of a quantity

[151-16-10]

2.5.3
rated value
value of a quantity used for specification purposes, established for a specified set of operating conditions of a component, device, equipment, or system

[151-16-08]

2.5.4
rating
set of rated values and operating conditions

[151-16-11]

2.5.5
prospective current (of a circuit and with respect to a switching device or a fuse)
current that would flow in the circuit if each pole of the switching device or the fuse were replaced by a conductor of negligible impedance

[441-17-01]

NOTE The method to be used to evaluate and to express the prospective current is to be specified in the relevant product standard.

2.5.6
prospective peak current
peak value of a prospective current during the transient period following initiation

[441-17-02]

NOTE The definition assumes that the current is made by an ideal switching device, i.e. with instantaneous transition from infinite to zero impedance. For circuits where the current can follow several different paths, e.g. polyphase circuits, it further assumes that the current is made simultaneously in all poles, even if only the current in one pole is considered.

2.5.7
prospective symmetrical current (of an a.c. circuit)
prospective current when it is initiated at such an instant that no transient phenomenon follows the initiation

[441-17-03]

NOTE 1 For polyphase circuits the condition of non-transient period can only be satisfied for the current in one pole at a time.

NOTE 2 The prospective symmetrical current is expressed by its r.m.s. value.

2.5.8
maximum prospective peak current (of an a.c. circuit)
prospective peak current when initiation of the current takes place at the instant which leads to the highest possible value

[441-17-04]

NOTE For a multipole device in a polyphase circuit, the maximum prospective peak current refers to one pole only.

2.5.9
prospective making current (for a pole of a switching device)
prospective current when initiated under specified conditions

[441-17-05]

NOTE The specified conditions may relate to the method of initiation, e.g. by an ideal switching device, or to the instant of initiation, e.g., leading to the maximum prospective peak current in an a.c. circuit, or to the highest rate of rise. The specification of these conditions is given in the relevant product standard.

2.5.10
prospective breaking current (for a pole of a switching device or a fuse)
prospective current evaluated at a time corresponding to the instant of the initiation of the breaking process

[441-17-06]

NOTE Specifications concerning the instant of the initiation of the breaking process are given in the relevant product standard. For mechanical switching devices or fuses, it is usually defined as the moment of initiation of the arc during the breaking process.

2.5.11
breaking current (of a switching device or a fuse)
current in a pole of a switching device or in a fuse at the instant of initiation of the arc during a breaking process

[441-17-07]

NOTE For a.c., the current is expressed as the symmetrical r.m.s. value of the a.c. component.

2.5.12
breaking capacity (of a switching device or a fuse)
value of prospective breaking current that a switching device or a fuse is capable of breaking at a stated voltage under prescribed conditions of use and behaviour

[441-17-08]

NOTE 1 The voltage to be stated and the conditions to be prescribed are dealt with in the relevant product standard.

NOTE 2 For a.c., the current is expressed as the symmetrical r.m.s. value of the a.c. component.

NOTE 3 For short-circuit breaking capacity, see 2.5.14.

2.5.13
making capacity (of a switching device)
value of prospective making current that a switching device is capable of making at a stated voltage under prescribed conditions of use and behaviour

[441-17-09]

NOTE 1 The voltage to be stated and the conditions to be prescribed are dealt with in the relevant product standard.

NOTE 2 For short-circuit making capacity, see 2.5.15.

2.5.14
short-circuit breaking capacity
breaking capacity for which prescribed conditions include a short circuit at the terminals of the switching device

[441-17-11]

2.5.15
short-circuit making capacity
making capacity for which prescribed conditions include a short circuit at the terminals of the switching device

[441-17-10]

2.5.16
critical load current
value of breaking current, within the range of service conditions, at which the arcing time is significantly extended

2.5.17
critical short-circuit current
value of breaking current, less than the rated short-circuit breaking capacity, at which the arc energy is significantly higher than at the rated short-circuit breaking capacity

2.5.18
Joule integral (I^2t)
integral of the square of the current over a given time interval

[441-18-23]

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

2.5.19
cut-off current – let-through current
maximum instantaneous value of current attained during the breaking operation of a switching device or a fuse

[441-17-12]

NOTE This concept is of particular importance when the switching device or the fuse operates in such a manner that the prospective peak current of the circuit is not reached.

2.5.20
time-current characteristic
curve giving the time, e.g. pre-arcing time or operating time, as a function of the prospective current, under stated conditions of operation

[441-17-13]

2.5.21
cut-off (current) characteristic – let-through (current) characteristic
curve giving the cut-off current as a function of the prospective current, under stated conditions of operation

[441-17-14]

NOTE In the case of a.c., the values of the cut-off currents are the maximum values which can be reached whatever the degree of asymmetry. In the case of d.c., the values of the cut-off currents are the maximum values reached related to the time constant as specified.

2.5.22
over-current protective co-ordination of over-current protective devices
co-ordination of two or more over-current protective devices in series to ensure overcurrent discrimination (selectivity) and/or back-up protection

2.5.23
over-current selectivity
co-ordination of the operating characteristics of two or more over-current protective devices such that, on the incidence of over-currents within stated limits, the device intended to operate within these limits does so, while the other(s) does (do) not

NOTE Distinction is made between series discrimination involving different over-current protective devices passing substantially the same over-current and network selectivity involving identical protective devices passing different proportions of the over-current.

2.5.24
back-up protection
over-current co-ordination of two over-current protective devices in series where the protective device, generally but not necessarily on the supply side, effects the over-current protection with or without the assistance of the other protective device and prevents any excessive stress on the latter

2.5.25
take-over current
current co-ordinate of the intersection between the time-current characteristics of two over-current protective devices

[441-17-16]

2.5.26
short-time delay
any intentional delay in operation within the limits of the rated short-time withstand current

2.5.27
short-time withstand current
current that a circuit or a switching device in the closed position can carry during a specified short time under prescribed conditions of use and behaviour

[441-17-17]

2.5.28
peak withstand current
value of peak current that a circuit or a switching device in the closed position can withstand under prescribed conditions of use and behaviour

[441-17-18]

2.5.29
conditional short-circuit current (of a circuit or a switching device)
prospective current that a circuit or a switching device, protected by a specified short-circuit protective device, can satisfactorily withstand for the total operating time of that device under specified conditions of use and behaviour

NOTE 1 For the purpose of this standard, the short-circuit protective device is generally a circuit-breaker or a fuse.

NOTE 2 This definition differs from IEV 441-17-20 by broadening the concept of current limiting device into a short-circuit protective device, the function of which is not only to limit the current.

2.5.30
conventional non-tripping current (of an over-current relay or release)
specified value of current which the relay or release can carry for a specified time (conventional time) without operating

2.5.31
conventional tripping current (of an over-current relay or release)
specified value of current which causes the relay or release to operate within a specified time (conventional time)

2.5.32
applied voltage (for a switching device)
voltage which exists across the terminals of a pole of a switching device just before the making of the current

[441-17-24]

NOTE This definition applies to a single-pole device. For a multipole device it is the phase-to-phase voltage across the supply terminals of the device.

2.5.33
recovery voltage
voltage which appears across the terminals of a pole of a switching device or a fuse after the breaking of the current

[441-17-25]

NOTE 1 This voltage may be considered in two successive intervals of time, one during which a transient voltage exists, followed by a second one during which the power-frequency voltage or the steady-state recovery voltage alone exists.

NOTE 2 This definition applies to a single-pole device. For a multipole device it is the phase-to-phase voltage across the supply terminals of the device.

2.5.34
transient recovery voltage (abbreviation TRV)
recovery voltage during the time in which it has a significant transient character

[441-17-26]

NOTE The transient voltage may be oscillatory or non-oscillatory or a combination of these depending on the characteristics of the circuit, the switching device or the fuse. It includes the voltage shift of the neutral of a polyphase circuit.

2.5.35
power-frequency recovery voltage
recovery voltage after the transient voltage phenomena have subsided

[441-17-27]

2.5.36
d.c. steady-state recovery voltage
recovery voltage in a d.c. circuit after the transient voltage phenomena have subsided, expressed by the mean value where ripple is present

[441-17-28]

2.5.37
prospective transient recovery voltage (of a circuit)
transient recovery voltage following the breaking of the prospective symmetrical current by an ideal switching device

[441-17-29]

NOTE The definition assumes that the switching device or the fuse, for which the prospective transient recovery voltage is sought, is replaced by an ideal switching device, i.e. having instantaneous transition from zero to infinite impedance at the very instant of zero current, i.e. at the "natural" zero. For circuits where the current can follow several different paths, e.g. a polyphase circuit, the definition further assumes that the breaking of the current by the ideal switching device takes place only in the pole considered.

2.5.38
peak arc voltage (of a mechanical switching device)
maximum instantaneous value of voltage which, under prescribed conditions, appears across the terminals of a pole of a switching device during the arcing time

[441-17-30]

2.5.39
opening time (of a mechanical switching device)
interval of time between the specified instant of initiation of the opening operation and the instant when the arcing contacts have separated in all poles

[441-17-36]

NOTE The instant of initiation of the opening operation, i.e. the application of the opening command (e.g. energizing the release), is given in the relevant product standard.

2.5.40
arcing time (of a pole or a fuse)
interval of time between the instant of the initiation of the arc in a pole or a fuse and the instant of final arc extinction in that pole or that fuse

[441-17-37]

2.5.41
arcing time (of a multipole switching device)
interval of time between the instant of the first initiation of an arc and the instant of final arc extinction in all poles

[441-17-38]

2.5.42
break time
interval of time between the beginning of the opening time of a mechanical switching device (or the pre-arcing time of a fuse) and the end of the arcing time

[441-17-39]

2.5.43
make time
interval of time between the initiation of the closing operation and the instant when the current begins to flow in the main circuit

[441-17-40]

2.5.44
closing time
interval of time between the initiation of the closing operation and the instant when the contacts touch in all poles

[441-17-41]

2.5.45
make-break time
interval of time between the instant when the current begins to flow in a pole and the instant of final arc extinction in all poles, with the opening release energized at the instant when current begins to flow in the main circuit

[441-17-43]

2.5.46
clearance
distance between two conductive parts, along a string stretched the shortest way between these conductive parts

[441-17-31]

2.5.47
clearance between poles
clearance between any conductive parts of adjacent poles

[441-17-32]

2.5.48
clearance to earth
clearance between any conductive parts and any parts which are earthed or intended to be earthed

[441-17-33]

2.5.49
clearance between open contacts (gap)
total clearance between the contacts, or any conductive parts connected thereto, of a pole of a mechanical switching device in the open position

[441-17-34]

2.5.50
isolating distance (of a pole of a mechanical switching device)
clearance between open contacts meeting the safety requirements specified for disconnectors

[441-17-35]

2.5.51
creepage distance
shortest distance along the surface of an insulating material between two conductive parts

NOTE A joint between two pieces of insulating material is considered part of the surface.

2.5.52
working voltage
highest r.m.s. value of the a.c. or d.c. voltage across any particular insulation which can occur when the equipment is supplied at rated voltage

NOTE 1 Transients are disregarded.

NOTE 2 Both open-circuit conditions and normal operating conditions are taken into account.

2.5.53
temporary overvoltage
phase-to-earth, phase-to-neutral or phase-to-phase overvoltage at a given location and of relatively long duration (several seconds)

2.5.54
transient overvoltages
transient overvoltages in the sense of this standard are the following:

2.5.54.1
switching overvoltage
transient overvoltage at a given location on a system due to a specific switching operation or a fault

2.5.54.2
lightning overvoltage
transient overvoltage at a given location on a system due to a specific lightning discharge

[see also IEC 60060 and IEC 60071-1]

2.5.54.3
functional overvoltage
deliberately imposed overvoltage necessary for the functioning of a device

2.5.55
impulse withstand voltage
highest peak value of an impulse voltage, of prescribed form and polarity, which does not cause breakdown under specified conditions of test

2.5.56
power-frequency withstand voltage
r.m.s. value of a power-frequency sinusoidal voltage which does not cause breakdown under specified conditions of test

2.5.57
pollution
any condition of foreign matter, solid, liquid or gaseous (ionized gases), that may affect dielectric strength or surface resistivity

2.5.58
pollution degree (of environmental conditions)
conventional number based on the amount of conductive or hygroscopic dust, ionized gas or salt and on the relative humidity and its frequency of occurrence, resulting in hygroscopic absorption or condensation of moisture leading to reduction in dielectric strength and/or surface resistivity

NOTE 1 The pollution degree to which equipment is exposed may be different from that of the macro-environment where the equipment is located because of protection offered by means such as an enclosure or internal heating to prevent absorption or condensation of moisture.

NOTE 2 For the purpose of this standard, the pollution degree is that of the micro-environment.

2.5.59
micro-environment (of a clearance or creepage distance)
ambient conditions which surround the clearance or creepage distance under consideration

NOTE The micro-environment of the creepage distance or clearance and not the environment of the equipment determines the effect on the insulation. The micro-environment might be better or worse than the environment of the equipment. It includes all factors influencing the insulation, such as climatic and electromagnetic conditions, generation of pollution, etc.

2.5.60
overvoltage category (of a circuit or within an electrical system)
conventional number based on limiting (or controlling) the values of prospective transient overvoltages occurring in a circuit (or within an electrical system having different nominal voltages) and depending upon the means employed to influence the overvoltages

NOTE In an electrical system, the transition from one overvoltage category to another of lower category is obtained through appropriate means complying with interface requirements, such as an overvoltage protective device or a series-shunt impedance arrangement capable of dissipating, absorbing, or diverting the energy in the associated surge current, to lower the transient overvoltage value to that of the desired lower overvoltage category.

2.5.61
co-ordination of insulation
correlation of insulating characteristics of electrical equipment with the expected overvoltages and the characteristics of overvoltage protective devices on the one hand, and with the expected micro-environment and the pollution protective means on the other hand

2.5.62
homogeneous (uniform) field
electric field which has an essentially constant voltage gradient between electrodes, such as that between two spheres where the radius of each sphere is greater than the distance between them

2.5.63
inhomogeneous (non-uniform) field
electric field which has not an essentially constant voltage gradient between electrodes

2.5.64
tracking
progressive formation of conducting paths which are produced on the surface of a solid insulating material, due to the combined effects of electric stress and electrolytic contamination on this surface

2.5.65
comparative tracking index (CTI)
numerical value of the maximum voltage in volts at which a material withstands 50 drops of a test solution without tracking

NOTE 1 The value of each test voltage and the CTI should be divisible by 25.

NOTE 2 This definition reproduces 2.3 of IEC 60112.

2.5.66
rated control circuit voltage
U_c
rated voltage which is controlling the input signal of the control device

2.5.67
rated control circuit supply voltage
U_s
rated voltage applied to energize the power supply terminals of the control circuit

2.6 Tests

2.6.1
type test
test of one or more devices made to a certain design to show that the design meets certain specifications

2.6.2
routine test
test to which each individual device is subjected during and/or after manufacture to ascertain whether it complies with certain criteria

2.6.3
sampling test
test on a number of devices taken at random from a batch

2.6.4
special test
test, additional to type tests and routine tests, made either at the discretion of the manufacturer or according to an agreement between manufacturer and user

2.7 Ports

2.7.1
port
particular interface of the specified apparatus with the external electromagnetic environment (see Figure 17)

2.7.2
enclosure port
physical boundary of the apparatus which electromagnetic fields may radiate through or impinge on

2.7.3
cable port
port at which a conductor or cable is connected to the apparatus

NOTE Examples are signal ports used for the transfer of data.

2.7.4
functional earth port
cable port other than main, signal or power port, intended for connection to earth for purposes other than electrical safety

2.7.5
signal port
port at which a conductor or cable carrying information for transferring data is connected to the apparatus

NOTE Examples are data buses, communication networks, control networks.

2.7.6
power port (control supply port)
port at which a conductor or cable carrying the primary electrical power needed for the operation (functioning) of an apparatus or associated apparatus is connected to the apparatus

2.7.7
main port
port at which a conductor or cable is connected to a pole of the main circuit of the equipment

NOTE 1 Examples are main circuit terminals of a contactor.

NOTE 2 In some equipment a main port is also a power port.

3 Classification

This clause is intended to list the characteristics of an equipment on which information may be given by the manufacturer and which may not necessarily have to be verified by testing.

This clause is not mandatory in product standards which should, however, leave space for it in order to list, where necessary, classification criteria.

4 Characteristics

Alphabetical list of characteristics (whether rated or not) and symbols

Characteristic	Symbol	Subclause
Conventional enclosed thermal current	I_{the}	4.3.2.2
Conventional free air thermal current	I_{th}	4.3.2.1
Eight-hour duty	–	4.3.4.1
Intermittent duty	–	4.3.4.3
Periodic duty	–	4.3.4.5
Pole impedance of the switching device	Z	4.3.7
Rated breaking capacity	–	4.3.5.3
Rated conditional short-circuit current	I_q	4.3.6.4
Rated control circuit voltage	U_c	4.5.1
Rated control circuit supply voltage	U_s	4.5.1
Rated current	I_n	a
Rated frequency	–	4.3.3
Rated impulse withstand voltage	U_{imp}	4.3.1.3
Rated insulation voltage	U_i	4.3.1.2
Rated making capacity	–	4.3.5.2
Rated operational current	I_e	4.3.2.3
Rated operational power	–	4.3.2.3
Rated operational voltage	U_e	4.3.1.1
Rated rotor insulation voltage	U_{ir}	a
Rated rotor operational current	I_{er}	a
Rated rotor operational voltage	U_{er}	a
Rated service short-circuit breaking capacity	I_{cs}	a
Rated short-circuit breaking capacity	I_{cn}	4.3.6.3
Rated short-circuit making capacity	I_{cm}	4.3.6.2
Rated short-time withstand current	I_{cw}	4.3.6.1
Rated starting voltage of an autotransformer starter	–	a
Rated stator insulation voltage	U_{is}	a
Rated stator operational current	I_{es}	a
Rated stator operational voltage	U_{es}	a
Rated ultimate short-circuit breaking capacity	I_{cu}	a
Rated uninterrupted current	I_u	4.3.2.4
Rotor thermal current	I_{thr}	a
Selectivity limit current	I_s	a
Stator thermal current	I_{ths}	a

Characteristic	Symbol	Subclause
Take-over current	I_B	2.5.25
Temporary duty	–	4.3.4.4
Uninterrupted duty	–	4.3.4.2
Utilization category	–	4.4
[a] This rating is defined in the relevant product standard.		

NOTE – The above list is not exhaustive.

4.1 General

The characteristics of an equipment shall be stated in the relevant product standard in respect of the following, where applicable:

– type of equipment (4.2);

– rated and limiting values for the main circuit (4.3);

– utilization category (4.4);

– control circuits (4.5);

– auxiliary circuits (4.6);

– relay and releases (4.7);

– co-ordination with short-circuit protective devices (4.8);

– switching overvoltages (4.9).

4.2 Type of equipment

The product standard shall state the following, where applicable:

– kind of equipment: e.g. contactor, circuit-breaker, etc.;

– number of poles;

– kind of current;

– interrupting medium;

– operating conditions (method of operation, method of control, etc.).

NOTE The above list is not exhaustive.

4.3 Rated and limiting values for the main circuit

Ratings are assigned by the manufacturer. They shall be stated in accordance with 4.3.1 to 4.3.6 as required by the relevant product standard, but it is not necessary to establish all the ratings listed.

4.3.1 Rated voltages

An equipment is defined by the following rated voltages:

NOTE Certain types of equipment may have more than one rated voltage or may have a rated voltage range.

4.3.1.1 Rated operational voltage (U_e)

A rated operational voltage of an equipment is a value of voltage which, combined with a rated operational current, determines the application of the equipment and to which the relevant tests and the utilization categories are referred.

For single-pole equipment, the rated operational voltage is generally stated as the voltage across the pole.

For multipole equipment, it is generally stated as the voltage between phases.

NOTE 1 For certain devices and particular applications a different method of stating U_e, may apply: this should be stated in the relevant product standard.

NOTE 2 For multipole equipment for use on polyphase circuits a distinction may be made between

a) equipment for use on systems where a single fault to earth will not cause the full phase-to-phase voltage to appear across a pole;

– neutral earthed systems;

– unearthed and impedance earthed systems.

b) equipment for use on systems where a single fault to earth will cause the full phase-to-phase voltage to appear across a pole (i.e. phase earthed systems).

NOTE 3 An equipment may be assigned a number of combinations of rated operational voltages and rated operational currents or powers for different duties and utilization categories.

NOTE 4 An equipment may be assigned a number of rated operational voltages and associated making and breaking capacities for different duties and utilization categories.

NOTE 5 Attention is drawn to the fact that the operational voltage may differ from the working voltage (see 2.5.52) within an equipment.

4.3.1.2 Rated insulation voltage (U_i)

The rated insulation voltage of an equipment is the value of voltage to which dielectric tests and creepage distances are referred.

In no case shall the maximum value of the rated operational voltage exceed that of the rated insulation voltage.

NOTE For equipment not having a specified rated insulation voltage, the highest value of the rated operational voltage is considered to be the rated insulation voltage.

4.3.1.3 Rated impulse withstand voltage (U_{imp})

The peak value of an impulse voltage of prescribed form and polarity which the equipment is capable of withstanding without failure under specified conditions of test and to which the values of the clearances are referred.

The rated impulse withstand voltage of an equipment shall be equal to or higher than the values stated for the transient overvoltages occurring in the circuit in which the equipment is fitted.

NOTE Preferred values of rated impulse withstand voltage are given in Table 12.

4.3.2 Currents

An equipment is defined by the following currents:

4.3.2.1 Conventional free air thermal current (I_{th})

The conventional free air thermal current is the maximum value of test current to be used for temperature-rise tests of unenclosed equipment in free air (see 8.3.3.3).

The value of the conventional free air thermal current shall be at least equal to the maximum value of the rated operational current (see 4.3.2.3) of the unenclosed equipment in eight-hour duty (see 4.3.4.1).

Free air is understood to be air under normal indoor conditions reasonably free from draughts and external radiation.

NOTE 1 This current is not a rating and is not mandatorily marked on the equipment.

NOTE 2 An unenclosed equipment is an equipment supplied by the manufacturer without an enclosure or an equipment supplied by the manufacturer with an integral enclosure which is not normally intended to be the sole equipment protective enclosure.

4.3.2.2 Conventional enclosed thermal current (I_{the})

The conventional enclosed thermal current is the value of current stated by the manufacturer to be used for the temperature-rise tests of the equipment when mounted in a specified enclosure. Such tests shall be in accordance with 8.3.3.3 and are mandatory if the equipment is described as enclosed equipment in the manufacturer's catalogues and normally intended for use with one or more enclosures of specified type and size (see Note 3).

The value of the conventional enclosed thermal current shall be at least equal to the maximum value of the rated operational current (see 4.3.2.3) of the enclosed equipment in eight-hour duty (see 4.3.4.1).

If the equipment is normally intended for use in unspecified enclosures, the test is not mandatory if the test for conventional free air thermal current (I_{th}) has been made. In this case, the manufacturer shall be prepared to give guidance on the value of enclosed thermal current or the derating factor (see Note 1).

NOTE 1 Guidance may be in the form of a publication of the maximum rated current at a specified local ambient (surrounding, in the immediate vicinity of the device) air temperature (example 1: AC-1 I_e = 45 A at 40 °C local ambient air, AC-1 I_e = 40 A at 60 °C local ambient air − example 2: I_{th} = 200 A at 40 °C local ambient air, I_{th} = 150 A at 60 °C local ambient air). By publishing such values, the manufacturer informs the user of the limits of application of the product independently of the size or the type of the enclosure.

NOTE 2 This current is not a rating and is not mandatorily marked on the equipment.

NOTE 3 The conventional enclosed thermal current value may be for unventilated equipment, in which case the enclosure used for the test should be of the size stated by the manufacturer, being the smallest that is applicable in service. Alternatively, the value may be for a ventilated equipment according to the manufacturer's data.

NOTE 4 An enclosed equipment is an equipment normally intended for use with a specified type and size of enclosure or intended for use with more than one type of enclosure.

4.3.2.3 Rated operational current (I_e) or rated operational power

A rated operational current of an equipment is stated by the manufacturer and takes into account the rated operational voltage (see 4.3.1.1), the rated frequency (see 4.3.3), the rated duty (see 4.3.4), the utilization category (see 4.4) and the type of protective enclosure, if appropriate.

In the case of equipment for direct switching of individual motors, the indication of a rated operational current may be replaced or supplemented by an indication of the maximum rated power output, at the rated operational voltage considered, of the motor for which the equipment is intended. The manufacturer shall be prepared to state the relationship assumed between the operational current and the operational power, if any.

4.3.2.4 Rated uninterrupted current (I_u)

The rated uninterrupted current of an equipment is a value of current, stated by the manufacturer, which the equipment can carry in uninterrupted duty (see 4.3.4.2).

4.3.3 Rated frequency

The supply frequency for which an equipment is designed and to which the other characteristic values correspond.

NOTE The same equipment may be assigned a number or a range of rated frequencies or be rated for both a.c. and d.c.

4.3.4 Rated duties

The rated duties considered as normal are:

4.3.4.1 Eight-hour duty

A duty in which the main contacts of an equipment remain closed, whilst carrying a steady current long enough for the equipment to reach thermal equilibrium but not for more than eight hours without interruption.

NOTE 1 This is the basic duty on which the conventional thermal currents I_{th} and I_{the} of the equipment are determined.

NOTE 2 Interruption means breaking of the current by operation of the equipment.

4.3.4.2 Uninterrupted duty

A duty without any off-load period in which the main contacts of an equipment remain closed, whilst carrying a steady current without interruption for periods of more than eight hours (weeks, months, or even years).

NOTE This kind of service is set apart from the eight-hour duty because oxides and dirt can accumulate on the contacts and lead to progressive heating. Uninterrupted duty can be taken account of either by a derating factor, or by special design considerations (e.g. silver contacts).

4.3.4.3 Intermittent periodic duty or intermittent duty

A duty with on-load periods, in which the main contacts of an equipment remain closed, having a definite relation to off-load periods, both periods being too short to allow the equipment to reach thermal equilibrium.

Intermittent duty is characterized by the value of the current, the duration of the current flow and by the on-load factor which is the ratio of the in-service period to the entire period, often expressed as a percentage.

Standardized values of the on-load factor are 15 %, 25 %, 40 % and 60 %.

According to the number of operating cycles which they shall be capable of carrying out per hour, equipments are divided into the following classes:

– class 1: 1 operating cycle per hour;

– class 3: 3 operating cycles per hour;

– class 12: 12 operating cycles per hour;

– class 30: 30 operating cycles per hour;

– class 120: 120 operating cycles per hour;

– class 300: 300 operating cycles per hour;

– class 1 200: 1 200 operating cycles per hour;

– class 3 000: 3 000 operating cycles per hour;

– class 12 000: 12 000 operating cycles per hour;

– class 30 000: 30 000 operating cycles per hour;

– class 120 000: 120 000 operating cycles per hour;

– class 300 000: 300 000 operating cycles per hour.

For intermittent duty with a large number of operating cycles per hour, the manufacturer shall indicate, either in terms of the true cycle if this is known, or in terms of conventional cycles designated by him, the values of the rated operational currents which shall be such that:

$$\int_o^T i^2 \mathrm{d}t \leq I_{\mathrm{th}}^2 \times T \quad \text{or} \quad I_{\mathrm{the}}^2 \times T$$

whichever is applicable

where T is the total operating cycle time.

NOTE The above formula does not take account of the switching arc energy.

A switching device intended for intermittent duty may be designated by the characteristics of the intermittent duty.

Example: An intermittent duty comprising a current flow of 100 A for 2 min in every 5 min may be stated as 100 A, class 12, 40 %.

4.3.4.4 Temporary duty

Duty in which the main contacts of an equipment remain closed for periods insufficient to allow the equipment to reach thermal equilibrium, the unload periods being separated by off-load periods of sufficient duration to restore equality of temperature with the cooling medium.

Standardized values of temporary duty are 3 min, 10 min, 30 min, 60 min and 90 min, with contacts closed.

4.3.4.5 Periodic duty

A type of duty in which operation, whether at constant or variable load, is regularly repeated.

4.3.5 Normal load and overload characteristics

This subclause gives general requirements concerning ratings under normal load and overload conditions.

NOTE Where applicable, the utilization categories referred to in 4.4 may include requirements in respect of performance under overload conditions.

Detailed requirements are given in 7.2.4.

4.3.5.1 Ability to withstand motor switching overload currents

An equipment intended for switching motors shall be capable of withstanding the thermal stresses due to starting and accelerating a motor to normal speed and due to operating overloads.

The detailed requirements to meet these conditions are given in the relevant product standard.

4.3.5.2 Rated making capacity

The rated making capacity of an equipment is a value of current, stated by the manufacturer, which the equipment can satisfactorily make under specified making conditions.

The making conditions which shall be specified are:

– the applied voltage (see 2.5.32);

– the characteristics of the test circuit.

The rated making capacity is stated by reference to the rated operational voltage and rated operational current, according to the relevant product standard.

NOTE 1 Where applicable, the relevant product standard states the relationship between rated making capacity and utilization category.

For a.c., the rated making capacity is expressed by the r.m.s. value of the symmetrical component of the current, assumed to be constant.

NOTE 2 For a.c., the peak value of the current during the first half-cycles following the closing of the main contacts of the equipment may be appreciably greater than the peak value of the current under steady-state conditions used in the determination of making capacity, depending on the power-factor of the circuit and the instant on the voltage wave when closing occurs.

An equipment should be capable of closing on a current having the a.c. component equal to that which defines its rated making capacity, whatever the value of the inherent d.c. component, within the limits resulting from the powerfactors indicated in the relevant product standard.

4.3.5.3 Rated breaking capacity

The rated breaking capacity of all equipment is a value of current, stated by the manufacturer, which the equipment can satisfactorily break, under specified breaking conditions.

The breaking conditions which shall be specified are:

– the characteristics of the test circuit;

– the power-frequency recovery voltage.

The rated breaking capacity is stated by reference to the rated operational voltage and rated operational current, according to the relevant product standard.

An equipment shall be capable of breaking any value of current up to and including its rated breaking capacity.

NOTE 1 A switching device may have more than one rated breaking capacity, each corresponding to an operational voltage and a utilization category.

For a.c., the rated breaking capacity is expressed by the r.m.s. value of the symmetrical component of the current.

NOTE 2 Where applicable, the relevant product standard states the relationship between rated breaking capacity and utilization category.

4.3.6 Short-circuit characteristics

This subclause gives general requirements concerning ratings under short-circuit conditions.

4.3.6.1 Rated short-time withstand current (I_{cw})

The rated short-time withstand current of an equipment is the value of short-time current, assigned to the equipment by the manufacturer, that the equipment can carry without damage, under the test conditions specified in the relevant product standard.

4.3.6.2 Rated short-circuit making capacity (I_{cm})

The rated short-circuit making capacity of an equipment is the value of short-circuit making capacity assigned to that equipment by the manufacturer for the rated operational voltage, at rated frequency, and at a specified power-factor for a.c. or time constant for d.c. It is expressed as the maximum prospective peak current, under prescribed conditions.

4.3.6.3 Rated short-circuit breaking capacity (I_{cn})

The rated short-circuit breaking capacity of an equipment is the value of short-circuit breaking capacity assigned to that equipment by the manufacturer for the rated operational voltage, at rated frequency, and at a specified power-factor for a.c. or time constant for d.c. It is expressed as the value of the prospective breaking current (r.m.s. value of the a.c. component in the case of a.c.), under prescribed conditions.

4.3.6.4 Rated conditional short-circuit current (I_q)

The rated conditional short-circuit current of an equipment is the value of prospective current, stated by the manufacturer, which the equipment, protected by a short-circuit protective device specified by the manufacturer, can withstand satisfactorily for the operating time of this device under the test conditions specified in the relevant product standard.

The details of the specified short-circuit protective device shall be stated by the manufacturer.

NOTE 1 For a.c., the rated conditional short-circuit current is expressed by the r.m.s. value of the a.c. component.

NOTE 2 The short-circuit protective device may either form an integral part of the equipment or be a separate unit.

4.3.7 Pole impedance of the switching device (Z)

The pole impedance may be stated by the manufacturer and is determined by measuring the voltage drop resulting from the current flowing through the pole.

4.4 Utilization category

The utilization category of an equipment defines the intended application and shall be specified in the relevant product standard; it is characterized by one or more of the following service conditions:

– current(s), expressed as multiple(s) of the rated operational current;

– voltage(s), expressed as multiple(s) of the rated operational voltage;

– power-factor or time-constant;

– short-circuit performance;

– selectivity;

– other service conditions, as applicable.

Examples of utilization categories for low-voltage switchgear and controlgear are given in Annex A.

4.5 Control circuits

4.5.1 Electrically or electronically controlled circuits

Characteristics of electrical and electronic control circuits:

– type of current;

– rated frequency or d.c;

– rated control circuit voltage U_c (a.c., d.c.);

– rated control circuit supply voltage U_s (a.c., d.c.), where applicable;

– nature of external control circuit devices (contacts, sensors, optocouplers, electronic active components, etc);

– power consumption.

NOTE 1 Distinction is made between the rated control circuit voltage U_c and the rated control circuit supply voltage U_s which may be different from U_c due to the presence of built-in transformers, rectifiers, resistors, electronic circuitry, etc.

The correct operating conditions are based upon a value of the control circuit supply voltage not less than 85 % of its rated value U_s, with the highest value of control circuit current flowing, nor more than 110 % of its rated value.

The electronic part of an electronically controlled electromagnet may form an integral part or a separate part provided it is an intrinsic function of the device. In both cases, the device shall be tested with this electronic part mounted as in normal use.

Annex U gives examples and illustrations of different circuit configurations.

The ratings and characteristics of control circuit devices shall comply with the requirements of IEC 60947-5 (see note of Clause 1).

4.5.2 Air-supply control circuits (pneumatic or electro-pneumatic)

The characteristics of air-supply control circuits are:

– rated pressure and its limits;

– volumes of air, at atmospheric pressure, required for each closing and each opening operation.

The rated supply pressure of a pneumatic or electro-pneumatic equipment is the air pressure on which the operating characteristics of the pneumatic control system are based.

4.6 Auxiliary circuits

The characteristics of auxiliary circuits are the number and kind of contacts (a-contact, b-contact, etc.) in each of these circuits and their ratings according to IEC 60947-5 (see note of Clause 1).

The characteristics of auxiliary contacts and switches shall comply with the requirements of the above standard.

4.7 Relays and releases

The following characteristics of relays and releases shall be stated in the relevant product standard, where applicable:

– type of relay or release;

– rated values;

– current setting or current setting range;

– time/current characteristics (for presentation of time/current characteristics, see 4.8);

– influence of ambient air temperature;

– extended functions as given in Annex T.

4.8 Co-ordination with short-circuit protective devices (SCPD)

The manufacturer shall state the type or the characteristics of the SCPD to be used with or within the equipment, as the case may be, and the maximum prospective short-circuit current for which the equipment, including the SCPD, is suitable, at the stated operational voltage(s).

NOTE IEC/TR 61912-1 gives guidance on co-ordination with SCPDs.

4.9 Switching overvoltages

The manufacturer shall specify the maximum value of switching overvoltages caused by the operation of the switching device, when required by the product standard.

This value shall not exceed that of the rated impulse withstand voltage (see 4.3.1.3).

5 Product information

5.1 Nature of information

The following information shall be given by the manufacturer, when required by the relevant product standard:

Identification:

– manufacturer's name or trademark;

– type designation or serial number;

– number of the relevant product standard, if the manufacturer claims compliance.

Characteristics:

– rated operational voltages (see 4.3.1.1 and note to 5.2);

– utilization category and rated operational currents (or rated powers or rated uninterrupted currents), at the rated operational voltages of the equipment (see 4.3.1.1, 4.3.2.3, 4.3.2.4 and 4.4). In certain cases, this information may have to be completed by the value of the reference ambient air temperature at which the equipment has been calibrated;

– the value of the rated frequency/frequencies, e.g.: 50 Hz, 50 Hz/60 Hz, and/or the indication "d.c." or the symbol ⎓;

– rated duty, with the indication of the class of intermittent duty, if any (see 4.3.4);

– rated making and/or breaking capacities. These indications may be replaced, where applicable, by the indication of the utilization category;

– rated insulation voltage (see 4.3.1.2);

– rated impulse withstand voltage (see 4.3.1.3);

– relay or release characteristics (see 4.7);

– switching overvoltage (see 4.9);

– rated short-time withstand current together with its duration, where applicable (see 4.3.6.1);

– rated short-circuit making and/or breaking capacities, where applicable (see 4.3.6.2 and 4.3.6.3);

– rated conditional short-circuit current, where applicable (see 4.3.6.4);

– IP code, in case of enclosed equipment (see Annex C);

– pollution degree (see 6.1.3.2);

– type and maximum ratings of short-circuit protective device, where applicable;

– class of protection against electric shock (see IEC 61140), where applicable;

– rated control circuit voltage, kind of current and frequency;

– control circuit supply voltage, kind of current and frequency, if different from those of the control coil;

– rated supply pressure of the air-pressure and limits of pressure variations (for air-pressure controlled equipment);

– suitability for isolation;

– pole impedance of the switching device (Z);

– material declaration as per Annex W;

– length of insulation to be removed before insertion of the conductor into the terminal;

– maximum number of conductors which may be clamped.

For non-universal screwless terminals:

– “s” or "sol" for terminals declared for rigid-solid conductors;

– "r" for terminals declared for rigid (solid and stranded) conductors;

– "f" for terminals declared for flexible conductors.

In the case of electronically controlled electromagnets, other information may also be necessary, for example control circuit configuration (see 4.5 and Annex U).

NOTE This list is not exhaustive.

5.2 Marking

All relevant information, as detailed in 5.1, which is to be marked on the equipment, shall be specified in the relevant product standard.

Markings shall be indelible and easily legible.

Marking of the manufacturer's name or trademark and type designation or serial number is mandatory on the equipment and preferably on the nameplate, if any, in order to permit the complete data to be obtained from the manufacturer.

NOTE In the USA and Canada, the rated operational voltage U_e, may be marked as follows:

a) on equipment for use on three-phase – four-wire systems, by both the value of phase-to-earth voltage and that of phase-to-phase voltage, e.g. 277/480 V;

b) on equipment for use on three-phase – three-wire systems, by the value of phase-to-phase voltage, e.g. 480 V.

The following information shall also be marked and visible after mounting:

– direction of movement of the actuator (see 7.1.5.2), if applicable;

– indication of the position of the actuator (see also 7.1.6.1 and 7.1.6.2);

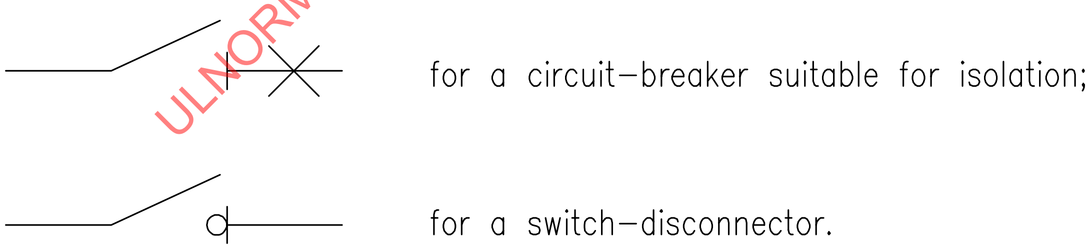
– approval or certification mark, if applicable;

– for miniaturized equipment, symbol, colour code or letter code;

– terminal identification and marking (see 7.1.8.4);

– IP code and class of protection against electric shock, when applicable (marked preferably on the equipment as far as possible);

– suitability for isolation, where applicable, with the isolation function symbol according to IEC 60617-7, reference 07-01-03, combined with the appropriate function symbol for the equipment, e.g.:



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This symbol shall be:

• clearly and unmistakably marked;

• visible when the equipment is installed as in service and the actuator is accessible.

This requirement applies whether the equipment is unenclosed, or enclosed according to 7.1.11.

This requirement also applies if the symbol is integrated into a wiring diagram and this diagram is the only marking indicating suitability for isolation.

In the case of electronically controlled electromagnets, information other than that given in 5.1 may also be necessary (see also 4.5 and Annex U).

The indication "s", "sol", "r" or "f" for non-universal screwless terminals shall be marked on the device or, if the space available is not sufficient, on the smallest package unit or in technical information provided with the product.

In the case of a group of terminals located together, a single marking on the device is acceptable.

5.2DV D2 *Add Subclauses 5.2DV.1 to 5.2DV.10 to Clause 5.2 as follows:*

5.2DV.1 An accessory that is not shipped from the factory in the same carton as the equipment with which it is intended to be used shall be plainly marked with:

a) The manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product may be identified;

b) The electrical rating, unless the accessory electrical rating is marked on the equipment for which it is intended; and

c) The catalog number or equivalent.

The accessory shall be provided with installation and wiring instructions.

5.2DV.2 See Table 25DV for marking locations.

5.2DV.3 When more than one disconnect switch is required to disconnect all power within a control assembly or compartment, the equipment shall be marked with the following or equivalent:

CAUTION – Risk of Electric Shock – More than one disconnect may be required to de-energize the equipment before servicing.

In Canada, such equipment shall also be marked with the following French wording or equivalent:

ATTENTION – Risque de choc électrique – Plusieurs sectionneurs peuvent être nécessaires pour couper l'alimentation de l'appareillage avant d'entreprendre l'entretien.

5.2DV.4 When field wiring terminals are evaluated for use with other than copper conductors, the equipment shall be marked with the types of conductors to be used, such as the following: "Use Aluminum Conductors Only" (AL), "Use Copper or Aluminum

Conductors" (CU/AL), "Use Copper (CU), Copper-Clad Aluminum, or Aluminum Conductors" (AL), or "Use Copper (CU) or Copper-Clad Aluminum Conductors".

5.2DV.5 Equipment shall be marked to indicate the temperature rating, 60 °C only, 60/75 °C, or 75 °C only, used in the evaluation of the power field wiring terminals.

5.2DV.6 Equipment shall be marked with the values of tightening torque in Newton-meters to be applied to the clamping screws of all field wiring terminals. Control field wiring terminals evaluated for 0,8 N·m are not required to be marked with their tightening torque value.

5.2DV.7 During the temperature test, when the temperature rise on the terminal is 50 °C or less and an aluminum bodied connector is used or aluminum wire is intended, the connector shall be marked AL7CU or AL9CU. When the terminal temperature rise exceeds 50 °C and does not exceed 65 °C, the connector shall be marked AL9CU.

5.2DV.8 Equipment incorporating two or more separate circuits intended to be connected to a common power source shall be marked with the following or equivalent:

All circuits must be connected to the same pole of the power source.

The wiring diagram of the equipment shall illustrate a typical connection of the various circuits connected to the common power source.

5.2DV.9 The equipment shall be marked stating which pressure wire connector or component terminal kits have been evaluated for use with the equipment. A wire connector of the type mentioned in the marking may be installed in the equipment at the factory with instructions, when needed to effect proper connection of the conductor.

5.2DV.10 Enclosure mounted components shall be marked with the following statement or equivalent: "For Use on a Flat Surface of a Type __ Enclosure". The type or types of enclosures for which the component has been evaluated shall be marked in the blank space.

5.3 Instructions for installation, operation and maintenance

The manufacturer shall specify in his documents or catalogues the conditions for installation, operation and maintenance, if any, of the equipment during operation and after a fault. The manufacturer shall also specify the measures to be taken with regard to EMC, if any.

For equipment only suitable in environment A (see 7.3.1) the manufacturer shall provide the following notice in documentation, available as information to potential customers and with the product for users:

NOTICE
This product has been designed for environment A. Use of this product in environment B may cause unwanted electromagnetic disturbances in which case the user may be required to take adequate mitigation measures.

If necessary, the instructions for the transport, installation and operation of the equipment shall indicate the measures that are of particular importance for the proper and correct installation, commissioning and operation of the equipment.

These documents shall indicate the recommended extent and frequency of maintenance, if any.

NOTE All equipment covered by this standard is not necessarily designed to be maintained.

5.3DV D2 *Modification of 5.3 by adding the following:*

Instructional information in paragraph 2 related to EMC is optional.

5.4 Environmental information

Material declarations according to Annex W shall be provided if required by the relevant product standard.

6 Normal service, mounting and transport conditions

6.1 Normal service conditions

Equipment complying with this standard shall be capable of operating under the following standard conditions:

NOTE For non-standard conditions in service, see Annex B. These may require agreement between manufacturer and user.

6.1.1 Ambient air temperature

The ambient air temperature does not exceed +40 °C and its average over a period of 24 h does not exceed +35 °C.

The lower limit of the ambient air temperature is –5 °C.

Ambient air temperature is that existing in the vicinity of the equipment if supplied without enclosure, or in the vicinity of the enclosure if supplied with an enclosure.

NOTE 1 Equipment intended to be used in ambient air temperature above +40 °C (e.g. in forges, boiler rooms, tropical countries) or below –5 °C (e.g. –25 °C, as required by IEC 61439 series for outdoor installed low-voltage switchgear and controlgear assemblies) should be designed or used according to the relevant product standard, where applicable, or according to agreement between manufacturer and user. Information given in the manufacturer’s catalogue may take the place of such an agreement.

NOTE 2 Ambient air temperature(s) for certain types of equipment, e.g. circuit-breakers or overload relays for starters, is indicated in the relevant product standard.

6.1.2 Altitude

The altitude of the site of installation does not exceed 2 000 m.

NOTE For equipment to be used at higher altitudes, it is necessary to take into account the reduction of the dielectric strength and the cooling effect of the air. Electrical equipment intended to operate under these conditions shall be designed or used in accordance with an agreement between manufacturer and user.

6.1.3 Atmospheric conditions

6.1.3.1 Humidity

The relative humidity of the air does not exceed 50 % at a maximum temperature of +40 °C. Higher relative humidities may be permitted at lower temperatures, e.g. 90 % at +20 °C. Special measures may be necessary in cases of occasional condensation due to variations in temperature.

NOTE Pollution degrees, as stated in 6.1.3.2, define the environmental conditions more precisely.

6.1.3.2 Pollution degree

The pollution degree (see 2.5.58) refers to the environmental conditions for which the equipment is intended.

NOTE 1 The micro-environment of the creepage distance or clearance and not the environment of the equipment determines the effect on the insulation. The micro-environment might be better or worse than the environment of the equipment. It includes all factors influencing the insulation, such as climatic and electromagnetic conditions, generation of pollution, etc.

For equipment intended for use within an enclosure or provided with an integral enclosure, the pollution degree of the environment in the enclosure is applicable.

For the purpose of evaluating clearances and creepage distances, the following four degrees of pollution of the micro-environment are established (clearances and creepage distances according to the different pollution degrees are given in Table 13 and Table 15):

Pollution degree 1:

No pollution or only dry, non-conductive pollution occurs.

Pollution degree 2:

Normally, only non-conductive pollution occurs. Occasionally, however, a temporary conductivity caused by condensation may be expected.

Pollution degree 3:

Conductive pollution occurs, or dry, non-conductive pollution occurs which becomes conductive due to condensation.

Pollution degree 4:

The pollution generates persistent conductivity caused, for instance, by conductive dust or by rain or snow.

Standard pollution degree of industrial applications:

Unless otherwise stated by the relevant product standard, equipment for industrial applications is generally for use in pollution degree 3 environment. However, other pollution degrees may be considered to apply depending upon particular applications or the micro-environment.

NOTE 2 The pollution degree of the micro-environment for the equipment may be influenced by installation in an enclosure.

Standard pollution degree of household and similar applications:

Unless otherwise stated by the relevant product standard, equipment for household and similar applications is generally for use in pollution degree 2 environment.

6.1.4 Shock and vibration

Standard conditions of shock and vibration to which the equipment can be submitted are under consideration.

6.2 Conditions during transport and storage

A special agreement shall be made between user and manufacturer if the conditions during transport and storage, e.g. temperature and humidity, differ from those defined in 6.1, except that, unless otherwise specified, the following temperature range applies during transport and storage: between –25 °C and +55 °C and, for short periods not exceeding 24 h, up to +70 °C.

Equipment subjected to these extreme temperatures without being operated shall not undergo any irreversible damage and shall then operate normally under the specified conditions.

6.3 Mounting

The equipment shall be mounted in accordance with the manufacturer's instructions.

6.3DV D2 ***Modification of 6.3 by adding the following:***

A bolt, screw, or other part used to mount a component to the equipment shall not also be used for securing the equipment to the supporting surface.

7 Constructional and performance requirements

7.1 Constructional requirements

7.1.1 General

The equipment with its enclosure, if any, whether integral or not, shall be designed and constructed to withstand the stresses occurring during installation and normal use and, in addition, shall provide a specified degree of resistance to abnormal heat and fire.

Glow-wire requirements for non-integral enclosure materials are given in relevant standards, e.g. IEC 62208.

NOTE The need to reduce the impact on the natural environment of a product during all phases of its life is recognized. Assistance in the consideration of environmental aspects relating to products according to the IEC 60947 series is given in Annex O.

7.1.1DV D2 ***Add Subclauses 7.1.1DV.1 to 7.1.1DV.7 and Table 7.1.1DV.7 to Clause 7.1.1 as follows:***

7.1.1DV.1 Disconnect and overcurrent protective devices

7.1.1DV.1.1 Power circuit devices

7.1.1DV.1.1.1 The number, arrangement, and ratings or settings of disconnect or protective devices intended to provide motor branch-circuit, short-circuit, and ground-fault

protection, motor-overload protection, or disconnection shall be as specified by Annex DVA, Table DVA.3, Ref. No. 1.

7.1.1DV.1.2 Control circuit devices

7.1.1DV.1.2.1 Control circuit transformer and conductors of control circuits shall be protected against overcurrent in accordance with Annex DVA, Table DVA.3, Ref. No. 2.

7.1.1DV.1.2.2 Conductors for control circuits shall be provided with overcurrent protection in each ungrounded conductor, located no more than 305 mm from the point where the conductor is connected to the source of power. Direct leads measuring a maximum of 305 mm long or printed-wiring assemblies having no connection external to the equipment are not required to be protected.

7.1.1DV.1.2.3 Unless protected by a power circuit protective device or as noted in 7.1.1DV.1.2.4, separate conductor protection shall be provided and, if necessary, a fuse holder shall also be provided with the equipment. Protection shall be as follows:

When protection is provided by fuses:

a) Branch-circuit type fuse: The fuse is not required to be provided with the equipment. When the fuse holder will accept a fuse having a higher current rating than permitted, a marking specifying the maximum fuse size shall be provided near the fuse holder.

b) Supplementary fuse: The fuse shall be provided with the equipment. The equipment shall be marked with the voltage and current rating of the replacement fuse.

When protection is provided by a supplementary protector:

c) In the United States and Mexico, an overcurrent trip-type supplementary protector shall comply with UL 1077. A supplementary protector that is connected to the load side of a branch circuit protective device (not in an isolated secondary circuit) shall be additionally evaluated as to its performance under fault conditions.

In Canada, an overcurrent trip-type supplementary protector shall comply with CSA C22.2 No. 235.

7.1.1DV.1.2.4 A controller may be removable without control circuit protection when:

a) The equipment has multiple ratings and the power circuit device provides protection for some but not all ratings as required by Annex DVA, Table DVA.3, Ref. No. 2; and

b) The manufacturer makes available an accessory kit intended for installation in the controller enclosure and the controller is marked in accordance with 5.2DV.1.

7.1.1DV.2 Protection of service personnel

7.1.1DV.2.1 Any uninsulated live part involving a potential of more than 30 V rms (42,4 volts peak) mounted to the inside of a door shall be guarded, recessed, or enclosed to provide protection against unintentional contact (IP1X) when the door is open. A mechanical obstacle, such as a barrier, cover, or guard, relied upon to comply with this requirement

shall be removable without the use of tools. A mechanical obstacle shall not be damaged or removed by the IP1X pushing force.

7.1.1DV.2.2 Other than for a control circuit fuse protecting a load within the same enclosure, equipment incorporating a fuse holder and the location of fuses, the normal function of which requires renewal, shall be constructed so that:

a) The fuses are readily accessible when the switch contacts are open; and

b) A person is not required to touch any live part when replacing a fuse.

7.1.1DV.2.3 The electrical arrangement of a single-throw switch shall be such that when it is connected as intended and the contacts are open, the fuse terminals are not energized.

7.1.1DV.2.4 Enclosed equipment with a door and containing a reset button, routine adjustment, or operating handle of a switch or circuit breaker shall be constructed so that:

a) The button, adjustment, or operating handle is readily accessible; and

b) A person is not required to touch any live part when performing the operation or adjustment.

When a barrier is relied upon to comply with this requirement, the barrier shall not be removable without the use of a key or tools.

7.1.1DV.3 Identification of neutral conductors and terminals for neutral conductors

7.1.1DV.3.1 Terminals for neutral conductors shall be identified by means of a metallic plated coating substantially white in color and shall be readily distinguishable from the other terminals; or clearly shown in some other manner, such as on an attached wiring diagram. If wire leads are provided, the lead intended to be connected to a grounded supply circuit shall have a white or gray color and shall be readily distinguishable from other leads.

a) For Mexico and the United States, the lead intended to be connected to a grounded supply circuit shall be identified by the color white or gray and shall be readily distinguishable from other leads.

b) For Canada, the lead intended to be connected to a grounded supply circuit shall be identified by the color white only.

7.1.1DV.3.2 For Mexico and the United States, insulated conductors that are connected to the grounded side of a transformer secondary and are intended to be extended outside an enclosure shall be identified by the color white or gray or by three continuous white stripes on other than green insulation, and no other conductor shall be so identified. For Canada, conductors shall be identified by the color white only.

7.1.1DV.4 Separation of Circuits

7.1.1DV.4.1 Internal wiring

7.1.1DV.4.1.1 Other than for Class 2 or Class 3 circuits, as defined in Annex DVA, Table DVA.3, Ref. No. 3, the equipment shall be constructed so that a conductor, including a field-installed conductor of any circuit, is segregated by means of a minimum permanent 6,4 mm physical separation or separated by means of a barrier from physical contact with:

a) A conductor connected to any other circuit, unless the conductors of both circuits are insulated for the maximum voltage of either circuit;

b) An uninsulated live part of any other circuit.

A conductor subject to movement during normal operation shall maintain separation of circuits during the full range of movement.

In Canada, Class 3 circuits are not defined.

7.1.1DV.4.2 Field wiring

7.1.1DV.4.2.1 Equipment shall be constructed so that a field-installed conductor of any circuit is segregated as specified in 7.1.1DV.4.2.3 or separated by a barrier (see 7.1.1DV.4.2.2) from:

a) A field-installed conductor connected to any other circuit unless:

1) Both circuits are Class 2 or Class 3 or both circuits are other than Class 2 or Class 3; and

2) The conductors of both circuits will be insulated for the maximum voltage of either circuit;

b) An uninsulated live part of any other circuit;

c) A factory-installed conductor connected to any other circuit, unless the conductors of both circuits will be insulated for the maximum voltage of either circuit.

Equipment may have field-installed conductors that are not segregated or separated by a barrier when specific installation instructions are included that explain the proper procedure to be followed to install the equipment to achieve required separation.

7.1.1DV.4.2.2 With respect to 7.1.1DV.4.2.1, if the intended uses of the device are such that in some applications a barrier is required while in other applications no barrier is required, a removable barrier or one having openings for the passage of conductors may be employed. Instructions for the use of such a barrier shall be a permanent part of the device.

7.1.1DV.4.2.3 Field installed conductors may be segregated from each other and from uninsulated live parts or factory-installed conductors of the equipment connected to different circuits by arranging the location of openings in an enclosure for the various field-installed conductors with respect to the terminals or other uninsulated live parts and factory or field-installed conductors. A minimum permanent 6,4 mm (1/4 inch) separation shall be provided.

7.1.1DV.5 Transformers

7.1.1DV.5.1 A transformer employed in equipment shall comply with the appropriate standards for transformers.

As an alternative, when the load is part of the equipment, the transformer shall comply with the construction requirements of this standard, the temperature test in 7.2.2DV.1, and the dielectric voltage-withstand test in 8.3.3.4.1DV.1 – 8.3.3.4.1DV.3.

Pulse and current transformers comply with this requirement when they withstand, without breakdown, a dielectric voltage withstand potential in accordance with 8.3.3.4.1DV.1 – 8.3.3.4.1DV.3, applied between the primary and the secondary windings.

7.1.1DV.6 Enclosure mounted components

7.1.1DV.6.1 A component, such as a pilot light, intended for use with a specific type enclosure shall be:

a) Evaluated by applicable performance tests in CSA C22.2 94.2 and UL 50E, while installed on a representative enclosure;

b) Provided with all hardware, gaskets, or other parts required to complete the installation unless they are available from the component manufacturer in the form of a kit and the component is marked as specified in 5.2DV.1;

c) Provided with installation instructions, including information such as mounting hole location and opening configuration, either on the component, in the component package, or on an instruction sheet; and

d) Marked as specified in 5.2DV.10.

7.1.1DV.7 Surge protective devices

7.1.1DV.7.1 Devices or systems used for overvoltage control shall:

a) comply with the requirements of the CSA C22.2 No. 269 series and UL 1449;

b) for Type 1, Type 2, and Type 3 surge protective devices, have a maximum continuous operating voltage not less than the operational voltage rating of the power system configuration to which the surge protective devices is connected;

c) for Type 4 and 5 surge protective devices, have a maximum continuous operating voltage at least equivalent to the line-to-line voltage of the input system of the assembly.

Type 4 surge protective devices that have been subjected to limited current, intermediate current, and short circuit current tests need only be rated for the maximum continuous operating voltage of the power system; and

d) be evaluated for use for one of the following:

1) Type 1 applications when used on the line side of service equipment;

2) Type 1 or Type 2 applications when used on the load side of service equipment feeder circuit applications or branch circuit applications;

3) Type 3 applications when used in branch circuit or control circuit applications;

4) Type 5 discrete component surge suppressors or Type 4 component assemblies when used in branch circuit or control circuit applications and rated with a nominal discharge current (I_n) where the In value is as specified in Table 7.1.1DV.7 based on the system operating voltage and the Over-Voltage category; or

5) Type 4 component surge suppressors when used in branch circuit or control circuit applications and provided with "other" rating where the Operating Duty Cycle is based on a kV/kA combination waveform test equal to the values given in Table 7.1.1DV.7 based on the system input voltage and Over-Voltage Category of the equipment.

Table 7.1.1DV.7
Correlation Between Equipment Overvoltage and Surge Protective Combination Waveform Test Values

Phase-to-ground[a] rated system voltage (rms and dc)				Raged impulse withstand voltage peak, kV	Combination Waveform Test Current or Nominal Discharge Current, I_n[b]
Overvoltage category					
I	II	III	IV		
50	–	–	–	0,33	165 A
100	50	–	–	0,50	250 A
150	100	50	–	0,80	400 A
300	150	100	50	1,5	750 A
600	300	150	100	2,5	1 250 A
1000	600	300	150	4,0	2 000 A
1500	1000	600	300	6,0	3 000 A

[a] For ungrounded systems or systems with one phase grounded, the phase-to-ground voltage is considered to be the same as the phase-to-phase voltage for the purposes of using this table.

[b] Based on Rated Impulse withstand voltage peak / 2 ohm upstream impedance.

7.1.2 Materials

7.1.2.1 General materials requirements

Parts of insulating materials which might be exposed to thermal stresses due to electrical effects within the equipment shall not be adversely affected by abnormal heat and by fire.

The manufacturer shall specify which test method, 7.1.2.2 or 7.1.2.3, is to be used.

7.1.2.1DV DE *Modification of 7.1.2.1 by adding the following:*

7.1.2.1DV.1 Insulating materials are considered to be exposed to thermal stresses due to electrical effects within the equipment when:

a) the equipment is in direct physical contact with or in close proximity [less than 0,8 mm (1/32 inch)] to the uninsulated live part; and

b) the equipment serves to physically support or maintain the relative position of the uninsulated live part with respect to creepage and clearance requirements.

7.1.2.2 Glow wire testing

The suitability of materials used is verified by:

a) making tests on the equipment; or

b) making tests on sections taken from the equipment; or

c) making tests on any parts of identical material having representative thickness; or

d) providing data from the insulating material supplier fulfilling the requirements according to IEC 60695-2-12.

The suitability shall be determined with respect to resistance to abnormal heat and fire.

The manufacturer shall indicate which methods, amongst a), b), c) and d), shall be used.

If an identical material having representative cross-sections has already satisfied the requirements of any of the tests of 8.2.1, then those tests need not be repeated.

Tests on equipment shall be made by the glow-wire end-product test of IEC 60695-2-10 and IEC 60695-2-11.

Parts of insulating materials necessary to retain current-carrying parts in position shall conform to the glow-wire tests of 8.2.1.1.1 at a test temperature of 850 °C or 960 °C according to the expected fire hazard. Product standards shall specify the value appropriate to the product, taking into account the Annex A of IEC 60695-2-11.

Parts of insulating materials other than those specified in the previous paragraph shall conform to the requirements of the glow-wire test of 8.2.1.1.1 at a temperature of 650 °C.

NOTE For small parts, as specified in IEC 60695-2-11, the relevant product standard may specify another test (for example needle flame test, according to IEC 60695-11-5). The same procedure may be applicable for other practical reasons when the metal part is large compared to the insulating material (such as terminal blocks). The needle flame test is used as an alternative test for addressing flame retardancy requirements for shipboard applications.

7.1.2.3 Test based on flammability category

For parts of insulating materials, hot wire ignition and, where applicable, arc ignition tests as specified in 8.2.1.1.2, shall be made based on flammability category.

Tests on materials shall be made in accordance with Annex M. The hot wire ignition (HWI) and arc ignition (AI) test value requirements related to the material flammability category shall conform to Table M.1 or Table M.2.

Alternatively, the manufacturer may provide data from the insulating material supplier fulfilling the requirements given in Annex M.

7.1.2.3DV D2 ***Modification of 7.1.2.3 by adding the following:***

7.1.2.3DV.1 Materials fulfilling the requirements in Annex M may be used when the minimum thickness, flame class, HWI, and HAI values comply with Table 7.1.2.3DV.1.

Table 7.1.2.3DV.1
Minimum material characteristics for the direct support of uninsulated live parts

Flame class	RTI (Elec)	Maximum performance level category (PLC)	
		HWI [b,c]	HAI [d, e]
HB	a	2	1
V-2, VTM-2	a	2	2
V-1, VTM-1	a	3	2
V-0, VTM-0	a	4	3

Relative Thermal Index (RTI)

[a] The electrical Relative Thermal Index (RTI) value of a material is dependent upon the minimum thickness at which the material is being used. The RTI shall not be exceeded during the Temperature-rise Test, Clause 8.3.3.3.

Hot Wire Ignition (HWI)

[b] The Hot Wire Ignition (HWI) value of a material is dependent upon the minimum thickness at which the material is being used. When the thickness of an insulating material is less than the minimum specified thickness corresponding to a HWI value, the material is evaluated as in footnote c.

[c] A material without an HWI Performance Level Category (PLC) value or with a HWI PLC value greater (worse) than the value specified above shall be subjected to the end-product Abnormal Overload Test or the Glow Wire End-Product Test specified per UL 746C.

High Current Arc Resistance to Ignition (HAI)

[d] The HAI value of a material is dependent upon the minimum thickness at which the material is being used. When the thickness of an insulating material is less than the minimum specified thickness corresponding to a HAI value, the material is evaluated as in footnote e.

[e] A material without an HAI PLC value or with an HAI PLC value greater (worse) than the value specified above shall be subjected to the end-product Arc Resistance Test specified per UL 746C.

7.1.2.3DV.2 Generic materials in Table 7.1.2.3DV.2 provided in the thickness indicated comply without additional evaluation.

Table 7.1.2.3DV.2
Generic materials

Generic material	Thickness		RTI, °C
	mm	(inch)	
Diallyl Phthalate	0,71	(0,028)	105
Epoxy	0,71	(0,028)	105
Melamine	0,71	(0,028)	130
Melamine-Phenolic	0,71	(0,028)	130
Phenolic	0,71	(0,028)	150
Unfilled Nylon	0,71	(0,028)	105
Unfilled Polycarbonate	0,71	(0,028)	105
Urea Formaldehyde	0,71	(0,028)	100
Ceramic, Porcelain, Slate	No limit		No limit
Beryllium Oxide	No limit		No limit

NOTE – Each material shall be used within its minimum thickness and its Relative Thermal Index (RTI) value shall not be exceeded during the Temperature-rise test, Clause 8.3.3.3.

7.1.3 Current-carrying parts and their connections

Current-carrying parts shall have the necessary mechanical strength and current-carrying capacity for their intended use.

For electrical connections, no contact pressure shall be transmitted through insulating material other than ceramic or other material with characteristics not less suitable, unless there is sufficient resiliency in the metallic parts to compensate for any possible shrinkage or yielding of the insulation material.

Compliance shall be verified by inspection and by conducting the test sequences according to the relevant product standard.

NOTE In the USA, the use of clamping units in which pressure is transmitted through insulating materials other than ceramic is permitted only in the following circumstances:

1 where the clamping unit is part of a terminal block;

2 where a temperature test demonstrates that the temperature limitations of the insulation material and of the terminals in accordance with the product standard are not exceeded; and

3 resilient metal is used in the clamping unit construction to compensate for loss of clamping pressure due to insulating material deformation.

7.1.3DV D2 ***Modification of 7.1.3 by adding the following:***

7.1.3DV.1 An uninsulated live part, including a terminal, shall be secured to its supporting surface by a method other than friction between surfaces so as to prevent it from turning or shifting in position when such motion results in reduction of creepage and/or clearance distances to less than those required elsewhere in this standard.

7.1.3DV.2 The insulation on all internal wires of the equipment shall be rated for the voltage and the temperature conditions of use. Internal wires used for grounding or bonding may be uninsulated.

7.1.3DV.3 Wiring that is subject to movement, flexing, handling, or manipulation during its intended use, or during mechanical maintenance such as wiring from a stationary part to a part mounted on a hinged cover or door, shall be:

a) Provided with insulation at least 0,8 mm at any point where it is flexed;

b) Stranded-type conductors;

c) Routed and secured so that the wire is not damaged during opening and closing of the door or cover; and

d) Comply with the Wire Flexing test per 8.2.7.4DV.3.

7.1.4 Clearances and creepage distances

7.1.4.1 General

For equipment tested according to 8.3.3.4 of this standard, minimum values are given in Table 13 and Table 15.

Electrical requirements are given in 7.2.3.

In the other cases, guidance for minimum values is given in the relevant product standard.

NOTE Depending on the risk level (severity of harm and the probability of occurrence), the non-accessibility to hazardous-live parts is considered under normal service conditions (see 6.1) or under single-fault conditions (see 4.2 of IEC 61140:2001, 7.1.10 and Annex N).

7.1.4.2 Insulation coordination barriers for creepage distances

When solid insulation is used as an insulation coordination barrier to comply with required creepage distances, the material used shall comply with the glow wire requirements in 7.1.2.2 or the flammability requirements in 7.1.2.3.

7.1.4.3 Insulation coordination barriers for clearance distances

When solid insulation is used as an insulation coordination barrier to comply with required clearance distances and does not physically support or maintain the relative position of uninsulated parts involved, the barrier material shall comply with the glow wire requirements in 7.1.2.2 and shall conform to the glow-wire test requirements of 8.2.1.1.1 at a temperature of 650 °C or the AI values in Table M.2. Alternatively the material shall comply with the requirements in 7.1.4.2.

7.1.4.4DV D2 *Add Clauses 7.1.4.4DV.1 to 7.1.4.4DV.4 to Clause 7.1.4 as follows:*

7.1.4.4DV.1 General

7.1.4.4DV.1.1 Clearance and creepage distances are not required to be evaluated within isolated secondary circuits that comply with Annex DVC.

7.1.4.4DV.1.2 Other than for providing isolation between different circuits or in a safety circuit, spacings between traces of different potential on a printed wiring board are exempt from the spacing requirements of this standard when:

a) The printed wiring board has a flammability rating of V-0;

b) The printed wiring board base material has a minimum Comparative Tracking Index (CTI) of 100 volts; and

c) The equipment complies with the Printed Wiring Board Abnormal Operation Test (8.2.7.4DV.5).

In Canada, this exemption shall only apply when used in a secondary circuit.

7.1.4.4DV.1.3 To determine whether spacings at specific points on printed wiring boards comply with 7.1.4.4DV.1.2, each point of the printed wiring board so identified shall be tested as described in 8.2.7.4DV.5 with adjacent printed circuit paths short-circuited one at a time until an integral protective device operates, a component as described in 8.2.7.4DV.5 opens, or until thermal conditions stabilize, up to a maximum of 7 hours.

7.1.4.4DV.1.4 For a magnetic coil winding with crossover-lead insulation or insulation under coil terminals secured to the coil winding less than 0,33 mm thick, or where a clearance is provided, the coil shall withstand without an indication of breakdown the tests in subclause 8.2.7.4DV.2.

7.1.4.4DV.2 Isolation devices

7.1.4.4DV.2.1 An optical isolator relied upon to provide isolation between circuits or a power switching semiconductor device relied upon to provide isolation to ground shall have an isolation voltage rating not less than 1 000 V plus twice rated voltage.

7.1.4.4DV.3 Clamped joint test

7.1.4.4DV.3.1 In the case of a clamped insulating joint, creepage and clearance distances shall be measured through cracks unless a clamped joint has passed the test described in 8.2.7.4DV.1. A clamped joint is a joint between two pieces of insulation that are under pressure as shown in Figure 24DV. Adhesives, cements, and the like, if used to effect a seal in place of a tightly mated joint, shall comply with UL 746C.

7.1.4.4DV.4 Insulation coordination barriers

7.1.4.4DV.4.1 Insulating materials used for barriers which support uninsulated live parts shall comply with one of the following:

a) Table 7.1.2.3DV.2; or

b) Table 7.1.2.3DV.1 at one of the following thicknesses:

1) Not less than 0,71 mm (0,028 in) thick;

2) Not less than 0,33 mm (0,013 in) thick plus one-half of the required clearance when used in lieu of the required clearance distance only; or

3) UL 746C, Section 10, Dielectric Strength when used in lieu of the required clearance distance only, and is not within 0,8 mm (1/32 in) of uninsulated live parts.

7.1.4.4DV.4.2 Insulating barriers that do not physically support or maintain the relative position of uninsulated parts may be comprised of materials per Table 7.1.4.4DV.4.2.

Table 7.1.4.4DV.4.2
Generic materials suitable as a barrier

Generic material	Minimum thickness		RTI, °C
	mm	(inch)	
Aramid Paper	0,25	(0,010)	105
Cambric	0,71	(0,028)	105
Electrical Grade Paper	0,71	(0,028)	105
Epoxy	0,71	(0,028)	105
Mica	0,15	(0,006)	105
Mylar (PET)	0,18	(0,007)	105
RTV	0,71	(0,028)	105
Silicone	0,71	(0,028)	105
Treated Cloth	0,71	(0,028)	105
Vulcanized Fiber	0,71	(0,028)	105

NOTE – Each material shall have at least the minimum thickness specified and its Relative Thermal Index (RTI) value shall not be exceeded during the Temperature-rise Test.

7.1.5 Actuator

7.1.5.1 Insulation

The actuator of the equipment shall be insulated from the live parts for the rated insulation voltage and, if applicable, the rated impulse withstand voltage.

Moreover:

– if it is made of metal, it shall be capable of being satisfactorily connected to a protective conductor unless it is provided with additional reliable insulation;

– if it is made of or covered by insulating material, any internal metal part, which might become accessible in the event of insulation failure, shall also be insulated from live parts for the rated insulation voltage.

7.1.5.2 Direction of movement

The direction of operation for actuators of devices shall normally conform to IEC 60447. Where devices cannot conform to these requirements, e.g. due to special applications or alternative mounting positions, they shall be clearly marked such that there is no doubt as to the "I" and "O" positions and the direction of operation.

7.1.6 Indication of the contact position

7.1.6.1 Indicating means

When an equipment is provided with means for indicating the closed and open positions, these positions shall be unambiguous and clearly indicated. This is done by means of a position indicating device (see 2.3.18).

NOTE In the case of enclosed equipment, the indication may or may not be visible from the outside.

The relevant product standard may specify whether the equipment is to be provided with such an indicating device.

If symbols are used, they shall indicate the closed and open positions respectively, in accordance with IEC 60417-2:

60417-2-IEC-5007 I On (power)

60417-2-IEC-5008 O Off (power)

For equipment operated by means of two push-buttons, only the push-button designated for the opening operation shall be red or marked with the symbol "O".

Red colour shall not be used for any other push-button.

The colours of other push-buttons, illuminated push-buttons and indicator lights shall be in accordance with IEC 60073.

7.1.6.2 Indication by the actuator

When the actuator is used to indicate the position of the contacts, it shall automatically take up or stay, when released, in the position corresponding to that of the moving contacts; in this case, the actuator shall have two distinct rest positions corresponding to those of the moving contacts, but for automatic opening a third distinct position of the actuator may be provided.

7.1.7 Additional requirements for equipment suitable for isolation

7.1.7.1 Additional constructional requirements

NOTE 1 In the USA, devices meeting these additional requirements are not accepted as assuring isolation by themselves. Isolation requirements and procedures are covered in the relevant Federal regulations and maintenance standards.

Equipment suitable for isolation shall provide in the open position (see 2.4.21) an isolation distance in accordance with the requirements necessary to satisfy the isolating function (see 7.2.3.1 and 7.2.7). Indication of the position of the main contacts shall be provided by one or more of the following means:

– the position of the actuator;

– a separate mechanical indicator;

– visibility of all moving main contacts.

The effectiveness of each of the means of indication provided on the equipment and its mechanical strength shall be verified in accordance with 8.2.5.

When means are provided or specified by the manufacturer to lock the equipment in the open position, locking in that position shall only be possible when the main contacts are in the open position. This shall be verified in accordance with 8.2.5.

Equipment shall be designed so that the actuator, front plate or cover are fitted to the equipment in a manner which ensures correct contact position indication and locking, if provided.

NOTE 2 Locking in the closed position is permitted for particular applications.

NOTE 3 If auxiliary contacts are provided for interlocking purposes, the operating time of the auxiliary and main contacts should be declared by the manufacturer. More specific requirements may be given in the relevant product standard.

The indicated open position is the only position in which the specified isolation distance between the contacts is ensured.

For equipment provided with positions such as “tripped position” or “standby position”, which are not the indicated open position, those positions shall be clearly identified. The marking of such positions shall not include the symbols “I” or “O”.

An actuator having only one position of rest shall not be considered as appropriate to indicate the position of the main contact.

7.1.7.2 Supplementary requirements for equipment with provision for electrical interlocking with contactors or circuit-breakers

If equipment suitable for isolation is provided with an auxiliary switch for the purpose of electrical interlocking with contactor(s) or circuit-breaker(s) and intended to be used in motor circuits, the following requirements shall apply unless the equipment is rated for AC-23 utilization category.

An auxiliary switch shall be rated according to IEC 60947-5-1 as stated by the manufacturer.

The time interval between the opening of the contacts of the auxiliary switch and the contacts of the main poles shall be sufficient to ensure that the associated contactor or circuit-breaker interrupts the current before the main poles of the equipment open.

Unless otherwise stated in the manufacturer's technical literature, the time interval shall be not less than 20 ms when the equipment is operated according to the manufacturer's instructions.

Compliance shall be verified by measuring the time interval between the instant of opening of the auxiliary switch and the instant of opening of the main poles under no-load conditions when the equipment is operated according to the manufacturer's instructions.

During the closing operation the contacts of the auxiliary switch shall close after or simultaneously with the contacts of the main poles.

A suitable opening time interval may also be provided by an intermediate position (between the ON an OFF positions) at which the interlocking contact(s) is (are) open and the main poles remain closed.

7.1.7.3 Supplementary requirements for equipment provided with means for padlocking the open position

The locking means shall be designed in such a way that it cannot be removed with the appropriate padlock(s) installed. When the equipment is locked by even of a single padlock, it shall not be possible by operating the actuator, to reduce the clearance between open contacts to the extent that it no longer complies with the requirements of 7.2.3.1b).

Alternatively, the design may provide padlockable means to prevent access to the actuator.

Compliance with the requirements to padlock the actuator shall be verified using a padlock specified by the manufacturer or an equivalent gauge, giving the most adverse conditions, to simulate locking. The force *F* specified in 8.2.5.2.1 shall be applied to the actuator in an attempt to operate the equipment from the open position to the closed position. Whilst the force F is applied the equipment shall be subjected to a test voltage across open contacts. The equipment shall be capable of withstanding the test voltage required according to Table 14 appropriate to the rated impulse withstand voltage.

7.1.8 Terminals

7.1.8.1 Constructional 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 force to connect the conductors may be applied by screws, screwless-type 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 voltage shall not be reduced below the rated values.

If required by the application, terminals and conductors may be connected by means of cable lugs for copper conductors only.

NOTE 1 Examples of overall dimensions of terminal lugs suitable to be directly connected to the stud terminals of equipment are given in Annex P.

Screwless-type clamping units, unless otherwise specified by the manufacturer, shall accept rigid and flexible conductors as indicated in Table 1.

On screwless-type clamping unit, the connection or disconnection of conductors shall be made as follows:

– on universal clamping units by the use of a general purpose tool or a convenient device, integral with the clamping unit to open it for the insertion or withdrawal of the conductors;

– on push-wire clamping units by simple insertion. For the disconnection of the conductors an operation other than a pull only on the conductor shall be necessary. The use of a general purpose tool or of a convenient device, integral with the clamping unit is allowed in order to "open" it and to assist the insertion or the withdrawal of the conductor.

Examples of terminals are given in Annex D.

The requirements of this subclause shall be verified by the tests of 8.2.4.2, 8.2.4.3 and 8.2.4.4, as applicable.

NOTE 2 North American countries have particular requirements for terminals suitable for aluminium conductors and marking to identify the use of aluminium conductors.

7.1.8.1DV D2 *Add Subclauses 7.1.8.1DV.1 to 7.1.8.1DV.4 to Clause 7.1.8.1 as follows:*

7.1.8.1DV.1 Field wiring terminal

7.1.8.1DV.1.1 Field wiring terminals shall be evaluated in accordance with 8.2.4DV and sized in accordance with 7.1.8.2DV.

7.1.8.1DV.1.2 Terminals for control, signal, or sensor circuits shall accept 2,1 mm^2 (14 AWG) minimum conductors, unless marked (on the product or installation instructions) for the connection of smaller conductor sizes as allowed. A terminal intended for field wiring of conductors smaller than 2,1 mm^2 (14 AWG) of other than Class 2 or Class 3 circuits as specified by the installation instructions or wiring diagram furnished with the device shall comply with 8.2.4DV for such conductors. When the specified conductors are smaller than 0,82 mm^2 (18 AWG), the terminal shall additionally be evaluated in accordance with 8.2.4DV for 0,82 mm^2 (18 AWG) conductors.

7.1.8.1DV.1.3 Where the field wiring terminal is not provided, a reference to terminal kits shall be given.

7.1.8.1DV.1.4 When a wiring terminal receives the next larger size conductor than required, it shall comply with the secureness and pullout requirements with that size conductor, unless the equipment is marked to restrict its use to only the smaller size conductor.

7.1.8.1DV.2 Splice

7.1.8.1DV.2.1 A lead that is intended to be spliced in the field to a circuit conductor shall not be smaller than 0,82 mm^2 (18 AWG), and the insulation, when rubber or thermoplastic, shall not be less than 0,8 mm thick.

7.1.8.1DV.2.2 The free length of a field wiring lead shall not be less than 100 mm long when intended for installation in an outlet box. For other equipment, the free length of a field wiring lead shall not be less than 152 mm long.

7.1.8.1DV.3 Wire binding screw

7.1.8.1DV.3.1 A terminal to which 5,3 mm^2 (10 AWG) or smaller wiring connections are to be made shall consist of a clamp or binding screw with a terminal plate having upturned lugs or the equivalent to hold the wire in position. A wire binding screw shall thread into metal.

7.1.8.1DV.3.2 A terminal plate tapped for a wire-binding screw shall be of metal not less than 0,76 mm thick for a 2,1 mm^2 (14 AWG) or smaller wire, and not less than 1,27 mm thick for a wire larger than 2,1 mm^2 (14 AWG). There shall be at least two full threads in the plate. An extruded hole may be used to provide two full threads. When fewer threads result in a secure connection in which the threads do not strip upon application of a 2,3 N-m tightening torque, a terminal plate may have fewer than two full threads.

7.1.8.1DV.3.3 A wire-binding screw intended for a maximum 5,3 mm^2 (10 AWG) field-wiring connection shall:

a) For the United States and Mexico, have a minimum major thread diameter of 3,91 mm; and

b) For Canada, have a minimum head diameter of 4,17 mm.

7.1.8.1DV.3.4 A wire-binding screw intended for a maximum 2,5 mm^2 (12 AWG) field wiring connection shall:

a) For the United States and Mexico, have a minimum major thread diameter of 3,91 mm; and

b) For Canada, have a minimum head diameter of 3,5 mm.

7.1.8.1DV.3.5 A wire-binding screw intended for a maximum 2,1 mm^2 (14 AWG) field wiring connection shall:

a) For the United States and Mexico, have a minimum major thread diameter of 3,5 mm; and

b) For Canada, have a minimum head diameter of 3,2 mm.

7.1.8.1DV.4 Pressure terminal connector

7.1.8.1DV.4.1 Equipment intended for use with field wiring larger than 3,3 mm^2 (10 AWG) may be provided without a pressure terminal connector, including one that is compression tool applied, when the construction complies with the following conditions:

a) Component terminal connectors are available from the equipment manufacturer, and one or more are specified for field installation on the equipment;

b) A fastening device, such as a stud, nut, bolt, spring, or flat washer, that is required for installation is provided as part of the component terminal assembly, mounted on, or separately packaged with the equipment;

c) When the pressure connector in a component terminal assembly requires the use of a special tool for securing the conductor, instructions referencing use of the tool are included with the component assembly or with the equipment; and

d) Installation of a pressure terminal connector in the intended manner results in a product that complies with the requirements in this standard.

7.1.8.2 Connecting capacity

The manufacturer shall state the type (rigid – solid or stranded – or flexible), the minimum and the maximum cross-sections of conductors for which the terminal is suitable and, if applicable, the number of conductors simultaneously connectable to the terminal. However, the maximum cross-section shall not be smaller than that stated in 8.3.3.3 for the temperature-rise test and the terminal shall be suitable for conductors of the same type (rigid – solid or stranded – or flexible) at least two sizes smaller, as given in the appropriate column of Table 1.

NOTE 1 Conductor cross-sections smaller than the minimum may be required in different product standards.

NOTE 2 Because of voltage drop and other considerations, the product standards may require the terminals to be suitable for conductors of cross-sections larger than those specified for the temperature-rise test. The relationship between conductor cross-sections and rated currents may be given in the relevant product standards.

Standard values of cross-section of round copper conductors (both metric and AWG/kcmil sizes) are shown in Table 1 which also gives the approximate relationship between ISO metric and AWG/kcmil sizes.

7.1.8.2DV D2 *Modification of 7.1.8.2 by adding the following:*

7.1.8.2DV.1 Wire shall be of the smallest size having an ampacity of at least 125 percent of:

a) The maximum full-load motor current;

b) Resistive heating loads;

c) The maximum full-load motor current for the component with the highest current-rated element for equipment employing an overload device with interchangeable current elements; or

d) The maximum full-load motor current for the overload relay for equipment employing an overload relay with non-interchangeable current elements.

7.1.8.2DV.2 For equipment controlling a DC motor and intended to be operated from a rectified single-phase power supply, the wire shall be of the smallest size having an ampacity of:

a) 190 percent of full-load current when a half-wave rectifier is used; or

b) 150 percent of full-load current when a full-wave rectifier is used.

7.1.8.2DV.3 For all other loads, the wire shall be of the smallest size having an ampacity of at least 100 percent of the rated current.

7.1.8.2DV.4 The wire size shall be in accordance with Annex DVA, Table DVA.3, Ref. No. 5 based on 60 °C only, 60/75 °C, or 75 °C only temperature-rated wire. The type of insulation is not specified; ambient correction factors do not apply. See 5.2DV.5 for marking requirements.

7.1.8.3 Connection

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

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.

7.1.8.4 Terminal identification and marking

Terminals shall be clearly and permanently identified in accordance with IEC 60445 and Annex L, unless superseded by the requirements of the relevant product standard.

Terminals intended exclusively for the neutral conductor shall be identified by the letter "N", in accordance with IEC 60445.

The protective earth terminal shall be identified in accordance with 7.1.10.3.

7.1.9 Additional requirements for equipment provided with a neutral pole

When an equipment is provided with a pole intended only for connecting the neutral, this pole shall be clearly identified to that effect by the letter N (see 7.1.8.4).

A switched neutral pole shall break not before and shall make not after the other poles.

If a pole having an appropriate short-circuit breaking and making capacity (see 2.5.14 and 2.5.15) is used as a neutral pole, then all poles, including the neutral pole, may operate substantially together.

NOTE The neutral pole may be fitted with an over-current release.

For equipment having a value of conventional thermal current (free air or enclosed, see 4.3.2.1 and 4.3.2.2) not exceeding 63 A, this value shall be identical for all poles.

For higher conventional thermal current values, the neutral pole may have a value of conventional thermal current different from that of the other poles, but not less than half that value or 63 A, whichever is the higher.

7.1.10 Provisions for protective earthing

7.1.10.1 Constructional requirements

The exposed conductive parts (e.g. chassis, framework and fixed parts of metal enclosures) other than those which cannot constitute a danger shall be electrically interconnected and connected to a protective earth terminal for connection to an earth electrode or to an external protective conductor.

This requirement can be met by the normal structural parts providing adequate electrical continuity and applies whether the equipment is used on its own or incorporated in an assembly.

NOTE If needed, requirements and tests may be specified in the relevant product standard.

Exposed conductive parts are considered not to constitute a danger if they cannot be touched on large areas or grasped with the hand or if they are of small size (approximately 50 mm × 50 mm) or are so located as to exclude any contact with live parts.

Examples of these are screws, rivets, nameplates, transformer cores, electromagnets of switching devices and certain parts of releases, irrespective of their size.

7.1.10.1DV DR *Modification of 7.1.10.1 by adding the following:*

7.1.10.1DV.1 Enclosure bonding requirements shall be evaluated in accordance with 7.1.11DV.1.

7.1.10.1DV.2 A secondary circuit of a power or control transformer shall be grounded under any of the following conditions when field wiring is intended to be connected to the circuit which extends beyond the enclosure in which the transformer is mounted:

a) When the secondary is less than 50 volts and the transformer supply is over 150 volts to ground or the transformer supply at any voltage is ungrounded; or

b) When the secondary is 50 volts or greater and the secondary circuit is able to be grounded so that the maximum voltage to ground on the ungrounded conductors does not exceed 15 volts.

7.1.10.1DV.3 A transformer secondary that is required to be grounded in accordance with 7.1.10.1DV.2 shall have a main bonding jumper factory-connected to the transformer secondary and to the grounding electrode conductor terminal (or to the enclosure when a grounding electrode conductor terminal is not provided). The main bonding jumper shall be sized in accordance with Table 30DV, based on the transformer secondary rating. A grounding electrode conductor terminal sized to retain the required grounding electrode conductor in accordance with Table 30DV, based on the transformer secondary rating, shall be provided in the enclosure containing the transformer and marked as specified in 7.1.10.3DV.2.

When the transformer is rated not more than 1 000 volt-amperes and supplies only remote control and signaling circuits, the transformer may be provided without a grounding electrode conductor terminal. When a grounding electrode conductor terminal is not provided, the main bonding jumper shall not be smaller than a 2,1 mm^2 (14 AWG) copper conductor. The jumper is not otherwise required to be larger than the phase conductors connected to the transformer secondary.

7.1.10.2 Protective earth terminal

The protective earth terminal shall be readily accessible and so placed that the connection of the equipment to the earth electrode or to the protective conductor is maintained when the cover or any other removable part is removed.

The protective earth terminal shall be suitably protected against corrosion.

In the case of equipment with conductive structures, enclosures, etc., means shall be provided, if necessary, to ensure electrical continuity between the exposed conductive parts of the equipment and the metal sheathing of connecting conductors.

The protective earth terminal shall have no other function, except when it is intended to be connected to a PEN conductor (see 2.1.15 – Note). In this case, it shall also have the function of a neutral terminal in addition to meeting the requirements applicable to the protective earth terminal.

7.1.10.2DV DR *Modification to 7.1.10.2 by adding the following:*

A terminal for a grounding electrode conductor or an equipment grounding conductor shall accept the minimum conductor size determined in accordance with Table 30DV.

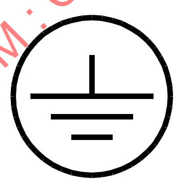
7.1.10.3 Protective earth terminal marking and identification

The protective earth terminal shall be clearly and permanently identified by its marking.

The identification shall be achieved by colour (green-yellow mark) or by the notation PE, or PEN, as applicable, in accordance with IEC 60445, subclause 5.3, or by a graphical symbol for use on equipment.

The graphical symbol to be used is the symbol:

60417-2-IEC-5019



Protective earth (ground)

in accordance with IEC 60417-2.

NOTE The symbol  (60417-2-IEC-5017), previously recommended, shall be progressively superseded by the preferred symbol 60417-2-IEC-5019 given above.

7.1.10.3DV DR *Modification of 7.1.10.3 by adding the following:*

7.1.10.3DV.1 The terminal shall be green-colored or plainly identified, such as being marked “G”, “GR”, “GND”, “GRND”, “Ground”, “Grounding”, or the like. The notation "PE" or "PEN" may be used but not as the sole means of identifying the terminal.

7.1.10.3DV.2 With respect to 7.1.10.1DV.3, equipment containing a power or control transformer feeding circuits leaving the enclosure from a secondary winding not conductively connected to the primary shall be marked to indicate the need for connecting

the secondary neutral conductor to a grounding electrode in accordance with the existing installation requirements pertaining to separately derived systems.

NOTE This marking is not required when the grounding electrode conductor terminal is not provided in accordance with 7.1.10.1DV.3.

7.1.11 Enclosures for equipment

The following requirements are only applicable to enclosures supplied or intended to be used with the equipment.

7.1.11DV.1 D2 *Modification of 7.1.11 by adding the following*

Enclosure construction and performance requirements are defined in CSA C22.2 No. 14, NMX-J-235-ANCE, and UL 508.

7.1.11DV.2 DR *Modification of 7.1.11 by adding the following:*

Enclosed equipment shall comply with the wire-bending space requirements in Annex DVA, Table DVA.3, Ref. No. 4.

7.1.11.1 Design

The enclosure shall be so designed that, when it is opened and other protective means, if any, are removed, all parts requiring access for installation and maintenance, as prescribed by the manufacturer, are readily accessible.

Sufficient space shall be provided inside the enclosure for the accommodation of external conductors from their point of entry into the enclosure to the terminals to ensure adequate connection.

The fixed parts of a metal enclosure shall be electrically connected to the other exposed conductive parts of the equipment and connected to a terminal which enables them to be earthed or connected to a protective conductor.

Under no circumstances shall a removable metal part of the enclosure be insulated from the part carrying the earth terminal when the removable part is in place.

The removable parts of the enclosure shall be firmly secured to the fixed parts by a device so that they cannot be accidentally loosened or detached owing to the effects of operation of the equipment or vibrations.

When an enclosure is so designed as to allow the covers to be opened without the use of tools, means shall be provided to prevent loss of the fastening devices.

An integral enclosure is considered to be a non-removable part.

If the enclosure is used for mounting push-buttons, removal of buttons should be from the inside of the enclosure. Removal from the outside shall only be by use of a tool intended for this purpose.

7.1.11.2 Insulation

If, in order to prevent accidental contact between a metallic enclosure and live parts, the enclosure is partly or completely lined with insulating material, then this lining shall be securely fixed to the enclosure.

7.1.12 Degrees of protection of enclosed equipment

Degrees of protection of enclosed equipment and relevant tests are given in Annex C.

7.1.12DV D2 *Modification of 7.1.12 by replacing it with the following:*

Enclosed equipment shall be evaluated in accordance with CSA C22.2 No. 94.1, CSA C22.2 No. 94.2, NMX-J-235/1-ANCE, NMX-J-235/2-ANCE, UL 50, and UL 50E according to the marked enclosure Type rating(s). In addition, open and enclosed equipment may be marked with an IP rating and evaluated according to the relevant tests given in Annex C.

7.1.13 Conduit pull-out, torque and bending with metallic conduits

Polymeric enclosures of equipment, whether integral or not, provided with threaded conduit entries, intended for the connection of extra heavy duty, rigid threaded metal conduits complying with IEC 60981, shall withstand the stresses occurring during its installation such as pull-out, torque, bending.

Compliance shall be verified by the test of 8.2.7.

7.1.13DV D2 *Modification of 7.1.13 by adding the following:*

Enclosure construction and performance requirements for metallic conduit entries are defined in CSA C22.2 No. 94.1, NMX-J-235/1-ANCE, and UL 50.

7.2 Performance requirements

The following requirements apply to clean new equipment unless otherwise stated in the relevant product standard.

7.2.1 Operating conditions

7.2.1.1 General

The equipment shall be operated in accordance with the manufacturer's instructions or the relevant product standard, especially for equipment with dependent manual operation where the making and breaking capacities may depend on the skill of the operator.

7.2.1.2 Limits of operation of power operated equipment

Unless otherwise stated in the relevant product standard, electromagnetic and electro-pneumatic equipment shall close with any control circuit supply voltage between 85 % and 110 % of its rated value U_s and an ambient air temperature between –5 °C and +40 °C. These limits apply to d.c. or a.c. as appropriate.

For pneumatic and electro-pneumatic equipment, unless otherwise stated, the limits of the air supply pressure are 85 % and 110 % of the rated pressure.

Where a range of operation is given, the value of 85 % shall apply to the lower limit of the range, and the value of 110 % to the upper limit of the range.

NOTE For latched equipment, operating limits should be agreed upon between manufacturer and user.

For electromagnetic and electro-pneumatic equipment, the drop-out voltage shall not be higher than 75 % of the rated control circuit supply voltage U_s nor lower than 20 % of U_s in the case of a.c. at rated frequency, or 10 % of U_s in the case of d.c.

The limits between which an equipment, with an electronically controlled electromagnet, shall drop out and open fully are

− for d.c.: 75 % to 10 % of their rated control circuit supply voltage U_s,

− for a.c.: 75 % to 20 % of their rated control circuit supply voltage U_s, or 75 % to 10 % of their rated control circuit supply voltage U_s if specified by the manufacturer.

For pneumatic and electro-pneumatic equipment, unless otherwise stated, opening shall occur at a pressure between 75 % and 10 % of the rated pressure.

Where a range of operation is given, the value of 20 % or 10 %, as the case may be, shall apply to the upper limit of the range, and the value of 75 % to the lower limit of the range.

In the case of coils, the limiting drop-out values apply when the coil circuit resistance is equal to that obtained at –5 °C. This may be verified by a calculation based on the values obtained at normal ambient temperature.

The drop out time may need to be specified for particular applications. In this case the drop out time shall be measured during the test associated with the verification of this subclause.

7.2.1.3 Limits of operation of under-voltage relays and releases

a) Operating voltage

An under-voltage relay or release, when associated with a switching device, shall operate to open the equipment even on a slowly falling voltage within the range between 70 % and 35 % of its rated voltage.

NOTE A no-voltage release is a special form of under-voltage release in which the operating voltage is between 35 % and 10 % of the rated supply voltage.

An under-voltage relay or release shall prevent the closing of the equipment when the supply voltage is below 35 % of the rated voltage of the relay or release; it shall permit closing of the equipment at supply voltages equal to or above 85 % of its rated value.

Unless otherwise stated in the relevant product standard, the upper limit of the supply voltage shall be 110 % of its rated value.

The figures given above apply equally to d.c. and to a.c. at rated frequency.

b) Operating time

For a time-delay under-voltage relay or release, the time-lag shall be measured from the instant when the voltage reaches the operating value until the instant when the relay or release actuates the tripping device of the equipment.

7.2.1.4 Limits of operation of shunt releases

A shunt release for opening shall cause tripping under all operating conditions of an equipment when the supply voltage of the shunt release measured during the tripping operation remains between 70 % and 110 % of the rated control circuit supply voltage and, if a.c., at the rated frequency.

7.2.1.5 Limits of operation of current operated relays and releases

Limits of operation of current operated relays and releases shall be stated in the relevant product standard.

NOTE The term "current operated relays and releases" covers over-current relays or releases, overload relays or releases, reverse current relays or releases, etc.

7.2.2 Temperature-rise

The temperature-rises of the parts of an equipment, measured during a test carried out under the conditions specified in 8.3.3.3, shall not exceed the values stated in this subclause.

NOTE 1 Temperature-rise in normal service may differ from the test values, depending on the installation conditions and size of connected conductors.

NOTE 2 The temperature-rise limits given in Table 2 and Table 3 apply to equipment tested in new and clean condition. Different values may be prescribed by product standards for different test conditions and for devices of small dimensions but not exceeding the above values by more than 10 K.

7.2.2DV D2 *Modification of 7.2.2 by replacing Subclauses 7.2.2.1 to 7.2.2.8 with Subclauses 7.2.2DV.1 to 7.2.2DV.3 as follows:*

7.2.2DV.1 Equipment tested shall not exceed the temperature rise above the test ambient at specific points greater than those specified in Table 27DV. Protective devices or circuitry shall not trip during the test.

7.2.2DV.2 For equipment provided with a thermostat or other thermal protective device and tested as in 8.3.3.3.1DV.2(a), the temperature of the thermal device shall be measured and corrected for the difference in ambient temperature. The resulting temperature shall not exceed the rated trip temperature of the thermal protective device.

7.2.2DV.3 Equipment shall be marked with the maximum ambient temperature rating when intended for service in any ambient temperature or surrounding air temperature of 40 °C or at a higher or lower ambient temperature or surrounding air temperature at an interval from 40 °C in a whole number multiple of ± 5 °C, such as 45, 50, 55, 60. Equipment intended for service in a 40 °C ambient temperature is not required to be marked with the ambient temperature rating.

7.2.2.1 Terminals

The temperature-rises of terminals shall not exceed the values stated in Table 2.

7.2.2.2 Accessible parts

The temperature-rises of accessible parts shall not exceed the values stated in Table 3.

NOTE The temperature-rise limits of other parts are given in 7.2.2.8.

7.2.2.3 Ambient air temperature

The temperature-rise limits given in Table 2 and Table 3 are applicable only if the ambient air temperature remains within the limits given in 6.1.1.

7.2.2.4 Main circuit

The main circuit of an equipment shall be capable of carrying the conventional thermal current of the equipment without the temperature-rises exceeding the limits specified in Table 2 and Table 3 when tested in accordance with 8.3.3.3.4.

7.2.2.5 Control circuits

The control circuits of an equipment, including control circuit devices to be used for the closing and operating operations of an equipment, shall permit the rated duty according to 4.3.4 and also the temperature-rises tests specified in 8.3.3.3.5 to be made without the temperature-rises exceeding the limits specified in Table 2 and Table 3.

Digital inputs and/or digital outputs contained in switchgear and controlgear, and intended to be compatible with programmable logic controllers (PLCs) are covered by Annex S.

7.2.2.6 Windings of coils and electromagnets

With current flowing through the main circuit the windings of coils and electromagnets shall withstand their rated voltage without the temperature-rises exceeding the limits specified in 7.2.2.8 when tested in accordance with 8.3.3.3.6.

NOTE This subclause does not apply to pulse-operated coils, whose operating conditions are defined by the manufacturer.

7.2.2.7 Auxiliary circuits

Auxiliary circuits of an equipment including auxiliary switches shall be capable of carrying their conventional thermal current without the temperature-rise exceeding the limits specified in Table 2 and Table 3, when tested in accordance with 8.3.3.3.7.

NOTE If an auxiliary circuit forms an integral part of the equipment, it suffices to test it at the same time as the main equipment, but at its actual service current.

7.2.2.8 Other parts

The temperature rises obtained during the test shall not impair the performance of the product. For insulating parts, the manufacturer shall demonstrate compliance by reference to the insulation temperature index (determined, for example, by the methods of IEC 60216) or by compliance with IEC 60085.

7.2.3 Dielectric properties

The dielectric properties are based on basic safety publications IEC 60664-1 and IEC 61140. For reduced clearances and creepage distances through the use of coating see IEC 60664-3; for clearances and creepage distances equal to or less than 2 mm see IEC 60664-5.

a) The following requirements provide the means of achieving co-ordination of insulation of equipment with the conditions within the installation.

b) The equipment shall be capable of withstanding:

– the rated impulse withstand voltage (see 4.3.1.3) in accordance with the overvoltage category given in Annex H;

– the impulse withstand voltage across the contact gaps of devices suitable for isolation as given in Table 14;

– the power-frequency withstand voltage.

NOTE The correlation between the nominal voltage of the supply system and the rated impulse withstand voltage of the equipment is given in Annex H.

The rated impulse withstand voltage for a given rated operational voltage (see notes 1 and 2 to 4.3.1.1) shall be not less than that corresponding in Annex H to the nominal voltage of the supply system of the circuit at the point where the equipment is to be used, and the appropriate overvoltage category.

c) The requirements of this subclause shall be verified by the tests of 8.3.3.4.

7.2.3.1 Impulse withstand voltage

1) Main circuit

a) Clearances from live parts to parts intended to be earthed and between poles shall withstand the test voltage given in Table 12 appropriate to the rated impulse withstand voltage.

b) Clearances across the open contacts shall withstand:

– the impulse withstand voltage specified, where applicable, in the relevant product standard;

– for equipment designated as suitable for isolation, the test voltage given in Table 14 appropriate to the rated impulse withstand voltage.

NOTE Solid insulation of equipment associated with clearances a) and/or b) above should be subjected to the impulse voltage specified in a) and/or b), as applicable.

2) Auxiliary and control circuits

a) For auxiliary and control circuits which operate directly from the main circuit at their rated voltage, clearances from live parts to parts intended to be earthed and between poles shall withstand the test voltage given in Table 12 appropriate to the rated impulse withstand voltage of the auxiliary/control circuit and to the appropriate overvoltage category of the main circuit (see also the note of 7.2.3.1, item 1)).

b) Auxiliary and control circuits which do not operate directly from the main circuit may have an overvoltage withstand capacity different from that of the main circuit. Clearances and associated solid insulation of such circuits, whether a.c. or d.c., shall withstand the appropriate voltage in accordance with Annex H.

7.2.3.2 Power-frequency withstand voltage of the main, auxiliary and control circuits

a) Power-frequency tests are used in the following cases:

– dielectric tests as type tests for the verification of solid insulation;

– dielectric withstand verification, as a criterion of failure, after switching or short-circuit type tests;

– routine tests.

b) Type tests of dielectric properties

The tests of dielectric properties, as type tests, shall be made in accordance with 8.3.3.4.

For equipment suitable for isolation, the maximum leakage current shall be in accordance with 7.2.7 and shall be tested according to 8.3.3.4.

c) Verification of dielectric withstand after switching or short-circuit tests

The verification of dielectric withstand after switching and short-circuit tests as a criterion of failure, is always made at power-frequency voltage in accordance with item 4) of 8.3.3.4.1.

For equipment suitable for isolation, the maximum leakage current shall be in accordance with 7.2.7, shall be tested according to 8.3.3.4 and shall not exceed the values specified in the relevant product standard.

d) Vacant

e) Verification of dielectric withstand during routine tests

Tests to detect faults in materials and workmanship are made at power-frequency voltage, in accordance with item 2) of 8.3.3.4.2.

7.2.3.2DV D2 ***Modification of 7.2.3.2 by adding the following:***

Leakage current measurements in Items b) and c) for equipment suitable for isolation do not apply.

7.2.3.3 Clearances

Clearances shall be sufficient to enable the equipment to withstand the rated impulse withstand voltage, according to 7.2.3.1.

Clearances shall be higher than the values given in Table 13, for case B (homogeneous field) (see 2.5.62) and verified by a sampling test according to 8.3.3.4.3. This test is not required if the clearances, related to the rated impulse withstand voltage and pollution degree, are equal to or higher than the values given in Table 13 for case A (inhomogeneous field).

The method of measuring clearances is given in Annex G.

7.2.3.3DV D2 ***Modification of 7.2.3.3 by adding the following:***

7.2.3.3DV.1 For the evaluation of clearances:

a) Equipment which operates in the direct line of the source of power to the load equipment shall be evaluated for Overvoltage Category III. Other equipment shall be evaluated for Overvoltage Category II;

b) The phase-to-ground rated system voltage used in the determination of impulse voltage associated with clearances shall be the equipment rated supply voltage rounded to the next higher value (in Table H.1 of Annex H for determining clearances for equipment) for all points on the supply side of an isolating transformer or the entire product when no isolating transformer is provided. The measured clearance distance used in the evaluation of isolated secondary circuitry may be interpolated when the secondary voltage occurs between voltages in the supply voltage column.

7.2.3.3DV.2 Surge protective devices may be employed in order to improve the transient impulse over-voltage control within an assembly and decrease required clearance distances. This reduction in required clearance distance shall be based on the voltage protection rating (VPR) of the surge protective device and the resulting clearance distance as shown in Table 7.1.1DV.7. The surge protective device shall comply with Table 7.1.1DV.7 and Items a) and b) below:

a) The Measured Limiting Voltage (MLV) of the surge protective device shall not exceed the impulse voltage withstand value provided in Table 7.1.1DV.7 for the measured clearance.

b) The surge protective device shall be provided with one of the following:

1) a Nominal Current Discharge Rating (I_n) or Operating Duty Cycle based on a kV/kA combination test waveform equal to the values given in Table 13. The impulse voltage withstand value chosen shall be at least that equal to the impulse voltage withstand value in Table 7.1.1DV.7 based on the system input voltage and Over-Voltage Category of the equipment under test;

2) a Nominal Current Discharge Rating (I_n) or Operating Duty Cycle based on a kV/kA combination test waveform equal to the impulse voltage value given in Table 13 and current value equal to the rated impulse voltage divided by the circuit impedance on the input side of the surge protective device plus 2 ohms. The impulse voltage withstand value chosen shall be at least equal to the impulse voltage withstand value in Table 7.1.1DV.7 based on the system input voltage and Over-Voltage Category of the equipment under test; or

3) an entire assembly that complies with the Operating Duty Cycle testing as outlined in the CSA C22.2 No. 269 series and UL 1449 using a combination waveform as defined in Item 1) above.

7.2.3.4 Creepage distances

a) Dimensioning

For pollution degrees 1 and 2, creepage distances shall be not less than the associated clearances selected according to 7.2.3.3. For pollution degrees 3 and 4, the creepage distances shall be not less than the case A clearances (Table 13) to reduce the risk of disruptive discharge due to overvoltages, even if the clearances are smaller than the values of case A as permitted in 7.2.3.3.

The method of measuring creepage distances is given in Annex G.

Creepage distances shall correspond to a pollution degree as specified in 6.1.3.2 or to that defined in the relevant product standard and to the corresponding material group at the rated insulation or working voltage given in Table 15.

Material groups are classified as follows, according to the range of values of the comparative tracking index (CTI) (see 2.5.65):

– Material Group I 600 ≤ CTI

– Material Group II 400 ≤ CTI < 600

– Material Group IIIa 175 ≤ CTI < 400

– Material Group IIIb 100 ≤ CTI < 175

NOTE 1 The CTI values refer to the values obtained in accordance with IEC 60112, method A, for the insulating material used.

NOTE 2 For inorganic insulating materials, for example glass or ceramics, which do not track, creepage distances need not be greater than their associated clearances. However, the risk of disruptive discharge should be considered.

b) Use of ribs

A creepage distance can be reduced to 0,8 of the relevant value of Table 15 by using ribs of 2 mm minimum height, irrespective of the number of ribs. The minimum base of the rib is determined by mechanical requirements (see G.2).

c) Special applications

Equipment intended for certain applications where severe consequences of an insulation fault have to be taken into account shall have one or more of the influencing factors of Table 15 (distances, insulating materials, pollution in the micro-environment) utilized in such a way as to achieve a higher insulation voltage than the rated insulation voltage given to the equipment according to Table 15.

7.2.3.4DV D2 *Modification of 7.2.3.4 by adding the following:*

Evaluating creepage distances

a) The comparative tracking index (CTI) value of a printed wiring board that complies with UL 796 shall be determined by one of the following methods:

1) the CTI value for the printed wiring board;

2) where a printed wiring board does not have a CTI value and the printed wiring board additionally complies with the requirements for direct support per UL 796, the CTI of 175 shall apply; or

3) where a printed wiring board does not have a CTI value and has not been evaluated for direct support, the CTI of 100 shall apply.

b) Unless otherwise specified in this standard or the relevant product standard, equipment shall be evaluated for pollution degree 3.

c) Printed wiring boards shall be evaluated as pollution degree 2 when adjacent conductive material is covered by any coating, such as a solder mask, that provides an uninterrupted covering over at least one side and covers the complete distance up to the other side of the conductive material.

d) Printed wiring boards shall be evaluated as pollution degree 1 under one of the following conditions:

1) when the printed wiring board has a coating which complies with the requirements for conformal coatings per UL 746C; or

2) at a specific printed wiring board location by application of a layer at least 0,79 mm (0.03125 in) thick of silicone rubber or through potting, without air bubbles, in epoxy or potting material.

Note: The CTI value has no relationship to the rated voltage of the device.

7.2.3.5 Solid insulation

Solid insulation shall be verified by either power-frequency tests, in accordance with item 3) of 8.3.3.4.1, or d.c. tests in the case of d.c. equipment.

NOTE For more information on the design of solid insulation, see 5.3.1 of IEC 60664-1:2007.

7.2.3.6 Spacing between separate circuits

For dimensioning clearances, creepage distances and solid insulation between separate circuits, the highest voltage ratings shall be used (rated impulse withstand voltage for clearances and associated solid insulation and rated insulation voltage or working voltage for creepage distances).

7.2.3.7 Requirements for equipment with protective separation

Requirements for equipment with protective separation are given in Annex N.

7.2.4 Ability to make, carry and break currents under no-load, normal load and overload conditions

7.2.4.1 Making and breaking capacities

The equipment shall be capable of making and breaking load and overload currents without failure under the conditions stated in the relevant product standard for the required utilization categories and the number of operations stated in the relevant product standard (see also general test conditions of 8.3.3.5).

7.2.4.2 Operational performance

Tests concerning the operational performance of equipment are intended to verify that the equipment is capable of making, carrying and breaking without failure the currents flowing in its main circuit under conditions corresponding to the specified utilization category, where relevant.

Specific requirements and test conditions shall be stated in the relevant product standard and may concern

– the operational performance off-load for which the tests are made with the control circuits energized and the main circuit not energized, in order to demonstrate that the equipment meets the operating conditions specified at the upper and lower limits of supply voltage and/or pressure specified for the control circuit during closing and opening operations;

– the operational performance on-load during which the equipment shall make and break the specified current corresponding, where relevant, to its utilization category for the number of operations stated in the relevant product standard.

The verification of operational performance off-load and on-load may be combined in one sequence of tests if so stated in the relevant product standard.

7.2.4.3 Durability

NOTE The term "durability" has been chosen, instead of "endurance" in order to express the expectancy of the number of operating cycles which can be performed by the equipment before repair or replacement of parts. Moreover the term "endurance" is also commonly used to cover operational performance as defined in 7.2.4.2 and it was deemed necessary not to use the term "endurance" in this standard in order to avoid confusion between the two concepts.

7.2.4.3.1 Mechanical durability

With respect to its resistance to mechanical wear, an equipment is characterized by the number, stated in the relevant product standard, of no-load operating cycles (i.e., without current at the main contacts) which can be effected before it becomes necessary to service or replace any mechanical parts; however, normal maintenance according to the manufacturer's instructions may be permitted for equipment designed to be maintained.

Each operating cycle consists of one closing operation followed by one opening operation.

The equipment shall be mounted for the test according to the manufacturer's instructions.

The preferred number of off-load operating cycles shall be specified in the relevant product standard.

7.2.4.3.2 Electrical durability

With respect to its resistance to electrical wear, an equipment is characterized by the number of on-load operating cycles, corresponding to the service conditions given in the relevant product standard, which can be made without repair or replacement.

The preferred number of on-load operating cycles shall be specified in the relevant product standard.

7.2.5 Ability to make, carry and break short-circuit currents

The equipment shall be so constructed as to be capable of withstanding, under conditions specified in the relevant product standard, the thermal, dynamic and electrical stresses resulting from short-circuit currents. In particular the equipment shall behave in such a manner that it complies with the requirements of 8.3.4.1.8.

Short-circuit currents may be encountered

– during current making;

– during current carrying in the closed position;

– during current interruption.

The ability of the equipment to make, carry and break short-circuit currents is stated in terms of one or more of the following ratings:

– rated short-circuit making capacity (see 4.3.6.2);

– rated short-circuit breaking capacity (see 4.3.6.3);

– rated short-time withstand current (see 4.3.6.1);

– in the case of equipment co-ordinated with short-circuit protective devices (SCPDs):

a) rated conditional short-circuit current (see 4.3.6.4),

b) other types of co-ordination, specified solely in the relevant product standard.

For ratings and limiting values according to items a) and b) above, the manufacturer shall indicate the type and the characteristics (e.g. current rating, breaking capacity, cut-off current, I^2t) of the SCPD necessary for the protection of the equipment.

7.2.6 Switching overvoltages

Product standards may specify switching overvoltage tests if applicable.

In this case the test procedure and the requirements shall be defined in the product standard.

7.2.7 Leakage currents of equipment suitable for isolation

For equipment suitable for isolation and having a rated operational voltage U_e greater than 50 V, the leakage current shall be measured through each pole with the contacts in the open position.

The value of leakage current, with a test voltage equal to 1,1 times the rated operational voltage shall not exceed

– 0,5 mA per pole for equipment in a new condition;

– 2 mA per pole for equipment having been subjected to the making and breaking operations in accordance with the test requirements of the relevant product standard.

A leakage current of 6 mA at 1,1 times the rated operational voltage is a limiting value for equipment suitable for isolation which value shall not be exceeded under any circumstances. Tests to verify this requirement may be specified in the relevant product standard.

7.2.7DV D2 ***Modification of 7.2.7 by replacing it with the following:***

Leakage current requirements for equipment suitable for isolation do not apply.

7.2.8 Pole impedance

Where the pole impedance is given, it shall be tested according to 8.3.3.8.

7.2.9DV D2 *Add Clause 7.2.9DV to Clause 7.2 as follows:*

7.2.9DV.1 Breakdown of components

7.2.9DV.1.1 Devices with solid state circuits, other than those in 7.2.9DV.1.2, shall be tested in accordance with 8.2.7.4DV.4.

7.2.9DV.1.2 This test shall not be required when meeting the following conditions:

a) when circuit analysis indicates that no other component or portion of the circuit will be overloaded as a result of the open circuiting or short circuiting of another component;

b) for components in Class 2 circuits. In Mexico, this does not apply;

c) for components in Limited Voltage/Current, Limited Energy involving open circuit potentials less than or equal to 30 V ac or 42,4 V peak, and Limiting Impedance secondary circuits;

d) on power semiconductor devices when equivalent testing is accomplished during short circuit tests;

e) for components complying with requirements applicable to the component; or

f) for components that have previously been investigated and found suitable for the application.

7.3 Electromagnetic compatibility (EMC)

7.3DV D2 *Modification of 7.3 and all subclauses by adding the following:*

Electromagnetic compatibility (EMC) tests are optional.

7.3.1 General

For products falling within the scope of this standard, two sets of environmental conditions are considered and are referred to as

a) environment A;

b) environment B.

Environment A relates to low-voltage non-public or industrial networks/locations/installations including highly disturbing sources.

NOTE 1 – Environment A corresponds to equipment class A in CISPR 11.

Environment B relates to low-voltage public networks such as domestic, commercial and light industrial locations/installations. Highly disturbing sources such as arc welders are not covered by this environment.

NOTE 1 Environment A corresponds to equipment class A in CISPR 11.

Environment B relates to low-voltage public networks such as domestic, commercial and light industrial locations/installations. Highly disturbing sources such as arc welders are not covered by this environment.

NOTE 2 Environment B corresponds to equipment class B in CISPR 11.

For the purpose of this standard, the phrase “electronic circuit” excludes circuits in which all components are passive (including diodes, resistors, varistors, capacitors, surge suppressors, inductors).

7.3.2 Immunity

7.3.2.1 Equipment not incorporating electronic circuits

Equipment not incorporating electronic circuits is not sensitive to electromagnetic disturbances in normal service conditions, and therefore no immunity tests are required.

7.3.2.2 Equipment incorporating electronic circuits

Equipment incorporating electronic circuits shall have a satisfactory immunity to electromagnetic disturbances.

For the appropriate tests to verify the compliance with these requirements, see 8.4.

Specific performance criteria shall be given in the relevant product standard based on the acceptance criteria given in Table 24.

7.3.3 Emission

7.3.3.1 Equipment not incorporating electronic circuits

The requirements for electromagnetic emissions for equipment not incorporating electronic circuits are deemed to be satisfied, and no verification is necessary.

NOTE For equipment not incorporating electronic circuits, electromagnetic disturbances can only be generated by equipment during occasional switching operations. The duration of the disturbances is less than 200 ms in accordance with CISPR 22.

The frequency, the level and the consequences of these emissions are considered as part of the normal electromagnetic environment of low-voltage installations.

7.3.3.2 Equipment incorporating electronic circuits

7.3.3.2.1 Limits for high-frequency emissions

The high-frequency (greater than 9 kHz) continuous emissions from equipment incorporating electronic switching circuits shall not exceed the limits specified in the relevant product standard, based on CISPR 11 for environment A and for environment B.

NOTE One-time disturbances no longer than 200 ms need no further evaluation.

7.3.3.2.2 Limits for low-frequency emissions

For equipment which generates low frequency harmonics, where applicable, the requirements of IEC 61000-3-2 apply.

For equipment which generates low frequency voltage fluctuations, where applicable, the requirements of IEC 61000-3-3 apply.

8 Tests

8.1 Kinds of test

8.1.1 General

Tests shall be made to prove compliance with the requirements laid down in this standard, where applicable, and in the relevant product standard.

Tests are as follows:

– type tests (see 2.6.1) which shall be made on representative samples of each particular equipment;

– routine tests (see 2.6.2) which shall be made on each individual piece of equipment manufactured to this standard, where applicable, and the relevant product standard;

– sampling tests (see 2.6.3) which are made if called for in the relevant product standard. For sampling tests for clearance verification, see 8.3.3.4.3.

The above tests may consist of test sequences, according to the requirements of the relevant product standard.

Where such test sequences are specified in a product standard, tests, the result of which are not influenced by preceding tests and have no significance for subsequent tests of a given test sequence may be omitted from that test sequence, and made on separate new samples, by agreement with the manufacturer.

The product standard shall specify such tests, where applicable.

The tests shall be carried out by the manufacturer, at his works or at any suitable laboratory of his choice.

Where appropriate, subject to specification in the relevant product standard, and to agreement between manufacturer and user, special tests (see 2.6.4) may also be performed.

8.1.2 Type tests

Type tests are intended to verify compliance of the design of a given equipment with this standard, where applicable, and the relevant product standard.

They may comprise, as appropriate, the verification of

– constructional requirements;

– temperature-rise;

– dielectric properties (see 8.3.3.4.1, where applicable);

– making and breaking capacities;

– short-circuit making and breaking capacities;

– operating limits;

– operational performance;

– degree of protection of enclosed equipment;

– tests for EMC.

NOTE The above list is not exhaustive.

The type tests to which the equipment shall be submitted, the results to be obtained, and, if relevant, the test sequences and the number of samples, shall be specified in the relevant product standard.

8.1.3 Routine tests

Routine tests are intended to detect faults in materials and workmanship and to ascertain proper functioning of the equipment. They shall be made on each individual piece of equipment.

Routine tests may comprise

a) functional tests;

b) dielectric tests.

Details of the routine tests and the conditions under which they shall be made shall be stated in the relevant product standard.

8.1.4 Sampling tests

If engineering and statistical analysis show that routine tests (on each product) are not required, sampling tests may be made instead, if so stated in the relevant product standard.

The tests may comprise

a) functional tests;

b) dielectric tests.

Sampling tests may also be made to verify specific properties or characteristics of an equipment, either on the manufacturer's own initiative, or by agreement between manufacturer and user.

8.2 Compliance with constructional requirements

The verification of compliance with the constructional requirements stated in 7.1 concerns, for example

– the materials;

– the equipment;

– the degrees of protection of enclosed equipment;

– the mechanical and electrical properties of terminals;

– the actuator;

– the position indicating device (see 2.3.18).

8.2.1 Materials

8.2.1.1 Test of resistance to abnormal heat and fire

8.2.1.1.1 Glow-wire test (on equipment)

The glow-wire test shall be made according to IEC 60695-2-10 and IEC 60695-2-11 under the conditions specified in 7.1.2.2.

For the purpose of this test, a protective conductor is not considered as a current-carrying part.

NOTE If the test is to be made at more than one place on the same sample, care should be taken to ensure that any deterioration caused by previous tests does not affect the test to be made.

8.2.1.1.1ADV D2 *Add Clause 8.2.1.1.1ADV as follows:*

8.2.1.1.1ADV.1 Abnormal overload test (on equipment)

As an alternative to the glow-wire test in 8.2.1.1.1, a material may be evaluated with the end-product abnormal overload test specified in UL 746C.

8.2.1.1.2 Flammability, hot wire ignition and arc ignition tests (on materials)

Suitable specimens of the material shall be subjected to the following tests:

a) flammability test, in accordance with IEC 60695-11-10;

b) hot wire ignition (HWI) test, as described in Annex M;

c) arc ignition (AI) test, as described in Annex M.

The test c) is required only if the material is located within the 13 mm of arcing parts or live parts which are subject to loosening of connections. Materials located within 13 mm of arcing parts are exempt from this test if the equipment is subjected to make/break testing.

8.2.2 Equipment

Covered by the various subclauses of 8.2.

8.2.3 Enclosures for equipment

For the degrees of protection of enclosed equipment, see Annex C.

8.2.4 Mechanical and electrical properties of terminals

This subclause does not apply to aluminium terminals nor to terminals for connection of aluminium conductors.

8.2.4DV D2 *Modification of 8.2.4 by replacing it with the following:*

Requirements for screw-type terminals are defined in CSA C22.2 No. 14, NMX-J-543-ANCE, and UL 486E. Requirements for screwless/spring pressure terminals are defined in CSA C22.2 No. 158, CSA C22.2 No. 60947-7-1, UL 486E, UL 60947-7-1 and NMX-J-538/7-1-ANCE.

The Stress corrosion/moist ammonia or Stress corrosion/mercurous nitrate tests per CSA C22.2 No. 65 and UL 486E are not required for terminals.

8.2.4.1 General conditions for tests

Unless otherwise stated by the manufacturer, each test shall be made on terminals in a clean and new condition.

When tests are made with round copper conductors, these shall be of copper according to IEC 60028.

When tests are made with flat copper conductors, these shall have the following characteristics:

– minimum purity: 99,5 %;

– ultimate tensile strength: 200-280 N/mm^2;

– Vickers hardness: 40 to 65.

8.2.4.2 Tests of mechanical strength of terminals

Tests shall be made with the appropriate type of conductor having the maximum cross-section.

Screwless-type clamping unit according to 7.1.8.1 are tested with conductors of the maximum cross-section.

The conductor shall be connected and disconnected five times.

For screw-type terminals, the tightening torque shall be in accordance with Table 4 or 110 % of the torque specified by the manufacturer, whichever is the greater.

The test shall be conducted on two separate clamping units.

Where a screw has a hexagonal head with means for tightening with a screwdriver and the values in columns II and III are different, the test is made twice, first applying to the hexagonal head the torque specified in column III, and then, on another set of samples, applying the torque specified in column II by means of a screwdriver.

If the values in columns II and III are the same, only the test with the screwdriver is made.

Each time the clamping screw or nut is loosened, a new conductor shall be used for each tightening test.

During the test, clamping units and terminals shall not work loose and there shall be no damage, such as breakage of screws or damage to the head slots, threads, washers or stirrups that will impair the further use of the screwed connections.

8.2.4.3 Testing for damage to and accidental loosening of conductors (flexion test)

The test applies to terminals for the connection of unprepared round copper conductors, of number, cross-section and type (flexible and/or rigid (stranded and/or solid)), specified by the manufacturer.

NOTE An appropriate test for flat copper conductors may be made by agreement between manufacturer and user.

The following tests shall be carried out using two new samples with

a) the maximum number of conductors of the minimum cross-section connected to the terminal;

b) the maximum number of conductors of the maximum cross-section connected to the terminal;

c) the maximum number of conductors of the minimum and maximum cross-sections connected to the terminal.

Terminals intended for connection of either flexible or rigid (solid and/or stranded) conductors shall be tested with each type of conductor with different sets of samples.

Terminals intended for connection of both flexible or rigid (solid and/or stranded) conductors simultaneously shall be tested as stated in c) above.

The test is to be carried out with suitable test equipment. The specified number of conductors shall be connected to the terminal. The length of the test conductors should be 75 mm longer than the height *H* specified in Table 5. The clamping screws shall be tightened with a torque in accordance with Table 4 or with the torque specified by the manufacturer. The device tested shall be secured as shown in Figure 1.

Each conductor is subjected to circular motions according to the following procedure:

The end of the conductor under test shall be passed through an appropriate size bushing in a platen positioned at a height H below the equipment terminal, as given in Table 5. The other conductors shall be bent in order not to influence the result of the test. The bushing shall be positioned in the horizontal platen concentric with the conductor. The bushing shall be moved so that its centreline describes a circle of 75 mm diameter about its centre in the horizontal plane at 10 rpm ± 2 rpm. The distance between the mouth of the terminal and the upper surface of the bushing shall be within 15 mm of the height *H* in Table 5. The bushing is to be lubricated to prevent binding, twisting or rotation of the insulated conductor. A mass as specified in Table 5 is to be suspended from the end of the conductor. The test shall consist of 135 continuous revolutions.

During the test, the conductor shall neither slip out of the terminal nor break near the clamping unit.

Immediately after the flexion test, each conductor under test shall be submitted in the test equipment to the test of 8.2.4.4 (pull-out test).

8.2.4.4 Pull-out test

8.2.4.4.1 Round copper conductors

Following the test of 8.2.4.3, the pulling force given in Table 5 shall be applied to the conductor tested in accordance with 8.2.4.3.

The clamping screws shall not be tightened again for this test.

The force shall be applied without jerks for 1 min, in the direction of the axis of the conductor.

During the test, the conductor shall neither slip out of the terminal nor break near the clamping unit.

8.2.4.4.2 Flat copper conductors

A suitable length of conductor shall be secured in the terminal and the pulling force given in Table 6 applied without jerks for 1 min in a direction opposite to that of the insertion of the conductor.

During the test, the conductor shall neither slip out of the terminal nor break near the clamping unit.

8.2.4.5 Test for insertability of unprepared round copper conductors having the maximum cross-section

8.2.4.5.1 Test procedure

The test shall be carried out using the appropriate gauge form A or form B specified in Table 7.

The measuring section of the gauge shall be able to penetrate freely into the terminal aperture to the full depth of the terminal (see also note to Table 7).

Alternatively, the test can be carried out by inserting the largest conductor of type and rated cross-section among those recommended by the manufacturer, the diameter of which corresponds to the theoretical diameter according to Table 7a, after the insulation has been removed and the end has been reshaped. The stripped end of the conductor shall be able to enter completely within the clamping unit aperture, without use of undue force.

NOTE The manufacturer may specify the test method.

8.2.4.5.2 Construction of gauges

The construction of the gauges is shown in Figure 2.

Details of dimensions a and b and their permissible deviations are shown in Table 7. The measuring section of the gauge shall be made from gauge steel.

8.2.4.6 Tests for insertability of flat conductors with rectangular cross-section

Under consideration.

8.2.4.7 Electrical performance of screwless-type clamping units

Subclauses 9.8 of IEC 60999-1 and 9.8 of IEC 60999-2 apply.

NOTE 1 The terms “smallest cross-sectional area” and “largest cross-sectional area” of IEC 60999 series are respectively "minimum cross section" (2.3.24) and "maximum cross section" (2.3.35) defined in this standard.

NOTE 2 For the largest cross-sectional area the test current generally applied is I_{th} or I_{the} declared for the product. For the smallest cross-sectional area, the test current is given in Table 4 and Table 5 of IEC 60947-7-1:2009.

The detailed test requirements may be adapted in the product standards.

NOTE 3 The product standard should consider the practicality of the detailed test requirements.

8.2.4.8 Ageing test for screwless-type clamping units

Subclauses 9.10 of IEC 60999-1 and 9.10 of IEC 60999-2 apply.

NOTE 1 The terms “smallest cross-sectional area” and “largest cross-sectional area” of IEC 60999 series are respectively "minimum cross section" (2.3.24) and "maximum cross section" (2.3.35) defined in this standard.

NOTE 2 For the largest cross-sectional area the test current generally applied is I_{th} or I_{the} declared for the product. For the smallest cross-sectional area, the test current is given in Table 4 and Table 5 of IEC 60947-7-1:2009.

The detailed test requirements may be adapted in the product standards.

NOTE 3 The product standard should consider the practicality of the detailed test requirements.

8.2.5 Verification of the effectiveness of indication of the main contact position of equipment suitable for isolation

To verify the effectiveness of the indication of the main contact position as required by 7.1.7, all means of indication of contact position shall continue to function correctly after the operational performance type tests, and special durability tests if performed.

8.2.5.1 Condition of equipment for the tests

The condition of the equipment for the tests shall be stated in the relevant product standard.

8.2.5.2 Method of test

8.2.5.2.1 Dependent and independent manual operation

The force necessary to operate the device to the open position shall be measured at the extremity of the actuator. The measured force *F* shall be equal to the average value of maximum force obtained from three consecutive operations, with the device in a clean and new condition. This force *F* shall then be used for the establishment of the test force in Table 17.

With the equipment in the closed position, the fixed and moving contacts of the pole for which the test is deemed to be the most severe shall be fixed together, for example, by welding.

The actuator shall be submitted to a test force of 3*F* but which, however, shall not be less than the minimum nor more than the maximum values given in Table 17, corresponding to the type of actuator.

Where the device has more than one contact system in series, all contact systems that are in series shall be held in the closed position.

In the case of multiple tip contact systems, the least number of parallel contact tips shall be fixed together as necessary to hold the contact system closed in order to allow the test force to be applied without the contacts separating.

The appropriate means to keep the contact(s) closed and the number of contacts shall be specified by the manufacturer. The number of contacts and the method shall be stated in the report.

The test force shall be applied without shock to the extremity of the actuator, for a period of 10 s, in the direction to open the contacts.

The direction of the test force with respect to the actuator, as shown in Figure 16, shall be maintained throughout the test.

Verification shall be made according to 8.2.5.3.1.

8.2.5.2.2 Dependent power operation

With the equipment in the closed position, the fixed and moving contacts of the pole for which the test is deemed to be the most severe shall be fixed together, e.g. by welding.

Where the device has more than one contact system in series, all contact systems that are in series shall be held in the closed position.

In the case of multiple tip contact systems, the least number of parallel contact tips shall be fixed together as necessary to hold the contact system closed in order to allow the test force to be applied without the contacts separating.

The appropriate means to keep the contact(s) closed and the number of contacts shall be specified by the manufacturer. The number of contacts and the method shall be stated in the report.

The supply voltage to the power operator shall be applied at 110 % of its normal rated value to attempt to open the contact system of the equipment.

Three attempts to operate the equipment at 5 min intervals by the power operator shall be made, each for a period of 5 s, unless an associated protective device of the power operator limits the time to a shorter period.

Verification shall be made to 8.2.5.3.2.

NOTE In Canada and the United States of America devices meeting these requirements are not accepted as assuring isolation by themselves.

8.2.5.2.3 Independent power operation

With the equipment in the closed position, the fixed and moving contacts of the pole for which the test is deemed to be the most severe shall be fixed together, e.g. by welding.

Where the device has more than one contact system in series, all contact systems that are in series shall be held in the closed position.

In the case of multiple tip contact systems, the least number of parallel contact tips shall be fixed together as necessary to hold the contact system closed in order to allow the test force to be applied without the contacts separating.

The appropriate means to keep the contact(s) closed and the number of contacts shall be specified by the manufacturer. The number of contacts and the method shall be stated in the report.

The stored energy of the power operator shall be released to attempt to open the contact system of the equipment.

Three attempts to operate the equipment by releasing the stored energy shall be made.

Verification shall be made to 8.2.5.3.2.

NOTE In Canada and the United States of America devices meeting these requirements are not accepted as assuring isolation by themselves.

8.2.5.3 Condition of equipment during and after test

8.2.5.3.1 Dependent and independent manual operation

After the test, when the test force is no longer applied, the actuator being left free, the open position shall not be indicated by any of the means provided and the equipment shall not show any damage such as to impair its normal operation.

When the equipment is provided with a means of locking in the open position, it shall not be possible to lock the equipment while the test force is applied.

8.2.5.3.2 Dependent and independent power operation

During and after the test, the open position shall not be indicated by any of the means provided and the equipment shall not show any damage such as to impair its normal operation.

When the equipment is provided with means for locking in the open position, it shall not be possible to lock the equipment during the test.

8.2.6 Vacant

8.2.7 Conduit pull-out test, torque test and bending test with metallic conduits

The test shall be made with an appropriate sized metal conduit (300 ± 10) mm long.

The polymeric enclosure shall be installed according to the manufacturer's instructions, in the most unfavourable position.

The tests shall be made on the same conduit entry, this being the most unfavourable entry.

The tests shall be made in the sequence 8.2.7.1, 8.2.7.2 and 8.2.7.3.

8.2.7DV D2 ***Modification of 8.2.7 by replacing it with the following:***

Enclosure construction and performance requirements for metallic conduit entries are defined in CSA C22.2 No. 94.1, NMX-J-235/1-ANCE, and UL 50.

8.2.7.1 Pull-out test

The conduit shall be screwed without jerk into the entry with a torque equal to two-thirds of the values given in Table 22. A direct pull shall be applied, without jerk, to the conduit for 5 min.

Unless otherwise specified in the relevant product standard, the pulling force shall be according to Table 20.

After the test, the displacement of the conduit in relation with the entry shall be less than one thread depth and there shall be no evidence of damage impairing further use of the enclosure.

8.2.7.2 Bending test

A slowly increasing bending moment shall be applied without jerk to the free end of the conduit.

When the bending moment results in a deflection of the conduit of 25 mm per 300 mm length, or the bending moment has reached the value given in Table 21, the moment is maintained for 1 min. The test is then repeated in a perpendicular direction.

After the test there shall be no evidence of damage impairing further use of the enclosure.

8.2.7.3 Torque test

The conduit shall be tightened without jerk with a torque according to Table 22.

The torque test does not apply to an enclosure that is not provided with a pre-assembled conduit entry, and that has instructions stating that the conduit entry is to be mechanically connected to the conduit before being connected to the enclosure.

For enclosures provided with a single conduit connection up to and including 16 H, the tightening torque is reduced to 25 N·m.

After the test, it shall be possible to unscrew the conduit and there shall be no evidence of damage impairing further use of the enclosure.

8.2.7.4DV D2 *Add Clause 8.2.7.4DV as follows:*

8.2.7.4DV.1 Clamped joint test

8.2.7.4DV.1.1 A clamped joint between two insulators shall be tested using two samples. See Figure 24DV.

8.2.7.4DV.1.2 For the first sample, the clamped joint shall be opened by either loosening the clamping means to produce a space 3.2 mm wide, or by drilling a 3.2 mm diameter hole at the joint where the minimum spacing occurs. The drilled hole shall not decrease creepage or clearance distances between the opposite polarity parts as measured through the joint between the insulators. The 60-hertz dielectric breakdown voltage through this hole shall be determined by applying a gradually increasing voltage (500 volts per second) until breakdown occurs.

8.2.7.4DV.1.3 The second sample with the clamped joint intact shall be subjected to a gradually increasing 60 hertz voltage until 110 percent of the breakdown voltage, determined from the first sample, has been reached. When the breakdown voltage is less

than 4600 V rms, the voltage applied to the second sample shall be further increased to 5000 V rms and held for 1 second. The clamped joint complies with the requirement when there is no dielectric breakdown of the second sample.

8.2.7.4DV.2 Coil breakdown test

8.2.7.4DV.2.1 Three separate samples of the assembly of coil and frame shall be subjected to this test. While heated from the normal temperature-rise test, the coil terminals shall be connected to an alternating current source of twice the normal rated voltage at any frequency up to 400 hertz.

8.2.7.4DV.2.2 The required test voltage shall be obtained by starting at one-quarter or less of the full rated value and increasing to twice full rated value in not more than 15 seconds. After being held for 7200 electrical cycles or for 60 seconds, whichever is less, the voltage shall be reduced within 5 seconds to one-quarter or less of the maximum rated value and the circuit shall be opened.

8.2.7.4DV.2.3 While heated, following operation at 110 percent of its rated voltage, each of the three samples shall be subjected to the above test, except that the test voltage shall be 130 percent of the temperature-rise test voltage.

8.2.7.4DV.3 Wire flexing

8.2.7.4DV.3.1 The wiring to components mounted on a door shall be tested by opening the door as far as possible and then closing it for 500 cycles of operation. Restraints, such as a chain, shall remain in place. Following this test, the equipment shall be subjected to the dielectric voltage withstand test described in 8.3.3.4.1 applied between conductors and between conductors and ground.

8.2.7.4DV.4 Breakdown of components test

8.2.7.4DV.4.1 In Mexico and the United States, the breakdown of the component shall be simulated after the device is fully energized and in operation.

8.2.7.4DV.4.2 Components, such as capacitors or diodes, are short or open-circuited. For an open type device, a wire mesh cage that is 1.5 times the size of the device may be provided to simulate the intended enclosure. The outer enclosure or wire mesh cage (when provided) and any grounded or exposed dead-metal part shall be connected through a 30-ampere fuse to the supply B phase pole or neutral to ground.

8.2.7.4DV.4.3 A layer of surgical cotton shall be placed over all openings of ventilated equipment or totally around open devices. There shall be no emission of flame or molten metal nor ignition of cotton, and the 30-ampere fuse shall not open.

8.2.7.4DV.5 Printed wiring board abnormal operation test

8.2.7.4DV.5.1 As a result of this test:

a) The overcurrent protection in the branch circuit to which the equipment is connected shall not open.

b) The cheesecloth or tissue paper shall not glow or flame.

c) The 3-ampere fuse connected in the equipment grounding circuit shall not open.

8.2.7.4DV.5.2 Operation of an overcurrent protection device, other than the branch circuit overcurrent protection device, before any abnormal condition results is acceptable. If at any time a wire or a printed wiring board trace opens, the gap shall be electrically shorted, and the test continued. When the circuit is interrupted by the opening of a component, the test shall be repeated twice, using new components as necessary.

8.2.7.4DV.5.3 A sample of the equipment employing the printed wiring board shall be wired as intended to an electrical supply circuit sized and protected to simulate end-use conditions.

8.2.7.4DV.5.4 A 3-ampere fuse shall be connected between the supply circuit pole least likely to arc to ground and the outer enclosure and grounded or exposed dead metal parts. Where the enclosure is of polymeric construction, the enclosure shall be wrapped in metal foil.

8.2.7.4DV.5.5 The equipment shall be placed on a white-tissue-paper covered softwood surface. A single layer of cheesecloth shall be draped loosely over the entire enclosure.

8.3 Performance

8.3.1 Test sequences

Where applicable, the relevant product standard shall specify the test sequences to which the equipment is to be submitted.

8.3.2 General test conditions

NOTE Tests according to the requirements of this standard do not preclude the need for additional tests concerning equipment incorporated in assemblies, for example tests in accordance with IEC 61439 series.

8.3.2.1 General requirements

The equipment to be tested shall agree in all its essential details with the design of the type which it represents.

Unless otherwise stated in the relevant product standard, each test, whether individual or test sequence, shall be made on equipment in a clean and new condition.

Unless otherwise stated, the tests shall be made with the same kind of current (and, in the case of a.c., at the same rated frequency and with the same number of phases) as in the intended service.

The relevant product standard shall specify those values of test quantities not specified in this standard.

If, for convenience of testing, it appears desirable to increase the severity of a test (e.g. to adopt a higher rate of operation in order to reduce the duration of the test), this may be done only with the consent of the manufacturer.

Equipment under test shall be mounted complete on its own support or an equivalent support and connected as in normal service, in accordance with the manufacturer's instructions and under the ambient conditions stated in 6.1.

The tightening torques to be applied to the terminal screws shall be in accordance with the manufacturer's instructions or, in the absence of such instructions, in accordance with Table 4.

Equipment having an integral enclosure (see 2.1.17) shall be mounted complete and any opening normally closed in service shall be closed for tests.

Equipment intended for use only in an individual enclosure shall be tested in the smallest of such enclosures stated by the manufacturer.

All other equipment shall be tested in free air. If such equipment may also be used in specified individual enclosures and has been tested in free air, it shall be additionally tested in the smallest of such enclosures stated by the manufacturer, for specific tests which shall be specified in the relevant product standard and stated in the test report.

However, if such equipment may also be used in specified individual enclosures and is tested throughout in the smallest of such enclosures stated by the manufacturer, the tests in free air need not be made provided that such enclosure is bare metallic, without insulation. Details, including the dimensions of the enclosure, shall be stated in the test report.

For the test in free air, unless otherwise specified in the relevant product standard, for the test concerning making and breaking capacities and performance under short-circuit conditions, a metallic screen shall be placed at all points of the equipment likely to be a source of external phenomena capable of producing a breakdown, in accordance with the arrangements and distances specified by the manufacturer. Details, including distance from the equipment under test to the metallic screen, shall be stated in the test report.

The characteristics of the metallic screen shall be as follows:

− structure: woven wire mesh; or

perforated metal; or

expanded metal;

− material: steel;

− thickness or diameter of material: 1,5 mm minimum;

− ratio hole area/total area: 0,45 – 0,65;

− size of hole: not exceeding 30 mm^2;

− coating: bare, or conductive plating;

− resistance: shall be included in the calculation for the prospective fault current in the fusible element circuit (see 8.3.3.5.2 g) and 8.3.4.1.2 d)), measured from the furthest point on the metallic screen likely to be reached by arc emissions.

Maintenance or replacement of parts is not permitted, unless otherwise specified in the relevant product standard.

The equipment may be operated without load prior to beginning a test.

For the tests, the actuating system of mechanical switching devices shall be operated as for the intended use in service stated by the manufacturer and at the rated values of control quantities (such as voltage or pressure), unless otherwise specified in this standard or the relevant product standard.

8.3.2.1DV D2 ***Modification of 8.3.2.1 by adding Subclauses 8.3.2.1DV.1 to 8.3.2.1DV3 as follows:***

8.3.2.1DV.1 Mounting and wiring

8.3.2.1DV.1.1 An open type device shall be mounted in an enclosure representative of the intended use. The maximum enclosure dimensions shall be determined by one of the following methods:

a) 150 percent of the dimensions of the device, that is, length, width, and height;

b) The dimensions needed to meet the wire-bending space that are specified in Annex DVA, Table DVA.3, Ref. No. 4;

c) The intended enclosure, such as a standard outlet box; or

d) An enclosure larger than indicated in Items (a) – (c) when the size is marked on the device or on a separate instruction sheet.

8.3.2.1DV.2 Frequency and voltage

8.3.2.1DV.2.1 Unless otherwise indicated, the tests shall be conducted at rated frequency at the applicable voltage specified in Table 28DV.

8.3.2.1DV.3 Temperature or current sensitive devices

8.3.2.1DV.3.1 Temperature or current sensitive devices or systems that result in termination of a test shall be additionally evaluated for the application.

8.3.2.2 Test quantities

8.3.2.2.1 Values of test quantities

All the tests shall be made with the values of test quantities corresponding to the ratings assigned by the manufacturer, in accordance with the relevant tables and data of the relevant product standard.

8.3.2.2.2 Tolerances on test quantities

The test recorded in the test report shall be within the tolerances given in Table 8, unless otherwise specified in the relevant subclauses. However, with the agreement of the manufacturer, the tests may be made under more severe conditions than those specified.

8.3.2.2.3 Recovery voltage

a) Power-frequency recovery voltage

For all breaking capacity and short-circuit breaking capacity tests, the value of the powerfrequency recovery voltage shall be 1,05 times the value of the rated operational voltage as assigned by the manufacturer or as specified in the relevant product standard.

NOTE 1 The value of 1,05 times the rated operational voltage for the power frequency recovery voltage, together with the test voltage tolerance according to Table 8, is deemed to cover the effects of variations of the supply network voltage under normal service conditions, according to IEC 60038.

NOTE 2 This may require that the applied voltage be increased but the prospective peak making current should not be exceeded without the consent of the manufacturer.

NOTE 3 The upper limit of the power-frequency recovery voltage may be increased with the approval of the manufacturer (see 8.3.2.2.2).

b) Transient recovery voltage

Transient recovery voltages, where required in the relevant product standard, are determined according to 8.3.3.5.2.

8.3.2.3 Evaluation of test results

Behaviour of the equipment during the tests and its condition after the tests shall be specified in the relevant product standard. For short-circuit tests, see also 8.3.4.1.7 and 8.3.4.1.9.

8.3.2.4 Test reports

Written reports on type tests proving compliance with the relevant product standard shall be made available by the manufacturer. The details of test arrangements such as type and size of the enclosure, if any, size of conductors, distance from the live parts to the enclosure or to parts normally earthed in service, method of operation of the actuating system, etc., shall be given in the test report.

Test values and parameters shall form part of the test report.

8.3.3 Performance under no-load, normal load and overload conditions

8.3.3.1 Operation

Tests shall be made to verify that the equipment operates correctly according to the requirements of 7.2.1.1.

8.3.3.2 Operating limits

8.3.3.2.1 Power operated equipment

It shall be verified that the equipment opens and closes correctly within the limiting values of the control quantities, such as voltage, current, air pressure and temperatures, specified in the relevant product standard. Tests are made with no current flowing through the main circuit, unless otherwise specified.

In the case of a power operated equipment with electronically controlled electromagnet, supplied with a.c., where a drop out range is declared with limits between 75 % to 10 % of their rated control circuit supply voltage U_s, the equipment shall, in addition, be submitted to the capacitive drop out test as follows:

A capacitor C shall be inserted in series in the supply circuit U_s, the total length of the connecting conductors being ≤3 m. The capacitor is short-circuited by a switch of negligible impedance. The supply voltage shall then be adjusted to 110 % U_s.

It shall be verified that the equipment drops out when the switch is operated to the open position.

The value of the capacitor shall be

$$C = 30 + 200\,000 / (f \times U)$$

where

C is expressed in nF;

f is the minimum rated frequency expressed in Hz;

U is the maximum value of U_s expressed in V.

For example for a coil rated 12...24 V – 50 Hz, the capacitor value is 196 nF (calculation made with U_s max).

The test voltage is the highest value of the declared rated supply voltage range U_s.

NOTE The value of the capacitor simulates a typical control wiring of 100 m long cable of 1,5 mm^2 (0,3 nF/m that is 30 nF for 100 m) connected to a static output having a 1,3 mA leakage current (200 000 in the formula ≈ 10 E+9 *1,3 E-3/2*π).

8.3.3.2.2 Relays and releases

The operating limits of relays and releases shall comply with the requirements of 7.2.1.3, 7.2.1.4 and 7.2.1.5 and shall be verified according to the test procedure defined in the relevant product standard.

For undervoltage relays and releases, see 7.2.1.3.

For shunt releases, see 7.2.1.4.

For current operated relays and releases, see 7.2.1.5.

8.3.3.3 Temperature-rise

8.3.3.3.1 Ambient air temperature

The ambient air temperature shall be recorded during the last quarter of the test period by at least two temperature sensing means, e.g. thermometers or thermocouples, equally distributed around the equipment at about half its height and at a distance of about 1 m from the equipment. The temperature sensing means shall be protected against air currents, heat radiation and indicating errors due to rapid temperature changes.

During the test, the ambient air temperature shall be between +10 °C and +40 °C and shall not vary by more than 10 K. The ambient temperature shall not vary by more than 3 K during the last quarter of the test or the last hour of the test, whichever is the shorter. The test shall be conducted until this condition is achieved.

8.3.3.3.1DV D2 *Modification of 8.3.3.3.1 by adding the following:*

8.3.3.3.1DV.1 Enclosed equipment shall be tested in the enclosure provided by the manufacturer. Open type equipment shall be tested in an enclosure as specified in 8.3.2.1DV.1.1. Open type equipment may be tested without an enclosure when marked with a surrounding air temperature rating.

8.3.3.3.1DV.2 The temperature-rise test shall be conducted with the equipment placed in:

a) An ambient in accordance with 7.2.2DV.1; or

b) A non-air circulating test chamber with the ambient temperature of the test chamber adjusted to the rated ambient.

8.3.3.3.2 Measurement of the temperature of parts

For parts other than coils, the temperature of the different parts shall be measured by suitable temperature sensing means at those points most likely to attain the maximum temperature; these points shall be stated in the test report.

The oil temperature of oil-immersed equipment shall be measured at the upper part of the oil; this measurement may be made by means of a thermometer.

The temperature sensing means shall not significantly affect the temperature-rise.

Good thermal conductivity between the temperature sensing means and the surface of the part under test shall be ensured.

For electromagnet coils, the method of measuring the temperature by variation of resistance shall generally be used. Other methods are permitted only if it is impracticable to use the resistance method, for example for electronically controlled electromagnet. When measured by another method than the resistance method the limits of temperature rise permitted shall be adjusted accordingly. The product standard shall state the method and the limits.

In the case of an electronically controlled electromagnet, coil temperature measuring by variation of resistance may be impracticable; in such a case, other methods are permitted, e.g. thermocouples or other suitable methods. When measured by another method than the resistance method the limits of temperature rise permitted shall be adjusted accordingly. The product standard shall state the method and the limits.

The temperature of the coils before beginning the test shall not differ from that of the surrounding medium by more than 3 K.

For copper conductors, the value of the hot temperature T_2, may be obtained from the value of the cold temperature T_1, as a function of the ratio of the hot resistance R_2 to the cold resistance R_1 by the following formula:

$$T_2 = \frac{R_2}{R_1}(T_1 + 234{,}5) - 234{,}5$$

where T_1 and T_2 are expressed in degrees Celsius.

The test shall be made for a time sufficient for the temperature-rise to reach a steady-state value, but not exceeding 8 h. It is assumed that a steady state is reached when the variation does not exceed 1 K per hour.

8.3.3.3.3 Temperature-rise of a part

The temperature-rise of a part is the difference between the temperature of the part measured in accordance with 8.3.3.3.2, and the ambient air temperature measured in accordance with 8.3.3.3.1.

8.3.3.3.4 Temperature-rise of the main circuit

The equipment shall be mounted as specified in 8.3.2.1 and shall be protected against abnormal external heating or cooling.

For the conventional thermal current test (free air or enclosed), equipment having an integral enclosure and equipment only intended for use with a specified type of enclosure shall be tested in its enclosure. No opening giving false ventilation shall be allowed.

Equipment intended for use with more than one type of enclosure shall be tested either in the smallest enclosure stated by the manufacturer to be suitable or tested without an enclosure. If tested without an enclosure the manufacturer shall be prepared to state a value of conventional enclosed thermal current (see 4.3.2.2).

For tests with multiphase currents, the current shall be balanced in each phase within ±5 %, and the average of these currents shall be not less than the appropriate test current.

Unless otherwise specified in the relevant product standard, the temperature-rise test of the main circuit is made at one or both of the conventional thermal currents, as defined in 4.3.2.1 and 4.3.2.2 and may be made at any convenient voltage.

When the heat exchange between the main circuit, the control circuit and the auxiliary circuits may be of significance, the temperature-rise tests stated in 8.3.3.3.4, 8.3.3.3.5, 8.3.3.3.6 and 8.3.3.3.7 shall be made simultaneously, in so far as this is allowed by the relevant product standard.

Tests on d.c. rated equipment may be made with an a.c. supply for convenience of testing, but only with the consent of the manufacturer.

In the case of multipole equipment fitted with identical poles and tested with a.c. the test may be carried out, subject to the manufacturer's agreement, with single-phase current, with all poles connected in series provided that magnetic effects can be neglected.

In the case of three-pole equipment provided with a neutral pole different from the phase poles, the test shall comprise

– a three-phase test on the three identical poles;

– a single-phase test on the neutral pole connected in series with the adjacent pole, the value of the test quantities being determined according to the value of the conventional thermal current (free air or enclosed) of the neutral pole (see 7.1.9).

Equipment provided with short-circuit protective devices shall be tested according to the requirements given in the relevant product standard.

At the end of the test, the temperature-rise of the different parts of the main circuit shall not exceed the values given in Table 2 and Table 3, unless otherwise specified in the relevant product standard.

Depending on the value of the conventional thermal current (free air or enclosed), one of the following test connection arrangements shall be used:

i) For values of test current up to and including 400 A:

a) The connections shall be single-core, PVC insulated, copper conductors with crosssections as given in Table 9.

b) The connections shall be in free air, and spaced at approximately the distance existing between the terminals.

c) For single-phase or multi-phase tests the minimum length of any temporary connection from an equipment terminal to another terminal or to the test supply or to a star point shall be

– 1 m for cross-sections up to and including 35 mm^2 (or AWG 2);

– 2 m for cross-sections larger than 35 mm^2 (or AWG 2).

ii) For values of test current higher than 400 A but not exceeding 800 A:

a) The connections shall be single-core, PVC insulated, copper conductors with crosssectional areas as given in Table 10, or the equivalent copper bars given in Table 11, as recommended by the manufacturer.

b) The connections specified in a) shall be spaced at approximately the same distance as that between the terminals. Copper bars shall be painted matt black. Multiple parallel conductors per terminal shall be bunched together and arranged with approximately 10 mm air space between each other. Multiple copper bars per terminal shall be spaced at a distance approximately equal to the bar thickness. If the sizes stated for the bars are not suitable for the terminals, or are not available, other bars having approximately the same cross-sections and approximately the same or smaller cooling areas may be used. Copper conductors or bars shall not be laminated.

c) For single-phase or multi-phase tests the minimum length of any temporary connection from the equipment terminal to another terminal or to the test supply shall be 2 m. The minimum length to a star point may be reduced to 1,2 m.

iii) For values of test current higher than 800 A but not exceeding 3 150 A:

a) The connections shall be copper bars of the sizes stated in Table 11 unless the equipment is designed only for cable connection. In this case, the size and arrangement of the cables shall be as specified by the manufacturer.

b) Copper bars shall be spaced at approximately the same distance as that between the terminals. Copper bars shall be painted matt black. Multiple copper bars per terminal shall be spaced at a distance approximately equal to the bar thickness. If the sizes stated for the bars are not suitable for the terminals, or are not available, other bars having approximately the same or smaller cooling areas may be used. Copper bars shall not be laminated.

c) For single-phase or multi-phase tests the minimum length of any temporary connection from an equipment terminal to another terminal or to the supply shall be 3 m, but this can be reduced to 2 m provided that the temperature-rise at the supply end of the connection is not more than 5 K below the temperature-rise in the middle of the connection length. The minimum length to a star point shall be 2 m.

iv) For values of test current higher than 3 150 A:

Agreement shall be reached between manufacturer and user on all relevant items of the test, such as: type of supply, number of phases and frequency (where applicable), cross-sections of test connections, etc. This information shall form part of the test report.

8.3.3.3.4DV D2 ***Modification of 8.3.3.3.4 by adding the following:***

8.3.3.3.4DV.1 Conductor size selection for testing

8.3.3.3.4DV.1.1 Equipment shall be tested with 1.2 meters of conductor attached to each field-wiring terminal.

8.3.3.3.4DV.1.2 Wire shall be sized in accordance with Clause 7.1.8.2DV.

8.3.3.3.4DV.1.3 When there is only provision for the connection of bus bars to equipment rated at 450 amperes or more, copper bus bars specified in Table 26DV (or bus bars with the equivalent cross-sectional area) shall be used.

8.3.3.3.5 Temperature-rise of control circuits

The temperature-rise tests of control circuits shall be made with the specified current and, in the case of a.c., at the rated frequency. Control circuits shall be tested at their rated voltage.

Circuits intended for continuous operation shall be tested for a sufficient time for the temperature-rise to reach a steady-state value.

Circuits for intermittent duty shall be tested as prescribed in the relevant product standard.

At the end of these tests the temperature-rise of the different parts of the control circuits shall not exceed the values specified in 7.2.2.5, unless otherwise specified in the relevant product standard.

8.3.3.3.6 Temperature-rise of coils of electromagnets

Coils and electromagnets shall be tested according to the conditions given in 7.2.2.6.

They shall be tested for a sufficient time for the temperature-rise to reach a steady-state value.

The temperature shall be measured when thermal equilibrium is reached in both the main circuit and the coil of the electromagnet.

Coils and electromagnets of equipment intended for intermittent duty shall be tested as prescribed in the relevant product standard.

At the end of these tests the temperature-rise of the different parts shall not exceed the values specified in 7.2.2.6.

8.3.3.3.7 Temperature-rise of auxiliary circuits

The temperature-rise tests of auxiliary circuits shall be made under the same conditions as those specified in 8.3.3.3.5, but may be carried out at any convenient voltage.

At the end of these tests the temperature-rise of the auxiliary circuits shall not exceed the values specified in 7.2.2.7.

8.3.3.4 Dielectric properties

8.3.3.4.1 Type tests

1) General conditions for withstand voltage tests

The equipment to be tested shall comply with the general requirements of 8.3.2.1.

If the equipment is to be used without an enclosure, it shall be mounted on a metal plate and all exposed conductive parts (frame, etc.) intended to be connected to the protective earth in normal service shall be connected to that plate.

When the base of the equipment is of insulating material, metallic parts shall be placed at all of the fixing points in accordance with the conditions of normal installation of the equipment and these parts shall be considered as part of the frame of the equipment.

Any actuator of insulating material and any integral non-metallic enclosure of equipment intended to be used without an additional enclosure shall be covered by a metal foil and connected to the frame or the mounting plate. The foil shall only be applied to those parts of surface which can be touched with the standard test finger during operation or adjustment of the equipment. If the insulation part of an integral enclosure cannot be touched by the standard test finger due to the presence of an additional enclosure, no foil shall be required.

NOTE 1 This corresponds to accessible parts by the operator during operation or adjustment of the equipment (for example, actuator of a push-button). Annex R gives guidance for application of the metal foil on accessible parts during operation or adjustment.

When the dielectric strength of the equipment is dependent upon the taping of leads or the use of special insulation, such taping or special insulation shall also be used during the tests.

For the dielectric test between phases, all circuits between these phases may be disconnected for the test.

NOTE 2 The purpose of this test is to check the functional insulation only.

When the circuits of equipment include devices such as motors, instruments, snap switches, capacitors and solid state devices which, according to their relevant specifications, have been subjected to dielectric test voltages lower than those specified in this standard, such devices shall be disconnected for the test.

Where the control circuit normally connected to the main circuit is disconnected, the method used to maintain the main contacts closed shall be indicated in the test report.

For the dielectric test between phase and earth, all circuits shall be connected.

NOTE 3 The connection of all circuits for this test takes into account the function of protection against electric shock of the insulation between phase and earth.

Printed circuit boards and modules with multi-point connectors may be disconnected or replaced by dummies during the insulation test. This does not apply, however, to auxiliaries for which, in case of an insulation fault, voltage may pass onto accessible parts not connected to the housing or from the side of higher voltage to the side of lower voltage, e.g. auxiliary transformers, measuring equipment, pulse transformers, the insulation stress of which is equal to that for the main circuit.

2) Verification of impulse withstand voltage

a) General

The equipment shall comply with the requirements stated in 7.2.3.1.

The verification of the insulation is made by a test at the rated impulse withstand voltage.

If equipment contains any part for which the dielectric properties are not sensitive to altitude (e.g. optocouplers, encapsulated parts), then the verification of the insulation may be alternatively performed by a test at the rated impulse withstand voltage without application of the altitude correction factor. These parts shall then be disconnected and the remainder of the equipment shall be tested with the rated impulse withstand voltage using the altitude correction factor.

Clearances equal to or larger than the values of case A of Table 13 may be verified by measurement, according to the method described in Annex G.

b) Test voltage

The test voltage shall be that specified in 7.2.3.1.

For equipment incorporating overvoltage suppressing means, the energy content of the test current shall not exceed the energy rating of the overvoltage suppressing means. The latter shall be suitable for the application.

NOTE 1 Such ratings are under consideration.

The test equipment shall be calibrated to produce a 1,2/50 μs waveform as defined in IEC 61180. The output is then connected to the equipment to be tested and the impulse applied five times for each polarity at intervals of 1 s minimum. The influence of the equipment under test on the waveshape, if any, is ignored.

If, in the course of a test procedure, repeated dielectric testing is required, the relevant product standard shall state the dielectric test conditions.

NOTE 2 An example of test equipment is under consideration.

c) Application of test voltage

With the equipment mounted and prepared as specified in item a) above, the test voltage is applied as follows:

i) between all the terminals of the main circuit connected together (including the control and auxiliary circuits connected to the main circuit) and the enclosure or mounting plate, with the contacts in all normal positions of operation;

ii) between each pole of the main circuit and the other poles connected together and to the enclosure or mounting plate, with the contacts in all normal positions of operation;

iii) between each control and auxiliary circuit not normally connected to the main circuit and:

– the main circuit,

– the other circuits

– the exposed conductive parts,

– the enclosure or mounting plate,

which, wherever appropriate, may be connected together;

iv) for equipment suitable for isolation, across the poles of the main circuit, the line terminals being connected together and the load terminals connected together.

The test voltage shall be applied between the line and load terminals of the equipment with the contacts in the open position and its value shall be as specified in item 1) b) of 7.2.3.1.

For equipment not suitable for isolation, the requirements for testing with the contacts in the open position shall be stated in the relevant product standard.

d) Acceptance criteria

There shall be no unintentional disruptive discharge during the tests.

NOTE 1 An exception is an intentional disruptive discharge, for example by transient overvoltage suppressing means.

NOTE 2 The term "disruptive dicharge" related to phenomena associated with the failure of insulation under electrical stress, in which the discharge completely bridges the insulation under test, reducing the voltage between the electrodes to zero or nearly to zero.

NOTE 3 The term "sparkover" is used when a disruptive discharge occurs in a gaseous or liquid dielectric.

NOTE 4 The term "flashover" is used when a disruptive discharge occurs over the surface of a dielectric in a gaseous or liquid medium.

NOTE 5 The term "puncture" is used when a disruptive discharge occurs through a solid dielectric.

NOTE 6 A disruptive discharge in a solid dielectric produces permanent loss of dielectric strength; in a liquid or gaseous dielectric, the loss may be only temporary.

3) Power-frequency withstand verification of solid insulation

a) General

This test applies to the verification of solid insulation and the ability to withstand temporary overvoltages.

The values of Table 12A are deemed to cover the ability to withstand temporary overvoltages (see the footnote b of Table 12A).

b) Test voltage

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

NOTE "practically sinusoidal" means that the ratio between the peak value and the r.m.s. value is √2 ±3 %.

The high-voltage transformer used for the test shall be so designed that, when the output terminals are short-circuited after the output voltage has been adjusted to the appropriate test voltage, the output current shall be at least 200 mA.

The overcurrent relay shall not trip when the output current is less than 100 mA.

The value of the test voltage shall be as follows:

i) for the main circuit, and for the control and auxiliary circuits, in accordance with Table 12A. The uncertainty of measurement of the test voltage shall not exceed ±3 %.

ii) if an alternating test voltage cannot be applied, for example due to EMC filter components, a direct test voltage may be used having the value of Table 12A, third column. The uncertainty of measurement of the test voltage shall not exceed ±3 %.

c) Application of test voltage

The test voltage shall be applied to for 60 s in accordance with items i), ii) and iii) of 2) c) above.

NOTE For devices already type-tested according to this standard and its Amendment 1 or earlier, a retesting according to 60 s is not necessary.

d) Acceptance criteria

During the test, no flashover, breakdown of insulation either internally (puncture) or externally (tracking) or any other manifestation of disruptive discharge shall occur. Any glow discharge shall be ignored.

Components connected between phase and earth may be damaged during the tests but such failure shall not result in a condition that would lead to a hazardous situation. Product standards may give specific acceptance criteria.

NOTE The voltage levels to earth are based on IEC 60664-1 under worst case conditions which generally do not occur in practice.

4) Power-frequency withstand verification after switching and short-circuit tests

a) General

The test should be performed on the equipment whilst it remains mounted for the switching or short-circuit tests. If this is not practicable, it may be disconnected and removed from the test circuit, although measures shall be taken to ensure that this does not influence the result of the test.

b) Test voltage

The requirements of 3) b) above shall apply except that the value of the test voltage shall be 2 U_e with a minimum of 1 000 V r.m.s.
The requirements of 3) b) above shall apply except that the value of the test voltage shall be 2 U_e with a minimum of 1 000 V r.m.s. or 1 415 V d.c. if an a.c. voltage test cannot be applied. The value of U_e referred to is that at which switching and/or shortcircuit tests have been performed.

NOTE The product standards should be adapted to this decision when reprinted.

c) Application of test voltage

The requirements of 3) c) above shall apply. The application of the metal foil, according to 8.3.3.4.1 1), is not required.

d) Acceptance criteria

The requirements of 3) d) above shall apply.

5) Vacant

6) Verification of d.c. withstand voltage

Equipment with d.c. ratings only shall be tested with d.c. test voltage

7) Verification of creepage distances

The shortest creepage distances between phases, between circuit conductors at different voltages and live and exposed conductive parts shall be measured. The measured creepage distance with respect to material group and pollution degree shall comply with the requirements of 7.2.3.4.

8) Verification of leakage current of equipment suitable for isolation

Tests shall be specified in the relevant product standard.

8.3.3.4.1DV.1 D2 *Modification of 8.3.3.4.1(1) by adding the following:*

Testing with metal foil is not required.

8.3.3.4.1DV.2 D2 *Modification of 8.3.3.4.1(3)(a) by replacing the second paragraph with the following:*

The test potential shall be in accordance with Table 29DV.

8.3.3.4.1DV.3 D2 *Modification of 8.3.3.4.1(3)(b) by adding the following:*

The transformer used for the test shall have either a capacity of not less than 500 VA or a voltmeter is provided to directly measure the secondary output voltage.

8.3.3.4.2 Routine tests

1) Impulse withstand voltage

The tests shall be performed in accordance with item 2) of 8.3.3.4.1. The test voltage shall be not less than 30 % of the rated impulse withstand voltage (without altitude correction factor) or 2 U_i whichever is the higher.

2) Power-frequency withstand voltage

a) Test voltage

The test apparatus shall be the same as that stated in item 3) b) of 8.3.3.4.1 except that the overcurrent trip should be set at 25 mA.

However, at the discretion of the manufacturer for safety reasons, test apparatus of a lower power or trip setting may be used, but the short-circuit current of the test apparatus shall be at least eight times the nominal trip setting of the overcurrent relay, for example for a transformer with a short-circuit current of 40 mA, the maximum trip setting of the overcurrent relay shall be 5 mA ± 1 mA.

NOTE 1 The capacitance of the equipment may be taken into account.

The value of the test voltage shall be 2 U_e with a minimum of 1 000 V r.m.s.

NOTE 2 In the case of multiple values, U_e refers to the highest value marked on the equipment or given in the manufacturer's documentation.

b) Application of test voltage

The requirements of item 3) c) of 8.3.3.4.1 shall apply, except that the duration of the test voltage shall be 1 s only.

However, as an alternative, a simplified test procedure may be used if it is considered to subject the insulation to an equivalent dielectric stress.

c) Acceptance criteria

The overcurrent relay shall not trip.

3) Combined impulse voltage and power-frequency withstand voltage

Product standards may specify if the tests of items 1) and 2) above may be replaced by a single power frequency withstand test where the peak value of the sinusoidal wave corresponds to the value stated in items 1) or 2), whichever is the higher.

4) In no case the application of the metal foil according to 8.3.3.4.1 1) is required.

8.3.3.4.2DV D2 *Modification of 8.3.3.4.2 by replacing it with the following:*

Routine tests are optional.

8.3.3.4.3 Sampling tests for verification of clearances

1) General

These tests are intended to verify the maintaining of the design conformity regarding clearances and are only applicable to equipment with clearances smaller than those corresponding to Table 13, case A.

2) Test voltage

The test voltage shall be that corresponding to the rated impulse withstand voltage.

The relevant product standards shall state sampling plans and procedure.

3) Application of test voltage

The requirements of item 2) c) of 8.3.3.4.1 shall apply, except that the metal foil need not be applied to the actuator or the enclosure.

4) Acceptance criteria

No disruptive discharge shall occur.

8.3.3.4.4 Tests for equipment with protective separation

Tests for equipment with protective separation are given in Annex N.

8.3.3.5 Making and breaking capacities

8.3.3.5.1 General test conditions

Tests for verification of making and breaking capacities shall be made according to the general test requirements stated in 8.3.2.

The tolerances for individual phases shall be in accordance with Table 8, unless otherwise stated.

Four-pole equipment shall be tested as three-pole equipment with the unused pole, which in the case of equipment provided with a neutral pole is the neutral pole, connected to the frame. If all poles are identical, one test on three adjacent poles is sufficient. If not, an additional test shall be made between the neutral pole and the adjacent pole, according to Figure 4, at the rated current of the neutral pole and at the phase-to-neutral voltage, with the other two unused poles connected to the frame.

For transient recovery voltages, in the case of breaking capacity tests under normal load and overload conditions, values shall be specified in the relevant product standard.

8.3.3.5.2 Test circuit

a) Figure 3, Figure 4, Figure 5 and Figure 6 give the diagrams of the circuits to be used for the tests concerning

– single-pole equipment on single-phase a.c. or d.c. (Figure 3);

– two-pole equipment on single-phase a.c. or d.c. (Figure 4);

– three-pole equipment or three single-phase equipment on three-phase a.c. (Figure 5);

– four-pole equipment on three-phase four-wire a.c. (Figure 6);

A detailed diagram of the circuit used for the test shall be given in the test report.

b) The prospective current at the supply terminals of the equipment shall be not less than 10 times the test current or 50 kA, whichever is the lower.

c) The test circuit comprises the supply source, the equipment D under test and the load circuit.

d) The load circuit shall consist of resistors and air-cored reactors in series. Air-cored reactors in any phase shall be shunted by resistors taking approximately 0,6 % of the current through the reactor.

However, where a transient recovery voltage is specified, instead of the 0,6 % shunt resistors, parallel resistors and capacitors shall be included across the load, the complete load circuit being as shown in Figure 8a and Figure 8b

NOTE For d.c. tests where L/R > 10 ms an iron-cored reactor may be used with series resistors, if necessary, verifying with an oscilloscope that the L/R value is as specified ($^{+15}_{0}$ %), and that the time required to obtain 95 % of the current made is equal to 3 × L/R ± 20 %.

Where a transient inrush current is specified (e.g. utilization categories AC-5b, AC-6 and DC-6), a different type of load may be specified in the relevant product standard.

e) The loads shall be adjusted to obtain, at the specified voltage:

– the value of current and power-factor or time-constant specified in the relevant product standard;

– the value of the power-frequency recovery voltage;

– where specified, the oscillatory frequency of the transient recovery voltage and the value of the factor γ.

The factor γ is the ratio of the value U_1 of the highest peak of the transient recovery voltage to the instantaneous value U_2, at the instant of current zero, of the component of the recovery voltage at power frequency (see Figure 7).

f) The test circuit shall be earthed at one point only. This could be either the load star-point or the supply star-point. The position of this point shall be stated in the test report.

NOTE The sequence of connection of R and X (see Figure 8a and Figure 8b) should not be changed between the adjustment and the test.

g) All parts of the equipment normally earthed in service, including the enclosure or the screens, shall be insulated from earth and connected as indicated in Figure 3, Figure 4, Figure 5 or Figure 6.

This connection shall comprise a fusible element F consisting of a copper wire 0,8 mm in diameter and at least 50 mm long, or an equivalent fusible element, for the detection of the fault current.

The prospective fault current in the fusible-element circuit shall be 1 500 A ± 10 %, except as stated in notes 2 and 3. If necessary, a resistor limiting the current to that value shall be used.

NOTE 1 A copper wire of 0,8 mm in diameter will melt at 1 500 A in approximately half a cycle at a frequency between 45 Hz to 67 Hz (or 0,01 s for d.c.).

NOTE 2 In the case of a supply having an artificial neutral, a lower prospective fault current may be accepted, subject to the manufacturer's agreement, with a smaller diameter wire according to the following table.

Diameter of copper wire mm	Prospective fault current in the fusible element circuit A
0,1	50
0,2	150
0,3	300
0,4	500
0,5	800
0,8	1 500

NOTE 3 For the value of the resistance of the fusible element see 8.3.2.1.

8.3.3.5.3 Characteristics of transient recovery voltage

To simulate the conditions in circuits including individual motor loads (inductive loads), the oscillatory frequency of the load circuit shall be adjusted to the value

$$f = 2\ 000 \cdot I_c^{0,2} \cdot U_e^{-0,8} \pm 10\ \%$$

where

f is the oscillatory frequency, in kilohertz;

I_c is the breaking current, in amperes;

U_e is the rated operational voltage of the equipment in volts.

The factor γ shall be adjusted to the value

$$\gamma = 1,1 \pm 0,05$$

The value of reactance necessary for the test may be obtained by coupling several reactors in parallel on condition that the transient recovery voltage can still be considered as having only one oscillatory frequency. This is generally the case when the reactors have practically the same time-constant.

The load terminals of the equipment shall be connected as closely as possible to the terminals of the adjusted load circuit. The adjustment should be made with these connections in place.

Depending on the position of the earthing, two procedures for the adjustment of the load circuit are given in Annex E.

8.3.3.5.4 Vacant

8.3.3.5.5 Test procedure for making and breaking capacities

The number of operations, the "on" and "off" times and the ambient conditions shall be stated in the relevant product standard.

8.3.3.5.6 Behaviour of the equipment during and after making and breaking capacity tests

The criteria for acceptance during and after the tests shall be stated in the relevant product standard.

8.3.3.6 Operational performance capability

Tests shall be made to verify compliance with the requirements of 7.2.4.2. The test circuit shall be in accordance with 8.3.3.5.2 and 8.3.3.5.3.

Detailed test conditions shall be stated in the relevant product standard.

8.3.3.7 Durability

Durability tests are intended to verify the number of operating cycles that an equipment is likely to be capable of performing without repair or replacement of parts.

The durability tests form the basis of a statistical life estimate, where the manufactured quantities permit this.

8.3.3.7.1 Mechanical durability

During the test, there shall be no voltage or current in the main circuit. The equipment may be lubricated before the test, if lubrication is prescribed in normal service.

The control circuit shall be supplied at its rated voltage and, where applicable, at its rated frequency.

Pneumatic and electro-pneumatic equipment shall be supplied with compressed air at the rated pressure.

Manually operated equipment shall be operated as in normal service.

The number of operating cycles shall be not less than that prescribed in the relevant product standard.

For equipment fitted with opening relays or releases, the total number of opening operations to be performed by such relays or releases shall be stated in the relevant product standard.

Evaluation of test results shall be defined in the relevant product standard.

8.3.3.7.2 Electrical durability

The test conditions are those of 8.3.3.7.1 except that the main circuit is energized according to the requirements of the relevant product standard.

Evaluation of test results shall be defined in the relevant product standard.

8.3.3.8 Pole impedance

The pole impedance shall be determined during the test and with the conditions given in 8.3.3.3.4. The test in an enclosure is not deemed necessary even if the switching device can be used in an individual enclosure.

The voltage drop U_d shall be measured between the line and load terminals (terminals included) of the switching device using the same measuring points as for the temperature rise. The measurement shall be performed after a time sufficient for the temperature-rise to reach a steady-state value.

The impedance per pole is defined as follows:

$$Z = U_d / I_{th} [\Omega]$$

The declared value (see 5.1 modified by this Amendment 2), in the case of multiple identical poles, shall be the average value obtained from the tests.

Care should be taken that voltage drop measurement does not significantly affect the temperature rise nor affect significantly the impedance.

NOTE The method is the same irrespective of the number of poles of the switching device.

8.3.4 Performance under short-circuit conditions

This subclause specifies the test conditions for verification of the ratings and limiting values of 7.2.5. Additional requirements regarding test procedure, operating and test sequences, condition of equipment after the tests and tests of co-ordination of the equipment with shortcircuit protective devices (SCPD) are given in the relevant product standard.

8.3.4.1 General conditions for short-circuit tests

8.3.4.1.1 General requirements

The general requirements of 8.3.2.1 apply. The control mechanism shall be operated under the conditions specified in the relevant product standard. If the mechanism is electrically or pneumatically controlled, it shall be supplied at the minimum voltage or the minimum pressure as specified in the relevant product standard. It shall be verified that the equipment operates correctly on no-load when it is operated under the above conditions.

Additional test conditions may be specified in the relevant product standard.

8.3.4.1.2 Test circuit

a) Figure 9, Figure 10, Figure 11 and Figure 12 give the diagrams of the circuits to be used for the tests concerning

– single-pole equipment on single-phase a.c. or d.c. (Figure 9);

– two-pole equipment on single-phase a.c. or d.c. (Figure 10);

– three-pole equipment on three-phase a.c. (Figure 11);

– four-pole equipment on three-phase four-wire a.c. (Figure 12).

A detailed diagram of the circuit used shall be given in the test report.

NOTE For combinations with SCPDs, the relevant product standard should specify the relative arrangement between the SCPD and the equipment under test.

b) The supply S feeds a circuit including resistors R_1, reactors X and the equipment D under test.

In all cases the supply shall have sufficient power to permit the verification of the characteristics given by the manufacturer.

The resistance and reactance of the test circuit shall be adjustable to satisfy the specified test conditions. The reactors X shall be air-cored. They shall be connected in series with the resistors R_1, and their value shall be obtained by series coupling of individual reactors; parallel connecting of reactors is permitted when these reactors have practically the same time-constant.

Since the transient recovery voltage characteristics of test circuits including large air-cored reactors are not representative of usual service conditions, the air-cored reactor in each phase shall be shunted by a resistor taking approximately 0,6 % of the current through the reactor, unless otherwise agreed between manufacturer and user.

c) In each test circuit (Figure 9, Figure 10, Figure 11 and Figure 12), the resistors and reactors are inserted between the supply source S and the equipment D under test. The positions of the closing device A and the current sensing devices (I_1, I_2, I_3) may be different. The closing device A may be located on low voltage side or alternatively on the primary side. In the latter case the testing station has to demonstrate that the voltage wave is not distorted by the residual flux of the short-circuit transformer. The connections of the equipment under test to the test circuit shall be stated in the relevant product standard.

When tests are made with current less than the rated value, the additional impedances required should be inserted on the load side of the equipment between it and the short circuit; they may, however, be inserted on the line side, in which case this shall be stated in the test report.

This need not apply to short-time withstand current tests (see 8.3.4.3).

Unless a special agreement has been drawn up between manufacturer and user and details noted in the test report, the diagram of the test circuit shall be in accordance with the figures.

There shall be one and only one point of the test circuit which is earthed; this may be the short-circuit link of the test circuit or the neutral point of the supply or any other convenient point, but the method of earthing shall be stated in the test report.

d) All parts of the equipment normally earthed in service, including the enclosure or the screens, shall be insulated from earth and connected to a point as indicated in Figure 9, Figure 10, Figure 11 or Figure 12.

This connection shall comprise a fusible element F consisting of a copper wire 0,8 mm in diameter and at least 50 mm long, or of an equivalent fusible element for the detection of the fault current.

The prospective fault current in the fusible element circuit shall be 1 500 A ± 10 %, except as stated in notes 2 and 3. If necessary, a resistor limiting the current to that value shall be used.

NOTE 1 A copper wire of 0,8 mm in diameter will melt at 1 500 A in approximately half a cycle at a frequency between 45 Hz and 67 Hz (or 0,01 s for d.c.).

NOTE 2 In the case of a supply having an artificial neutral, a lower prospective fault current may be accepted, subject to the manufacturer's agreement, with a smaller diameter wire according to the following table.

Diameter of copper wire mm	Prospective fault current in the fusible element circuit A
0,1	50
0,2	150
0,3	300
0,4	500
0,5	800
0,8	1 500

NOTE 3 For the value of the resistance of the fusible element see 8.3.2.1.

8.3.4.1.3 Power-factor of the test circuit

For a.c., the power-factor of each phase of the test circuit should be determined according to an established method which shall be stated in the test report.

Two examples are given in Annex F.

The power-factor of a polyphase circuit is considered as the mean value of the power-factors of each phase.

The power-factor shall be in accordance with Table 16.

The difference between the mean value and the maximum and minimum values of the power-factors in the different phases shall remain within ±0,05.

8.3.4.1.4 Time-constant of the test circuit

For d.c., the time-constant of the test circuit may be determined according to the method given in Annex F, Clause F.2.

The time-constant shall be in accordance with Table 16.

8.3.4.1.5 Calibration of the test circuit

The calibration of the test circuit is carried out by placing temporary connections B of negligible impedance as close as reasonably possible to the terminals provided for connecting the equipment under test.

For a.c., resistors R_1 and reactors X are adjusted so as to obtain, at the applied voltage, a current equal to the rated short-circuit breaking capacity as well as the power-factor specified in 8.3.4.1.3.

In order to determine the short-circuit making capacity of the device under test from the calibration oscillogram, it is necessary to calibrate the circuit so as to ensure that the prospective making current is achieved in one of the phases.

NOTE The applied voltage is the open-circuit voltage necessary to produce the specified power-frequency recovery voltage (but see also NOTE 1 of 8.3.2.2.3).

For d.c., resistors R_1 and reactors X are adjusted so as to obtain, at the test voltage, a current the maximum value of which is equal to the rated short-circuit breaking capacity as well as the time-constant specified in 8.3.4.1.4.

The test circuit is energized simultaneously in all poles and the current curve is recorded for a duration of at least 0,1 s.

For d.c. switching devices parting their contacts before the peak value of the calibration curve is reached, it is sufficient to make a calibration record with additional pure resistance in the circuit to demonstrate that the rate of rise of the current expressed in amperes/second is the same as for the test current and the time-constant specified (see Figure 15). This additional resistance shall be such that the peak value of the calibration current curve is at least equal to the peak value of the breaking current. This resistance shall be removed for the actual test (see 8.3.4.1.8, item b)).

8.3.4.1.6 Test procedure

After calibration of the test circuit in accordance with 8.3.4.1.5, the temporary connections are replaced by the equipment under test, and its connecting cables, if any.

Tests for the performance under short-circuit conditions shall be made according to the requirements of the relevant product standard.

8.3.4.1.7 Behaviour of the equipment during short-circuit making and breaking tests

There shall be neither arcing nor flashover between poles, or between poles and frame, and no melting of the fusible element F in the leakage detection circuit (see 8.3.4.1.2).

Additional requirements may be stated in the relevant product standard.

8.3.4.1.8 Interpretation of records

a) Determination of the applied voltage and power-frequency recovery voltage

The applied voltage and the power-frequency recovery voltage are determined from the record corresponding to the break test made with the apparatus under test, and evaluated as indicated in Figure 13 for a.c. and in Figure 14 for d.c.

The voltage on the supply side shall be measured during the first complete cycle after arc extinction in all poles and after high-frequency phenomena have subsided (see Figure 13).

If additional information is required regarding, for example, the voltage across individual poles, arcing time, arcing energy, switching overvoltage, etc., this may be obtained by means of additional sensing devices across each pole, in which case the resistance of each of these measuring circuits shall be not less than 100 ohms per volts of the r.m.s. value of voltage across individual poles; this value shall be stated in the test report.

b) Determination of the prospective breaking current

This determination is made by comparing the current curves, recorded during the calibration of the circuit, with those recorded during the break test of the equipment (see Figure 13).

For a.c., the a.c. component of the prospective breaking current is taken as being equal to the r.m.s. value of the a.c. component of the calibration current at the instant which corresponds to the separation of the arcing contacts (value corresponding to A_2 /22 of Figure 13, item a)). The prospective breaking current shall be the average of the prospective currents in all phases with the tolerance according to Table 8; the prospective current in each phase shall be within ±10 % of the rated value.

NOTE With the agreement of the manufacturer, the current in each phase may be within ±10 % of the average value.

For d.c., the value of the prospective breaking current is taken as being equal to the maximum value A_2 as determined from the calibration curve for equipment breaking before the current has reached its maximum value, and to the value A for equipment breaking after the current has passed its maximum value (see Figure 14, items a) and b)).

For d.c. equipment tested according to the requirements of 8.3.4.1.5, when the calibration of the test circuit has been made at a current I_1 lower than the rated breaking capacity, the test is considered void if the actual breaking current I_2 is higher than I_1, and it shall be carried out again after a calibration at a current I_3 of a higher value than I_2 (see Figure 15).

The prospective breaking current $A_2 = U / R$ shall be determined by calculating the resistance R of the test circuit from the resistors R_1 of the corresponding calibration circuits. The time-constant of the test circuit is given by

$$T = \frac{A_2}{\mathrm{d}i / \mathrm{d}t}$$

The tolerances shall be in accordance with Table 8.

c) Determination of the prospective peak making current

The prospective peak making current is determined from the calibration record and its value shall be taken as being that corresponding to A_1 of Figure 13, item a) for a.c. and to A_2 of Figure 14 for d.c. In the case of a three-phase test it shall be taken as the highest of the three A_1 values obtained from the record.

NOTE For tests on single-pole equipment, the prospective peak making current determined from the calibration record may differ from the value of the actual making current corresponding to the test, depending on the instant of making.

8.3.4.1.9 Condition of the equipment after the tests

After the tests, the equipment shall comply with the requirements of the relevant product standard.

8.3.4.2 Short-circuit making and breaking capacities

The test procedure for verification of the rated short-circuit making and breaking capacities of the equipment shall be given in the relevant product standard.

8.3.4.3 Verification of the ability to carry the rated short-time withstand current

The test shall be made with the equipment in the closed position, at a prospective current equal to the rated short-time withstand current and the corresponding operational voltage under the general conditions of 8.3.4.1.

In the case of the testing station having difficulty in making this test at the operational voltage, it may be made at any convenient lower voltage, the actual test current being, in this case, equal to the rated short-time withstand current I_{cw}. This shall be stated in the test report. If, however, momentary contact separation occurs during the test, the test shall be repeated at the rated operational voltage.

For this test, over-current releases, if any, likely to operate during the test, shall be rendered inoperative.

a) For a.c.

The tests shall be made at the rated frequency of the equipment with a tolerance of ±25 %, and at the power-factor appropriate to the rated short-time withstand current in accordance with Table 16.

The value of the current during the calibration is the average of the r.m.s. values of the a.c. components in all phases (see 4.3.6.1). The average value shall be equal to the rated value within the tolerances specified in Table 8.

In each phase the current shall be within ±5 % of the rated value.

When making the test at the rated operational voltage, the calibration current is the prospective current.

When making the test at any lower voltage, the calibration current is the actual test current.

The current shall be applied for the specified time during which the r.m.s. value of its a.c. component shall remain constant.

NOTE With the agreement of the manufacturer, the current in each phase may be within ±10 % of the average value in case of testing station difficulties.

The highest peak value of the current during its first cycle shall be not less than *n* times the rated short-time withstand current, the value of *n* being that corresponding to this value of current according to Table 16.

When, however, the characteristics of the testing station are such that the above requirements cannot be obtained, the following alternatives are permitted provided that

$$\int_0^{t_{test}} i_{test}^2 \mathrm{d}t \geq I^2 \cdot t_{st}$$

where

t_{test} is the duration of the test;

t_{st} is the short time;

i_{test} is the calibration current if the a.c. component is not constant or $\geq I_{cw}$;

I is the actual calibration current assumed to have a constant a.c. component.

If the decrement of the short-circuit current of the testing station is such that the rated short-time withstand current cannot be obtained for the rated time without applying initially an excessively high current, the r.m.s. value of the current may be permitted to fall during the test below the specified value, the duration being increased appropriately, provided that the value of the highest peak current is not less than that specified.

If, in order to obtain the required peak value, the r.m.s. value of the current has to be increased above the specified current, the duration of the test shall be reduced accordingly.

b) For d.c.

The current shall be applied for the specified time and its mean value determined from the record shall be at least equal to the specified value.

When the characteristics of the testing station are such that the above requirements cannot be obtained for the rated time without applying initially an excessively high current, the value of the current may be permitted to fall during the test below the specified value, the duration being increased appropriately, provided that the maximum value of the current is not less than that specified.

If the testing station is unable to make these tests on d.c., they may, if agreed between manufacturer and user, be made on a.c., provided suitable precautions are taken: for instance, the peak value of current shall not exceed the permissible current.

c) Behaviour of the equipment during and after the test

Behaviour of the equipment during the test shall be defined in the relevant product standard.

After the test, it shall be possible to operate the equipment by its normal operating means.

8.3.4.4 Co-ordination with short-circuit protective devices and rated conditional short-circuit current

Test conditions and procedures, where applicable, shall be stated in the relevant product standard.

8.4 Tests for EMC

Emission and immunity tests are type tests and shall be carried out using the manufacturer's instructions for installation in accordance with the reference EMC standards.

The product standard shall specify any particular test condition (e.g. use of an enclosure) and additional measures necessary to verify the performance criteria of the product (e.g. application of dwell times).

8.4.1 Immunity

8.4.1.1 Equipment not incorporating electronic circuits

No tests are necessary. See 7.3.2.1.

8.4.1.2 Equipment incorporating electronic circuits

8.4.1.2.1 General

Equipment utilizing circuits in which all components are passive (see 7.3.2.2) are not required to be tested.

Performance criteria shall be given in the product standard based on the acceptance criteria given in Table 24.

8.4.1.2.2 Electrostatic discharges

The test shall be performed according to IEC 61000-4-2 with the values given in Table 23 except where a different test level is given and justified in the product standard and shall be repeated 10 times at each measuring point, with a minimum time interval of 1 s between pulses.

The test set-up shall be in accordance with Figure 18.

8.4.1.2.3 Radiated radio-frequency electromagnetic fields

The test shall be performed according to IEC 61000-4-3 with the values given in Table 23 except where a different test level is given and justified in the product standard.

The test set-up shall be in accordance with Figure 19.

The test is performed in two steps: a first step (step 1) where the EUT is tested for resistance to unwanted operation on the whole range of frequencies, and a second step (step 2) where the EUT is tested for correct operation at discrete frequencies.

For step 1, the frequency shall be swept over the ranges of 80 MHz to 1 000 MHz and 1 400 MHz to 2 000 MHz in accordance with Clause 8 of IEC 61000-4-3. The dwell time of the amplitude modulated carrier for each frequency shall be between 500 ms and 1 000 ms unless otherwise stated in the product standard, and the step size shall be 1 % of the previous frequency. The actual dwell time shall be stated in the test report.

For step 2, to verify the functional characteristics at discrete frequencies, the test shall be performed in accordance with the relevant product standard.

8.4.1.2.4 Electrical fast transients/bursts (EFT/B)

The test shall be performed according to IEC 61000-4-4 with the values given in Table 23 with a repetition rate of 5 kHz, except where a different test level and/or repetition rate is given and justified in the product standard.

The test set-up shall be in accordance with Figure 20 for all ports except signal ports.

For the tests on signal ports, the connecting leads shall be placed in a capacitive coupling clamp, with a total cable length between the EFT generator and the capacitive coupling clamp of maximum 1 m.

8.4.1.2.5 Surges

The test shall be performed according to IEC 61000-4-5 with the values given in Table 23, taking into account the footnote d of Tables 2 and 3 of IEC 61000-6-2.

Pulses with both positive and negative polarity shall be applied, the preferred phase angles being 0°, 90° and 270°.

A series of five pulses is applied for each polarity and each phase angle, the interval between two pulses being approximately 1 min.

Where three-phase equipment employs an identical circuit configuration for each phase then tests are required on only one phase.

8.4.1.2.6 Conducted disturbances induced by radio-frequency fields

The test shall be performed according to IEC 61000-4-6 with the values given in Table 23. The tests shall be carried out with the EUT in free air.

The disturbances shall be injected, on power lines, by means of a coupling-decoupling network M1, M2 or M3 as applicable.

On signal lines, disturbances shall be injected by means of coupling-decoupling network. If not feasible, an E.M. clamp may be used.

The particular test set-up shall be in accordance with Figure 21 or Figure 22 and detailed in the test report.

The test is performed in two steps: a first step (step 1) where the EUT is tested for resistance to unwanted operation on the whole range of frequencies, and a second step (step 2) where the EUT is tested for correct operation at discrete frequencies.

For step 1, the frequency shall be swept over the range of 150 kHz to 80 MHz in accordance with Clause 8 of IEC 61000-4-6. The dwell time of the amplitude modulated carrier for each frequency shall be between 500 ms and 1 000 ms unless otherwise stated in the product standard and the step size shall be 1 % of the previous frequency. The actual dwell time shall be stated in the test report.

For step 2, to verify the functional characteristics at discrete frequencies, the test shall be performed in accordance with the relevant product standard.

8.4.1.2.7 Power frequency magnetic fields

This test is applicable only to equipment containing devices susceptible to power frequency magnetic fields as defined by the relevant product standard.

The test method shall be in accordance with IEC 61000-4-8 and the test shall be performed with the EUT in free air unless it is only used in a dedicated enclosure. The test levels are given in Table 23. The field shall be applied to the EUT in the three perpendicular axes (see Figure 23).

8.4.1.2.8 Voltage dips and interruptions

This test is applicable only to equipment susceptible to unwanted operation in case of voltage dips and interruptions as defined by the relevant product standard.

The test shall be performed in accordance with IEC 61000-4-11. The EUT shall be connected to the test generator with the shortest power supply cable as specified by the EUT manufacturer. If no cable length is specified, it shall be the shortest possible length suitable to the application of the EUT. The test levels are given in Table 23, the given percentage means percentage of the rated operational voltage.

8.4.1.2.9 Harmonics in the supply

Under consideration.

8.4.2 Emission

8.4.2.1 Equipment not incorporating electronic circuits

No tests are necessary. See 7.3.3.1.

8.4.2.2 Equipment incorporating electronic circuits

The product standard shall specify the details of the test methods. See 7.3.3.2.

Table 1
Nominal cross-sections of round copper conductors and approximate relationship between mm² and AWG/kcmil sizes

(see 7.1.8.2)

Nominal cross-section mm²	AWG/kcmil size	Equivalent metric area mm²
0,2	24	0,205
0,34	22	0,324
0,5	20	0,519
0,75	18	0,82
1	–	–
1,5	16	1,3
2,5	14	2,1
4	12	3,3
6	10	5,3
10	8	8,4
16	6	13,3
25	4	21,2
35	2	33,6
–	1	42,4
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
–	400 kcmil	203
240	500 kcmil	253
300	600 kcmil	304
NOTE The dash, when it appears, counts as a size when considering connecting capacity (see 7.1.8.2).		

Table 2
Temperature-rise limits of terminals

(see 7.2.2.1 and 8.3.3.3.4)

Terminal material	Temperature-rise limits[a, c] K
Bare copper	60
Bare brass	65
Tin plated copper or brass	65
Silver plated or nickel plated copper or brass	70
Other metals	b

[a] The use in service of connected conductors significantly smaller than those listed in Table 9 and Table 10 could result in higher terminals and internal part temperatures and such conductors should not be used without the manufacturer's consent since higher temperatures could lead to equipment failure.

[b] Temperature-rise limits to be based on service experience or life tests but not to exceed 65 K.

[c] Different values may be prescribed by product standards for different test conditions and for devices of small dimensions, but not exceeding by more than 10 K the values of this table.

Table 3
Temperature-rise limits of accessible parts

(see 7.2.2.2 and 8.3.3.3.4)

Accessible parts	Temperature-rise limits [a] K
Manual operating means:	
Metallic	15
Non-metallic	25
Parts intended to be touched but not hand-held:	
Metallic	30
Non-metallic	40
Parts which need not be touched during normal operation:	
Exteriors of enclosures adjacent to cable entries:	
Metallic	40
Non-metallic	50
Exterior of enclosures for resistors	200[b]
Air issuing from ventilation openings of enclosures for resistors	200[b]

[a] Different values may be prescribed by product standards for different test conditions and for devices of small dimensions but not exceeding by more than 10 K the values of this table.

[b] The equipment shall be protected against contact with combustible materials or accidental contact with personnel. The limit of 200 K may be exceeded if so stated by the manufacturer. Guarding and location to prevent danger is the responsibility of the installer. The manufacturer shall provide appropriate information, in accordance with 5.3.

Table 4
Tightening torques for the verification of the mechanical strength of screw-type terminals

(see 8.2.4.2 and 8.3.2.1)

Diameter of thread mm		Tightening torque N·m		
Metric standard values	**Range of diameter**	**I**	**II**	**III**
1,6	≤1,6	0,05	0,1	0,1
2,0	>1,6 up to and including 2,0	0,1	0,2	0,2
2,5	>2,0 up to and including 2,8	0,2	0,4	0,4
3,0	>2,8 up to and including 3,0	0,25	0,5	0,5
–	>3,0 up to and including 3,2	0,3	0,6	0,6
3,5	>3,2 up to and including 3,6	0,4	0,8	0,8
4,0	>3,6 up to and including 4,1	0,7	1,2	1,2
4,5	>4,1 up to and including 4,7	0,8	1,8	1,8
5	>4,7 up to and including 5,3	0,8	2,0	2,0
6	>5,3 up to and including 6,0	1,2	2,5	3,0
8	>6,0 up to and including 8,0	2,5	3,5	6,0
10	>8,0 up to and including 10,0	–	4,0	10,0
12	>10 up to and including 12	–	–	14,0
14	>12 up to and including 15	–	–	19,0
16	>15 up to and including 20	–	–	25,0
20	>20 up to and including 24	–	–	36,0
24	>24	–	–	50,0
Column I	Applies to screws without heads which, when tightened, do not protrude from the hole, and to other screws which cannot be tightened by means of a screwdriver with a blade wider than the root diameter of the screw.			
Column II	Applies to nuts and screws which are tightened by means of a screwdriver.			
Column III	Applies to nuts and screws which can be tightened by means other than a screwdriver.			

Table 5
Test values for flexion and pull-out tests for round copper conductors

(see 8.2.4.4.1)

Conductor cross-section		Diameter of bushing hole [a,b]	Height H [a]	Mass	Pulling force
mm^2	**AWG/kcmil**	**mm**	**mm**	**kg**	**N**
0,2	24	6,5	260	0,2	10
0,34	22	6,5	260	0,2	15
0,5	20	6,5	260	0,3	20
0,75	18	6,5	260	0,4	30
1,0	–	6,5	260	0,4	35
1,5	16	6,5	260	0,4	40

Table 5 Continued on Next Page

Table 5 Continued

Conductor cross-section		Diameter of bushing hole [a,b]	Height H [a]	Mass	Pulling force
mm²	AWG/kcmil	mm	mm	kg	N
2,5	14	9,5	280	0,7	50
4,0	12	9,5	280	0,9	60
6,0	10	9,5	280	1,4	80
10	8	9,5	280	2,0	90
16	6	13,0	300	2,9	100
25	4	13,0	300	4,5	135
–	3	14,5	320	5,9	156
35	2	14,5	320	6,8	190
–	1	15,9	343	8,6	236
50	0	15,9	343	9,5	236
70	00	19,1	368	10,4	285
95	000	19,1	368	14	351
–	0000	19,1	368	14	427
120	250 kcmil	22,2	406	14	427
150	300 kcmil	22,2	406	15	427
185	350 kcmil	25,4	432	16,8	503
–	400 kcmil	25,4	432	16,8	503
240	500 kcmil	28,6	464	20	578
300	600 kcmil	28,6	464	22,7	578

[a] Tolerances: for height H ± 15 mm, for diameter of the bushing hole ± 2 mm.

[b] If the bushing hole diameter is not large enough to accommodate the conductor without binding, a bushing having the next larger hole size may be used.

Table 6
Test values for pull-out test for flat copper conductors

(see 8.2.4.4.2)

Maximum width of flat conductors mm	Pulling force N
12	100
14	120
16	160
20	180
25	220
30	280

Table 7
Maximum conductor cross-sections and corresponding gauges

(see 8.2.4.5.1)

Conductor cross-section		Gauge (see Figure 2)					
Flexible conductors	Rigid conductors (solid or stranded)	Form A			Form B		Permissible deviation for a and b
		Marking	Diameter a	Width b	Marking	Diameter a	
mm²	mm²		mm	mm		mm	mm
1,5	1,5	A1	2,4	1,5	B1	1,9	
2,5	2,5	A2	2,8	2,0	B2	2,4	0
2,5	4	A3	2,8	2,4	B3	2,7	-0,05
4	6	A4	3,6	3,1	B4	3,5	
6	10	A5	4,3	4,0	B5	4,4	0
10	16	A6	5,4	5,1	B6	5,3	-0,06
16	25	A7	7,1	6,3	B7	6,9	
25	35	A8	8,3	7,8	B8	8,2	0
35	50	A9	10,2	9,2	B9	10,0	-0,07
50	70	A10	12,3	11,0	B10	12,0	
70	95	A11	14,2	13,1	B11	14,0	
95	120	A12	16,2	15,1	B12	16,0	0
120	150	A13	18,2	17,0	B13	18,0	-0,08
150	185	A14	20,2	19,0	B14	20,0	
185	240	A15	22,2	21,0	B15	22,0	0
240	300	A16	26,5	24,0	B16	26,0	-0,09

NOTE For conductor cross-sections of differently shaped solid or stranded standard conductors other than those given in this table, an unprepared conductor of appropriate cross-section may be used as the gauge, the force of insertion being not greater than 5 N.

Table 7a
Relationship between conductor cross-section and diameter

Conductor cross-section	Theoretical diameter of the largest conductor						
	Metric			AWG/kcmil			
	Rigid		Flexible	Rigid			Flexible
					b	b Class B	c Classes I.K.M.
	Solid	Stranded		Gauge	Solid	Stranded	Stranded
mm²	mm	mm	mm		mm	mm	mm
0,2	0,51	0,53	0,61	24	0,54	0,61	0,64
0,34	0,63	0,66	0,8	22	0,68	0,71	0,80
0,5	0,9	1,1	1,1	20	0,85	0,97	1,02
0,75	1,0	1,2	1,3	18	1,07	1,23	1,28
1,0	1,2	1,4	1,5	–	–	–	–
1,5	1,5	1,7	1,8	16	1,35	1,55	1,60

Table 7a Continued on Next Page

Table 7a Continued

Conductor cross-section	Theoretical diameter of the largest conductor						
	Metric			AWG/kcmil			
	Rigid		Flexible	Rigid			Flexible
					b	b Class B	c Classes I.K.M.
	Solid	Stranded		Gauge	Solid	Stranded	Stranded
mm²	mm	mm	mm		mm	mm	mm
2,5	1,9	2,2	2,3[a]	14	1,71	1,95	2,08
4,0	2,4	2,7	2,9[a]	12	2,15	2,45	2,70
6,0	2,9	3,3	3,9[a]	10	2,72	3,09	3,36
10,0	3,7	4,2	5,1	8	3,43	3,89	4,32
16,0	4,6	5,3	6,3	6	4,32	4,91	5,73
25,0	–	6,6	7,8	4	5,45	6,18	7,26
35,0	–	7,9	9,2	2	6,87	7,78	9,02
50		9,1	11,0[a]	0		9,64	12,08
70		11,0	13,1[a]	00		11,17	13,54
95		12,9	15,1[a]	000		12,54	15,33
–		–	–	0000		14,08	17,22
120		14,5	17,0[a]	250		15,34	19,01
150		16,2	19,0[a]	300		16,80	20,48
185		18,0	21,0[a]	350		18,16	22,05
–		–	–	400		19,42	24,05
240		20,6	24,0[a]	500		21,68	26,57
300		23,1	27,0[a]	600		23,82	30,03

NOTE Diameters of the largest rigid and flexible conductors are based on Table 1 and Table 3 of IEC 60228A and on IEC 60344 and, for AWG conductors, on ASTM B172-71 [1], ICEA Publication S-19-81 [2], ICEA Publication S-66-524 [3] and ICEA Publication S-66-516 [4].

Figures in square brackets refer to the bibliography.

[a] Dimensions for class 5 flexible conductors only, according to IEC 60228A.

[b] Nominal diameter +5 %.

[c] Largest diameter for any of the three classes I, K, M +5 %.

Table 8
Tolerances on test quantities

(see 8.3.4.3, item a))

All tests	Tests under no-load, normal load and overload conditions	Tests under short-circuit conditions
– Current $^{+5}_{0}$ % – Voltage $^{+5}_{0}$ % (including power frequency recovery voltage)	– Power factor ± 0,05 – Time-constant $^{+15}_{0}$ % – Frequency ±5 %	– Power factor $^{0}_{-0,05}$ – Time-constant $^{+25}_{0}$ % – Frequency ±5 %

NOTE 1 Where maximum and/or minimum operating limits are stated in the product standard, the above tolerances do not apply.

NOTE 2 By agreement between manufacturer and user, tests made at 50 Hz may be accepted for operation at 60 Hz and vice versa.

Table 9
Test copper conductors for test currents up to 400 A inclusive

(see 8.3.3.3.4)

Range of test current [a]		Conductor size [b, c, d]	
A		mm²	AWG/kcmil
0	8	1,0	18
8	12	1,5	16
12	15	2,5	14
15	20	2,5	12
20	25	4,0	10
25	32	6,0	10
32	50	10	8
50	65	16	6
65	85	25	4
85	100	35	3
100	115	35	2
115	130	50	1
130	150	50	0
150	175	70	00
175	200	95	000
200	225	95	0000
225	250	120	250 kcmil
250	275	150	300 kcmil
275	300	185	350 kcmil
300	350	185	400 kcmil
350	400	240	500 kcmil

[a] The value of test current shall be greater than the first value in the first column and less than or equal to the second value in that column.

[b] For convenience of testing and with the manufacturer's consent, smaller conductors than those given for a stated test current may be used.

[c] The tables give alternative sizes for conductors in the metric and AWG/kcmil system and for bars in millimetres and inches. Comparison between AWG/ kcmil and metric sizes is given in Table 1.

[d] Either of the two conductors specified for a given test current range may be used.

Table 10
Test copper conductors for test currents above 400 A and up to 800 A inclusive

(see 8.3.3.3.4)

Range of test current [a]		Conductors [b, c, d]			
		Metric		kcmil	
A		Number	Size mm²	Number	Size kcmil
400	500	2	150	2	250
500	630	2	185	2	350
630	800	2	240	3	300

Table 10 Continued on Next Page

Table 10 Continued

Range of test current [a]	Conductors [b, c, d]			
	Metric		kcmil	
A	Number	Size mm^2	Number	Size kcmil

[a] The value of test current shall be greater than the first value in the first column and less than or equal to the second value in that column.

[b] For convenience of testing and with the manufacturer's consent, smaller conductors than those given for a stated test current may be used.

[c] The tables give alternative sizes for conductors in the metric and AWG/kcmil system and for bars in millimetres and inches. Comparison between AWG/ kcmil and metric sizes is given in Table 1.

[d] Either of the two conductors specified for a given test current range may be used.

Table 11
Test copper bars for test currents above 400 A and up to 3 150 A inclusive

(see 8.3.3.3.4)

Range of test current [a] A		Copper bars [b, c, d, e, f]		
		Number	Dimensions mm	Dimensions Inches
400	500	2	30 × 5	1 × 0,250
500	630	2	40 × 5	1,25 × 0,250
630	800	2	50 × 5	1,5 × 0,250
800	1 000	2	60 × 5	2 × 0,250
1 000	1 250	2	80 × 5	2,5 × 0,250
1 250	1 600	2	100 × 5	3 × 0,250
1 600	2 000	3	100 × 5	3 × 0,250
2 000	2 500	4	100 × 5	3 × 0,250
2 500	3 150	3	100 × 10	6 × 0,250

[a] The value of test current shall be greater than the first value in the first column and less than or equal to the second value in that column.

[b] For convenience of testing and with the manufacturer's consent, smaller conductors than those given for a stated test current may be used.

[c] The tables give alternative sizes for conductors in the metric and AWG/kcmil system and for bars in millimetres and inches. Comparison between AWG/kcmil and metric sizes is given in Table 1.

[d] Either of the two conductors specified for a given test current range may be used.

[e] Bars are assumed to be arranged with their long faces vertical. Arrangements with long faces horizontal may be used if specified by the manufacturer.

[f] Where four bars are used they shall be in two sets of two bars with not more than 100 mm between pair centres.

Table 12
Impulse withstand test voltages

Rated impulse withstand voltage U_{imp} kV	Test voltages and corresponding altitudes $U_{1,2/50}$ kV				
	Sea level	200 m	500 m	1 000 m	2 000 m
0,33	0,35	0,35	0,35	0,34	0,33
0,5	0,55	0,54	0,53	0,52	0,5
0,8	0,91	0,9	0,9	0,85	0,8
1,5	1,75	1,7	1,7	1,6	1,5
2,5	2,95	2,8	2,8	2,7	2,5
4,0	4,8	4,8	4,7	4,4	4,0
6,0	7,3	7,2	7,0	6,7	6,0
8,0	9,8	9,6	9,3	9,0	8,0
12	14,8	14,5	14	13,3	12

NOTE Table 12 uses the characteristics of a homogeneous field, case B (see 2.5.62).

Table 12A
Dielectric test voltage corresponding to the rated insulation voltage

Rated insulation voltage U_i V	AC test voltage (r.m.s.) V	DC test voltage [b, c] V
$U_i \leq 60$	1 000	1 415
$60 < U_i \leq 300$	1 500	2 120
$300 < U_i \leq 690$	1 890	2 670
$690 < U_i \leq 800$	2 000	2 830
$800 < U_i \leq 1\,000$	2 200	3 110
$1\,000 < U_i \leq 1\,500$[a]	–	3 820

[a] For d.c. only.

[b] Test voltages based on 6.1.3.4.1, fifth paragraph of IEC 60664-1:2007.

[c] A direct current test voltage may be used only if an alternating test voltage cannot be applied. See also 3) b) ii) of 8.3.3.4.1.

Table 13
Minimum clearances in air

Rated impulse withstand voltage U_{imp} kV	Minimum clearances mm							
	Case A Inhomogeneous field conditions (see 2.5.63)				Case B Homogeneous field ideal conditions (see 2.5.62)			
	Pollution degree				Pollution degree			
	1	2	3	4	1	2	3	4
0,33	0,01				0,01			
0,5	0,04	0,2	0,8	1,6	0,04	0,2	0,8	1,6
0,8	0,1				0,1			

Table 13 Continued on Next Page

Table 13 Continued

Rated impulse withstand voltage	Minimum clearances mm							
	Case A Inhomogeneous field conditions (see 2.5.63)				Case B Homogeneous field ideal conditions (see 2.5.62)			
U_{imp}	Pollution degree				Pollution degree			
kV	1	2	3	4	1	2	3	4
1,5	0,5	0,5			0,3	0,3		
2,5	1,5	1,5	1,5		0,6	0,6		
4,0	3	3	3	3	1,2	1,2	1,2	
6,0	5,5	5,5	5,5	5,5	2	2	2	2
8,0	8	8	8	8	3	3	3	3
12	14	14	14	14	4,5	4,5	4,5	4,5

NOTE The values of minimum clearances in air are based on 1,2/50 µs impulse voltage, for barometric pressure of 80 kPa, equivalent to normal atmospheric pressure at 2 000 m above sea level.

Table 14
Test voltages across the open contacts of equipment suitable for isolation

Rated impulse withstand voltage	Test voltages and corresponding altitudes				
U_{imp}	$U_{1,2/50}$ kV				
kV	Sea level	200 m	500 m	1 000 m	2 000 m
0,33	1,8	1,7	1,7	1,6	1,5
0,5	1,8	1,7	1,7	1,6	1,5
0,8	1,8	1,7	1,7	1,6	1,5
1,5	2,3	2,3	2,2	2,2	2
2,5	3,5	3,5	3,4	3,2	3
4,0	6,2	6,0	5,8	5,6	5
6,0	9,8	9,6	9,3	9,0	8
8,0	12,3	12,1	11,7	11,1	10
12	18,5	18,1	17,5	16,7	15

Table 15
Minimum creepage distances

Rated insulation voltage of equipment or working voltage a.c. r.m.s. or d.c. [b, c]	Minimum creepage distances for equipment subject to long term stress														
	Printed wiring material														
	Pollution degree														
	1	2	1	2			3				4				
	Material group			Material group			Material group				Material group				
	All	All except IIIb	All	I	II	III	I	II	IIIa	IIIb	I	II	IIIa	IIIb	
V	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	
10	0,025	0,04	0,08	0,4	0,4	0,4	1	1	1		1,6	1,6	1,6		
12,5	0,025	0,04	0,09	0,42	0,42	0,42	1,05	1,05	1,05		1,6	1,6	1,6		
16	0,025	0,04	0,1	0,45	0,45	0,45	1,1	1,1	1,1		1,6	1,6	1,6		
20	0,025	0,04	0,11	0,48	0,48	0,48	1,2	1,2	1,2		1,6	1,6	1,6		
25	0,025	0,04	0,125	0,5	0,5	0,5	1,25	1,25	1,25		1,7	1,7	1,7		
32	0,025	0,04	0,14	0,53	0,53	0,53	1,3	1,3	1,3		1,8	1,8	1,8		
40	0,025	0,04	0,16	0,56	0,8	1,1	1,4	1,6	1,8		1,9	2,4	3		
50	0,025	0,04	0,18	0,6	0,85	1,2	1,5	1,7	1,9		2	2,5	3,2		
63	0,04	0,063	0,2	0,63	0,9	1,25	1,6	1,8	2		2,1	2,6	3,4		
80	0,063	0,1	0,22	0,67	0,95	1,3	1,7	1,9	2,1		2,2	2,8	3,6		
100	0,1	0,16	0,25	0,71	1	1,4	1,8	2	2,2		2,4	3	3,8		
125	0,16	0,25	0,28	0,75	1,05	1,5	1,9	2,1	2,4		2,5	3,2	4		
160	0,25	0,4	0,32	0,8	1,1	1,6	2	2,2	2,5		3,2	4	5		
200	0,4	0,63	0,42	1	1,4	2	2,5	2,8	3,2		4	5	6,3		
250	0,56	1	0,56	1,25	1,8	2,5	3,2	3,6	4		5	6,3	8		
320	0,75	1,6	0,75	1,6	2,2	3,2	4	4,5	5		6,3	8	10		
400	1	2	1	2	2,8	4	5	5,6	6,3		8	10	12,5		
500	1,3	2,5	1,3	2,5	3,6	5	6,3	7,1	8		10	12,5	16		
630	1,8	3,2	1,8	3,2	4,5	6,3	8	9	10		12,5	16	20	a	
800	2,4	4	2,4	4	5,6	8	10	11	12,5		16	20	25		
1 000	3,2	5	3,2	5	7,1	10	12,5	14	16		20	25	32		
1 250			4,2	6,3	9	12,5	16	18	20		25	32	40		
1 600			5,6	8	11	16	20	22	25		32	40	50		
2 000			7,5	10	14	20	25	28	32		40	50	63		
2 500			10	12,5	18	25	32	36	40		50	63	80		
3 200			12,5	16	22	32	40	45	50	a	63	80	100		
4 000			16	20	28	40	50	56	63		80	100	125		
5 000			20	25	36	50	63	71	80		100	125	160		
6 300			25	32	45	63	80	90	100		125	160	200		
8 000			32	40	56	80	100	110	125		160	200	250		
10 000			40	50	71	100	125	140	160		200	250	320		

[a] Values of creepage distances in this area have not been established. Material group IIIb is in general not recommended for application in pollution degree 3 above 630 V and in pollution degree 4.

[b] As an exception, for rated insulation voltages 127 V, 208 V, 415/440 V, 660/690 V and 830 V, creepage distances corresponding to the lower values 125 V, 200 V, 400 V, 630 V and 800 V respectively may be used.

Table 15 Continued on Next Page

Table 15 Continued

Rated insulation voltage of equipment or working voltage a.c. r.m.s. or d.c. [b, c]	Minimum creepage distances for equipment subject to long term stress													
	Printed wiring material													
	Pollution degree													
	1	2	1	2			3				4			
	Material group			Material group			Material group				Material group			
	All	All except IIIb	All	I	II	III	I	II	IIIa	IIIb	I	II	IIIa	IIIb
V	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm

[c] The values of creepage distances stated for 250 V can be used for 230 V (±10 %) nominal voltage.

NOTE 1 It is appreciated that tracking or erosion will not occur on insulation subjected to working voltages of 32 V and below. However, the possibility of electrolytic corrosion has to be considered and for this reason minimum creepage distances have been specified.

NOTE 2 Voltage values are selected in accordance with the R_{10} series.

Table 16
Values of power-factors and time-constants corresponding to test currents, and ratio *n* between peak and r.m.s. values of current

(see 8.3.4.3, item a))

Test current A	Power-factor	Time-constant ms	*n*
I ≤ 1 500	0,95	5	1,41
1 500 < *I* ≤ 3 000	0,9	5	1,42
3 000 < *I* ≤ 4 500	0,8	5	1,47
4 500 < *I* ≤ 6 000	0,7	5	1,53
6 000 < *I* ≤ 10 000	0,5	5	1,7
10 000 <*I* ≤ 20 000	0,3	10	2,0
20 000 < *I* ≤ 50 000	0,25	15	2,1
50 000 < *I*	0,2	15	2,2

Table 17
Actuator test force

(see 8.2.5.2.1)

Type of actuator [a]	Test force [a]	Minimum test force N	Maximum test force N
Push-button (a)	3*F*	50	150
One-finger operated (b)	3*F*	50	150
Two-finger operated (c)	3*F*	100	200
One-hand operated (d) and (e)	3*F*	150	400
Two-hand operated (f) and (g)	3*F*	200	600

[a] *F* is the normal operating force in new condition. The test force shall be 3*F* with the stated minimum and maximum values and be applied as shown in Figure 16.

Table 18 – Vacant

Table 19 – Vacant

Table 20
Test values for conduit pull-out test

(see 8.2.7.1)

Conduit designation according to IEC 60981	Conduit diameter		Pulling force
	Inside mm	Outside mm	N
12 H	12,5	17,1	900
16 H to 41 H	16,1 to 41,2	21,3 to 48,3	900
53 H to 155 H	52,9 to 154,8	60,3 to 168,3	900

Table 21
Test values for conduit bending test

(see 8.2.7.2)

Conduit designation according to IEC 60981	Conduit diameter		Bending moment
	Inside mm	Outside mm	N·m
12 H	12,5	17,1	35 [a]
16 H to 41 H	16,1 to 41,2	21,3 to 48,3	70
53 H to 155 H	52,9 to 154,8	60,3 to 168,3	70

[a] This value is reduced to 17 Nm for enclosures which have only provision for an incoming conduit, but not for an outgoing conduit.

Table 22
Test values for conduit torque test

(see 8.2.7.1 and 8.2.7.3)

Conduit designation according to IEC 60981	Conduit diameter		Torque
	Inside mm	Outside mm	N·m
12 H	12,5	17,1	90
16 H to 41 H	16,1 to 41,2	21,3 to 48,3	120
53 H to 155 H	52,9 to 154,8	60,3 to 168,3	180

Table 23
Tests for EMC – Immunity

(see 8.4.1.2)

Type of test	Test level required	
Electrostatic discharge immunity test IEC 61000-4-2	8 kV / air discharge or 4 kV / contact discharge	
Radiated radio-frequency electromagnetic field immunity test 80 MHz to 1 GHz IEC 61000-4-3	10 V/m	
Radiated radio-frequency electromagnetic field immunity test 1,4 GHz to 2 GHz IEC 61000-4-3	3 V/m	
Radiated radio-frequency electromagnetic field immunity test 2 GHz to 2,7 GHz IEC 61000-4-3	1 V/m	
Electrical fast transient/burst immunity test IEC 61000-4-4	2 kV / 5 kHz on power ports 1 kV / 5 kHz on signal ports	
1,2/50 μs – 8/20 μs surge immunity test [a] IEC 61000-4-5	2 kV (line to earth) 1 kV (line to line)	
Conducted radio-frequency immunity test (150 kHz to 80 MHz) IEC 61000-4-6	10 V	
Power frequency magnetic field immunity test [b] IEC 61000-4-8	30 A/m	
Voltage dips immunity test (50 Hz/ 60 Hz) IEC 61000-4-11[e]	Class 2 [c, d, e] 0 % during 0,5 cycle and 1 cycle 70 % during 25/30 cycles	Class 3 [c, d, e] 0 % during 0,5 cycle and 1 cycle 40 % during 10/12 cycles 70 % during 25/30 cycles 80 % during 250/300 cycles
Short interruptions immunity test IEC 61000-4-11	Class 2 [c, d, e] 0 % during 250/300 cycles	Class 3 [c, d, e] 0 % during 250/300 cycles
Immunity to harmonics in the supply IEC 61000-4-13	No requirements [f]	

NOTE Performance criteria are given in the relevant product standard based on the acceptance criteria given in Table 24.

[a] Regarding applicability see 7.2 and 8.2 of IEC 61000-4-5 (Not applicable for low voltage d.c. input/output ports (≤ 60 V), when the secondary circuits (isolated from the a.c. mains) are not subject to transient overvoltages).

[b] Applicable only to equipment containing devices susceptible to power frequency magnetic fields (see 8.4.1.2.7).

[c] The given percentage means percentage of the rated operational voltage, e.g. 0 % means 0 V.

[d] Class 2 applies to points of common coupling and in-plant points of common coupling in the industrial environment in general.

Class 3 applies to in-plant couplings in industrial environment only. This class should be considered when a major part of the load is fed through converters; welding machines are present; large motors are frequently started or loads vary rapidly.

The product standard shall state the applicable class.

[e] The value in front of the slash mark (/) is for 50 Hz and the value behind for 60 Hz tests.

[f] Requirements are under study for the future.

Table 24
Acceptance criteria when EM disturbances are present

Item	Acceptance criteria (performance criteria during tests)		
	A	B	C
Overall performance	No noticeable changes of the operating characteristic. Operating as intended	Temporary degradation or loss of performance which is self-recoverable	Temporary degradation or loss of performance which requires operator intervention or system reset [a]
Operation of power and control circuits	No unwanted operation	Temporary degradation or loss of performance which is self-recoverable [a]	Temporary degradation or loss of performance which requires operator intervention or system reset [a]
Operation of displays and control panels	No changes to visible display information. Only slight light intensity fluctuation of LEDs, or slight movement of characters	Temporary visible changes or loss of information. Undesired LED illumination	Shut down or permanent loss of display. Wrong information and/or unpermitted operating mode, which should be apparent or an indication should be provided. Not self-recoverable
Information processing and sensing functions	Undisturbed communication and data interchange to external devices	Temporarily disturbed communication, with possible error reports of the internal and external devices	Erroneous processing of information. Loss of data and/or information. Errors in communication. Not self-recoverable

[a] Specific requirements shall be detailed in the product standard.

Table 25DV D2 *Addition:*

Table 25DV
Marking locations

References without the "DV" designation refer to IEC 60947-1.

Clause reference	Required marking[a]	Locations[b]	
		Enclosed	Open
General			
7.1.12DV	Enclosure environmental type rating	A	–
5.2DV	Manufacturers name, trademark, or identifier, electrical rating, catalog number or equivalent	A	A
5.2DV.4	Terminal marking for wire type (Al, Cu)	B	B
5.2DV.5	Temperature rating of field wiring	B	B
5.2DV.6	Torque marking for field wiring terminals	B	B
5.2DV.7 , Table 27DV footnote f	Aluminum body wire connector	B	B
7.1.1DV.6	Marking for enclosure mounted components	–	B
7.1.8.1DV.1.3	Marking for providing terminals separately in terminal kit	B	B
7.1.10.3DV	Terminal connection of ground supply conductor	B	B

Table 25DV Continued on Next Page

Table 25DV Continued

Clause reference	Required marking[a]	Locations[b]	
		Enclosed	Open
7.2.2DV.3	Enclosure ambient when ambient temperature is other than 40 °C	B	B
7.1.1DV.1.2.3(b)	Marking for supplementary fuse near fuse holder	A	A
7.1.1DV.1.2.4	Marking for supplementary protection kit when maximum branch circuit protective-device size exceeds control-circuit wire ampacity	A	A
7.1.1DV.1.2.3(a)	When the branch circuit fuse holder accepts higher fuse size	A	A
5.2DV.8	Circuits capable of being connected to separate supplies and intended to be connected to common supply	B	B
7.1.8.4	Marking for proper connections	B	B
7.1.8.1DV.1.4	Field wiring terminal not intended to receive conductor one size larger	B	B
7.1.1DV.4.2	Marking for installation of low voltage field wiring to maintain separation of circuits	B	B
7.1.10.3DV.2	Grounding electrode conductor terminal marking	B	B
Annex DVC.1.4	Marking for secondary circuit supplied from a Class 2 source in the field	A	A
CAUTIONARY MARKINGS			
5.2DV.3	Marking for more than one disconnect means to de-energize equipment	A	–
ACCESSORIES			
5.2DV.1 (a), (b), and (c)	Manufacturer name, rating and catalog number of accessory	–	B
5.2DV.1	Accessories provided with instructions	–	B
5.2DV.10	Enclosure mounted components	–	B

a) These are a brief summary of marking requirements. For complete details see the specific requirement reference.

b) For marking locations identified below, "A" is the highest order of location, and "B" is the lowest order of location. At the option of the manufacturer, a higher order of location category may be used.
A) Enclosed Devices: Marking shall be on the product and visible when the enclosure cover is removed or the door is open.
Open Devices: Marking shall be on the product.
B) Marking is shipped with the product.

c) Small devices, such as proximity or photoelectric switches, may be marked with only one electrical rating, and all other markings are provided on a separate sheet or on the device carton.

d) Cautionary markings – Cautionary markings shall be located on a part that is not capable of being removed without impairing the operation or appearance of the equipment. A cautionary marking intended to instruct the operator shall be legible and visible to the operator during normal operation of the equipment. A marking that provides servicing instructions shall be legible and visible when such servicing is being performed.

Table 26DV D2 *Addition:*

Table 26DV
Width of copper bus bars

(see 8.3.3.3.4DV.1.3)

Product rating, Amperes	Bus bars per terminal [a]	Width of bus bars, mm
450 – 600	1	50,8
601 – 1000	1	76,2
1001 – 1200	1	101,6
1201 – 1600	2[b]	76,2
1601 – 2000	2[b]	101,6
2001 – 2500	2[b]	127,0
	4[b]	63,5
2501 – 3000	3[b]	127,0
	4[b]	101,6

[a] All bus bars 6,35 mm thick.

[b] The spacing between multiple bus bars shall be 6,35 mm with no intentional wider spacing except at the individual terminals of the equipment.

Table 27DV D2 *Addition:*

Table 27DV
Maximum temperature rises[a]

(see 7.2.2DV.1)

Materials and components		°C
1.	Field-wiring terminals[c, f]	
	Equipment marked 60 °C or 60/75 °C supply wires	50
	Equipment marked 75 °C supply wires	65
2.	Buses and connecting straps or bars[d]	g
3.	Contacts:	
	Solid and built-up silver, silver alloy, and silver faced	e
	All other metals	65
4.	In the issuing air, 25,4 mm above the enclosure	175
5.	On the embedding material of a resistor or a rheostat	300
6.	On bare resistor material, thermocouple method	375
7.	Any component or material not specifically identified in 1 – 6	b

[a] For equipment rated for an ambient temperature other than 40°C, the allowable temperature rises in this table are adjusted in accordance with the following formula:

$$T_R = T_T + 40\,°C - T_M$$

in which:

T_R = Allowable temperature rise;

Table 27DV Continued on Next Page

Table 27DV Continued

Materials and components	°C
T_T = Maximum temperature rise allowed by Table 27DV; and T_M = Ambient temperature marked on the equipment.	
[b] The maximum temperature rise shall not exceed the temperature rating specified for the component or material minus the ambient temperature marked on the equipment.	
[c] The temperature on a wiring terminal or lug is measured at the point able to be contacted by the insulation of a conductor installed as in actual service.	
[d] The limit does not apply to connections to a source of heat, such as a resistor and a current element of an overload relay.	
[e] Temperature is limited by the temperature limitations on the material for adjacent parts. There shall be no structural deterioration of the contact assembly, loosening of parts, cracking or flaking of materials, loss of temper of spring, annealing of parts, or other visible damage.	
[f] When the rise is 50 °C or less and an aluminum bodied connector is used or aluminum wire is intended, the connector shall be marked AL7CU or AL9CU; when the terminal temperature rise exceeds 50 °C and does not exceed 65 °C, the connector shall be marked AL9CU.	
[g] The limit applies only to bus bars and connecting straps used for distribution of power to industrial control devices. The limit does not apply to short pieces of copper located within industrial control devices and used for the support of stationary contact assemblies of factory or field wiring terminations. The maximum temperature rises for this type of construction are determined by the temperature limitations on the support material, adjacent part material, or 100 °C temperature rise on the copper material, whichever is lower. There shall be no structural deterioration of the assembly, loosening of parts, cracking or flaking of material, loss of temper of spring, annealing of parts, or other visible damage.	

Table 28DV D2 *Addition:*

Table 28DV
Values of voltage for tests

(see 8.3.2.1DV.2.1 and DVC.2.1.1)

	Voltage rating of equipment[a]					
	110 – 120	220 – 240	254 – 277	380 – 415	440 – 480	560 – 600
Required test voltage	120	240	277	415	480	600

[a] When the rating of the equipment does not fall within any of the indicated voltage ranges, it shall be tested at its rated voltage.

Table 29DV D2 *Addition:*

Table 29DV
Dielectric voltage withstand test voltages

(see 8.3.3.4.1DV.2)

Voltage rating, Volts (rms) or DC	Test voltage (rms)[a]
0 – 50	500 volts
51 – 250	1 000 Volts [b]
51 – 600	1 000 Volts + (2 × nominal voltage rating)
601 – 1 500	2 000 Volts + (2,25 × nominal voltage ratings)

[a] For alternating-current, or 1,414 times the values for direct-current.

[b] 1 000 volts shall be used for equipment rated more than 50 volts and not more than 250 volts and intended for use in a pollution degree 2 location.

Table 30DV DR *Addition:*

Table 30DV
Size of bonding, equipment grounding, and grounding electrode conductors

(See 7.1.10.1DV.3, 7.1.10.2DV)

Maximum ampere rating [a]	Size of equipment bonding or grounding conductor, minimum (AWG or kcmil)		Size of grounding electrode conductor, minimum (AWG or kcmil)		Size of main bonding jumper, minimum (AWG or kcmil)	
	Copper	Aluminum	Copper	Aluminum	Copper	Aluminum
15	14 [b]	12 [b]	8	6	8	6
20	12 [b]	10 [b]	8	6	8	6
30	10 [b]	8 [b]	8	6	8	6
40	10 [b]	8 [b]	8	6	8	6
60	10 [b]	8 [b]	8	6	8	6
90	8	6	8	6	8	6
100	8	6	6	4	6	4
150	6	4	6	4	6	4
200	6	4	5	3	4	2
300	4	2	2	0	2	0
400	3	1	0 [b]	3/0 [c]	0 [c]	3/0 [c]
500	2	1/0	0	3/0	0	3/0
600	1	2/0	2/0	4/0	2/0	4/0
800	0	3/0	2/0	4/0	2/0	4/0
1 000	2/0	4/0	3/0	250	3/0	250
1 200	3/0	250	3/0	250	250 [d]	250
1 600	4/0	350	3/0	250	300 [d]	400 [d]
2 000	250	400	3/0	250	400 [d]	500 [d]
2 500	350	600	3/0	250	500 [d]	700 [d]
3 000	400	600	3/0	250	600 [d]	750 [d]

Table 30DV Continued on Next Page

Table 30DV Continued

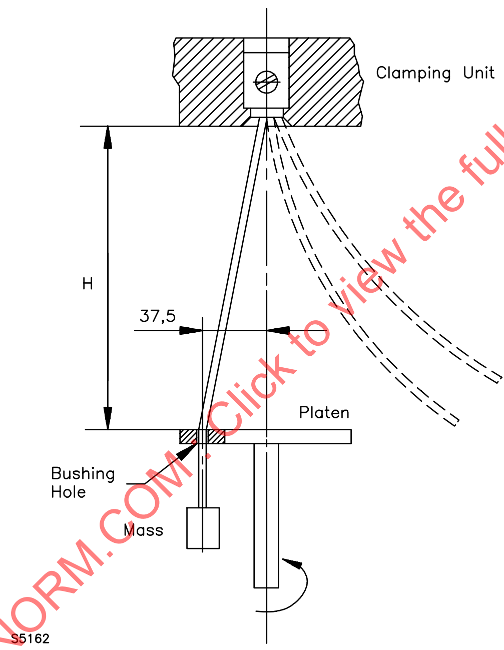
Maximum ampere rating [a]	Size of equipment bonding or grounding conductor, minimum (AWG or kcmil)		Size of grounding electrode conductor, minimum (AWG or kcmil)		Size of main bonding jumper, minimum (AWG or kcmil)	
	Copper	Aluminum	Copper	Aluminum	Copper	Aluminum
4 000	500	800	3/0	250	750 [d]	1 000 [d]
5 000	700	1 200	3/0	250	900	1 250
6 000	800	1 200	3/0	250	1 250	1 500

[a] Maximum ampere rating of equipment or circuit overcurrent device ahead of equipment-grounding means.

[b] Values are applicable to equipment-grounding conductors only.

[c] When the ampere rating is 400 and the wire terminal connectors for the main service conductors are rated for two 3/0 AWG copper or two 250 kcmil aluminum conductors and does not accept a 600 kcmil conductor, these values are able to be reduced to 2 AWG copper or 0 AWG aluminum.

[d] The cross section is able to be reduced to 12.5 percent of the total cross section of the largest main service conductor of the same material (copper or aluminum) for any phase on the equipment rated 1 200 amperes and over. This applies when the wire terminal connectors provided limit the cross section of the service conductors.

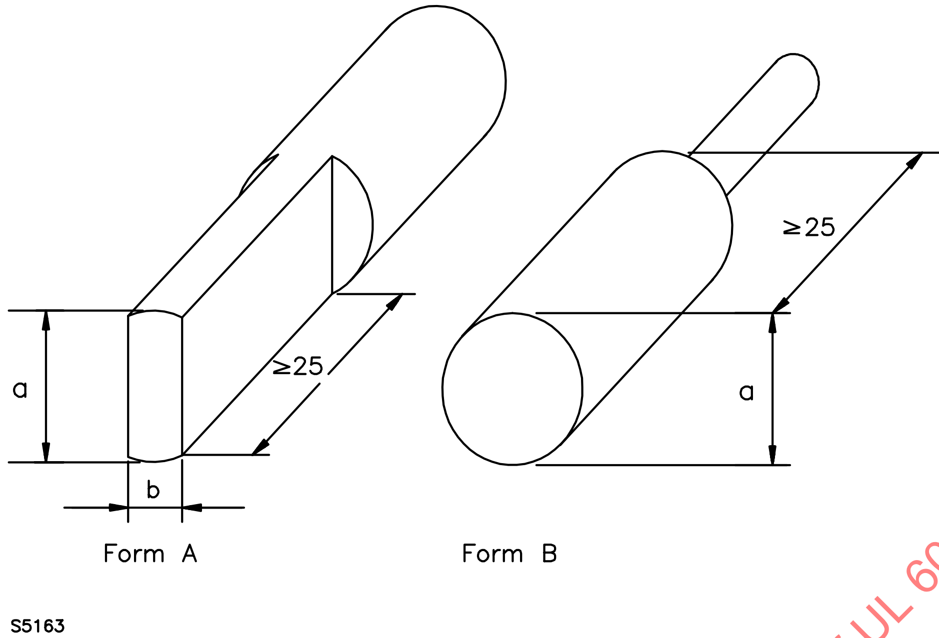


Dimensions in millimetres

Figure 1

Test equipment for flexion test

(see 8.2.4.3 and Table 5)

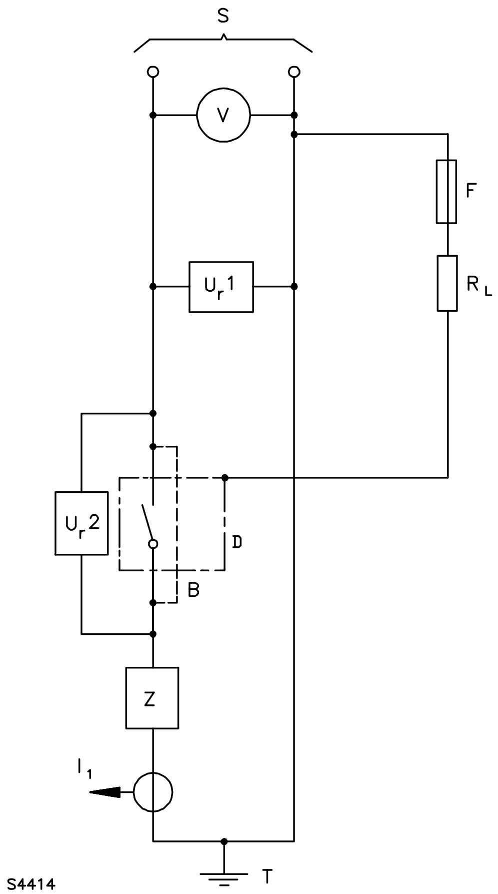


Dimensions in millimetres

Figure 2

Gauges of form A and form B

(see 8.2.4.5.2 and Table 7)



S = Supply

U_r1, U_r2 = Voltage sensors

V = Voltage measuring device

F = Fusible element (8.3.3.5.2, item g))

Z = Load circuit (see figure 8)

R_L = Fault current limiting resistor

D = Equipment under test (including connecting cables)

NOTE — Outline includes metallic screen or enclosure.

B = Temporary connection for calibration

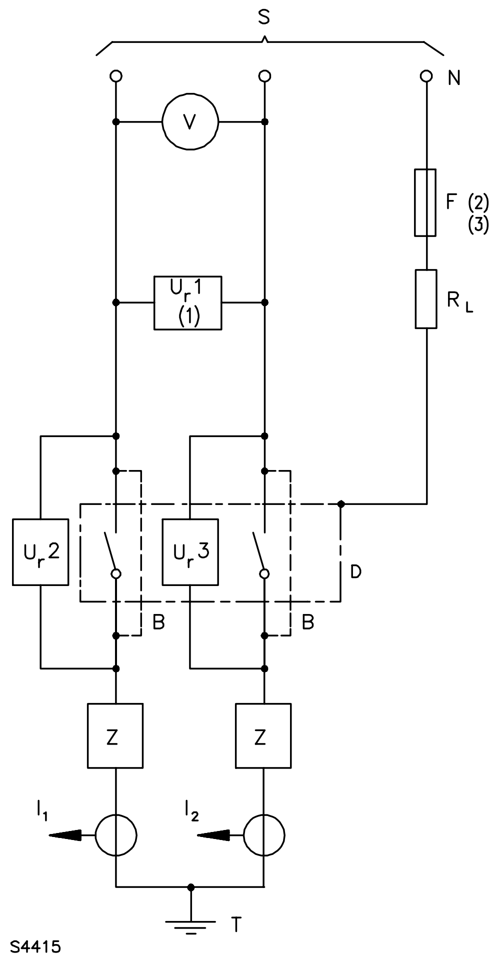
I_1 = Current sensor

T = Earth — One earthing point only (load side or supply side)

Figure 3

Diagram of the test circuit for the verification of making and breaking capacities of a single-pole equipment on single-phase a.c. or on d.c.

(see 8.3.3.5.2)



S	=	Supply
U_r1, U_r2, U_r3	=	Voltage sensors
V	=	Voltage measuring device
N	=	Neutral of supply (or artificial neutral)
F	=	Fusible element (8.3.3.5.2, item g))
Z	=	Load circuit (see figure 8)
R_L	=	Fault current limiting resistor
D	=	Equipment under test (including connecting cables) NOTE – Outline includes metallic screen or enclosure.
B	=	Temporary connections for calibrations
I_1, I_2	=	Current sensors
T	=	Earth – One earthing point only (load side or supply side)

NOTE 1 U_r1 may, alternatively, be connected between phase and neutral.

NOTE 2 In the case of equipment intended for use in phase-earthed systems or if this diagram is used for the test of the neutral and adjacent poles of a 4-pole equipment, F shall be connected to one phase of the supply.

In the case of d.c., F shall be connected to the negative of the supply.

NOTE 3 In the USA and Canada, F shall be connected

– to one phase of the supply for equipment marked with a single value of U_e;

– to the neutral for equipment marked with a twin voltage (see note to 5.2).

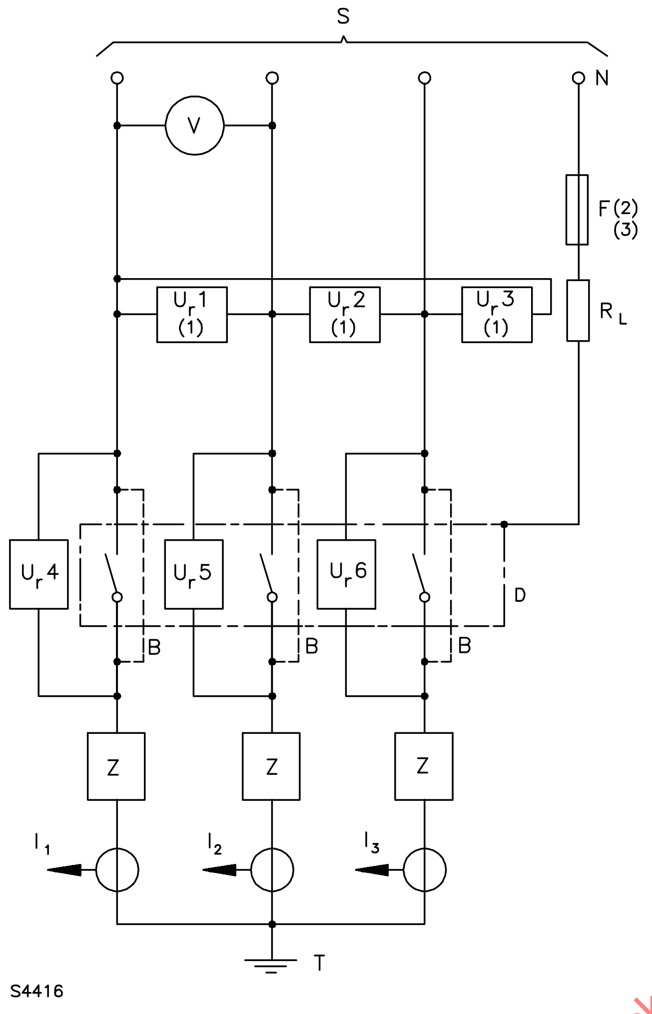
Figure 4

Diagram of the test circuit for the verification of making and breaking capacities of a two-pole equipment on single-phase a.c. or on d.c.

(see 8.3.3.5.2)

Figure 4DV D2 ***Modification of Figure 4 by adding NOTE 4DV:***

NOTE 4DV For devices not marked "break all lines", only a single pole of "D" shall be connected between the supply and the load. The other pole of the test device shall be connected to neutral.



S	=	Supply
U_r1, U_r2, U_r3, U_r4, U_r5, U_r6	=	Voltage sensors
V	=	Voltage measuring device
N	=	Neutral of supply (or artificial neutral)
F	=	Fusible element (8.3.3.5.2, item g))
Z	=	Load circuit (see figure 8)
R_L	=	Fault current limiting resistor
D	=	Equipment under test (including connecting cables) NOTE – Outline includes metallic screen or enclosure.
B	=	Temporary connections for calibration
I_1, I_2, I_3,	=	Current sensors
T	=	Earth – One earthing point only (load side or supply side)

NOTE 1 U_r1, U_r2 and U_r3 may, alternatively, be connected between phase and neutral.

NOTE 2 In the case of equipment intended for use in phase-earthed systems or if this diagram is used for the test of the neutral and adjacent poles of a 4-pole equipment, F shall be connected to one phase of the supply.

In the case of d.c., F shall be connected to the negative of the supply.

NOTE 3 In the USA and Canada, F shall be connected

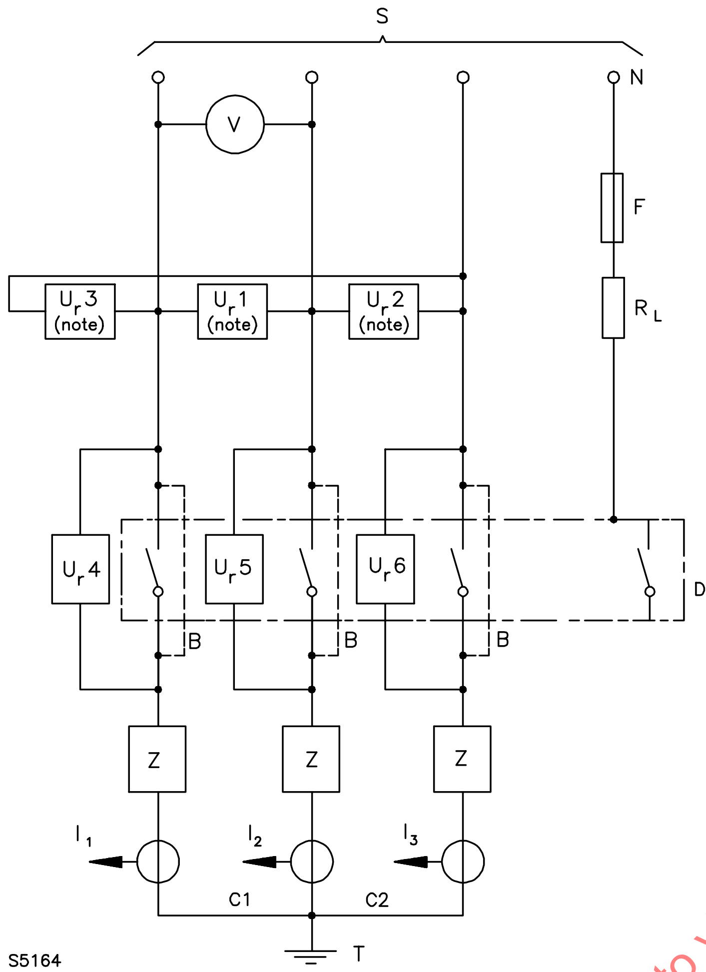
– to one phase of the supply for equipment marked with a single value of U_e;

– to the neutral for equipment marked with a twin voltage (see note to 5.2).

Figure 5

Diagram of the test circuit for the verification of making and breaking capacities of a three-pole equipment

(see 8.3.3.5.2)



S	=	Supply
U_r1, U_r2, U_r3, U_r4, U_r5, U_r6	=	Voltage sensors
V	=	Voltage measuring device
N	=	Neutral of supply (or artificial neutral)
F	=	Fusible element (8.3.3.5.2, item g)
Z	=	Load circuit (see figure 8)
R_L	=	Fault current limiting resistor
D	=	Equipment under test (including connecting cables) NOTE – Outline includes metallic screen or enclosure.
B	=	Temporary connections for calibration
I_1, I_2, I_3	=	Current sensors
T	=	Earth – One earthing point only (load side or supply side)

NOTE U_r1, U_r2 and U_r3 may, alternatively, be connected between phase and neutral.

Figure 6

Diagram of the test circuit for the verification of making and breaking capacities of a four-pole equipment

(see 8.3.3.5.2)

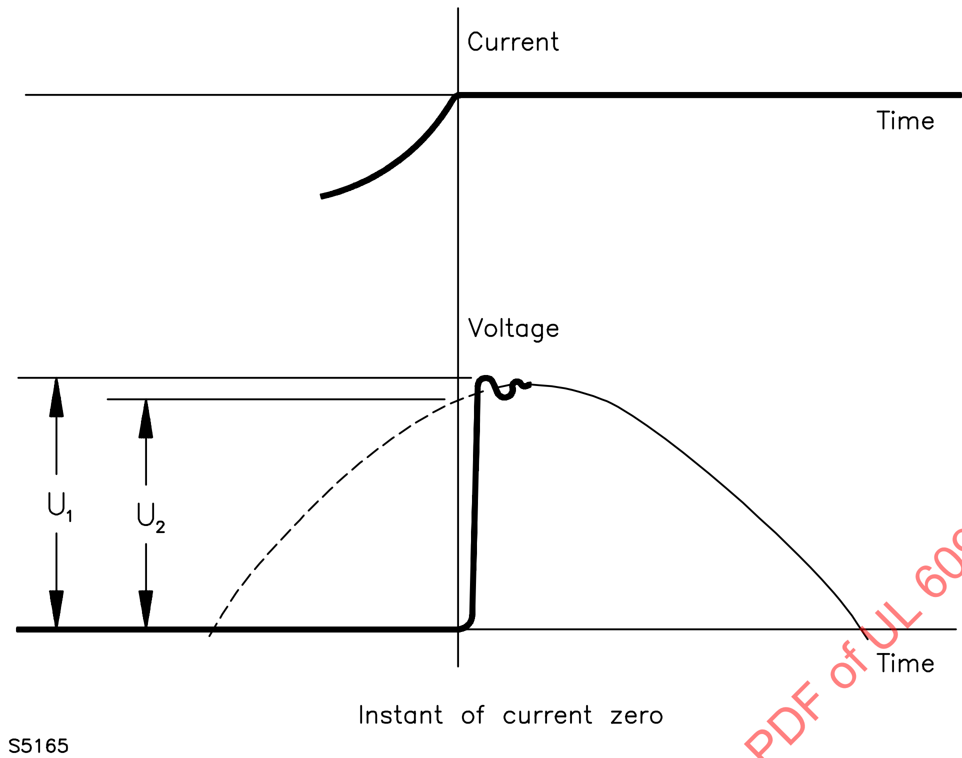
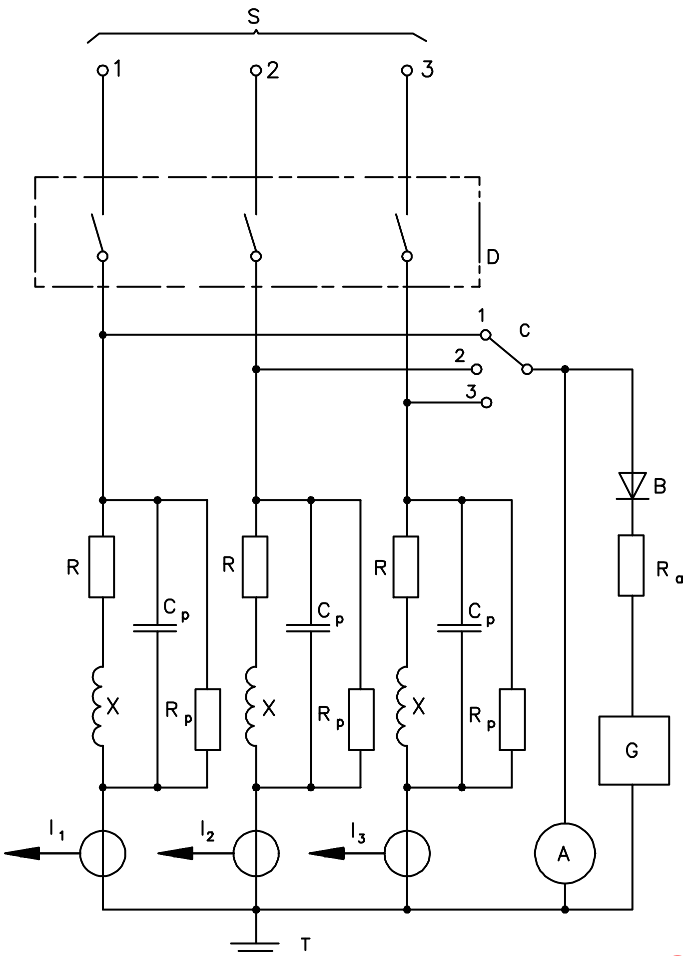


Figure 7

Schematic illustration of the recovery voltage across contacts of the first phase to clear under ideal conditions

(see 8.3.3.5.2, item e))



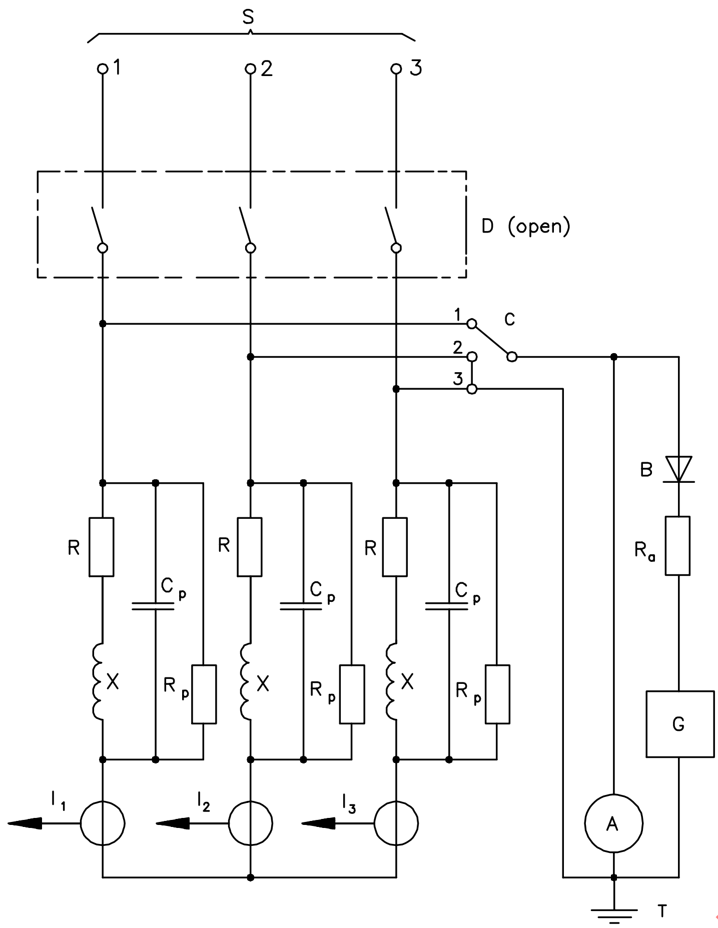
S	=	Supply
D	=	Equipment under test
C	=	Phase adjustment selector switch
B	=	Diode
A	=	Recorder
R_a	=	Resistor
G	=	High–frequency generator
R	=	Load circuit resistor
X	=	Load circuit reactor (8.3.3.5.2, item d))
R_p	=	Resistor in parallel
C_p	=	Capacitor in parallel
I_1, I_2, I_3	=	Current sensors

S5166

The relative positions of the high-frequency generator G and the diode shall be as shown. No other point of the circuit than the one indicated on the figure shall be earthed.

Figure 8a

Diagram of a load circuit adjustment method: load star-point earthed



S	=	Supply
D	=	Equipment under test
C	=	Phase adjustment selector switch
B	=	Diode
A	=	Recorder
R_a	=	Resistor
G	=	High–frequency generator
R	=	Load circuit resistor
X	=	Load circuit reactor (8.3.3.5.2d))
R_p	=	Resistor in parallel
C_p	=	Capacitor in parallel
I_1, I_2, I_3	=	Current sensors

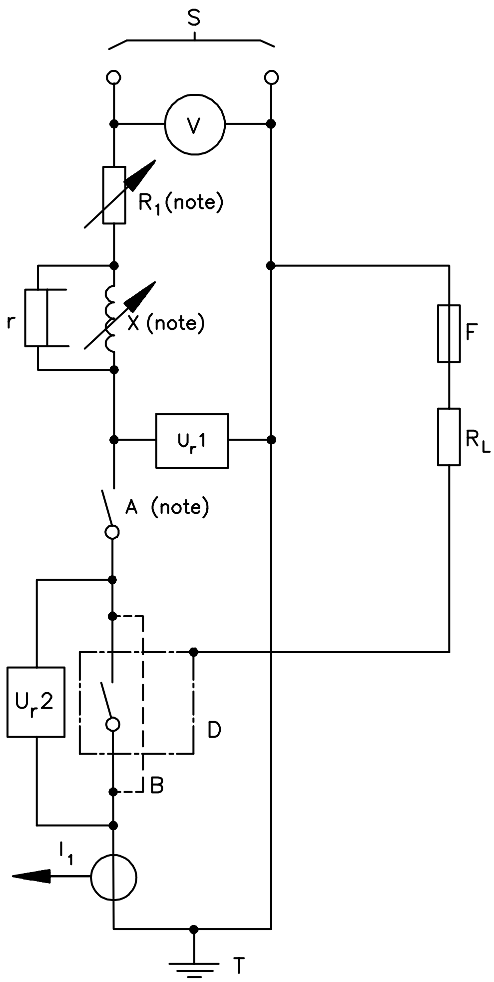
S4417

The relative positions of the high-frequency generator G and the diode shall be as shown. No other point of the circuit than the one indicated on the figure shall be earthed.

In this figure, as an example 1, 2 and 3 are represented in the position corresponding to the adjustment of phase 1 (the first phase to clear) in series with phases 2 and 3 connected in parallel.

Figure 8b

Diagram of a load circuit adjustment method: supply star-point earthed



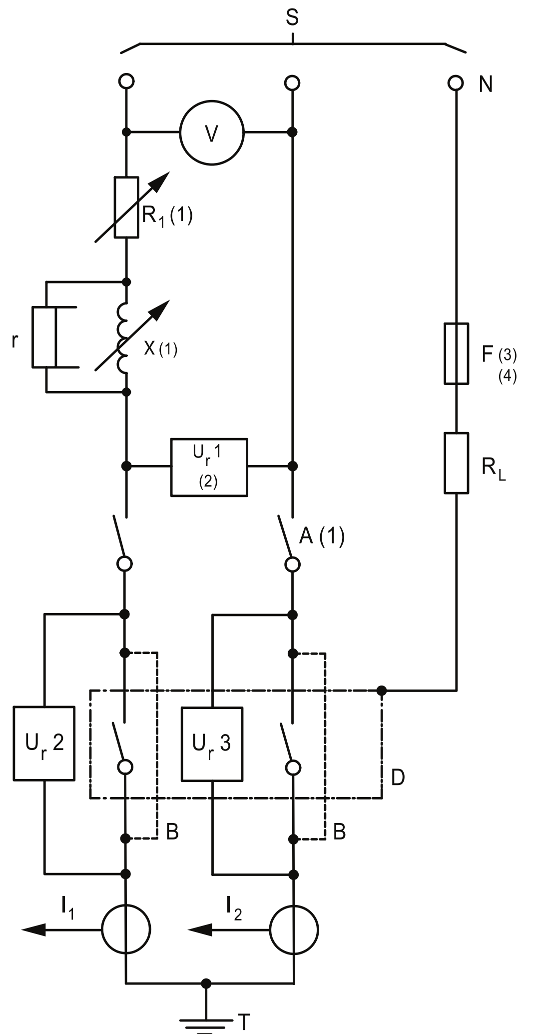
S	=	Supply
U_r1, U_r2	=	Voltage sensors
V	=	Voltage measuring device
A	=	Closing device
R_1	=	Adjustable resistor
F	=	Fusible element (8.3.4.1.2, item d))
X	=	Adjustable reactor
R_L	=	Fault current limiting resistor
D	=	Equipment under test (including connecting cables) NOTE – Outline includes metallic screen or enclosure.
B	=	Temporary connections for calibration
I_1	=	Current sensor
T	=	Earth – One earthing point only (load side or supply side)
r	=	Shunt resistor (8.3.4.1.2, item b))

NOTE Adjustable loads X and R_1 may be located either on the high-voltage side or on the low-voltage side of the supply circuit.

Figure 9

Diagram of the test circuit for the verification of short-circuit making and breaking capacities of a single-pole equipment on single-phase a.c. or on d.c.

(see 8.3.4.1.2)



S	=	Supply
U_r1, U_r2, U_r3	=	Voltage sensors
V	=	Voltage measuring device
A	=	Closing Device
R_1	=	Adjustable resistor
N	=	Neutral of supply (or artificial neutral)
F	=	Fusible element (8.3.4.1.2, item d))
X	=	Adjustable reactor
R_L	=	Fault current limiting resistor
D	=	Equipment under test (including connecting cables) NOTE - Outline includes metalic screen or enclosure.
B	=	Temporary connections for calibration
I_1, I_2	=	Current sensors
T	=	Earth - One earthing point only (load side or supply side)
r	=	Shunt resistor (8.3.4.1.2, item b))

NOTE 1 Adjustable loads X and R_1 may be located either on the high-voltage side or on the low-voltage side of the supply circuit.

NOTE 2 U_r1 may, alternatively, be connected between phase and neutral.

NOTE 3 In the case of equipment intended for use in phase-earthed systems or if this diagram is used for the test of the neutral and adjacent pole of a four-pole equipment, F shall be connected to one phase of the supply.

In the case of d.c., F shall be connected to the negative of the supply.

NOTE 4 In the USA and Canada, F shall be connected

− to one phase of the supply for equipment marked with a single value of U_e;

− to the neutral for equipment marked with a twin voltage of U_e (see note to 5.2).

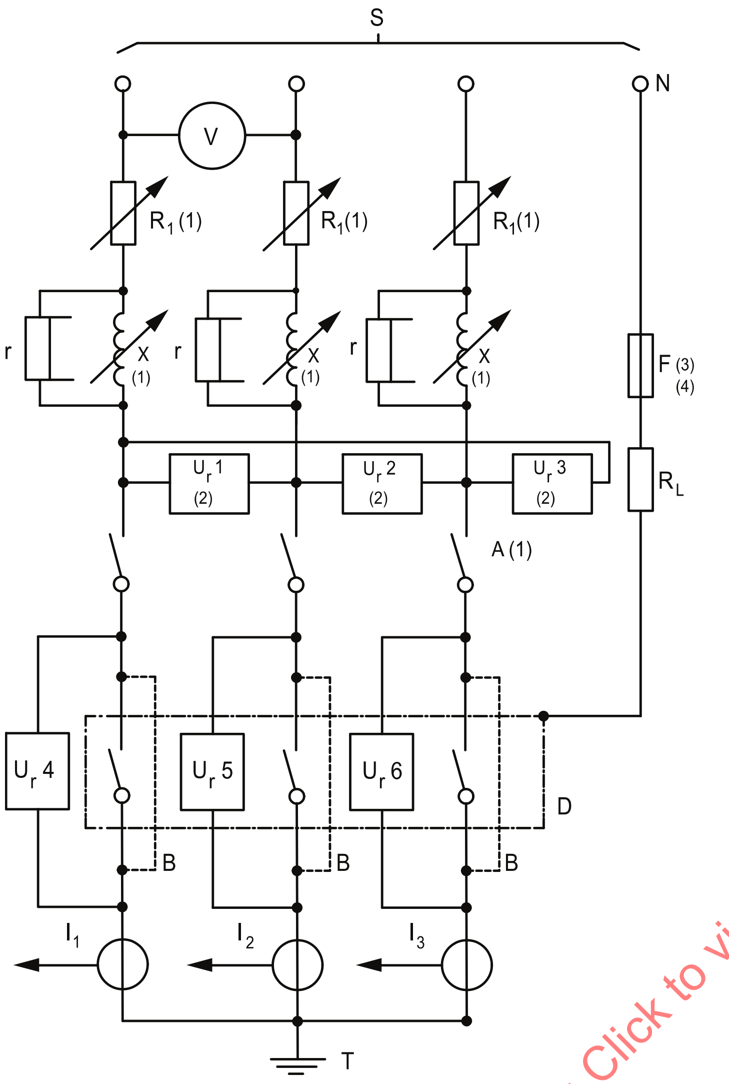
Figure 10

Diagram of the test circuit for the verification of short-circuit making and breaking capacities of a two-pole equipment on single-phase a.c. or on d.c.

(see 8.3.4.1.2)

Figure 10DV D2 ***Modification of Figure 10 by adding NOTE 5DV:***

NOTE 5DV For devices not marked "break all lines", only a single pole of "D" shall be connected between the supply and the load. The other pole of the test device shall be connected to neutral.



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S	=	Supply
U_r1, U_r2, U_r3, U_r4, U_r5, U_r6	=	Voltage sensors
V	=	Voltage measuring device
A	=	Closing Device
R_1	=	Adjustable resistor
N	=	Neutral of supply (or artificial neutral)
F	=	Fusible element (8.3.4.1.2, item d))
X	=	Adjustable reactors
R_L	=	Fault current limiting resistor
D	=	Equipment under test (including connecting cables) NOTE - Outline includes metalic screen or enclosure.
B	=	Temporary connections for calibration
I_1, I_2, I_3	=	Current sensors
T	=	Earth - One earthing point only (load side or supply side)
r	=	Shunt resistor (8.3.4.1.2, item b))

NOTE 1 Adjustable loads X and R_1 may be located either on the high-voltage side or on the low-voltage side of the supply circuit.

NOTE 2 U_r1, U_r2, U_r3 may, alternatively, be connected between phase and neutral.

NOTE 3 In the case of equipment intended for use in phase-earthed systems or if this diagram is used for the test of the neutral and adjacent pole of a four-pole equipment F, shall be connected to one phase of the supply.

NOTE 4 In the USA and Canada, F shall be connected

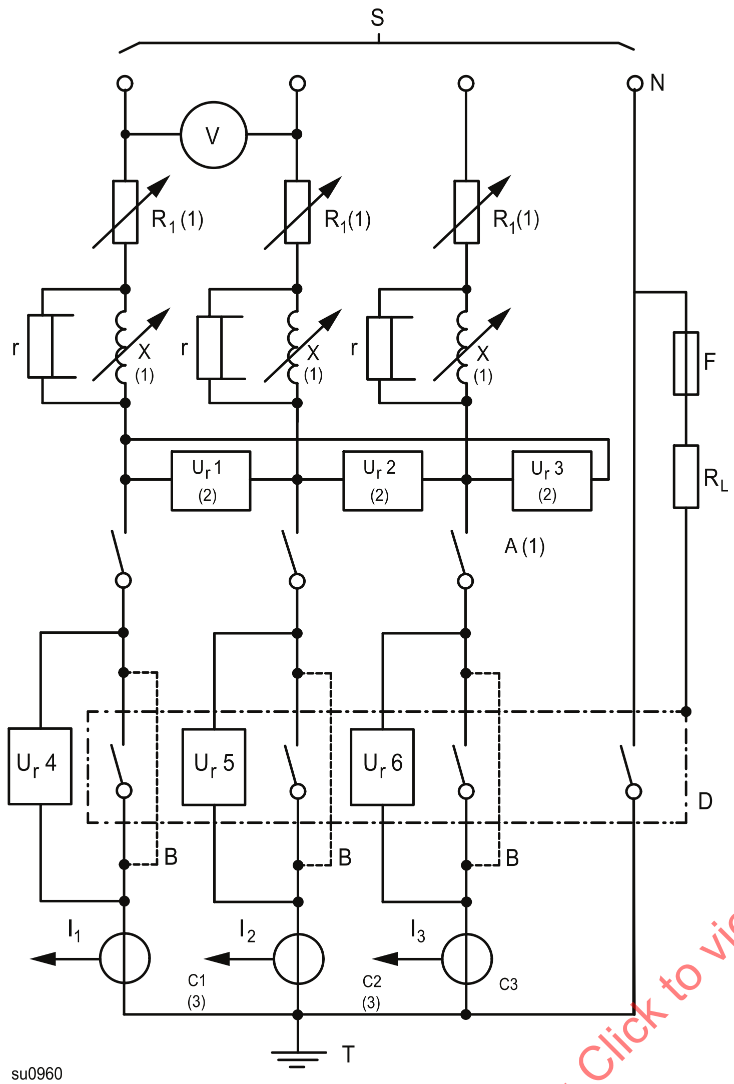
− to one phase of the supply for equipment marked with a single value of U_e;

− to the neutral for equipment marked with a twin voltage of U_e (see note to 5.2).

Figure 11

Diagram of the test circuit for the verification of short-circuit making and breaking capacities of a three-pole equipment

(see 8.3.4.1.2)



S	=	Supply
U_r1, U_r2, U_r3, U_r4, U_r5, U_r6	=	Voltage sensors
V	=	Voltage measuring device
R_1	=	Adjustable resistor
N	=	Neutral of supply
F	=	Fusible element (8.3.4.1.2, item d))
X	=	Adjustable reactors
R_L	=	Fault current limiting resistor
A	=	Closing device
D	=	Equipment under test (including connecting cables) NOTE - Outline includes metallic screen or enclosure.
B	=	Temporary connections for calibration
I_1, I_2, I_3	=	Current sensors
T	=	Earth - One earthing point only (load side or supply side)
r	=	Shunt resistor (8.3.4.1.2, item b))

NOTE 1 Adjustable loads X and R_1 may be located either on the high-voltage side or on the low-voltage side of the supply circuit.

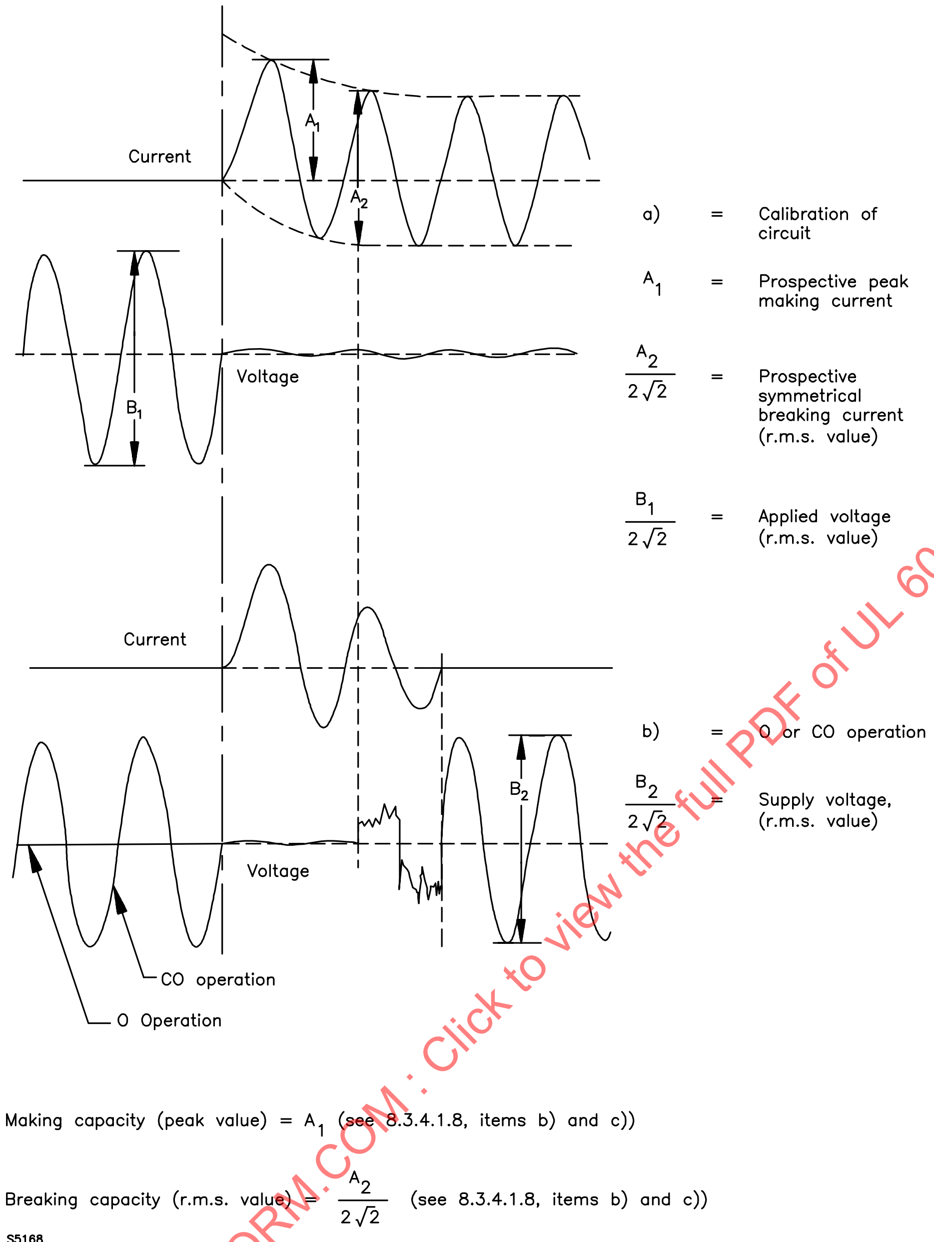
NOTE 2 U_r1, U_r2, U_r3 may, alternatively, be connected between phase and neutral.

NOTE 3 If an additional test is required between the neutral and the adjacent pole, the connections C1 and C2 are omitted.

Figure 12

Diagram of the test circuit for the verification of short-circuit making and breaking capacities of a four-pole equipment

(see 8.3.4.1.2)



NOTE 1 The amplitude of the voltage trace, after initiation of the test current, varies according to the relative positions of the closing device, the adjustable impedances, the voltage sensors and according to the test circuit diagram.

NOTE 2 It is assumed that the instant of making is the same for calibration and test.

Figure 13

Example of short-circuit making and breaking test record in the case of a single-pole equipment on single-phase a.c.

(see 8.3.4.1.8)

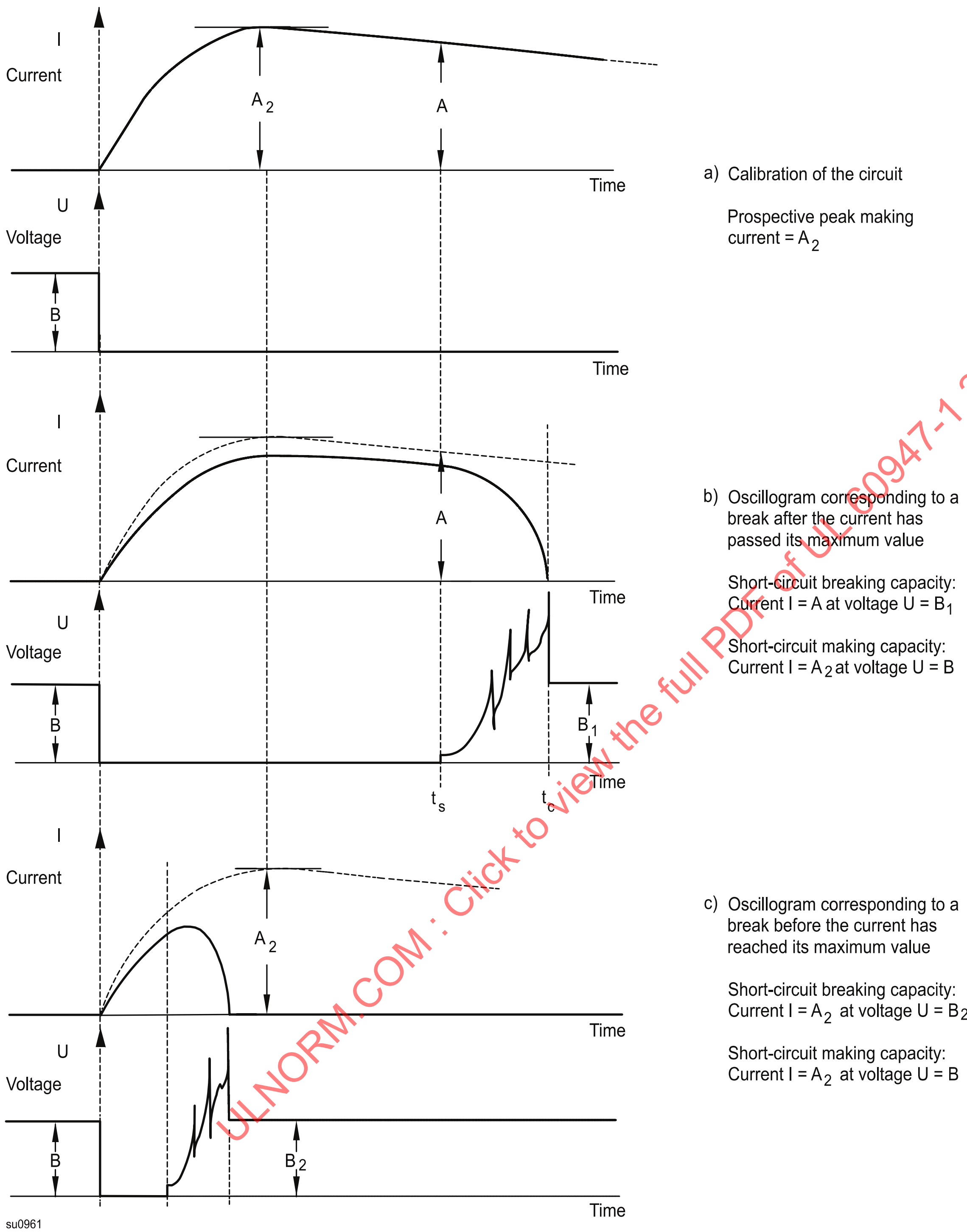


Figure 14

Verification of short-circuit making and breaking capacities on d.c.

(see 8.3.4.1.8)

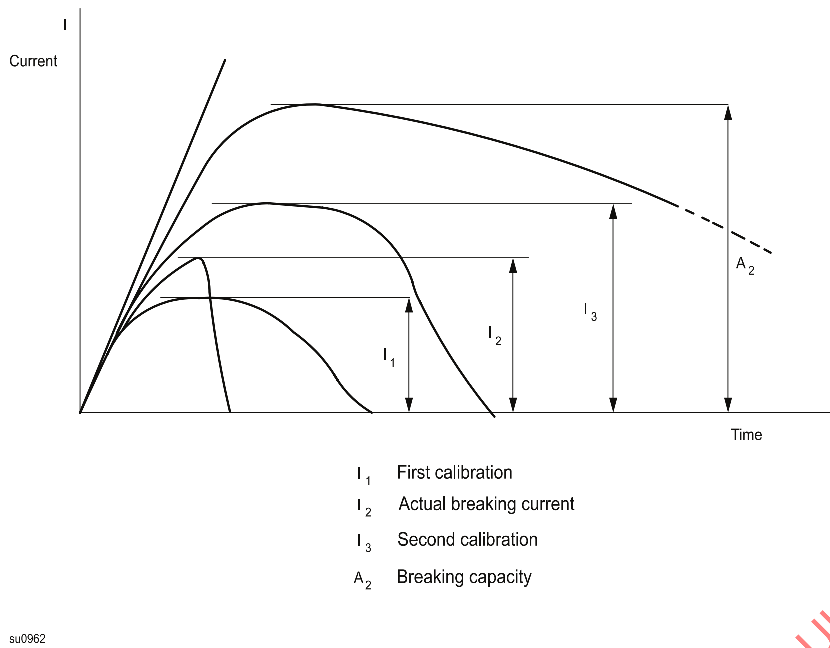


Figure 15

Determination of the prospective breaking current when the first calibration of the test circuit has been made at a current lower than the rated breaking capacity

(see 8.3.4.1.8, item b))

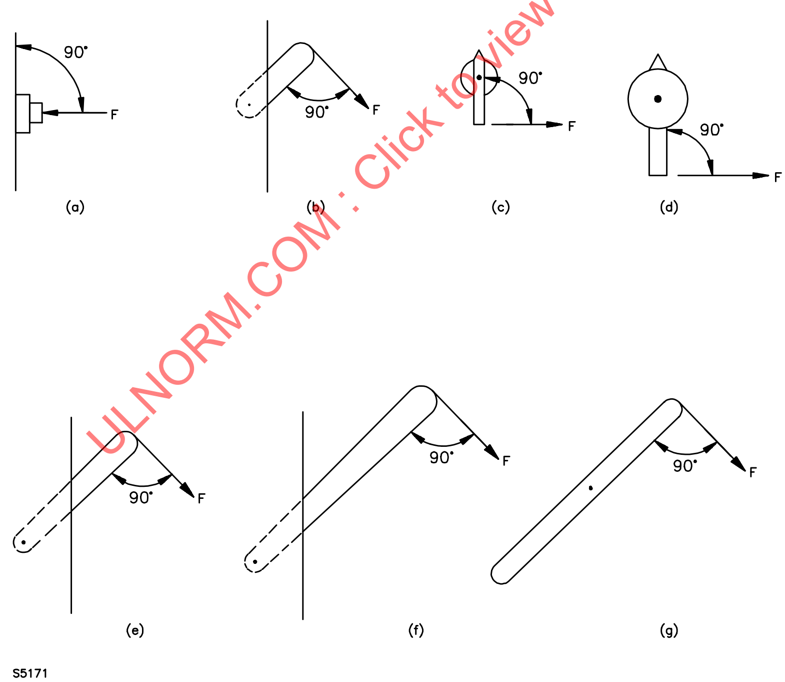


Figure 16

Actuator test force

(see 8.2.5.2.1 and Table 17)

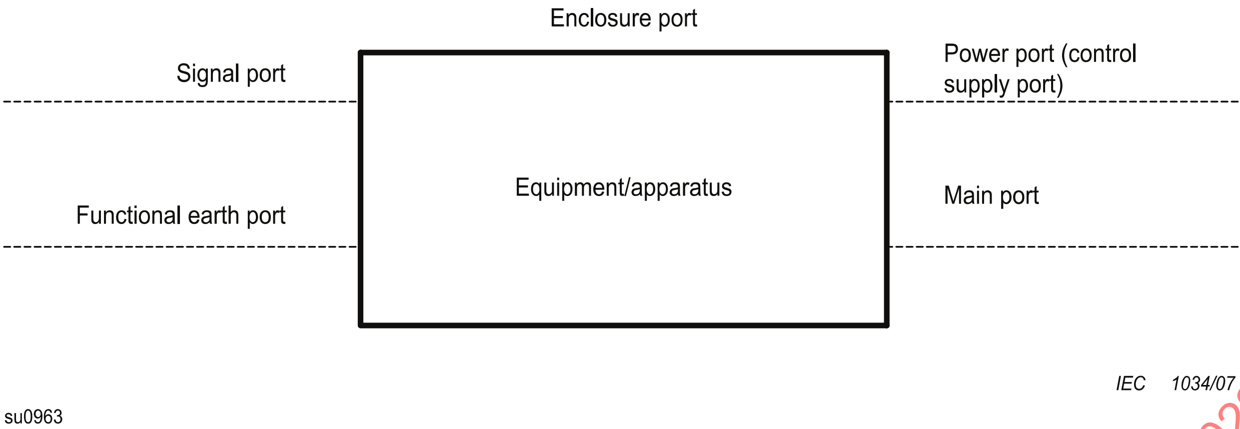


Figure 17

Examples of ports

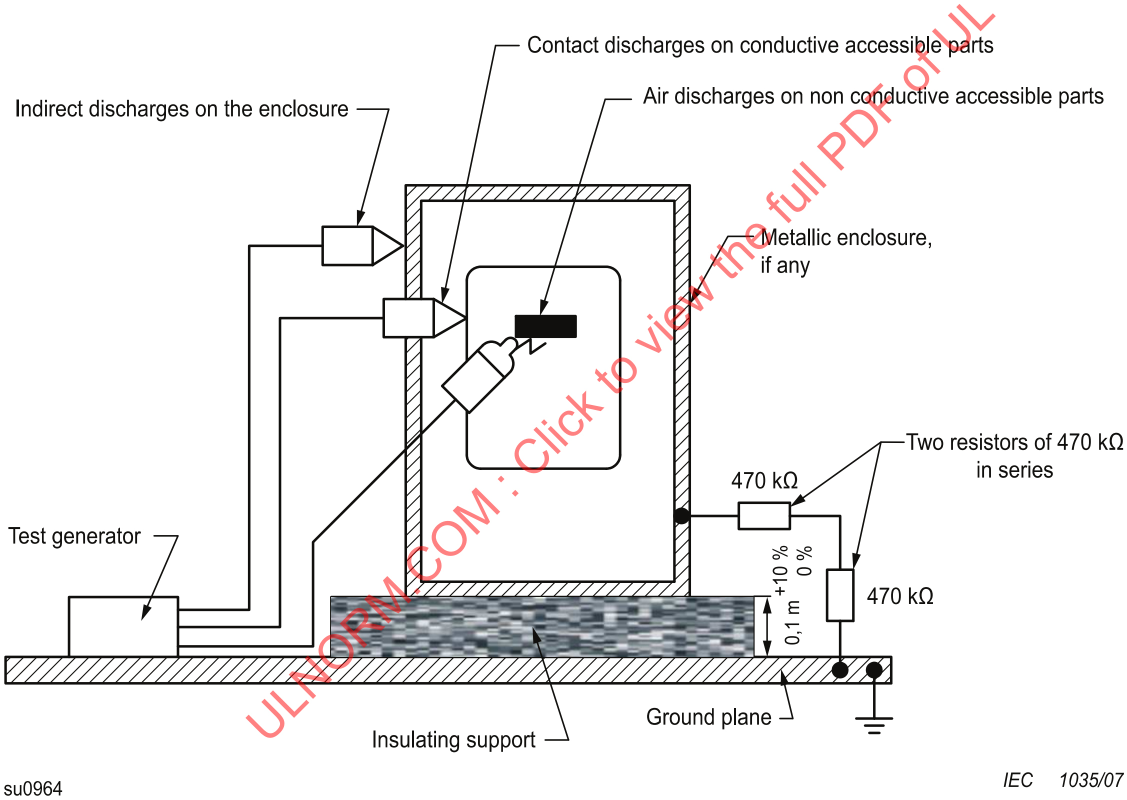
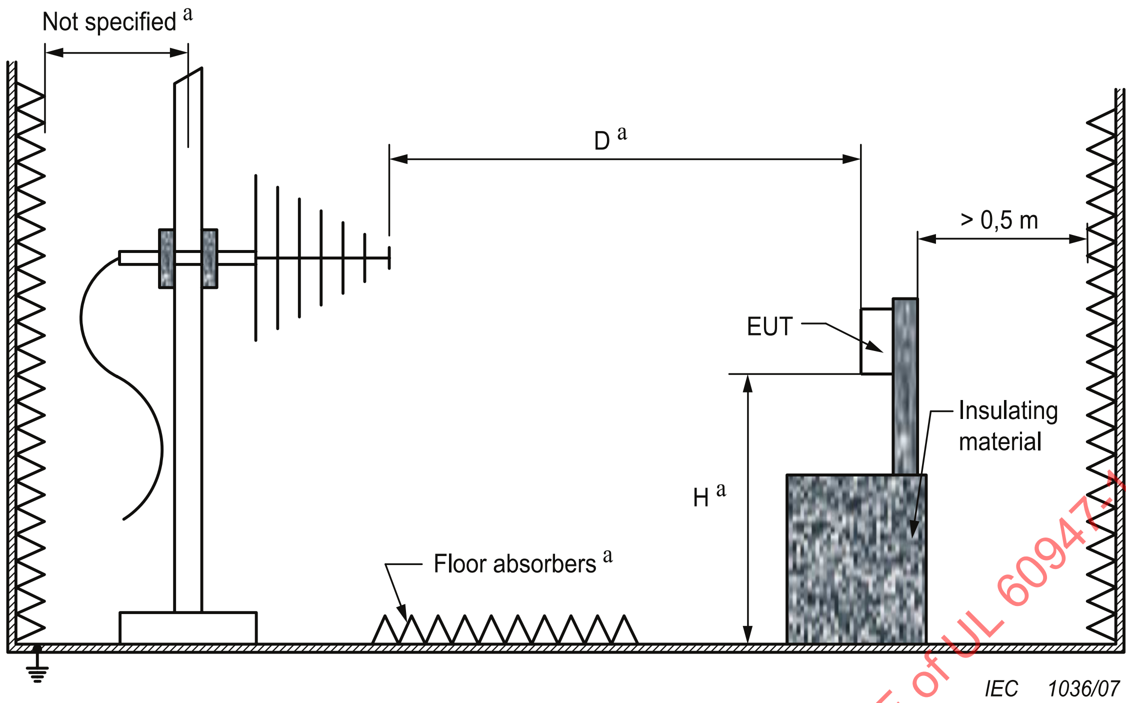


Figure 18

Test set-up for the verification of immunity to electrostatic discharges



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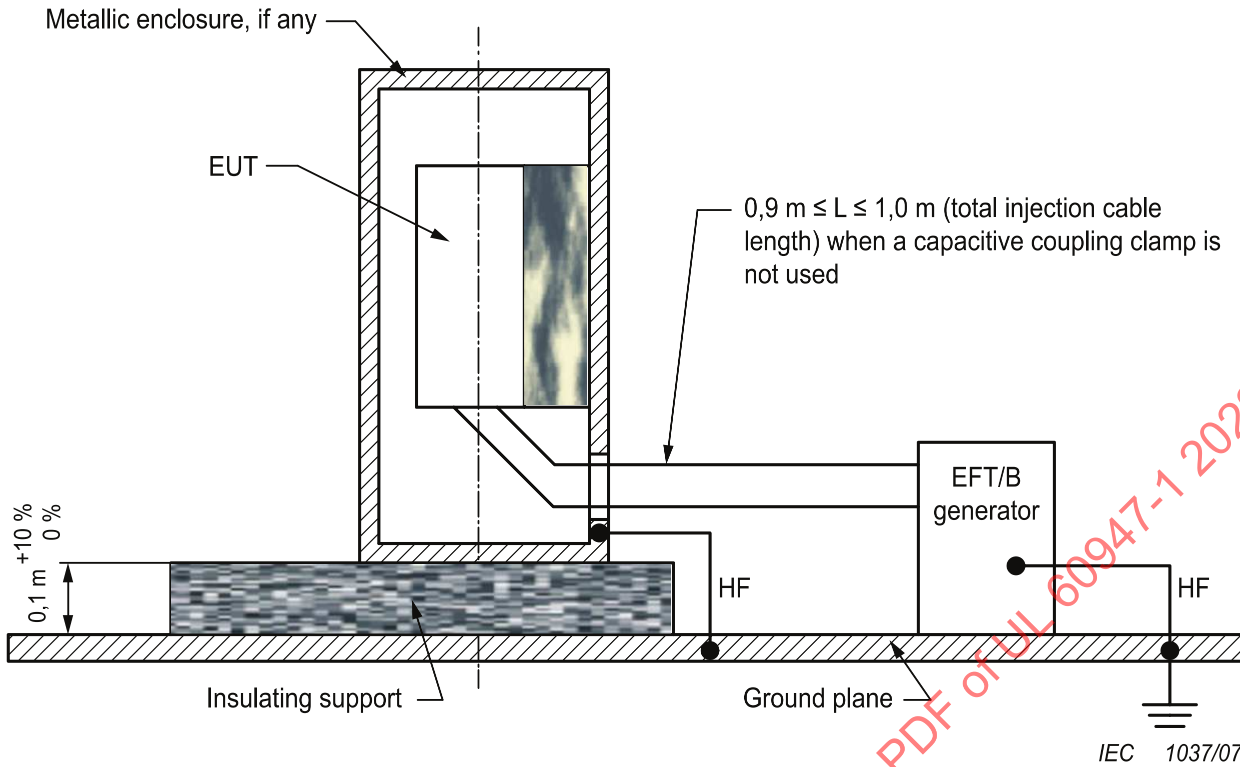
[a] See IEC 61000-4-3.

Figure 19

Test set-up for the verification of immunity to radiated radio-frequency electromagnetic fields



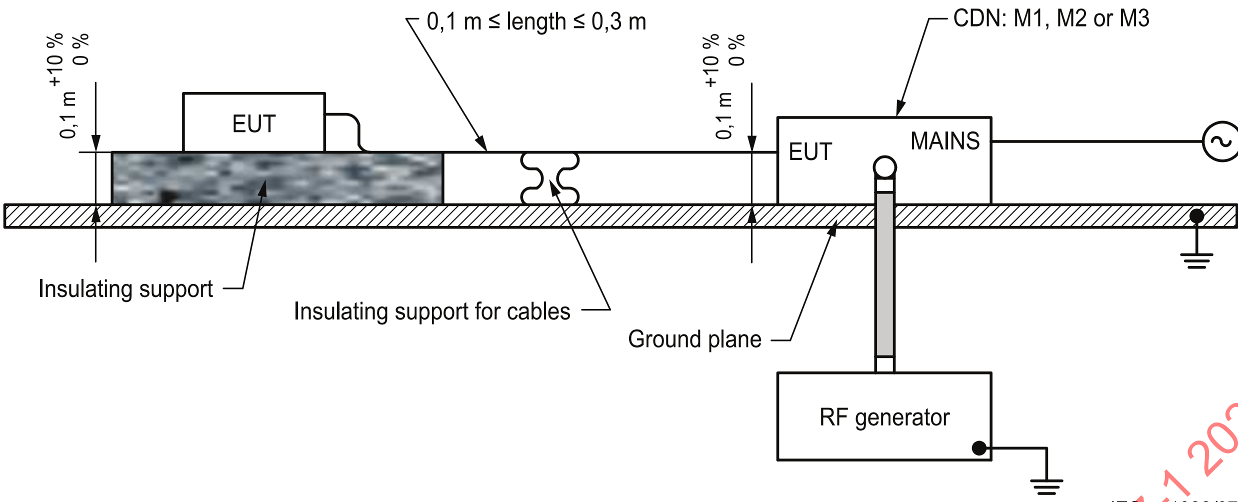
su0966

Key

HF high frequency connection

Figure 20

Test set-up for the verification of immunity to electrical fast transients/bursts



su0967

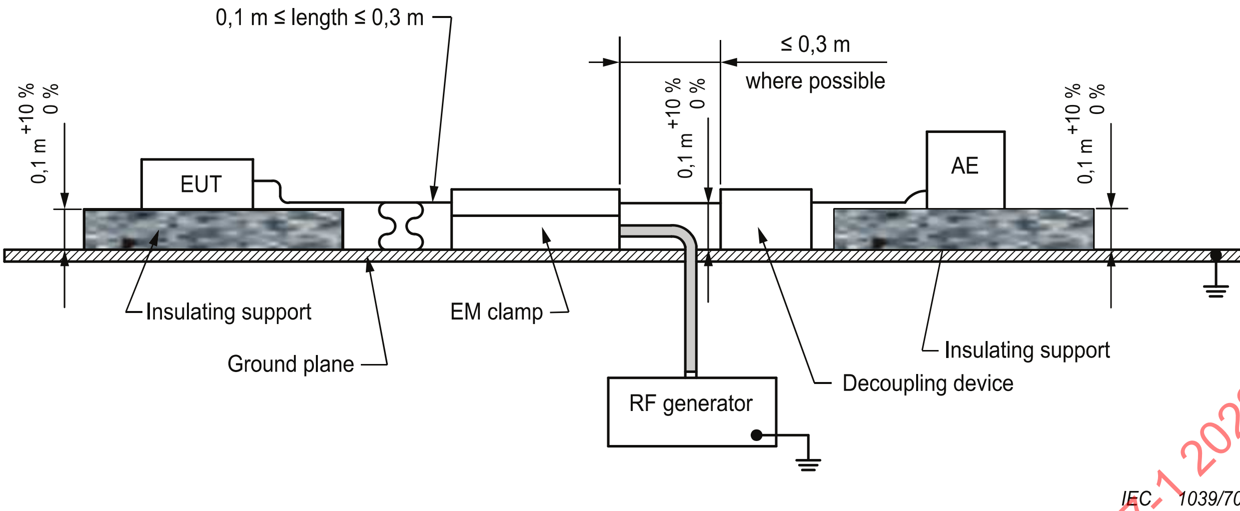
Key

CDN coupling-decoupling network

NOTE As an alternative to the coupling-decoupling network M1, the coupling-decoupling network M2 or M3 may be used in which case the two or three connecting wires, as applicable, are connected to the same point of the EUT.

Figure 21

Test set-up for the verification of immunity to conducted disturbances induced by r.f. fields on power lines



su0968

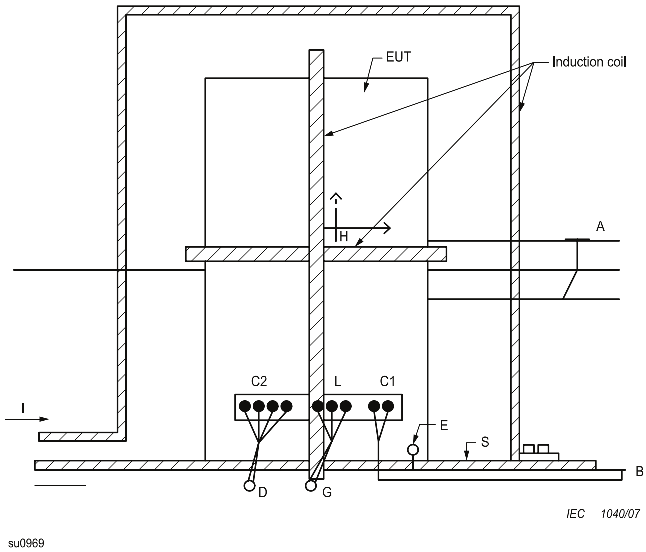
Key

AE auxiliary equipment

EM clamp electromagnetic clamp

Figure 22

Example of test set-up for the verification of immunity to conducted disturbances induced by r.f. fields on signal lines when CDŃs are not suitable



Key

A safety earth

B to power supply source

C1 power supply circuit

C2 signal circuit

D to signal source, simulator

E earth terminal

G to the test generator

H magnetic field strength

I induction current

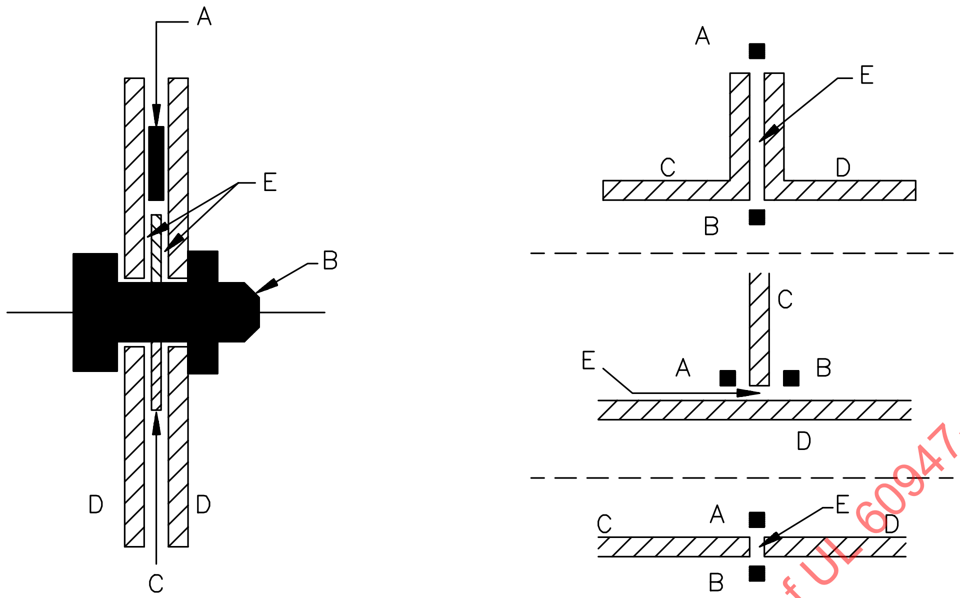
L communication line

S insulating support

Figure 23

Test set-up for the verification of immunity to power frequency magnetic fields

Figure 24DV D2 *Addition:*



Parts A, B – Live parts of opposite polarity, or a live part and grounded metal part with spacing through the crack between C and D less than required.

Parts C, D – Insulating barriers clamped tightly together so that the dielectric strength between A and B is greater than the equivalent air spacing.

Part E – The clamped joint.

Figure 24DV

Clamped joint

(see 7.1.4.4DV.3.1 and 8.2.7.4DV.1.1)

Annex A
(informative)

Harmonisation of utilization categories for low-voltage switchgear and controlgear

The IEC 60947 series contains different parts specifying requirements for different types of low-voltage switchgear. Standards for products covered by the IEC 60947 series have been developed at different periods of time and by various working groups. It results in many utilization categories for similar applications in the IEC 60947 series.

The objective of this annex is to give the harmonisation framework for the low-voltage switchgear and controlgear as given in Table A.1. A future objective under consideration is to specify a common set of requirements for testing of the products from different parts of the IEC 60947 series.

The intended benefits are to:

– simplify the standards by bringing all similar categories together under one common set of categories;

– help the user in the selection of equipment for specific applications.

Table A.1
Utilization categories used in the IEC 60947 series

Nature of current	Category		Typical switched load	Relevant IEC product Proposed standard
	Proposed standard [c]	Present [d]		
a.c.	AC-20	AC-20	No-load condition	IEC 60947-3:2008, Amd 1 (2012)
	AC-21	AC-21	Resistive loads, including moderate overloads	
	AC-22	AC-22	Mixed resistive and inductive loads, including moderate overloads	
	AC-23	AC-23	Motor loads or other highly inductive loads	
	AC-1	AC-1	Non-inductive or slightly inductive loads	IEC 60947-4-1:2009, Amd 1 (2012)
	AC-2	AC-2	Slip-ring motors or switching of mixed resistive and inductive loads, including moderate overloads	
	AC-3	AC-3	Squirrel-cage motors	
	AC-4	AC-4	Squirrel-cage motors: plugging[a], inching[b]	
	AC-5a	AC-5a	Discharge lamp ballasts	
	AC-5b	AC-5b	Incandescent lamps	
	AC-6a	AC-6a	Transformers	
	AC-6b	AC-6b	Capacitor banks	
	AC-8 AC-8	AC-8a AC-8b	Hermetic refrigerant compressor	
	AC-2a	AC-52a	Slip ring motor stators: 8 h duty with on-load currents for start, acceleration, run	IEC 60947-4-2:2011
	AC-2b	AC-52b	Slip ring motor stators: intermittent duty	
	AC-53a	AC-53a	Squirrel-cage motors: 8 h duty with on-load currents for start, acceleration, run	
	AC-3b	AC-53b	Squirrel-cage motors: intermittent duty	
	AC-8a	AC-58a	Hermetic refrigerant compressor motors with automatic resetting of overload releases: 8 h duty with on-load currents for start, acceleration, run	

Table A.1 Continued on Next Page

Table A.1 Continued

Nature of current	Category: Proposed standard [c]	Category: Present [d]	Typical switched load	Relevant IEC product Proposed standard
	AC-8b	AC-58b	Hermetic refrigerant compressor motors with automatic resetting of overload releases: intermittent duty	
	AC-1	AC-51	Non-inductive or slightly inductive loads	IEC 60947-4-3:1999 Amd 1 (2006) Amd 2 (2011)
	AC-5a	AC-55a	Discharge lamps ballast	
	AC-5b	AC-55b	Incandescent lamps	
	AC-6a	AC-56a	Transformers	
	AC-6b	AC-56b	Capacitor banks	
	AC-12	AC-12	Resistive loads and solid-state loads with isolation by optocouplers	IEC 60947-5-1:2003 Amd 1 (2009)
	AC-13	AC-13	Solid-state loads with transformer isolation	
	AC-14	AC-14	Small electromagnetic loads	
	AC-15	AC-15	a.c. electromagnetic loads	
	AC-12	AC-12	Resistive loads and solid state loads with optical isolation	IEC 60947- 5-2:2007 Amd 1 (2012)
	AC-140	AC-140	Small electromagnetic loads with holding (closed) current ≤ 0,2 A, e.g. contactor relays	
	AC-1	AC-31	Non inductive or slightly inductive loads	IEC 60947-6-1:2005
	AC-2	C-32	Slip-ring motors or switching of mixed resistive and inductive loads, including moderate overloads	
	AC-3	AC-33	Squirrel-cage motors	
	AC-5a	AC-35	Discharge lamp ballast	
	AC-5b	AC-36	Incandescent lamps	
	AC-40	AC-40	Distribution circuits comprising mixed resistive and reactive loads having a resultant inductive reactance	IEC 60947-6-2:2002 Amd 1 (2007)
	AC-1	AC-41	Non-inductive or slightly inductive loads	
	AC-2	AC-42	Slip-ring motors or switching of mixed resistive and inductive loads, including moderate overloads	
	AC-3	AC-43	Squirrel-cage motors	
	AC-4	AC-44	Squirrel-cage motors: plugging[a], inching[b]	
	AC-5a	AC-45a	Discharge lamp ballasts	
	AC-5b	AC-45b	Incandescent lamps	
	AC-7a	AC-7a	Slightly inductive loads for household appliances and similar applications	IEC 61095:2 009
	AC-7b	AC-7b	Motor-loads for household applications	
d.c.	DC-20	DC-20	Connecting and disconnecting under no-load conditions	IEC 60947-3:2008, Amd 1 (2012)
	DC-21	DC-21	Resistive loads, including moderate overloads	
	DC-22	DC-22	Mixed resistive and inductive loads, including moderate overloads (e.g. shunt motors)	
	DC-23	DC-23	Highly inductive loads (e.g. series motors)	
	DC-1	DC-1	Non-inductive or slightly inductive loads	IEC 60947- 4-1:2009, Amd 1 (2012)
	DC-3	DC-3	Shunt-motors	
	DC-5	DC-5	Series-motors	
	DC-6	DC-6	Incandescent lamps	
	DC-12	DC-12	Control of resistive loads and solid-state loads with isolation by optocouplers	IEC 60947-5-1:2003 Amd 1 (2009)

Table A.1 Continued on Next Page

Table A.1 Continued

Nature of current	Category: Proposed standard [c]	Category: Present [d]	Typical switched load	Relevant IEC product Proposed standard
	DC-13	DC-13	Control of electromagnets	
	DC-14	DC-14	Control of electromagnetic loads having economy resistors in circuit	
	DC-12	DC-12	Control of resistive loads and solid state loads with optical isolation	IEC 60947-5-2:2007 Amd 1 (2012)
	DC-13	DC-13	Control of electromagnets	
	DC-1	DC-31	Non-inductive or slightly inductive loads	IEC 60947-6-1:2005
	DC-3	DC-33	Shunt-motors	
	DC-6	DC-36	Incandescent lamps	
	DC-40	DC-40	Distribution circuits comprising mixed resistive and reactive loads having a resultant inductive reactance	IEC 60947-6-2:2002 Amd 1 (2007)
	DC-1	DC-41	Non-inductive or slightly inductive loads	
	DC-3	DC-43	Shunt-motors	
	DC-5	DC-45	Series-motors Incandescent lamps	
	DC-6	DC-46	Incandescent lamps	

[a] By plugging is understood stopping or reversing the motor rapidly by reversing motor primary connections while the motor is running.

[b] By inching (jogging) is understood energizing a motor once or repeatedly for short periods to obtain small movements of the driven mechanism.

[c] Utilization categories intended to be harmonized throughout product standards in their future editions.

[d] Present utilization category as defined in the referred edition of the product standard in the last column until it is changed to the proposed utilization category.

Annex B
(informative)

Suitability of the equipment when conditions for operation in service differ from the normal conditions

If the conditions for operation in service and the application differ from those given in this standard, the user shall state the deviations from the standard conditions and consult the manufacturer on the suitability of the equipment for use under such conditions.

B.1 Examples of conditions differing from normal

B.1.1 Ambient air temperature

The expected range of ambient air temperature can be lower than –5 °C or higher than +40 °C.

B.1.2 Altitude

The altitude of the place of installation is more than 2 000 m.

B.1.3 Atmospheric conditions

The atmosphere in which the equipment is to be installed may have a relative humidity greater than the values specified in 6.1.3 or contain an abnormal amount of dust, acids, corrosive gases, etc.

The equipment is to be installed near the sea.

B.1.4 Conditions of installation

The equipment may be fitted to a moving device, or its support may assume a sloping position either permanently or temporarily (equipment fitted aboard ships), or it may be exposed in service to abnormal shocks or vibrations.

B.2 Connections with other apparatus

The user shall inform the manufacturer of the type and dimensions of electrical connections with other apparatus in order to enable him to provide enclosures and terminals meeting the conditions of installation and temperature-rise prescribed by this standard and/or the relevant product standard and also to enable him to provide space, where necessary, to spread out conductors within the enclosure.

B.3 Auxiliary contacts

The user shall specify the number and type of auxiliary contacts to be supplied to satisfy requirements such as signalling, interlocking, and similar functions.

B.4 Special applications

The user shall indicate to the manufacturer if the equipment could be used for special applications not covered by this standard and/or the relevant product standard.

Annex C
(normative)

Degrees of protection of enclosed equipment

Introduction

Where an IP Code is stated by the manufacturer for enclosed equipment and for a device with integral enclosure it shall comply with the requirements of IEC 60529, and the following modifications and additions.

NOTE Figure C.1 gives further information to facilitate the understanding of the IP code covered by IEC 60529.

Clauses and subclauses of IEC 60529 applicable to enclosed equipment are explicitly detailed in this annex.

Clause and subclause numbers of this annex correspond to the numbers in IEC 60529.

C.1 Scope

This annex applies to the degrees of protection of enclosed switchgear and controlgear at rated voltages not exceeding 1 000 V a.c. or 1 500 V d.c. hereafter referred to as "Equipment".

C.2 Object

Clause 2 of IEC 60529 applies with the additional requirements of this annex.

C.3 Definitions

Clause 3 of IEC 60529 applies except that "Enclosure" (3.1) is replaced by the following, notes 1 and 2 remaining as they are.

"A part providing a specified degree of protection of equipment against certain external influences and a specified degree of protection against approach to or contact with live parts and moving parts."

NOTE This definition given in 2.1.16 of this standard is similar to IEV 441-13-01 which applies to assemblies.

C.4 Designation

Clause 4 of IEC 60529 applies except for letters H, M and S.

C.5 Degrees of protection against access to hazardous parts and against ingress of solid foreign objects indicated by the first characteristic numeral

Clause 5 of IEC 60529 applies.

C.6 Degrees of protection against ingress of water indicated by the second characteristic numeral

Clause 6 of IEC 60529 applies.

C.7 Degrees of protection against access to hazardous parts indicated by the additional letter

Clause 7 of IEC 60529 applies.

C.8 Supplementary letters

Clause 8 of IEC 60529 applies except for letters H, M and S.

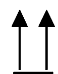
C.9 Examples of designations with IP Code

Clause 9 of IEC 60529 applies.

C.10 Marking

Clause 10 of IEC 60529 applies with the following addition:

If the IP Code is designated for one mounting position only, it shall be indicated by the symbol 0623 of ISO 7000 placed next to the IP Code specifying this position of the equipment, e.g. vertical:



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C.11 General requirements for tests

C.11.1 Subclause 11.1 of IEC 60529 applies.

C.11.2 Subclause 11.2 of IEC 60529 applies with the following additions:

All tests are made in the unenergized state.

Certain devices (e.g. exposed faces of push-buttons) can be verified by inspection.

The temperature of the test sample shall not deviate from the actual ambient temperature by more than 5 K.

Where equipment is mounted in an empty enclosure which already has an IP Code (see 11.5 of IEC 60529) the following requirements apply.

a) For IP1X to IP4X and additional letters A to D.

This shall be verified by inspection and compliance with the enclosure manufacturer's instructions.

b) For IP6X dust test.

This shall be verified by inspection and compliance with the enclosure manufacturer's instructions.

c) For IP5X dust test and IPX1 to IPX8 water tests.

Testing of the enclosed equipment is only required where the ingress of dust or water may impair the operation of the equipment.

NOTE IP5X dust and IPX1 to IPX8 water tests allow the ingress of a certain amount of dust and water provided that there are no harmful effects. Every internal equipment configuration should, therefore, be separately considered.

C.11.3 Subclause 11.3 of IEC 60529 applies with the following addition:

Drain and ventilating holes are treated as normal openings.

C.11.4 Subclause 11.4 of IEC 60529 applies.

C.11.5 Where an empty enclosure is used as a component of an enclosed equipment, subclause 11.5 of IEC 60529 applies.

C.12 Tests for protection against access to hazardous parts indicated by the first characteristic numeral

Clause 12 of IEC 60529 applies except for 12.3.2.

C.13 Tests for protection against ingress of solid foreign objects indicated by the first characteristic numeral

Clause 13 of IEC 60529 applies except for

C.13.4 Dust test for first characteristic numerals 5 and 6

Enclosed equipment having a degree of protection IP5X shall be tested according to category 2 of 13.4 of IEC 60529.

NOTE 1 A particular product standard for equipment having a degree of protection IP5X may require testing according to category 1 of 13.4 of IEC 60529.

Enclosed equipment having a degree of protection IP6X shall be tested according to category 1 of 13.4 of IEC 60529.

NOTE 2 For enclosed equipment according to this standard, a degree of protection IP5X is generally deemed satisfactory.

C.13.5.2 Acceptance conditions for first characteristic numeral 5

The following text to be added:

Where dust deposits could raise doubts as to the correct functioning and safety of equipment, a preconditioning and a dielectric test shall be conducted as follows:

The preconditioning, after the dust test, shall be verified by test Cab: Damp heat, steady state, according to IEC 60068-2-78, under the following test conditions.

The equipment shall be prepared so that the dust deposits are subject to the test by leaving open the lid and/or removing parts, where possible without the aid of tool.

Before being placed in the test chamber the equipment shall be stored at room temperature for at least 4 h before the test.

The test duration shall be 24 consecutive hours.

After this period the equipment is to be removed from the test chamber within 15 min and submitted to a power-frequency dielectric test for 1 min, the value being 2 U_e max with a minimum of 1 000 V. Application of the test voltage and the acceptance criteria shall be as specified in 8.3.3.4.1 item 3) c) and item 3) d).

C.14 Tests for protection against water indicated by second characteristic numeral

C.14.1 Test means

Subclause 14.1 of IEC 60529.

C.14.2 Test conditions

Subclause 14.2 of IEC 60529 applies.

C.14.3 Acceptance conditions

Subclause 14.3 of IEC 60529 applies with the following addition:

The equipment is then submitted to a power-frequency dielectric test for 1 min, the value being 2 U_e max. with a minimum of 1 000 V. Application of the test voltage and the acceptance criteria shall be as specified in 8.3.3.4.1 item 3) c) and item 3) d).

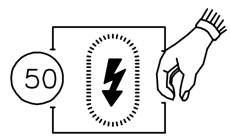
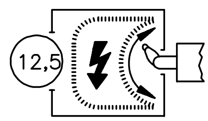
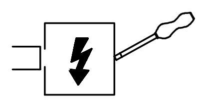
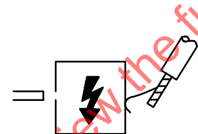
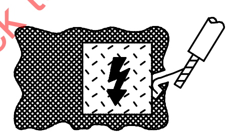
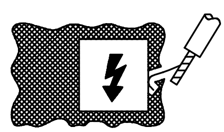
C.15 Tests for protection against access to hazardous parts indicated by additional letter

Clause 15 of IEC 60529 applies.

C.16 Summary of responsibilities of relevant technical committees

The relevant product standards specify the detailed information listed, as a guide, in Annex B of IEC 60529, taking into account the supplements specified above in this Annex C.

Further illustrations are included to facilitate the understanding of the IP Codes (see Figure C.1).

C.1a — FIRST NUMERAL			
Protection against ingress of solid objects			Protection of persons against access to hazardous parts with:
IP	Requirements	Example	
0	No protection		Non–protected
1	Full Penetration of 50 mm diameter sphere not allowed. Contact with hazardous parts not permitted.		Back of hand
2	Full Penetration of 12,5 mm diameter sphere not allowed. The jointed test fingert shall have adequate clearance from hazardous parts.		Finger
3	The access probe of 2,5 mm diameter shall not penetrate		Tool
4	The access probe of 1,0 mm diameter shall not penetrate		Wire
5	Limited ingress of dust permitted (no harmful deposit)		Wire
6	Totally protected against ingress of dust		Wire

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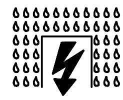
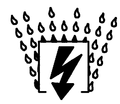
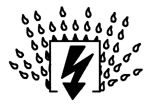
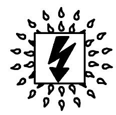
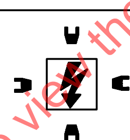
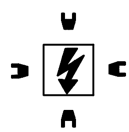
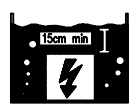
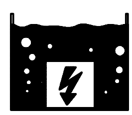
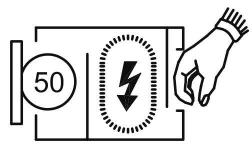
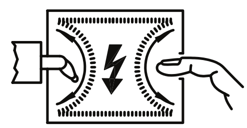
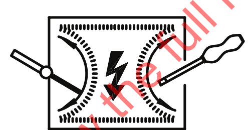
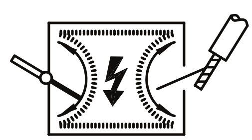
(continued)

Figure C.1

IP Codes

C.1b — SECOND NUMERAL			
Protection against harmful ingress of water			Protection from water
IP	Prescriptions	Example	
0	No protection		Non–protected
1	Protected against vertically falling drops of water. Limited ingress permitted		Vertically dripping
2	Protected against vertically falling drops of water with enclosure tilted 15° from the vertical . Limited ingress permitted		Dripping up to 15° from the vertical
3	Protected against sprays to 60° from the vertical. Limited ingress permitted		Limited spraying
4	Protected against water splashed from all directions. Limited ingress permitted		Splashing from all directions
5	Protected against jets of water. Limited ingress permitted		Hosing jets from all directions
6	Protected against strong jets of water. Limited ingress permitted		Strong hosing jets from all directions
7	Protected against the effects of immersion between 15 cm and 1 m		Temporary immersion
8	Protected against long periods of immersion under pressure		Continuous immersion

S5173 *(continued)*

C.1c - ADDITIONAL LETER (optional)			
IP	Requirements	Example	Protection of persons against access to hazardous parts with:
A For use with first numeral 0	Penetration of 50 mm diameter sphere up to barrier must not contact hazardous parts		Back of hand
B For use with first numerals 0 and 1	Test finger penetration to a maximum of 80 mm must not contact hazardous parts		Finger
C For use with first numerals 1 and 2	Wire of 2,5 mm diameter x 100 mm long must not contact hazardous parts when spherical stop face is partially entered		Tool
D For use with first numerals 2 and 3	Wire of 1,0 mm diameter x 100 mm long must not contact hazardous parts when spherical stop face is partially entered		Wire

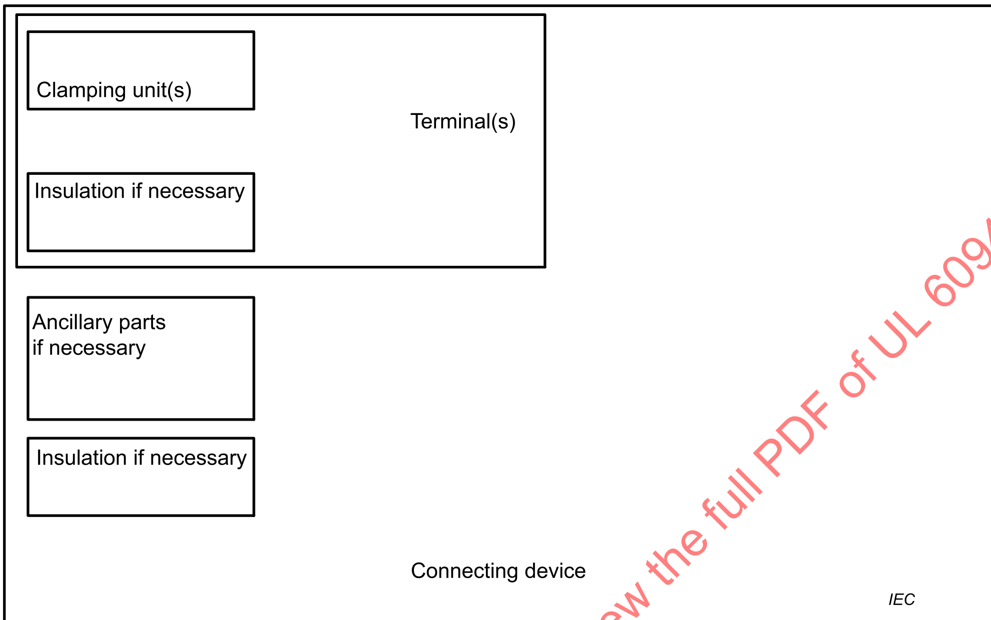
su0970

Annex D
(informative)

Examples of clamping units and relationship between clamping unit and connecting device

D.1 Clamping unit in a connecting device

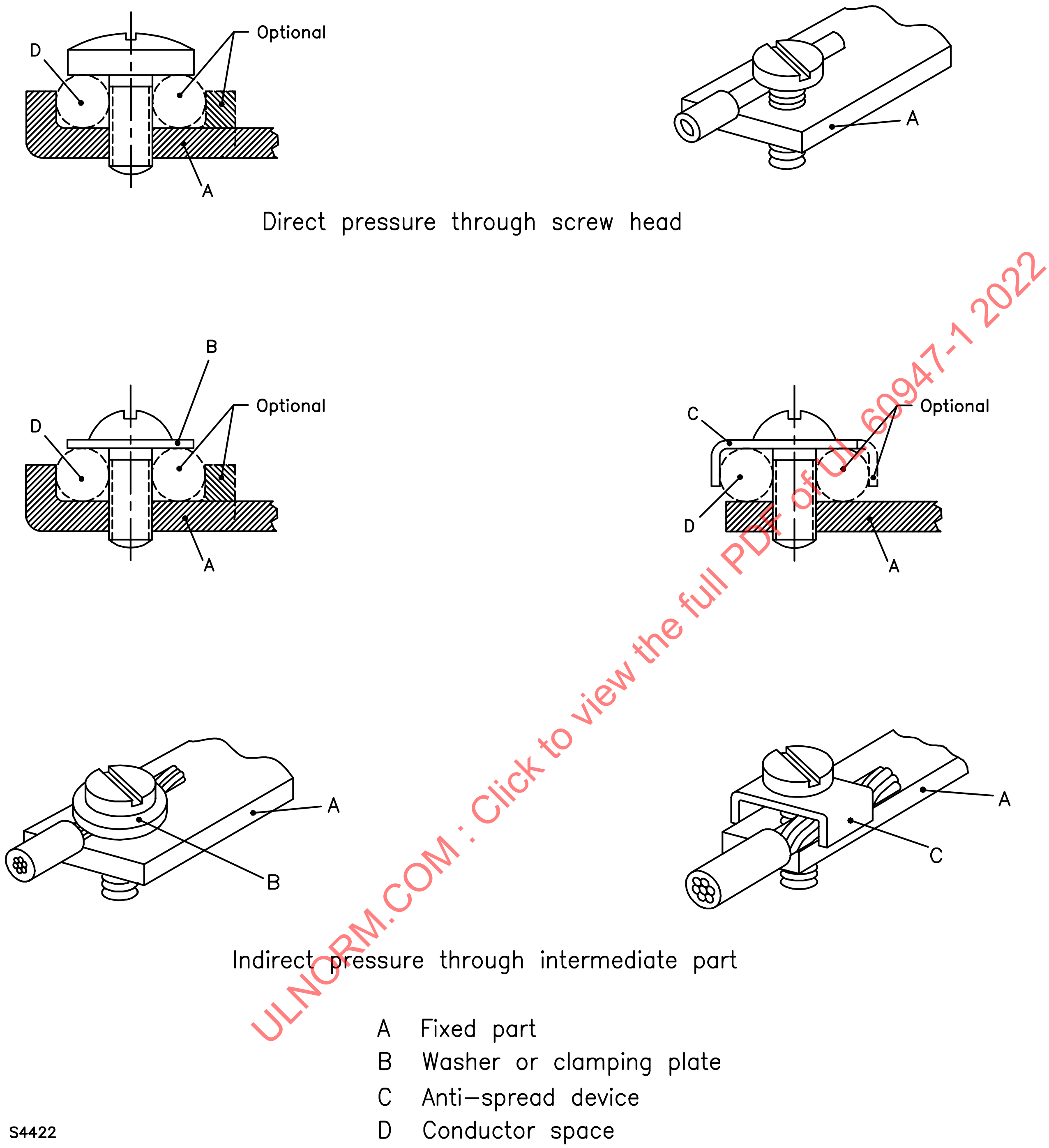
For clarification of the definitions, see Figure D.8.



su4408

Figure D.8
Clamping unit in a connecting device

D.2 Examples of clamping units



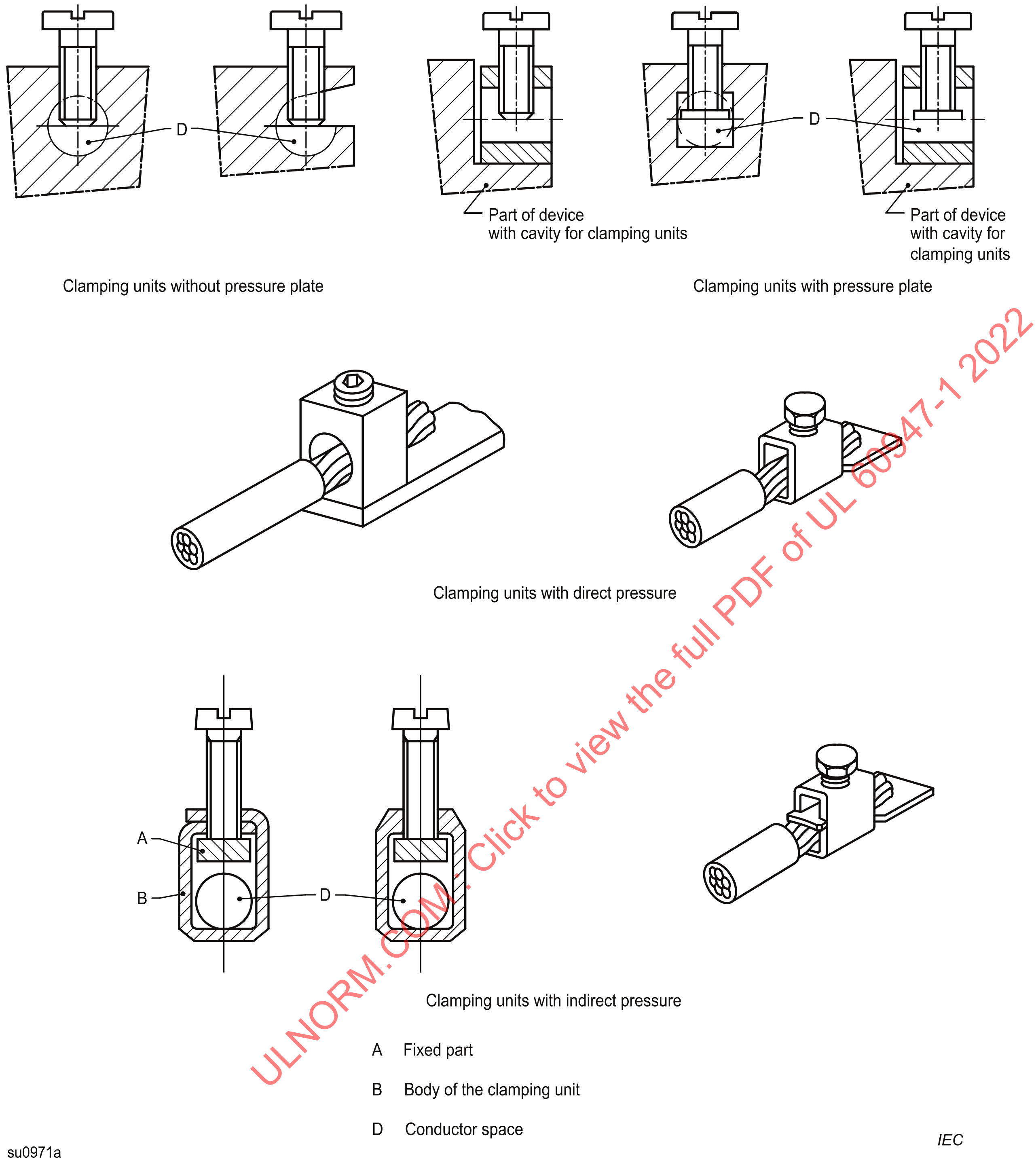
NOTE Examples shown here do not prohibit the conductor being divided either side of the screw.

Screw clamping unit

Screw-type clamping unit in which the conductor is clamped under the head of one or more screws. The clamping pressure may be applied directly by the head of the screw or through an intermediate part, such as a washer, clamping plate or anti-spread device.

Figure D.1

Screw clamping units



Pillar clamping unit

Screw-type clamping unit in which the conductor is inserted into a hole or cavity, where it is clamped under the shank of the screw or screws. The clamping pressure may be applied directly by the shank of the screw or through an intermediate part to which pressure is applied by the shank of the screw.

Figure D.2

Pillar clamping units

A Fixed part
B Washer or clamping plate
C Anti–spread device
D Conductor space
E Stud

S4424

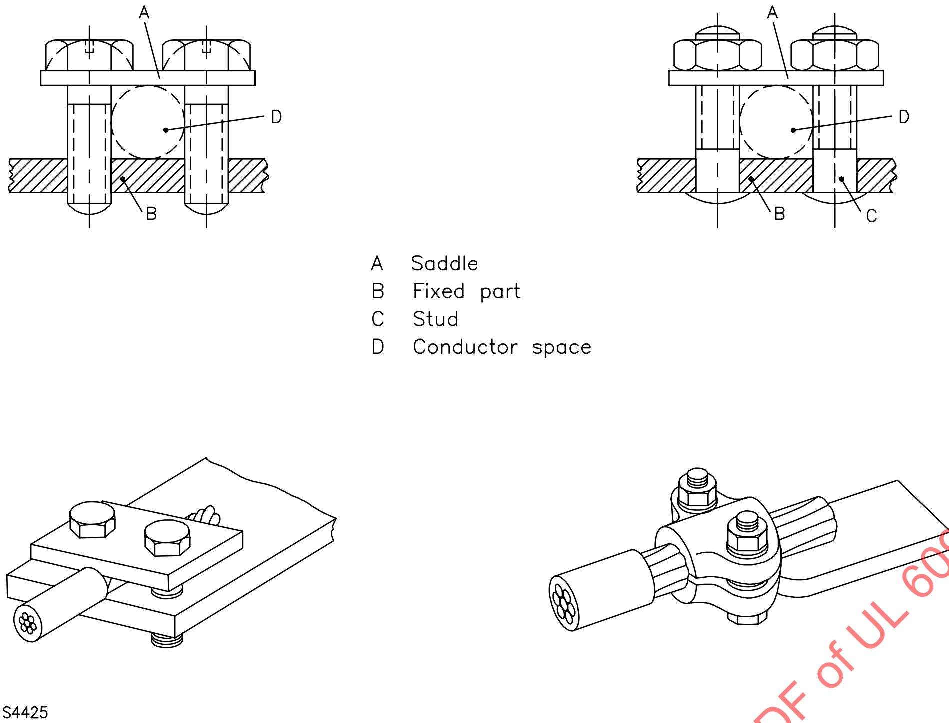
NOTE The part which retains the conductor in position may be of insulating material, provided the pressure necessary to clamp the conductor is not transmitted through the insulating material.

Stud clamping unit

Screw-type clamping unit in which the conductor is clamped under one or two nuts. The clamping pressure may be applied directly by a suitably shaped nut or through an intermediate part, such as a washer, clamping plate or anti-spread device.

Figure D.3

Stud clamping units



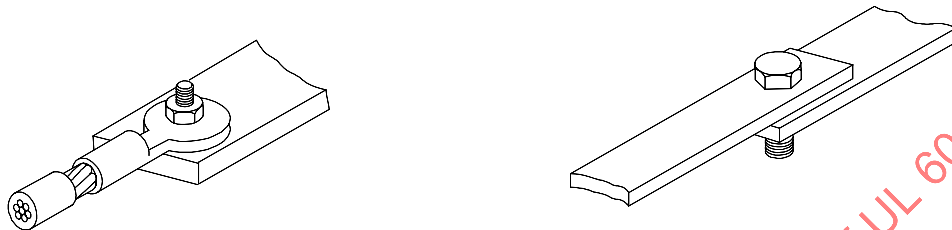
Saddle clamping unit

Screw-type clamping unit in which the conductor is clamped under a saddle by means of two or more screws or nuts.

Figure D.4

Saddle clamping units

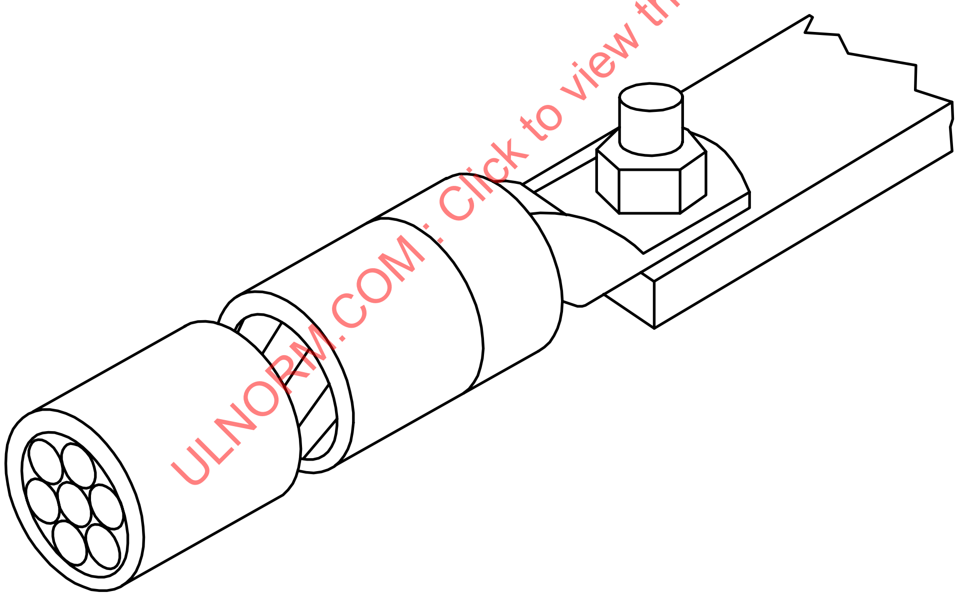
A Locking means
B Cable lug or bar
E Fixed part
F Stud



S4426A

Lug clamping unit

Screw clamping unit or stud clamping unit designed for clamping a cable lug or bar by means of a screw or nut.

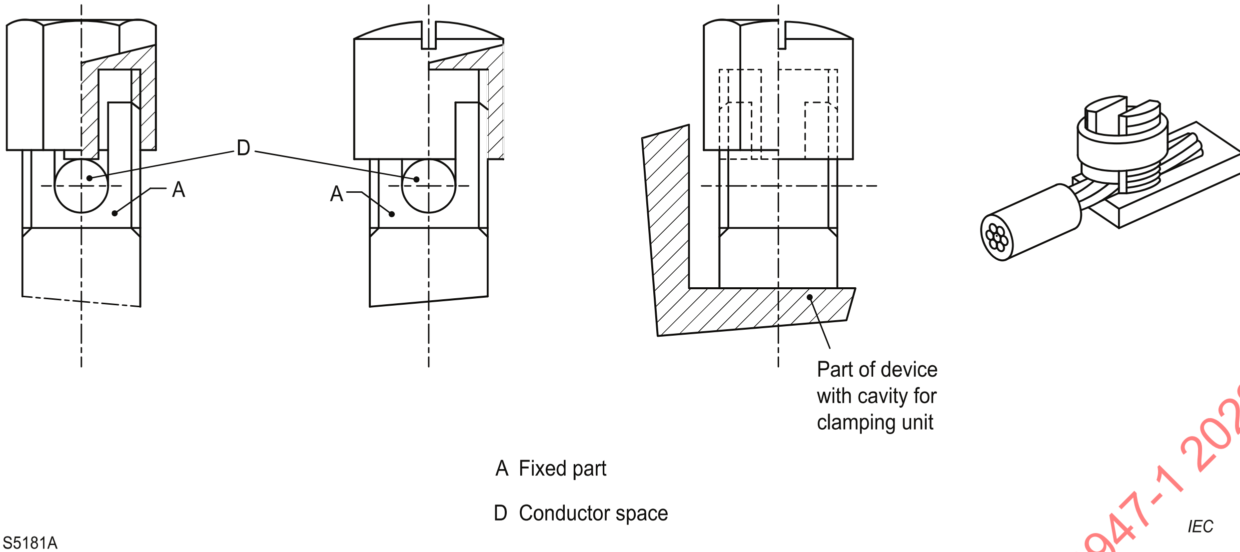


S4542

NOTE Examples of overall dimensions of cable lugs are given in Annex P.

Figure D.5

Lug clamping units



Mantle clamping unit

Screw-type clamping unit in which the conductor is clamped against the base of a slot in a threaded stud by means of a nut. The conductor is clamped against the base of the slot by a suitable shaped washer under the nut, by a central peg if the nut is a cap nut, or by equally effective means for transmitting the pressure from the nut to the conductor within the slot.

Figure D.6

Mantle clamping units

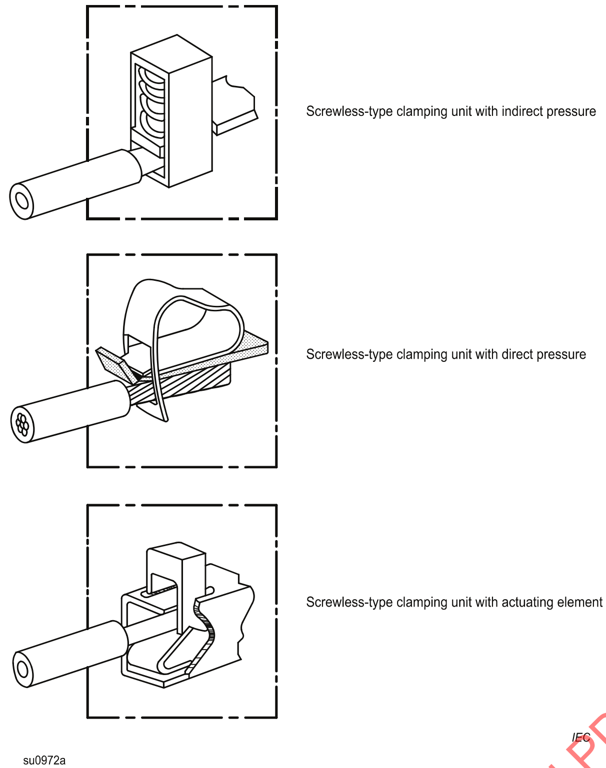


Figure D.7

Screwless-type clamping units

Annex E
(informative)

Description of a method for adjusting the load circuit

To adjust the load circuit to obtain the characteristics prescribed above, several methods may be applicable in practice. One of them is described below.

The principle is illustrated in Figure 8a and Figure 8b.

The oscillatory frequency *f* of the transient recovery voltage and the value of the factor *γ* are essentially determined by the natural frequency and the damping of the load circuit. Since these values are independent of the voltage and frequency applied to the circuit, the adjustment can be made by energizing the load circuit from an a.c. power supply, the voltage and frequency of which may be different from those of the supply source utilized for the test of the equipment. The circuit is interrupted at a current zero by a diode, and the oscillations of the recovery voltage are observed on the screen of a cathode-ray oscilloscope, the sweep of which is synchronized with the frequency of the power supply (see Figure E.1).

To permit reliable measurements to be made, the load circuit is energized by means of a high-frequency generator G giving a voltage suitable for the diode. The frequency of the generator is chosen equal to

a) 2 kHz for test currents up to and including 1 000 A;

b) 4 kHz for test currents higher than 1 000 A.

Connected in series with the generator are

– a dropping resistor having a resistance value R_a high with respect to the load circuit impedance ($R_a \geq 10$ Z, where

$$Z = \sqrt{R^2 + (\omega L)^2}$$

and where ω = 2 π. 2 000 s^{-1} or 2 π. 4 000 s^{-1}) for cases a) and b) respectively;

– an instantaneously blocking switching diode B; switching diodes commonly used in computers such as diffused junction silicon switching diodes of not over 1 A forward rated current are suitable for this application.

Due to the value of frequency of the generator G, the load circuit is practically purely inductive and, at the instant of current zero, the applied voltage across the load circuit will be at its peak value. To ensure that the components of the load circuit are suitable, it must be checked on the screen that the curve of the transient voltage at its initiation (point A in Figure E.1) has a practically horizontal tangent.

The actual value of the factor *γ* is the ratio U_{11}/U_{12} ; U_{11} is read on the screen, U_{12} is read between the ordinate of point A and the ordinate of the trace when the load circuit is no longer energized by the generator (see Figure E.1).

When observing the transient voltage in the load circuit with no resistor R_p or capacitor C_p in parallel, one reads on the screen the natural oscillatory frequency of the load circuit. Care should be taken that the capacitance of the oscilloscope or of its connecting leads does not influence the resonant frequency of the load circuit.

If that natural frequency exceeds the upper limit of the required value *f*, the suitable values of frequency and factor *γ* can be obtained by connecting in parallel capacitors C_p and resistors R_p of appropriate values. The resistors R_p shall be practically non-inductive.

Depending on the position of the earthing, the following two procedures for the adjustment of the load circuit are recommended.

a) In the case of the earthed load star-point: each of the three phases of the load circuit shall be adjusted individually as shown in Figure 8a.

b) In the case of the earthed supply star-point: one phase shall be connected in series with the other two phases in parallel as shown in Figure 8b. The adjustment shall be repeated by successively connecting to the high frequency generator the three phases in all possible combinations.

NOTE 1 A higher value of frequency obtained from the generator G facilitates the observation on the screen and improves the resolution.

NOTE 2 Other methods of determining frequency and factor γ (such as the impression of a square-wave current on the load circuit) may also be used.

NOTE 3 For connecting the load in star, either the R-end or either the X-end of the load could be connected, if the mode of shorting the load (earthed or floating) is not changed between the adjustment and the test.

Reason: Depending on which side of the load is shorted, different oscillatory frequencies occur.

NOTE 4 Care should also be taken that the leakage capacitance to earth of the high-frequency generator does not have any effect on the natural oscillatory frequency of the load circuit.

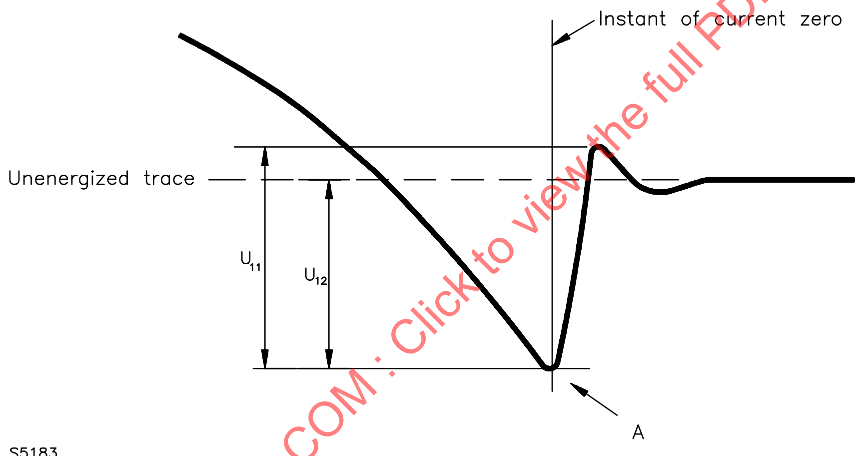


Figure E.1

Determination of the actual value of the factor γ

Annex F
(informative)

Determination of short-circuit power-factor or time-constant

There is no method by which the short-circuit power-factor or time-constant can be determined with precision, but for the purpose of this standard, the determination of the power-factor or the time-constant of the test circuit may be made by one of the following methods.

F.1 Determination of short-circuit power-factor

Method I – Determination from d.c. component

The angle φ may be determined from the curve of the d.c. component of the asymmetrical current wave between the instant of the short circuit and the instant of contact separation as follows:

1 To determine the time-constant *L/R* from the formula for the d.c. component.

The formula for the d.c. component is

$$i_{\mathrm{d}} = I_{\mathrm{do}} \mathrm{e}^{-Rt/L}$$

where

i_d is the value of the d.c. component at the instant *t*;

I_{do} is the value of the d.c. component at the instant taken as time origin;

L/R is the time-constant of the circuit, in seconds;

t is the time, in seconds, taken from the initial instant;

e is the base of Napierian logarithms.

The time-constant *L/R* can be determined by

a) measuring the value of I_{do} at the instant of short-circuit and the value of i_d at another instant *t* before contact separation;

b) determining the value of $e^{-Rt/L}$ by dividing i_d by I_{do};

c) determining the value of –*X* corresponding to the ratio i_d/I_{do}, from a table of values of e^{-X};

The value *X* then represents *Rt/L*, from which *R/L* is obtained.

2 To determine the angle φ from

$$\varphi = \text{arc tg}\frac{\omega L}{R}$$

where ω is 2 π times the actual frequency.

This method should not be used when the currents are measured by current transformers, except if suitable precautions are taken to eliminate errors due to

– the time-constant of the transformer and its burden in relation to that of the primary circuit;

– magnetic saturation which can result from the transient flux conditions combined with possible remanence.

Method II – Determination with pilot generator

When a pilot generator is used on the same shaft as the test generator, the voltage of the pilot generator on the oscillogram may be compared in phase first with the voltage of the test generator and then with the current of the test generator.

The difference between the phase angles between pilot generator voltage and main generator voltage on the one hand and pilot generator voltage and test generator current on the other hand gives the phase angle between the voltage and current of the test generator, from which the power-factor can be determined.

F.2 Determination of short-circuit time-constant (oscillographic method)

The value of the time-constant is given by the abscissa corresponding to the ordinate 0,632 A_2 of the ascending part of the curve of the oscillogram of calibration of the circuit (see Figure 14).

Annex G
(informative)

Measurement of creepage distances and clearances

G.1 Basic principles

The widths X of grooves specified in examples 1 to 11 basically apply to all examples as a function of pollution as follows:

Pollution degree	Minimum values of widths *X* of grooves mm
1	0,25
2	1,0
3	1,5
4	2,5

For creepage distance across the fixed and moving insulation of contact carriers, no minimum value of X is required across insulated parts which move relative to each other (see Figure G.2).

If the associated clearance is less than 3 mm, the minimum groove width may be reduced to one-third of this clearance.

The methods of measuring creepage distances and clearances are indicated in the following examples 1 to 11. These examples do not differentiate between gaps and grooves or between types of insulation.

Furthermore:

– any corner is assumed to be bridged with an insulating link of X mm width moved into the most unfavourable position (see example 3),

– where the distance across the top of a groove is X mm or more, a creepage distance is measured along the contours of the grooves (see example 2);

– creepage distances and clearances measured between parts moving in relation to each other are measured when these parts are in their most unfavourable positions.

G.2 Use of ribs

Because of their influence on contamination and their better drying-out effect, ribs decrease considerably the formation of leakage current. Creepage distances can therefore be reduced to 0,8 of the required value provided the minimum height of the ribs is 2 mm.

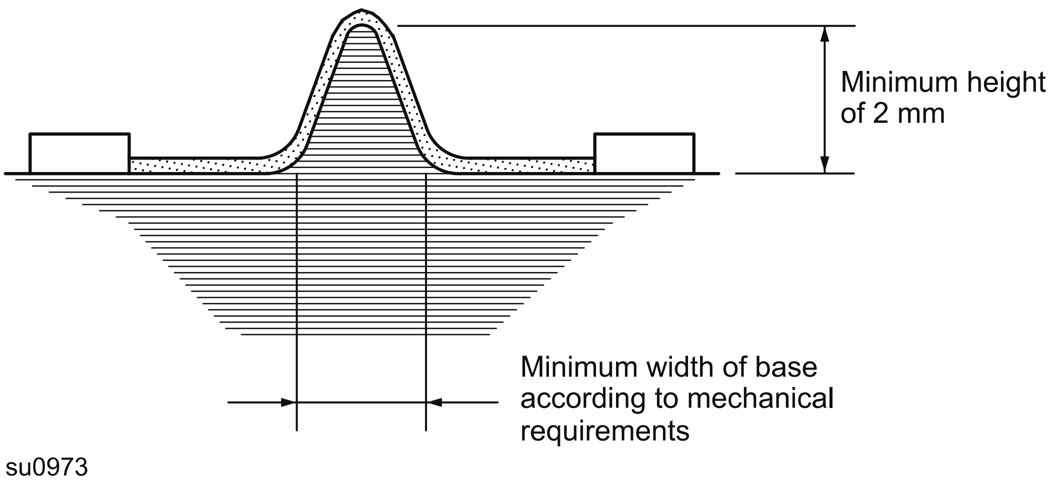


Figure G.1

Measurement of ribs

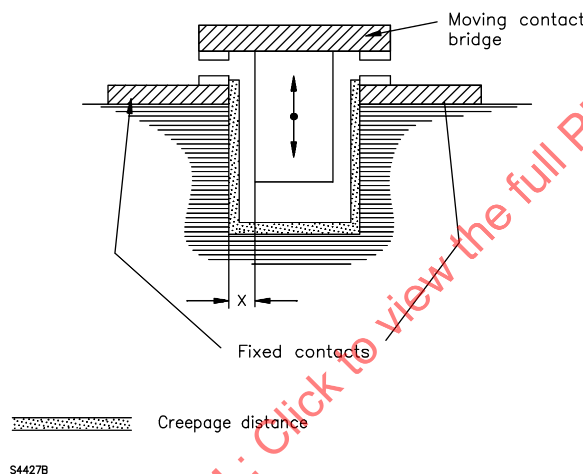
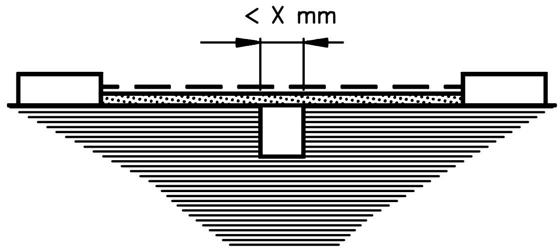


Figure G.2

Creepage distance across the fixed and moving insulation of contact carriers

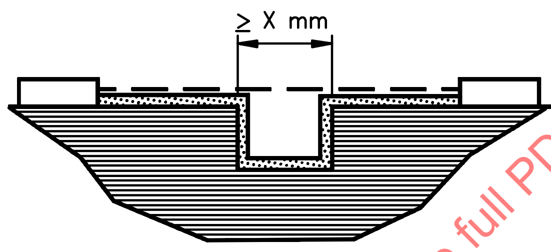
Example 1



Condition: This creepage distance path includes a parallel– or converging–sided groove of any depth with a width less than X mm.

Rule: Creepage distance and clearance are measured directly across the groove as shown.

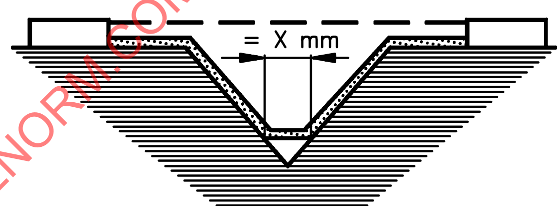
Example 2



Condition: This creepage distance path includes a parallel–sided groove of any depth and equal to or more than X mm.

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

Example 3



Condition: This creepage distance path includes a V–shaped groove with a width greater than X mm.

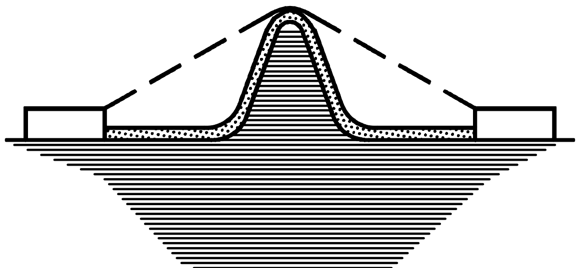
Rule: Clearance is the "line–of–sight" distance. Creepage distance path follows the contour of the groove but "short–circuits" the bottom of the groove by X mm link.

— — — — — — Clearance

Creepage distance

S4430

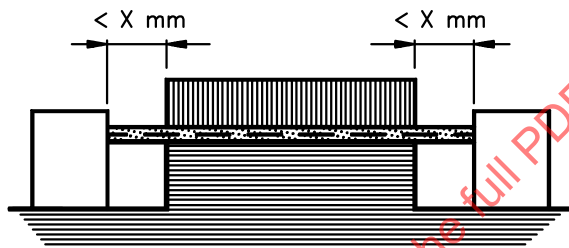
Example 4



Condition: This creepage distance path includes a rib.

Rule: Clearance is the shortest air path over the top of the rib. Creepage path follows the contour of the rib.

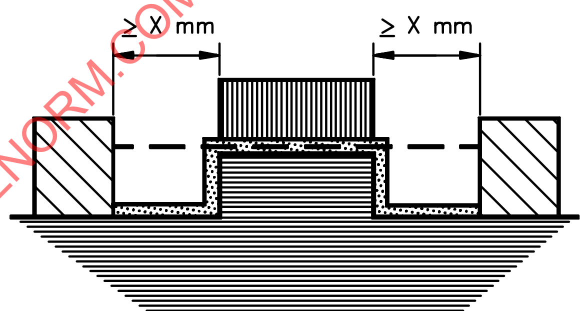
Example 5



Condition: This creepage distance path includes an uncemented joint with grooves less than X mm wide on each side.

Rule: Creepage distance and clearance path is the "line–of–sight" distance shown.

Example 6



Condition: This creepage distance path includes an uncemented joint with grooves equal to or more than X mm wide on each side.

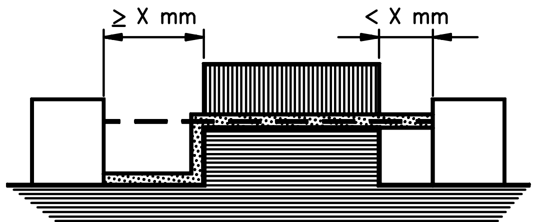
Rule: Clearance is the "line–of–sight" distance. Creepage distance path follows the contour of the grooves.

– – – – – – Clearance

Creepage distance

S4431

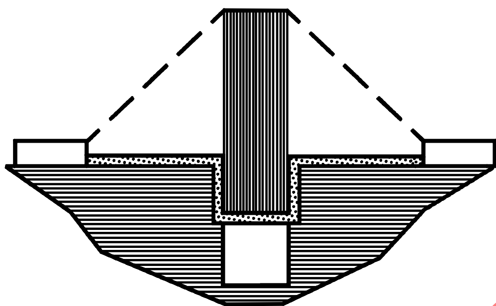
Example 7



Condition: This creepage distance path includes an uncemented joint with a groove on one side less than X mm wide and the groove on the other side equal to or more than X mm wide.

Rule: Clearance and creepage distance paths are as shown.

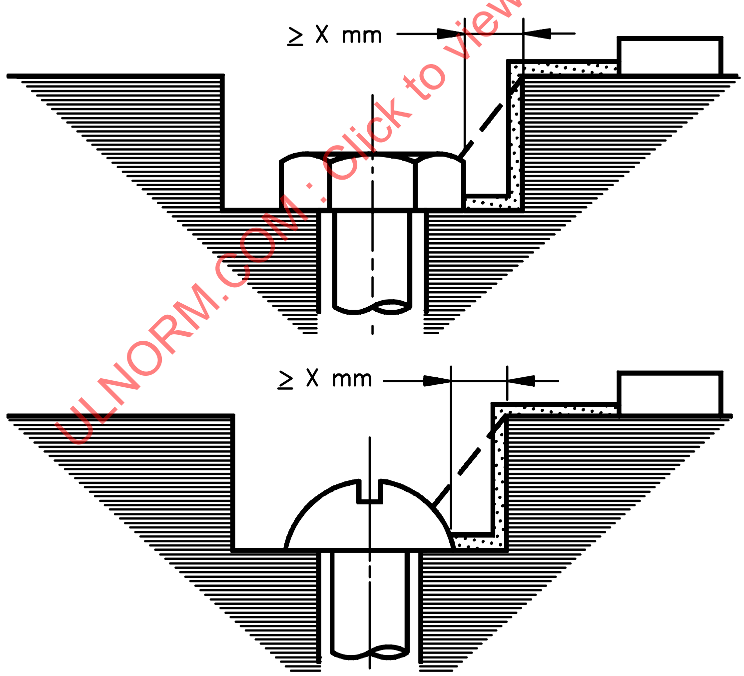
Example 8



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

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

Example 9



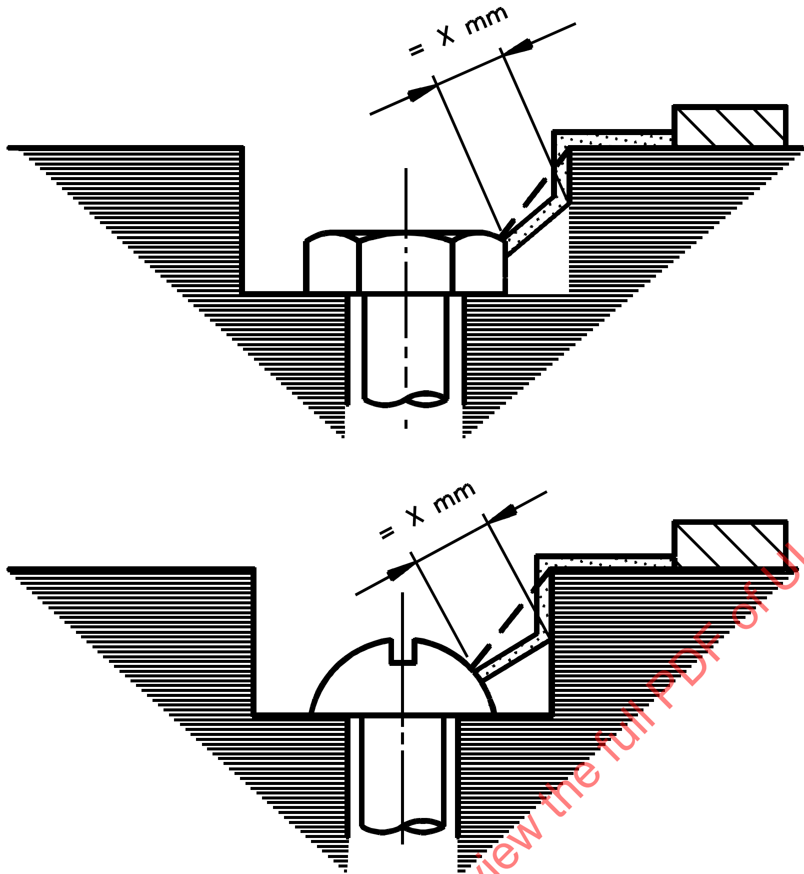
Condition: Gap between head of screw and wall of recess wide enough to be taken into account.

Rule: Clearance and creepage distance paths are as shown.

— — — — — — Clearance   Creepage distance

S4432

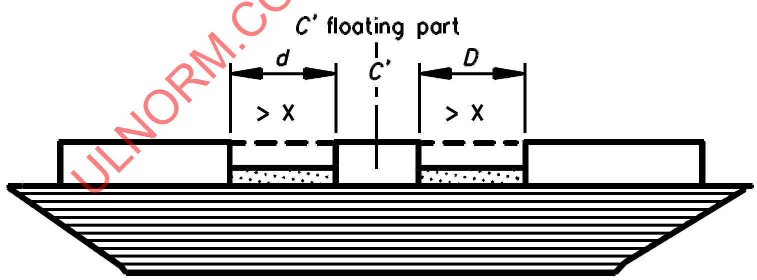
Example 10



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

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

Example 11



Clearance is the distance $d + D$

Creepage distance is also $d + D$

– – – – – – Clearance

Creepage distance

S4433

Annex H
(informative)

Correlation between the nominal voltage of the supply system and the rated impulse withstand voltage of equipment

INTRODUCTION

This annex is intended to give the necessary information concerning the choice of equipment for use in a circuit within an electrical system or part thereof.

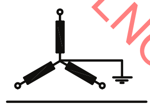
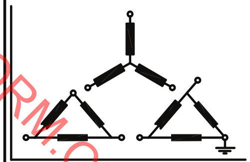
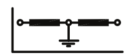
Table H.1 provides examples of the correlation between nominal supply system voltages and the corresponding rated impulse withstand voltage of equipment.

The values of rated impulse withstand voltage given in Table H.1 are based on the performance characteristics of surge arresters.

It should be recognized that control of overvoltages with respect to the values in Table H.1 can also be achieved by conditions in the supply system such as the existence of a suitable impedance or cable feed.

In such cases when the control of overvoltages is achieved by means other than surge arresters, guidance for the correlation between the nominal supply system voltage and the equipment rated impulse withstand voltage is given in IEC 60364-4-443.

Table H.1
Correspondence between the nominal voltage of the supply system and the equipment rated impulse withstand voltage, in case of overvoltage protection by surge-arresters according to IEC 60099-1

Maximum value of rated operational voltage to earth. a.c. r.m.s. or d.c. V	Nominal voltage of the supply system (≤ rated insulation voltage of the equipment)				Preferred values of rated impulse withstand voltage (1,2/50 μs) at 2 000 m kV			
	 a.c. r.m.s. V	 a.c. r.m.s. V	a.c. r.m.s. or d.c. V	 a.c. r.m.s. or d.c. V	Overvoltage category IV: Origin of installation (service entrance) level	III: Distribution circuit level	II: load (appliance, equipment) level	I: Specially protected level
50	-	-	12,5, 24, 25 30, 42, 48	60-30	1,5	0,8	0,5	0,33
100	66/115	66	60	-	2,5	1,5	0,8	0,5
150	120/208 127/220	115, 120 127	110, 120	220-110, 240-120	4	2,5	1,5	0,8
300	220/380, 230/400 240/415, 260/440 277/480	220, 230 240, 260 277	220	440-220	6	4	2,5	1,5
600	347/600, 380/660 400/690, 415/720 480/830	347, 380, 400 415, 440, 480 500, 577, 600	480	960-480	8	6	4	2,5
1 000	-	660 690, 720 830, 1 000	1 000	-	12	8	6	4

su0974

Annex J (informative)

Items subject to agreement between manufacturer and user

NOTE For the purpose of this annex:

– “agreement” is used in a very wide sense;

– “user” includes testing stations.

Clause or subclause number in this standard	Item
2.6.4	Special test.
6.1	See Annex B for non-standard conditions in service.
6.1.1	Equipment intended to be used in ambient air temperature above or below the range –5 °C +40 °C. See note.
6.1.2	Equipment intended to be used at higher altitudes than 2 000 m. See note.
6.2	Conditions during transport and storage, if different from those specified in this subclause.
7.2.1.2	Operating limits of latched equipment.
7.2.2.1 (Table 2)	Use in service of connected conductors of cross-section significantly smaller than those listed in Table 9 and Table 10.
7.2.2.2 (Table 3)	Information to be given by the manufacturer on temperature-rise limits of resistors for enclosures.
7.2.2.6	Operating conditions of pulse-operated coils (to be defined by the manufacturer).
7.2.2.8	Compliance with IEC 60085 and/or IEC 60216 for insulating materials (to be demonstrated by the manufacturer).
8.1.1	Special tests.
8.1.4	Sampling tests.
8.2.4.3	Flexion test on flat copper conductors.
8.3.2.1	To increase the degree of severity of a test for convenience of testing. Smallest enclosure for testing equipment intended for use in more than one type or size of enclosure.
8.3.2.2.2	More severe test conditions (with the manufacturer’s agreement). Acceptance of equipment tested at 50 Hz for use at 60 Hz (or vice versa). See note 2 of Table 8.
8.3.2.2.3	Increasing the upper limit of the power-frequency recovery voltage (subject to manufacturer’s agreement). See note 3.
8.3.3.3.4 Temperature-rise test of the main circuit	Testing d.c. rated equipment with an a.c. supply (subject to manufacturer’s agreement). Testing multipole equipment with single-phase current. Test connection arrangement for values of test current higher than 3 150 A. Use of conductors of smaller cross-section than those specified in Table 9, Table 10 and Table 11 (subject to manufacturer’s agreement). See note 2 of note to Table 9, Table 10 and Table 11.
8.3.3.4.1	Dielectric tests at power-frequency or d.c. voltage (subject to manufacturer’s agreement).
8.3.3.5.2 (note 3) 8.3.4.1.2 (note 3)	Conditions of acceptance of a prospective fault current < 1 500 A (with manufacturer’s agreement). b) In the test circuit for short-circuit testing, shunting the air-cored reactor by resistors different from those defined in item b); c) Diagram of the test circuit for short-circuit testing, if different from that of Figures Figure 9, Figure 10, Figure 11 or Figure 12.
8.3.4.3	Increase of the value of the test current for I_{cw} Verification of ability to carry I_{cw} on a.c. current for d.c. rated equipment.

Annex K
(normative)

Procedure to determine reliability data for electromechanical devices used in functional safety applications

K.1 General

K.1.1 Overview

Provision of these data is optional, at the discretion of the manufacturer.

K.1.2 Scope and object

This annex specifies procedures for the provision of specific data characterising the performance of electromechanical devices in functional safety applications for high demand or continuous mode of operation as defined in IEC 61508.

This method is not applicable to electronic parts.

NOTE 1 Non electromechanical devices should refer to IEC 61508-6 for guidance on the calculation of the probability of failure ratio. Failure rate of electronic parts should be evaluated with reliability data handbook for example IEC/TR 62380.

NOTE 2 The use of reliability data according to this annex is not appropriate for low demand applications. Low demand mode of operation is under consideration.

These data are required by functional safety standards including IEC 61508 series, IEC 62061, ISO 13849-1.

The product standard shall define the function(s) and the failure modes that will be considered.

K.1.3 General requirements

The specific data for functional safety shall be obtained with this procedure.

The procedure is based on statistical analysis of test results in order to generate reliability data.

The requirements of this annex may be further specified by the relevant product standard in terms of relevant tests, failure modes and their ratios.

The confidence level related to failure rate calculation during the useful life of the device shall be at least 60 %.

NOTE The parameters associated with the reliability data are chosen for being consistent with those of other products also used in functional safety applications.

The statistical data obtained according to this annex are valid only during the useful life of the device.

In this annex, to keep statistical consistency, the term "time" can refer to the number of operation cycles.

This annex does not consider replacement of parts of the devices during test and application.

K.2 Terms, definitions and symbols

K.2.1 Terms and definitions

K.2.1.1
reliability (performance)
ability of an item to perform a required function under given conditions for a given time interval

[191-02-06, modified]

K.2.1.2
useful life
under given conditions, the time interval beginning at a given instant of time, and ending when the failure rate becomes unacceptable

NOTE The useful life may be expressed in number of operations.

K.2.1.3
constant failure rate period
that period, if any, in the life of a non-repaired item during which the failure rate is approximately constant

[191-10-09]

K.2.1.4
overall lifetime
lifetime of the device which should not be exceeded in order to maintain the validity of the estimated failure rates due to random hardware failures

NOTE 1 Overall lifetime covers also periods of non-use e.g. storage. The overall lifetime is expressed in number of years.

NOTE 2 It corresponds to T_1 according to IEC 62061 and to T_M according to ISO 13849-1.

K.2.1.5
censoring
termination of the test after either a certain number of failures or a certain time at which there are still items functioning

K.2.1.6
suspension
situation in which an item that either has not failed or has not failed in the manner under investigation, i.e. failed due to some other cause, is removed from test

K.2.1.7
no-make-break-current utilization
conditions in which the switching device makes and breaks without load

K.2.1.8
time to failure
operating time accumulated from the first use, or from restoration, until failure

NOTE The time to failure may be expressed in number of operations.

K.2.2 Symbols

n number of samples tested

r number of failures

t number of operating cycles

η Weibull characteristic life or scale parameter

β Weibull shape parameter

c number of operations per hour

λ_u assessed failure rate (upper limit) at confidence level of 60 % expressed in per operation

λ failure rate expressed in per hour

λ_D dangerous failure rate expressed in per hour

r^2 coefficient of determination

K.3 Method based on durability test results

K.3.1 General method

In order to address random hardware failure the method is based on results given by continuous monitoring of the devices under the appropriate durability test.

K.3.2 Test requirements

The test environment shall be in accordance with Clause 6 and any related requirements from the relevant product standard.

Mechanical durability shall be determined in accordance with 7.2.4.3.1. For the no-make-breakcurrent utilization the mechanical durability is applicable.

Electrical durability shall be determined in accordance with 7.2.4.3.2 using the utilization category defined by the product standard or as stated by the manufacturer.

K.3.3 Number of samples

The number of samples to be tested has to be chosen as a matter of engineering judgment according to IEC 61649 and IEC 60300-3-5.

NOTE This determination of number of samples should take into account the statistical method (see Clause 4 of IEC 61649:2008) and the uncertainty of the confidence level of the reliability data to be obtained.

K.3.4 Characterization of a failure mode

If not otherwise specified by the relevant product standard or the manufacturer, the occurrence of one or more of the failure modes listed in Table K.1 shall lead to the conclusion of the test for that sample. These data shall be recorded.

NOTE The attainment of the specified number of operating cycles given by the manufacturer may also lead to the conclusion of the test (censoring or suspension of tests). Nevertheless a sufficient number of failures should be recorded in order to enable the statistical analysis.

Table K.1
Failure modes of devices

Failure modes	Characteristics for a switching contact
Failure to open	current remaining in one or more poles after the time for normal opening operation
Failure to close	no current in one or more poles after the normal time to close
Insulation failure	insulation failure between two poles or between any pole and any adjacent conductive parts that result in the loss of a safety function

K.3.5 Weibull modelling

K.3.5.1 Evaluation of data

For the determination of the Weibull characteristic life or scale parameter, the Weibull shape parameter and the failure rates proven statistical software or spreadsheet solutions are available. The following describe the necessary steps.

K.3.5.2 Modelling method

The reliability data are obtained by modelling the test result data with the Weibull distribution according to IEC 61649.

The median rank regression (MRR) shall be used if the number of failures is equal or less than 20. If the number of failures is greater than 10, the maximum likelihood estimation (MLE) method can be used to get the point estimates of the distribution parameters β and η. The Kolmogorov-Smirnov goodness-of-fit test (H) with the Fisher distribution (F_γ) at γ = 60 % shall be checked with Equation (K.1) to validate the result data:

$$H \geq F_\gamma(2[(r-1)/2], 2[r/2]) \qquad \text{(K.1)}$$

where the symbol [x] is used to denote the greatest integer less than or equal to x.

NOTE 1 IEC 61649 provides details and examples of calculation.

NOTE 2 In the case the numbers of failures is between 10 and 20 it is advisable to evaluate with the MRR and the MLE. The more severe result should be taken.

If a test is terminated at a specified time, T, before all items have failed, then the data are said to be time censored. An item on test that has not failed by the failure mode in question is a suspension. Normally, suspensions are included in the analysis by adjustment of the ranking. However this Annex provides a method for the estimation of Weibull parameters that is simplified by the omission of suspensions. Further discussion of censoring and suspension is covered in IEC 60300-3-5 and associated computations are covered by IEC 61649.

NOTE 3 IEC 61649 give further guidance for the evaluation with a spreadsheet.

K.3.5.3 Median rank regression

Median Rank Regression (MRR) is the preferred method for estimating the parameters of the distribution using linear regression techniques with the variables being the median rank and operation cycle.

If a table of median ranks and a means to calculate median ranks using the Beta distribution is not available, Bernard's approximation, Equation (K.2), may be used where:

$$F_i = \frac{i - 0,3}{N + 0,4} \times 100\ \% \tag{K.2}$$

where *N* is the sample size and *i* is the ranked position of the data item of interest.

NOTE 1 This equation is mostly used for $N \leq 30$; for $N > 30$ the correction of the cumulative frequency can be neglected: $F_i = (i/N) \times 100\ \%$.

Small sample size makes it difficult to gauge the goodness-of-fit. The coefficient of determination is the most commonly used for checking the Weibull distribution. This shall be calculated using Equation (K.3):

$$r^2 = \frac{\left(\sum_{i=1}^{n} x_i y_i - \frac{\sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{n}\right)^2}{\left(\sum_{i=1}^{n} x_i^2 - n(\overline{x})^2\right)\left(\sum_{i=1}^{n} y_i^2 - n(\overline{y})^2\right)} \tag{K.3}$$

where (x_i) and (y_i), i=[1..n] are the median ranks and the failure time respectively.

r^2 is the proportion of variation in the data that can be explained by the Weibull hypothesis. The closer this is to 1, the better the data are fitted to a Weibull distribution; the closer to 0 indicates a poor fit.

The following are the steps to plot data sets.

a) first, rank the times in operation cycle from earliest to latest;

b) use Bernard's approximation (Equation (K.2)) to calculate the median ranks;

c) plot the failure times (x) versus the median ranks F_i (y) on 1 × 1 Weibull paper or log-log paper to derive $x_{\ln}$ and $y_{\ln}$;

d) calculate a straight regression function to get the equation for the line

$$y_{In} = \widehat{\beta}\, x_{In} + b \tag{K.4}$$

e) calculate

$$\widehat{\eta} = e^{\left(\frac{b}{\widehat{\beta}}\right)}; \tag{K.5}$$

f) plot the regression line on the graph to verify the fit.

NOTE 2 Normally for an electromechanical devices, $\hat{\beta}$ is greater or equal to 1.

K.3.6 Useful life and upper limit of failure rate

K.3.6.1 Numerical method

Assuming a constant failure rate, the useful life is determined as the lower confidence level of the number of cycles by which 10 % of the device population will have failed ($B_{10|LowerLimit}$).

For 20 or fewer data points, with or without censoring times, the Weibull parameters $\hat{\beta}$ and $\hat{\eta}$ obtained with Median Rank Regression (MRR) in K.3.5.3 shall be used.

K.3.6.2 Point estimate of the fractile (10 %) of the time to failure

Compute $\hat{\beta}_{10}$ using Equation (K.6), the point estimate of B_{10}, the time by which 10 % of the population will have failed:

$$\widehat{B}_{10} = \widehat{\eta}\left[\ln\left(\frac{1}{0,9}\right)\right]^{1/\widehat{\beta}} \quad \text{(K.6)}$$

K.3.6.3 Useful life

Compute the lower (1 – *y*)100 % confidence level of B_{10} using Equations (K.7), (K.8), (K.9) and (K.10):

$$h_1 = \text{In}[-\text{In}(0,9)] \quad \text{(K.7)}$$

$$\delta_1 = \frac{-A_6x^2 - rh_1 + x\sqrt{(A_6^2 - A_4A_5)x^2 + rA_4 + 2rh_1A_6 + rA_5h_1^2}}{r - x^2A_5} \quad \text{(K.8)}$$

where

$x = u_y$

is the *y* fractile of the normal distribution. Unless otherwise specified by the manufacturer, a 60 % lower confidence level shall be used (hence y = 0,4 and u_y = 0,253 3).

A_4, A_5 and A_6

are computed as follows, using the ratio $q = r/n$:

$A_4 = 0,49q – 0,134 + 0,622\ q^{-1}$;

$A_5 = 0,244\ 5\ (1,78 – q)\ (2,25 + q)$;

$A_6 = 0,029 – 1,083\ \ln\ (1,325q)$.

NOTE For further reference, see 10.4 and 10.5 of IEC 61649:2008.

$$Q_1 = e^{\left(-\frac{\delta_1 + h_1}{\widehat{\beta}}\right)} \quad \text{(K.9)}$$

$$B_{10|\mathrm{LowerLimit}} = Q_1 \widehat{B}_{10} \quad \text{(K.10)}$$

This value of $B_{10|\mathrm{LowerLimit}}$ is considered as the useful life.

K.3.6.4 Upper limit of failure rate

The upper limit of failure rate per operation is given by the following Equation (K.11):

$$\lambda_{\mathrm{u}} = \frac{-In(0{,}9)}{B_{10|\mathrm{LowerLimit}}} \approx \frac{1}{10 \times B_{10|\mathrm{LowerLimit}}} \quad \text{(K.11)}$$

K.3.7 Reliability data

The resulting reliability data from the previous evaluations are:

– failure rate per operation: λ_u.

– useful life value = $B_{10|\mathrm{lowerLimit}}$

For a given application where the number of operation per hour c is lower than the maximum switching rate, the failure rate, λ, expressed in “per hour”, is given by the failure rate, expressed in “per operation”, λ_u, multiplied by c:

$$\lambda = \lambda_u \times c \quad \text{(K.12)}$$

The value for F (ratio between dangerous failures and total failures) for each of the failure modes of Table K.1 is defined by the relevant product standard. When this is available and relevant it shall be used for the evaluation of the dangerous failure rate.

If it can be shown that it is not relevant due to device design characteristics, the manufacturer can determine the value for F by analysis and the evaluation of the statistical data of the failure modes obtained during the tests. In this case the minimum percentage allowed for the value of F shall be 20 %.

In the case where no data are available in the product standard and it is not possible or practicable by these methods to determine the value for F, 50 % of the failures should be selected.

$$\lambda_D = \lambda \times F \quad \text{(K.13)}$$

NOTE B_{10} values can be used to provide $B_{10\mathrm{D}}$ values:

$$B_{10\mathrm{D}} = \frac{B_{10|\mathrm{LowerLimit}}}{F}$$

K.4 Data information

A set of reliability data of the product shall include a combination of the following characteristics where relevant:

– failure rate per operation λ_u (see K.3.7);

– useful life (see K.3.6.3);

– confidence level if different from 60 %;

– no-make-break-current or utilization category;

– maximum switching rate;

– maximum voltage if different from U_e;

– maximum operational current for the specified utilization category, if different from I_e;

– overall life time = 20 years unless otherwise specified by the manufacturer;

NOTE The overall life time of 20 years is generally used as a statistical reference for reliability analysis.

– environment conditions if different from the normal conditions.

Examples are given in K.5.1 to K.5.3.

K.5 Example

K.5.1 Test results

A total of 15 devices (n = 15) have been tested at the same time until all have failed. The 15 times to failure (r = 15) are ordered with i in the Table K.2.

Table K.2
Example of 15 sorted ascending times to failure of contactors

I	Cycles t_i
1	1 000 000
2	1 250 000
3	1 400 000
4	1 550 000
5	1 650 000
6	1 750 000
7	1 850 000
8	1 950 000
9	2 050 000
10	2 150 000
11	2 280 000
12	2 420 000
13	2 500 000
14	2 700 000
15	2 800 000

K.5.2 Weibull distribution and median rank regression

The calculation of median ranks gives the following results:

Table K.3
Example median rank calculation

I	Cycles t_i	Median ranks
1	1 000 000	4,5 %
2	1 250 000	11,0 %
3	1 400 000	17,5 %
4	1 550 000	24,0 %
5	1 650 000	30,5 %
6	1 750 000	37,0 %
7	1 850 000	43,5 %
8	1 950 000	50,0 %
9	2 050 000	56,5 %
10	2 150 000	63,0 %
11	2 280 000	69,5 %
12	2 420 000	76,0 %
13	2 500 000	82,5 %
14	2 700 000	89,0 %
15	2 800 000	95,5 %

The coefficient of determination r^2 = 0,998. This value, close to 1, indicates a good fit to a Weibull distribution.

The linear regression with two natural logarithm scales gives: $y = 3{,}908\ x - 57$.

From this equation, the distribution parameters can be derived: $\hat{\beta}$ = 3,908 and $\hat{\eta}$ = 2 149 131.

The fitting result obtained by MRR gives the assurance of a good Weibull distribution (see Figure K.1).

K.5.3 Useful life and failure rate

To calculate the lower confidence level of the number of cycles by which 10 % of the contactors will have failed, this example follows K.3.5.

The point estimate $\hat{B}_{10}$ = 1 212 879

The factor Q_1 = 0,960 1 and $B_{10|\text{lowerLimit}}$ = 1 164 541

Finally, the upper limit of the failure rate $\lambda_u = 9{,}05 \times 10^{-8}$

The result of this numerical method is illustrated by the Figure K.1.

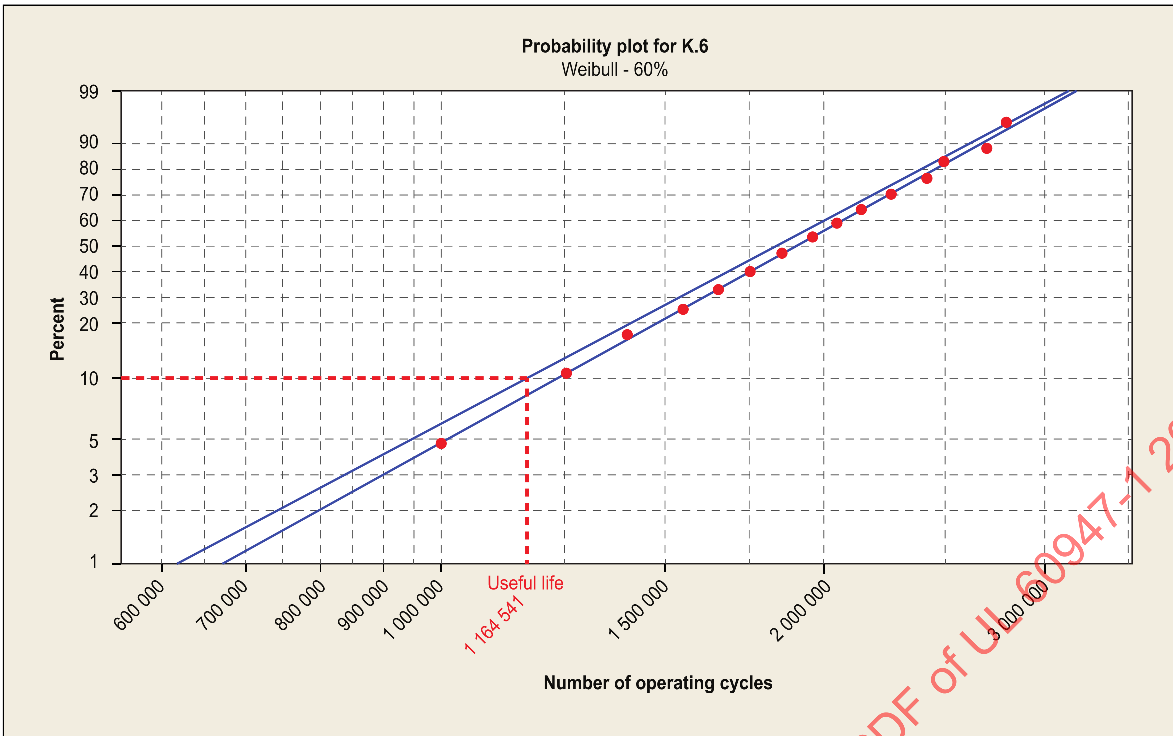


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Figure K.1

Plot of Weibull median rank regression

Annex L
(normative)

Terminal marking and distinctive number

Annex LDV D2 *Modification to Annex L:*

In Canada, Mexico, and the United States, Annex L is informative.

L.1 General

The purpose of identifying terminals of switching devices is to provide information regarding the function of each terminal, or its location with respect to other terminals, or for other use.

The terminal marking applies to switching devices as delivered by the manufacturer, and shall be free from ambiguity, that is each marking shall occur only once. However, two terminals connected by construction may have the same marking.

The marking of different terminals of a circuit element shall indicate that they are in the same current path.

The marking of the terminals of an impedance shall always be alphanumerical and have one or two letters indicating the function, followed by a number. The letters shall be capitals (upper case) Roman characters only and the numerals shall be Arabic numerals.

For contact element terminals, one of the terminals is marked with an odd number, the other terminals of the same contact element are marked with the immediately higher even numbers.

If incoming and outgoing terminals of an element are to be specifically identified as such, then the lower number shall be chosen for the incoming terminal (thus incoming 11 and outgoing 12, incoming A1 and outgoing A2).

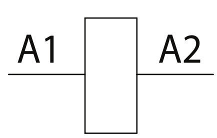
NOTE 1 The equipment dealt with in the following Clauses L.2 and L.3 is also illustrated by graphical symbols in accordance with IEC 60617-7. It should be understood, however, that these symbols are not intended to be used for terminal marking on the equipment.
NOTE 2 The position of the terminals shown in the illustrations is not intended to convey any information on the actual position of the terminals on the device itself.

For low-voltage switchgear not covered by the following clauses or examples, a manufacturer may choose a suitable terminal marking following the principles of this clause.

L.2 Terminal marking of impedances (alphanumerical)

L.2.1 Coils

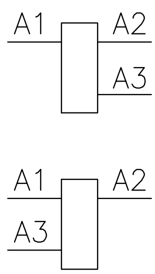
L.2.1.1 The two terminals of a coil for an electromagnetically operated drive shall be marked by A1 and A2.



S4434

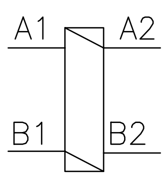
L.2.1.2 For a coil with tappings, the terminals of the tappings are marked in sequential order A3, A4, etc.

Examples:



S4435

L.2.1.3 For a coil having two windings, the terminals of the first winding shall be marked A1, A2 and of the second winding B1, B2.

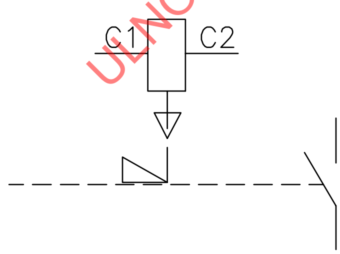


S4436

L.2.2 Electromagnetic releases

L.2.2.1 Shunt release

The two terminals of a shunt release shall be marked C1 and C2.

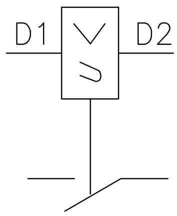


S4437

NOTE For a device with two shunt releases (for example with different ratings), the terminal of the second release should be marked preferably C3 and C4.

L.2.2.2 Under-voltage release

The two terminals of a coil intended to be used exclusively as an under-voltage release shall be marked D1 and D2.

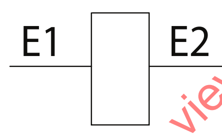


S4438

NOTE For a device with two shunt releases (for example with different ratings), the terminal of the second release should be marked preferably D3 and D4.

L.2.3 Interlocking electromagnets

The two terminals of an interlocking electromagnet shall be marked E1 and E2.

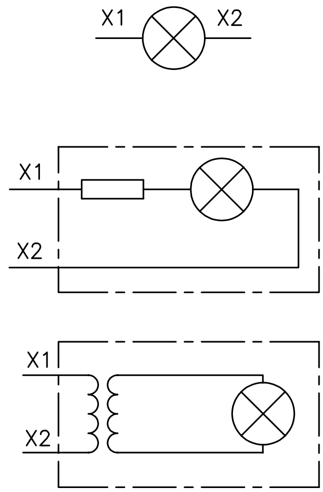


S4439

L.2.4 Indicating light devices

The two terminals of an indicating light device shall be marked X1 and X2.

Examples:



S4440

NOTE The term "indicating light devices" includes any incorporated resistor or transformer.

L.3 Terminal marking of contact elements for switching devices with two positions (numerical)

L.3.1 Contact elements for main circuits (main contact elements)

The terminals of main switching elements are identified by single figure numbers.

Each terminal marked by an odd number is associated with that terminal marked by the following even number.

Examples:

S4441

When a switching device has more than five main contact elements, alphanumerical marking shall be chosen, according to IEC 60445.

L.3.2 Contact elements for auxiliary circuit (auxiliary contact elements)

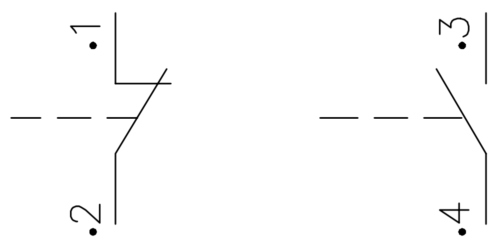
The terminals of auxiliary contact elements are identified by two-figure numbers:

– the figure of the units is a function number;

– the figure of the tens is a sequence number.

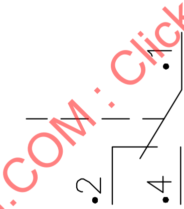
L.3.2.1 Function number

L.3.2.1.1 Function numbers 1 and 2 are allocated to break-contact elements and functions 3 and 4 to make-contact elements (break-contact element, make-contact element as defined in IEC 60050(441)).



S4442

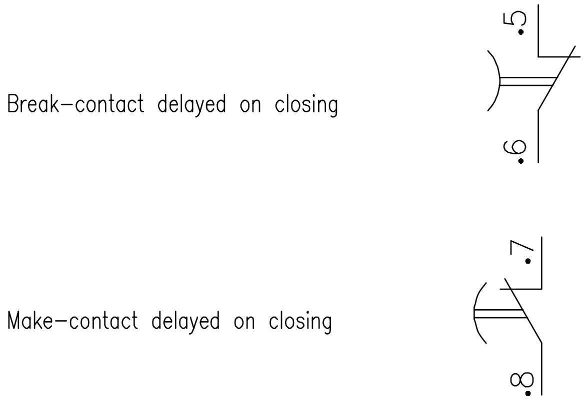
The terminals of change-over contact elements are marked by the function numbers 1, 2 and 4.



S4443

L.3.2.1.2 Auxiliary contact elements with special functions, such as time-delayed auxiliary contact elements, are identified by the function numbers 5 and 6, 7 and 8 for break-contact elements and make-contact elements respectively.

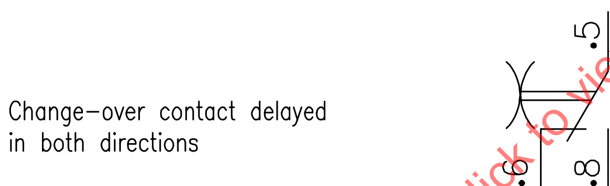
Examples:



S4444

The terminals of change-over contact elements with special functions are marked by the function numbers 5, 6 and 8.

Example:



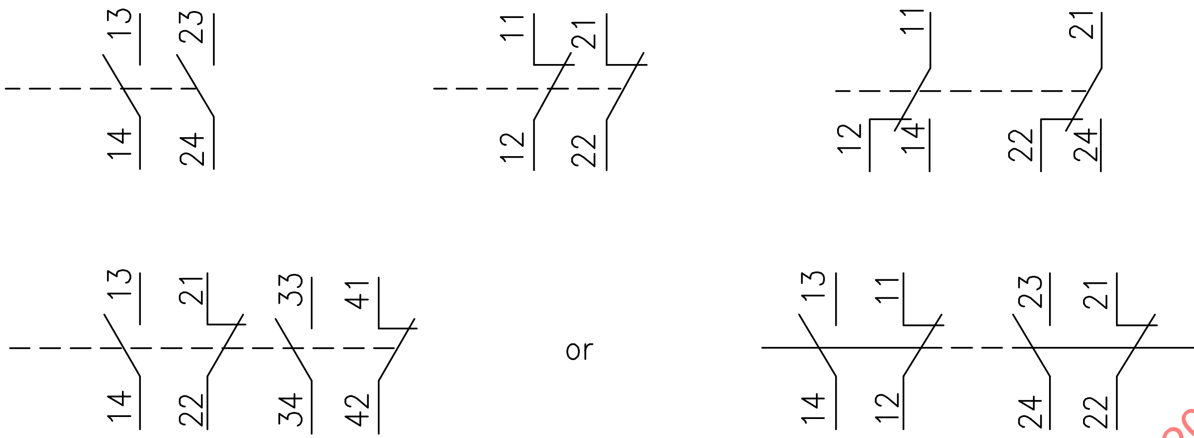
S4445

L.3.2.2 Sequence number

Terminals belonging to the same contact elements are marked with the same sequence numbers.

All contact elements having the same function shall have different sequence numbers.

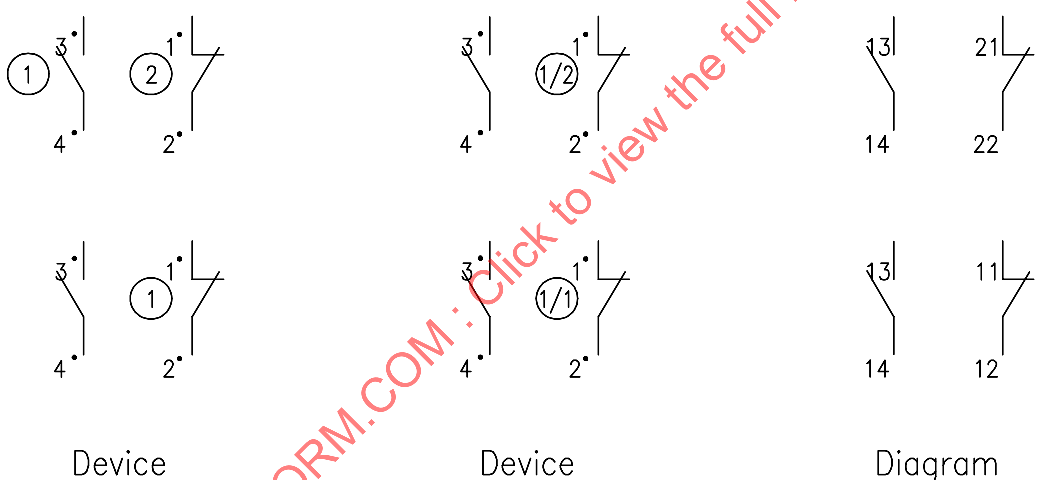
Examples:



S4446

L.3.2.2.2 The sequence number may be omitted from the terminals only if additional information provided by the manufacturer or the user clearly gives such a number.

Examples:



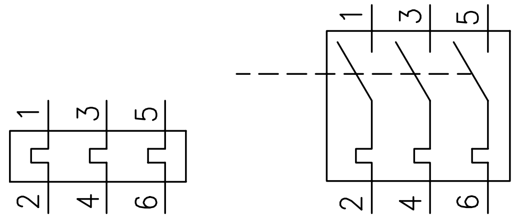
S4447

NOTE The dots shown in the examples of L.3.2 are merely used to show the relationship and do not need to be used in practice.

L.4 Terminal marking of overload protection devices

The terminals of the main circuits of an overload protection device are identified in the same manner as the terminals of main switching elements.

Examples:

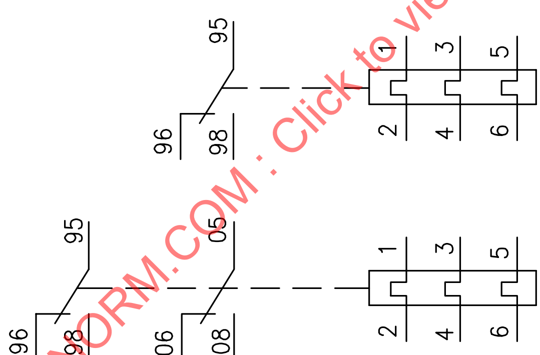


S4448

The terminals of an auxiliary contact element of an overload protection device are identified in the same manner as the terminals of a special contact element (see L.3.2.1.2) but with the sequence number 9.

If a second sequence number is required, it should be the number 0.

Examples:

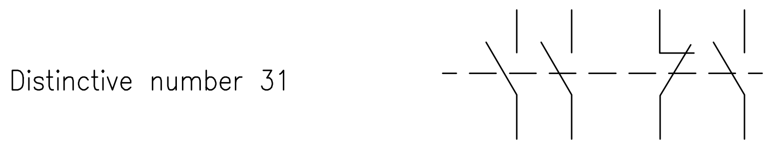


S4449

L.5 Distinctive number

A device with a fixed number of make-contact elements and break-contact elements may be allocated a two-figure distinctive number.

The first figure indicates the number of make-contact elements and the second figure the number of break-contact elements.



S4450

L.6 Marking of terminals for external associated electronic circuit components, contacts and complete devices

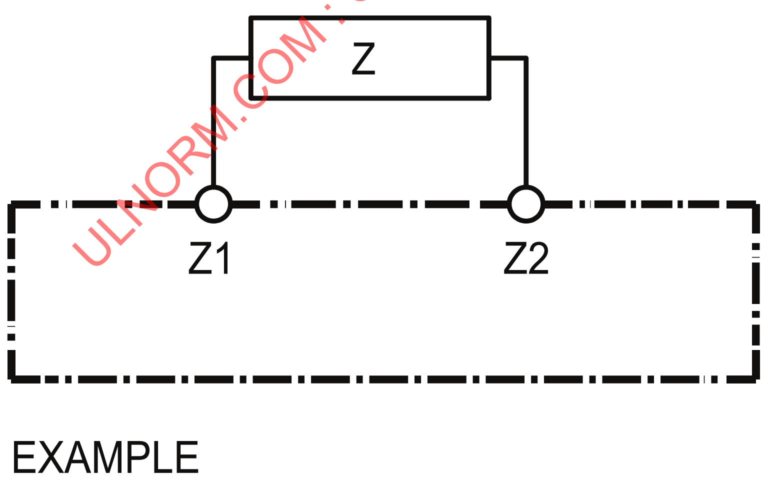
L.6.1 Marking of terminals for external associated electronic circuit components and contacts

L.6.1.1 General

Terminals for external associated electronic circuit components and contacts shall be marked in the following alphanumerical manner.

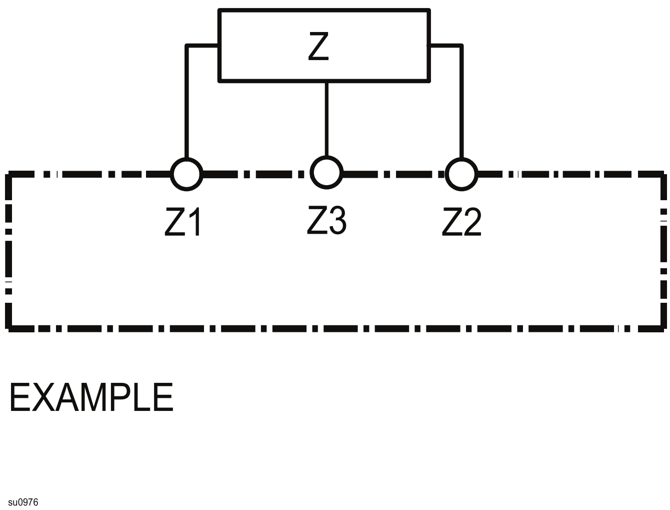
L.6.1.2 Marking of terminals for external associated impedances

L.6.1.2.1 The two terminals for an external associated impedance Z shall be marked Z1 and Z2.

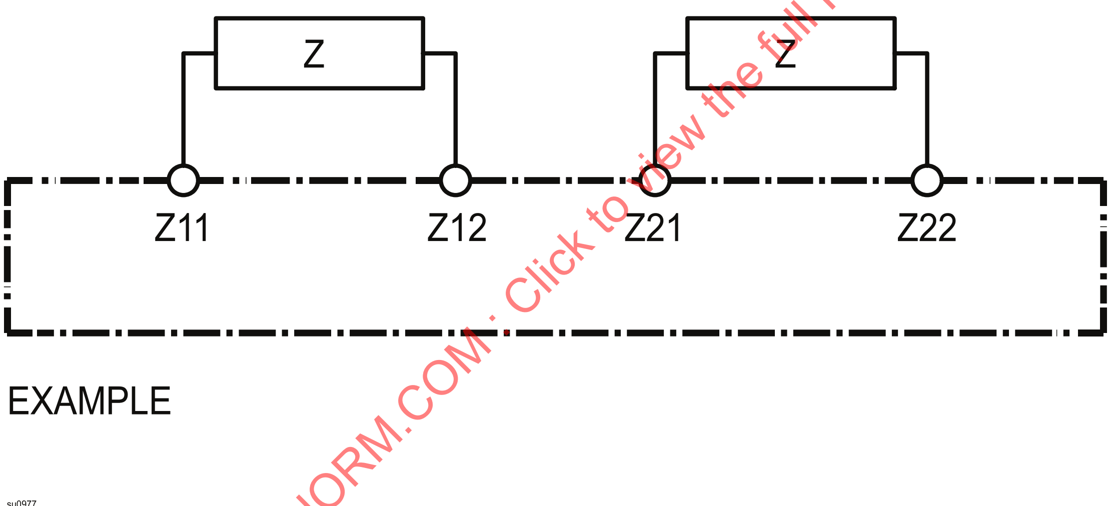


su0975

L.6.1.2.2 For an impedance Z with tappings, the terminals for the tappings shall be marked in sequential order Z3, Z4, etc.



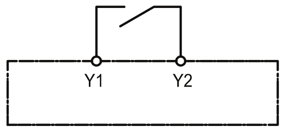
L.6.1.2.3 In case of more than one impedance, the terminals shall be marked by using the letter Z and two-figure numbers, the first figure being a sequence number.



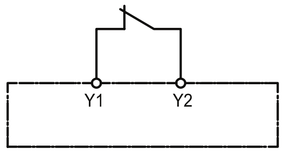
L.6.1.2.4 For particular application to a control system associated with thermistors for built-in thermal protection of rotating electrical machines, the rules for terminal marking T1, T2, ... or 1T1, 2T2, ... and 2T1, 2T2, ... are given in IEC 60947-8.

L.6.1.3 Marking of terminals for external associated contacts

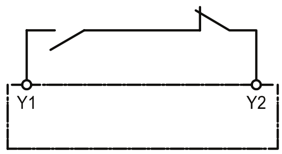
L.6.1.3.1 The two terminals for an external associated make or break contact or a group of contacts shall be marked Y1 and Y2.



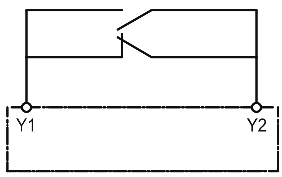
EXAMPLE 1



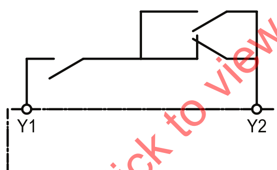
EXAMPLE 2



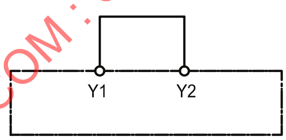
EXAMPLE 3



EXAMPLE 4

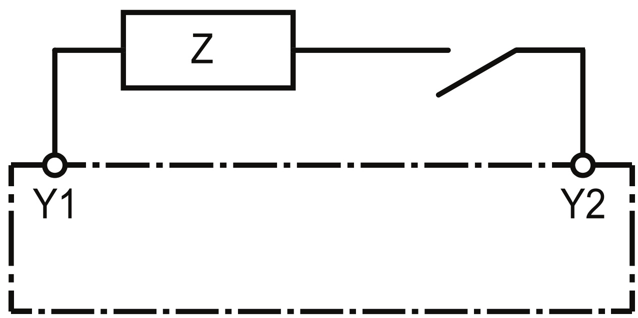


EXAMPLE 5



su1006

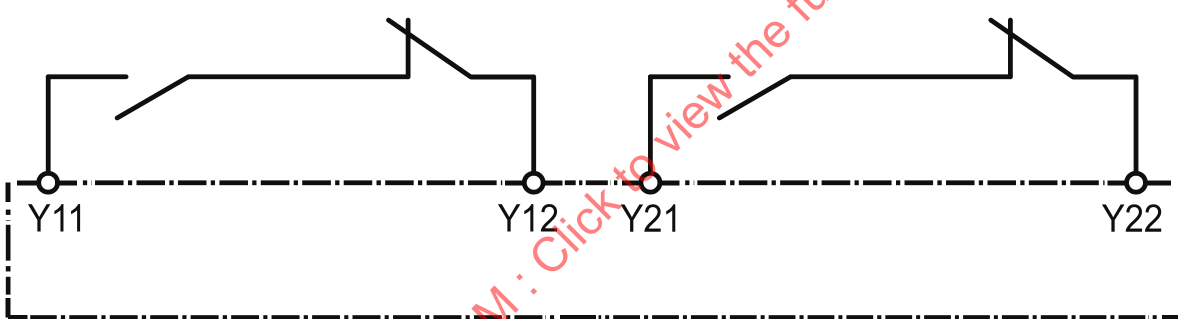
NOTE 1 A bridge between two terminals is considered as a permanently closed contact and the corresponding terminals shall be marked Y1 and Y2.



su1007

NOTE 2 For an external circuit comprising an association of impedance(s) and contact(s), the corresponding terminals shall be marked Y1 and Y2.

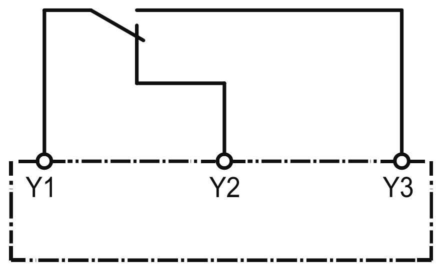
L.6.1.3.2 In the case of more than one contact or one group of contact, the terminals shall be marked by using the letter Y and two-figure numbers, the first figure being a sequence number.



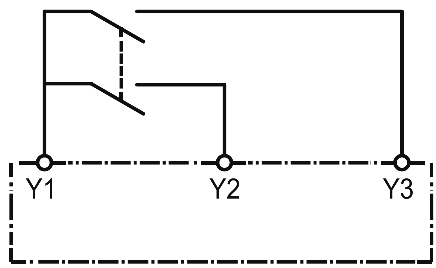
EXAMPLE

su1008

L.6.1.3.3 The three terminals necessary for connection of several contacts which operates simultaneously (e.g. forming a change-over contact) shall be marked Y1, Y2 and Y3, Y1 being the common.



EXAMPLE 1



EXAMPLE 2

su1009

L.6.2 Marking of terminals for external complete devices

To illustrate the association with the general rules, four examples of the terminal marking of a complete device are given hereafter.

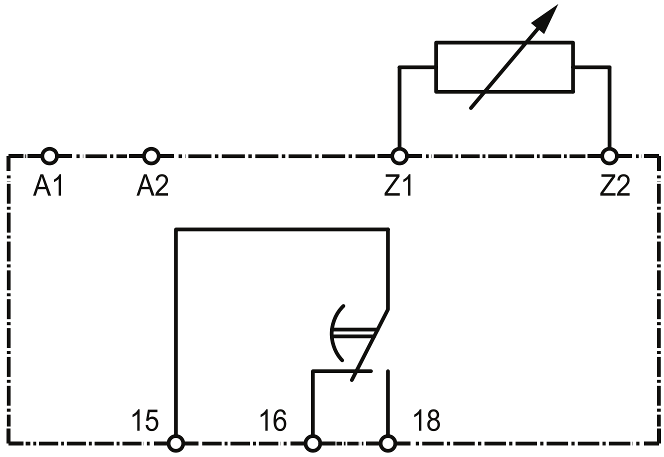
EXAMPLE 1

Switching device having:

– two control supply terminals A1 and A2,

– two terminals Z1 and Z2, for an external associated variable resistor, and

– three terminals 15, 16 and 18, for an internal delayed change-over contact.



su1010

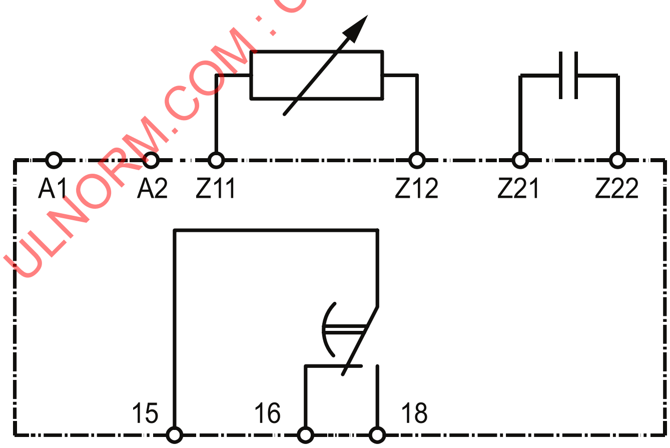
EXAMPLE 2

Switching device having:

– two control supply terminals A1 and A2,

– four terminals for two external associated impedances (Z11 and Z12 for a variable resistor, and Z21 and Z22 for a capacitor), and

– three terminals 15, 16 and 18, for an internal delayed change-over contact.



su1011

EXAMPLE 3

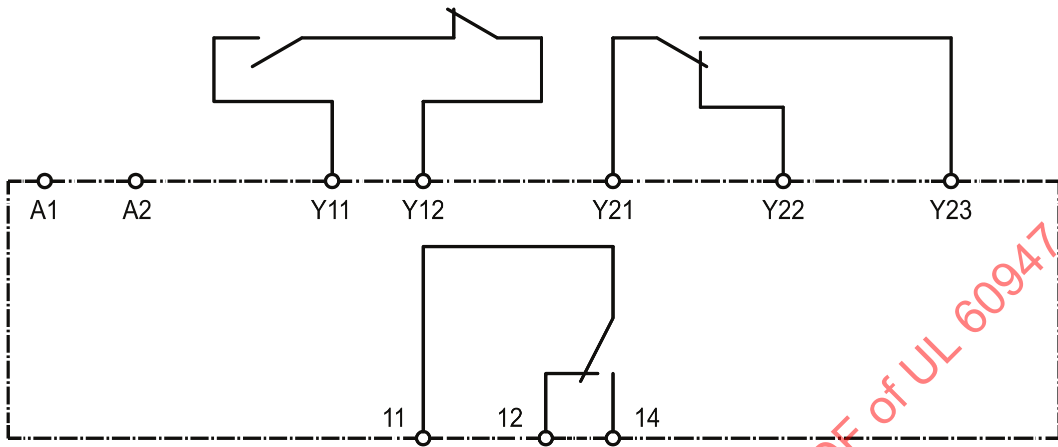
Switching device having:

– two control supply terminals A1 and A2,

– two terminals Y11 and Y12, for an external associated group of contacts,

– three terminals Y21, Y22 and Y23, for an external associated change-over contact, and

– three terminals 11, 12 and 14, for an internal change-over contact.



su1012

EXAMPLE 4

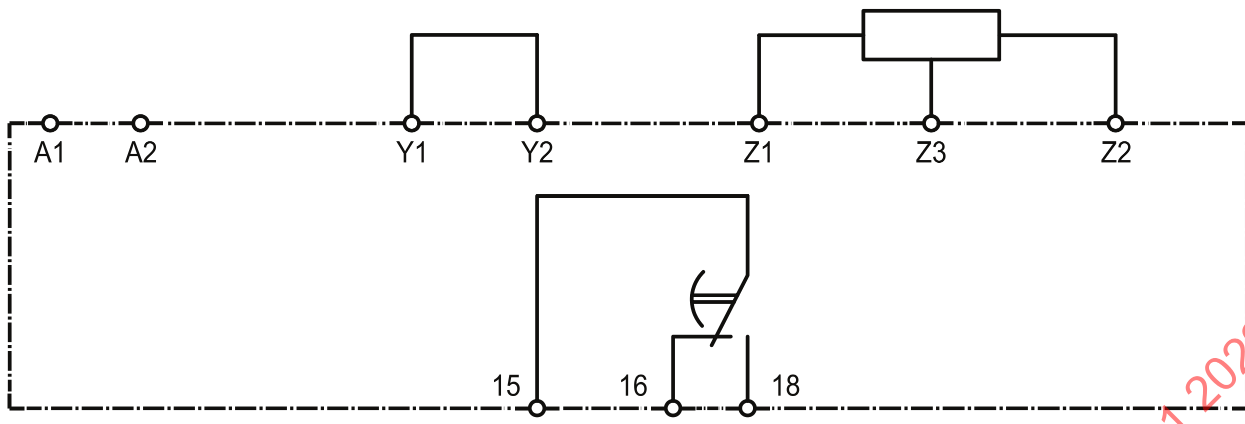
Switching device having:

– two control supply terminals A1 and A2,

– two terminals Y1 and Y2, for an external bridge,

– three terminals Z1, Z3 and Z2, for an external associated resistor with a tapping, and

– three terminals 15, 16 and 18, for an internal delayed change-over contact.



su1005

Annex M
(normative)

Flammability test

M.1 Hot wire ignition test (HWI)

M.1.1 Test sample

Five samples of each material shall be tested.

The rectangular bar-shaped samples shall be 125 mm ± 5 mm long by 13 mm ± 0,5 mm wide and of uniform thickness stated by the material manufacturer. The test method applies to moulded or sheet materials in thicknesses ranging from 0,25 mm to 6,4 mm.

Edges shall be free from burrs, fins, etc. and the radius on the corners shall not exceed 1,3 mm.

M.1.2 Description of test apparatus

The sample shall be fastened in a fixture which provides two supporting posts positioned 70 mm apart to support the test specimen in a horizontal position, at a height of 60 mm above the bottom of the chamber, in the approximate centre of the test chamber (see Figure M.1).

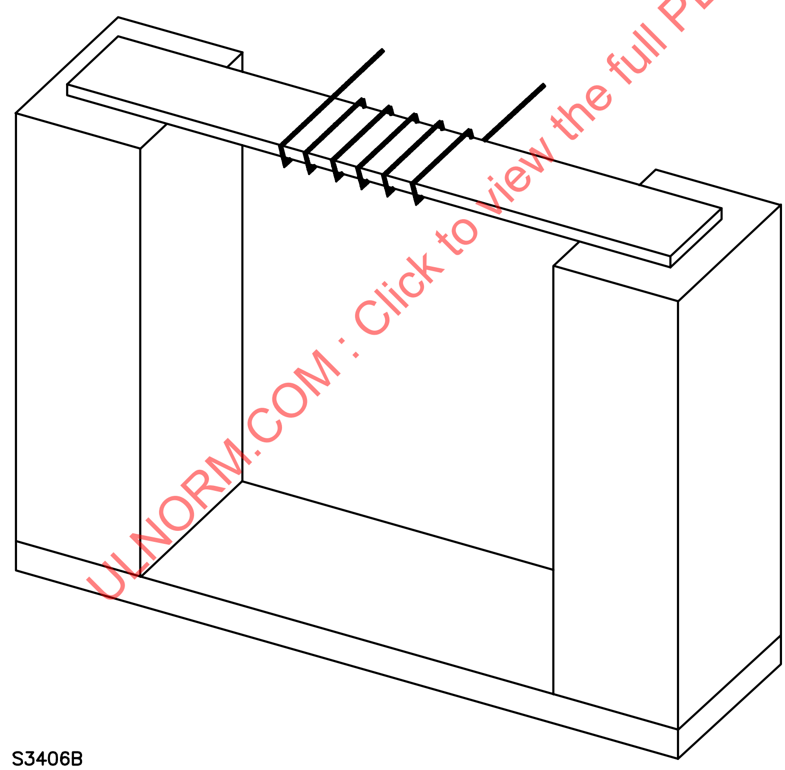


Figure M.1

Test fixture for hot wire ignition test

A 250 mm ± 5 mm length of NiCr-wire (80 % nickel, 20 % chromium, iron free) approximately 0,5 mm diameter and having a cold resistance of approximately 5,28 Ω/m and a length-to-mass ratio of 580 m/kg shall be used. Prior to testing, the wire shall be connected in a straight length to a variable source of power which is adjusted to cause a power dissipation of 0,26 W/mm in the wire for a period of 8 s to 12 s.

After cooling, the wire shall be wrapped around a sample to form five complete turns spaced 6,35 mm ± 0,05 mm apart. A winding fixture shall be used, which will uniformly position the wire in the centre portion of the sample with a winding force of 5,4 N ± 0,02 N.

The ends of the wire shall be connected to the variable power source.

The supply circuit capacity shall be sufficient to maintain a continuous linear 48 Hz to 62 Hz power density of at least 0,31 W/mm over the length of the heater wire at or near unity power factor. The power density of the supply circuit at 60 A and 1,5 V shall be approximate 0,3 W/mm. It shall be possible to adjust the power level, smoothly and continuously and measure the power to within ±2 %.

M.1.3 Conditioning

Prior to testing, the test samples shall be maintained in a dry-as-moulded condition or alternatively, if this is not practical, the test samples shall be dried in an air-circulating oven at 70 °C ± 2 °C for 168 h and cooled over silica-gel or other desiccant for a minimum of 4 h. Immediately prior testing, the specimens shall be conditioned for at least 40 h at 23 °C ± 2 °C and 50 % ± 5 % relative humidity.

M.1.4 Test procedure

Start the test by energizing the circuit so that a current is passed through the heater wire yielding a linear power density of 0,26 W/mm over the whole length during the test.

Continue heating until the test specimen ignites. When ignition occurs, shut off power and record time to ingnition. Ignition means an initiation of flaming produced by combustion in the gaseous phase which is accompanied by emission of light. Discontinue the test if ignition does not occur within 120 s. For specimens that melt through the wire without ignition, discontinue the test when the specimen is no longer in intimate contact with all five turns of the heater wire. The test shall be repeated on the remaining samples.

The thickness of each test sample and the time to ignition of each test sample or the time to melt through the wire of each test sample shall be recorded.

The test result for a given material within the tested thickness is the average time in seconds required for ignition.

M.2 Arc ignition test (AI)

M.2.1 Test sample

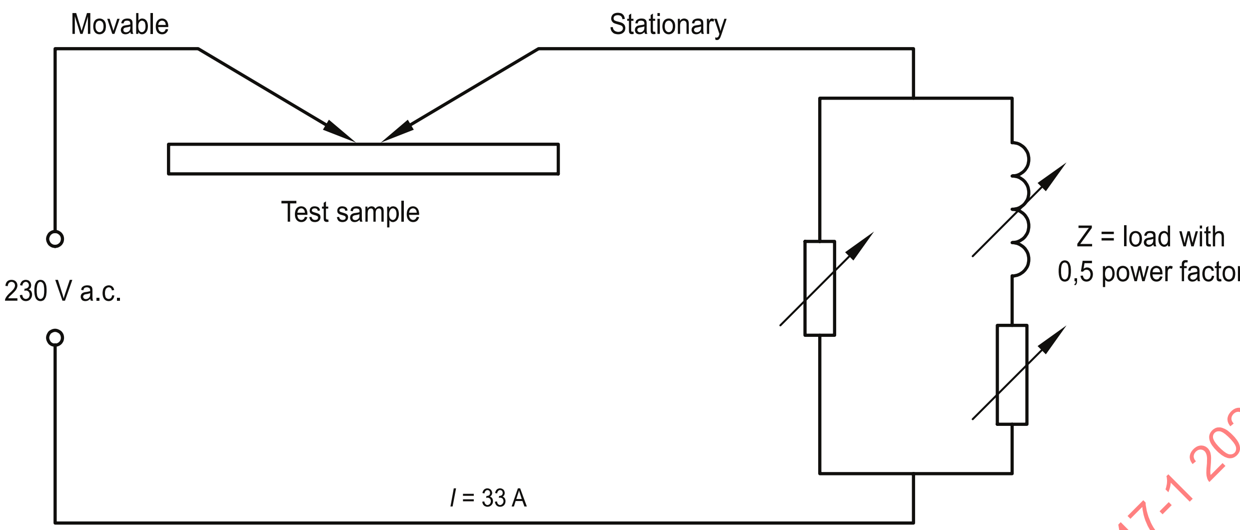
Five samples of each material shall be tested.

The rectangular bar-shaped samples shall be 125 mm ± 5 mm long by 13 mm ± 0,5 mm wide and of uniform thickness stated by the material manufacturer.

Edges shall be free from burrs, fins, etc. and the radius on the corners shall not exceed 1,3 mm.

M.2.2 Description of test apparatus

The test shall be made with a pair of test electrodes and a variable inductive impedance load connected in series to a source of 230 V a.c., 50 Hz or 60 Hz (see Figure M.2).



su0978

Figure M.2

Circuit for arc ignition test

One electrode shall be stationary and the other movable. The stationary electrode shall consist of a solid copper conductor having a horizontal symmetric chisel point with a total angle of 30°. The overall length of this fixed electrode shall be approximately 152 mm with a diameter of 3,2 mm.

The movable electrode shall be a stainless steel rod (X8CrNiS18-9), 3,2 mm diameter and approximately 152 mm long, having a symmetrical conical point with a total angle of 60°, and shall be capable of being moved along its own axis. The radius of curvature for both electrode tips shall not exceed 0,1 mm at the start of a given test. The electrodes shall be located opposing each other, at an angle of 45° to the horizontal in a common vertical plane, orthogonal to the axis of the sample.

With the electrodes short-circuited, the variable inductive impedance load shall be adjusted until the current is 32,5 A at a power factor of 0,5.

M.2.3 Conditioning

Unless otherwise specified, special conditioning is not required.

M.2.4 Test procedure

The sample under test shall be supported horizontally in air on a nonconductive, inflammable basis, so that the electrodes, when touching each other, are in contact with the surface of the sample. The movable electrode shall be manually or otherwise controlled so that it can be withdrawn along its axis 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 254 mm/s ± 25 mm/s. The test is to be continued until ignition of the sample occurs, a hole is burned through the sample, or a total of 200 make and break cycles has elapsed.

If a hole is burned through any sample of the set or ignition occurs, an extra set of three samples shall be tested, but with the electrodes making contact 1,6 mm above the surface of the sample. If ignition or a hole occurs to any of these samples, an additional set of three samples shall be tested with the electrodes making contact 3,2 mm above the surface of the sample.

The average number of arcs to ignition or the maximum number of 200 cycles and the thickness of each set of specimen shall be recorded.

M.3 HWI and AI requirements

The hot wire ignition (HWI) and arc ignition (AI) test value requirements related to the material's flammability category are indicated in Table M.1 and Table M.2. Each column represents HWI and AI minimum characteristics related to the flammability category.

NOTE Alternatively, the manufacturer may provide data from the insulating material supplier fulfilling the requirements given in Annex M.

Table M.1
HWI and AI characteristics for materials necessary to retain current carrying parts in position

Flammability category (IEC 60695-11-10)	V-0	V-1	V-2	HB
Part thickness[a] mm	Any[b]	Any[b]	Any[b]	Any[b]
HWI time to ignite, minimum s	7	15	30	30
AI minimum number of arcs to ignite	15	30	30	60

[a] According to 8.2.1.1.2.

[b] According to the smallest thickness in application.

NOTE 1 There is no direct correspondence between the glow-wire-test temperatures and Table M.1.

NOTE 2 A manufacturer may use any flammability category of his own choice, but the requirements of HWI and, if applicable, AI should be fulfilled.

EXAMPLE: A material with flammability category V-1 of any thickness shall have a HWI value of at least 15 s and, if applicable, an AI value of at least 30 arcs

Table M.2
HWI and AI characteristics for materials other than those covered by Table M.1

Flammability category (IEC 60695-11-10)	V-0	V-1	V-2	HB
Part thickness, mm	Any[a]	Any[a]	Any[a]	Any[a]
HWI time to ignite, minimum s	–	–	7	7
AI minimum number of arcs to ignite	–	–	15	15

[a] According to the smallest thickness in application.

Annex N
(normative)

Requirements and tests for equipment with protective separation

Annex NDV D2 ***Modification to Annex N:***

In Canada, Mexico, and the United States, Annex N is informative.

This annex applies to a device, one or more circuits of which are intended to be used in a SELV (PELV) circuit (the device by itself may not be class III – see 7.4 of IEC 61140).

N.1 General

The purpose of this annex is to harmonize as far as practicable all rules and requirements applicable to low voltage switchgear and controlgear having a protective separation between parts intended to be used in SELV (PELV) circuits and others, in order to obtain uniformity of requirements and tests and to avoid the need for testing to different standards.

N.2 Definitions

N.2.1
functional insulation
insulation between conductive parts which is necessary only for the proper functioning of the equipment.

N.2.2
basic insulation
insulation of hazardous live parts which provides basic protection against electric shock.

NOTE The term basic insulation does not apply to insulation used exclusively for functional purposes. (See N.2.1)

N.2.3
supplementary insulation
independent insulation applied in addition to basic insulation in order to provide protection against electric shock in the event of a failure of basic insulation.

N.2.4
double insulation
insulation comprising both basic insulation and supplementary insulation.

N.2.5
reinforced insulation
insulation of hazardous live parts which provides a degree of protection against electric shock equivalent to double insulation.

NOTE Reinforced insulation may comprise several layers which cannot be tested singly as basic or supplementary insulation.

N.2.6
(electrically) protective separation
separation of one electric circuit from another by means of:

– double insulation, or

– basic insulation and electrically protective screening (shielding), or

– reinforced insulation

[IEV 195-06-19]

N.2.7
SELV circuit
electrical circuit in which the voltage cannot exceed ELV:

– under normal conditions, and

– under single-fault conditions, including earth faults in other circuits

NOTE Definition adapted from the definition of SELV system given in IEC 61140.

N.2.8
PELV circuit
electrical circuit in which the voltage cannot exceed ELV:

– under normal conditions, and

– under single-fault conditions, except earth faults in other circuits

NOTE Definition adapted from the definition of PELV system given in IEC 61140.

N.2.9
limitation of steady-state touch current and charge
protection against electric shock by circuit or equipment design such that under normal and fault conditions the steady-state touch current and charge are limited to non-hazardous levels

[IEV 826-03-16 modified]

N.2.10
protective impedance device
component or assembly of components the impedance and construction of which are such as to ensure that steady-state touch current and charge are limited to non-hazardous levels

N.3 Requirements

N.3.1 General

Unless otherwise specified in the relevant product standard:

– The method considered in this standard to achieve the protective separation is based on double (or reinforced) insulation between SELV (PELV) circuit(s) and other circuits. If any component is connected between the separated circuits, that component shall comply with the requirements for protective impedance devices according to 5.3.4 of IEC 61140 (see Figure N.1).

– The effects of electrical arcs normally produced in the breaking chambers of switchgears and controlgears on insulation are deemed to be taken into account in the dimensioning of creepage distances and no specific verification is required.

– Partial discharge effects are not taken into consideration.

NOTE Double insulation may also be appropriate for parts accessible outside of the enclosure of the equipment, as for example HMI accessories.

N.3.2 Dielectric requirements

N.3.2.1 Creepages

It shall be verified that the creepage distances between SELV (PELV) circuit and other circuits are equal or higher than twice those given for basic insulation in Table 15 and corresponding to the voltage of the circuit having the highest rated voltage value.

NOTE This requirement follows the principles given in IEC 60664-1.

The creepage distances shall be verified in accordance with N.4.2.1.

N.3.3.2 Clearances

The clearances between SELV (PELV) circuit and other circuits of the device shall be dimensioned to withstand the rated impulse voltage as determined in accordance with Annex H relevant to the basic insulation for the specific utilisation class but one step higher in the series value (or a value equal to 160 % of the voltage value required for the basic insulation) following the principles given in 5.1.6 of IEC 60664-1:2007. The test conditions are given in N.4.2.2.

N.3.3 Construction requirements

Construction measures should be taken regarding:

– materials employed regarding aging;

– thermal stresses or mechanical risks of failure which will impair insulation between circuits;

– risks of electrical contact between different circuits in case of accidental disconnection of wiring.

Subclause N.4.3 gives examples of constructional risks which have to be taken into consideration.

N.4 Tests

N.4.1 General

These tests are normally conducted as type tests. Where the constructional design cannot ensure without doubt that the insulation intended for protective separation cannot be impaired by the effects of product conditions, the manufacturer or the relevant product standard may also conduct all or parts of these tests as routine tests.

Tests verification shall be made between the SELV (PELV) circuit and each other circuits, such as main circuit, control and auxiliary circuits.

Tests shall be done in all operating conditions of the device: open, close, trip positions.

N.4.2 Dielectric tests

N.4.2.1 Creepages verification

Conditions of measuring are those given in 8.3.3.4.1 and Annex G.

N.4.2.2 Clearances verification

N.4.2.2.1 Condition of the device for test

Tests shall be made on devices mounted as for service, including internal wiring and in a clean and dry condition.

N.4.2.2.2 Application of the test voltage

For each circuit of the device under test, external terminals shall be connected together.

N.4.2.2.3 Impulse test voltage

It shall be an impulse test voltage having a 1,2/50 μs wave form as described in 8.3.3.4.1, the value of which being chosen as defined in N.3.3.2.

N.4.2.2.4 Test

Clearances are verified by application of the test voltage of N.4.2.2.3. The test shall be conducted for a minimum of five impulses of each polarity with an interval of at least 1 s between pulses in accordance with in 8.3.3.4.1.

Application of test voltage may be avoided where clearances are equal or higher than those given in Table 13 for the determined test voltage value.

N.4.2.2.5 Results to be obtained

When the voltage is applied, the test is considered to have been passed if there is no puncture or flashover.

N.4.3 Examples of constructional measures

Measures should be taken that a single mechanical fault – e.g. a bent solder pin, a detached soldering point or a broken winding (coil), a loosened and fallen screw – should not have the result of impairing the insulation to such a degree that it no longer fulfils the requirements of the basic insulation; the design, however, should not consider that two or more of these events will appear simultaneously.

Examples of constructional measures:

– sufficient mechanical stability;

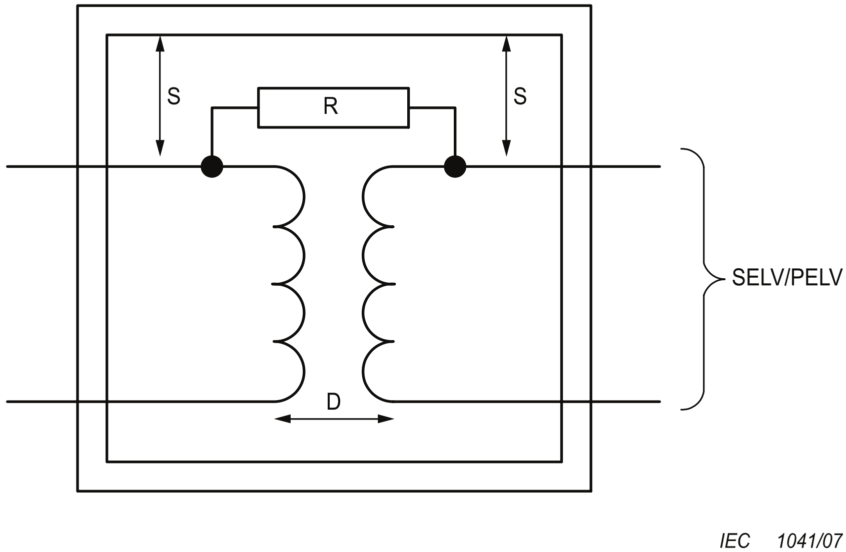
– mechanical barriers;

– employment of captive screws;

– impregnation or casting of components;

– inserting pins into an insulating sleeve;

– to avoid sharp-edges in the vicinity of conductors.



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Key

D double (or reinforced) insulation between circuits (including SELV/PELV circuit)

R component complying with protective impedance devices requirements

S basic insulation

Figure N.1

Example of application with component connected between separated circuits

Annex O
(informative)

Environmentally-conscious design

O.1 General

Every product has an effect on the environment, which may occur at any or all stages of its life cycle – raw-material acquisition, manufacture, distribution, use, maintenance, re-use and end of life. These effects may range from slight to significant; they may be short-term or long-term; and they may occur at the local, national, regional or global level (or a combination thereof).

The widespread use of electrical and electronic products has drawn increased awareness to their environmental impacts. As a result, legislation, as well as market-driven requirements for environmentally conscious design, is emerging.

The continuous introduction of new products and materials can make evaluation increasingly complex, since additional data shall be gathered to assess the life-cycle impacts of such new products and materials. The gathered data has to be used as a basis for improvement of the products with respect to environmental impacts. Life-Cycle Assessment (LCA) and environmentally conscious design (ECD) principles provide instruments that may be useful in this respect.

The goal of LCA and ECD is the reduction of adverse environmental impacts of a product throughout its entire life cycle. This can involve balancing the environmental aspects of the product with other factors, such as its intended use, performance, cost, safety, marketability, and quality and choosing methods to meet legal and regulatory requirements in an environmentally conscious way. In striving for this goal, multiple benefits can be achieved for the organization, its customers and other stakeholders. The consideration of environmental aspects particularly in the very early stage of the product design process can contribute to cost reduction and to better marketability. Environmentally conscious design is not a separate design activity; rather it is an integral part of the existing design process. The "design" in this context includes the activities associated with the processes of product planning, development and decision making as well as the creation of policies within the organization.

ECD is intended to be used by all those involved in the design and development of electrical and electronic products. This includes all parties in the supply chain regardless of organization type, size, location and complexity. It is applicable for all types of products, new as well as modified. Sector-specific documents may be developed to address needs not covered in this document. The use of this annex as a base reference is encouraged so as to ensure consistency throughout the electrotechnical sector.

This annex provides a set of requirements for the process of environmentally conscious design reflecting the contents of IEC 62430.

O.2 Scope of this annex

This annex specifies requirements and procedures to integrate environmental aspects into design and development processes of products of IEC 60947 series, including combination of products, and the materials and components of which they are composed (hereafter referred to as products), by the process of environmental conscious design (ECD).

NOTE 1 The existence of this annex does not preclude particular product sectors of the IEC 60947 series from generating their own, more specific, standards or guidelines. Where such documents are produced it is recommended that they use this annex or the IEC 62430 standard as the reference in order to ensure consistency throughout the electrotechnical sector.

The term environment, as used in this annex, differs from the term as used in the IEC publications dealing with the impact of environmental conditions on electrotechnical products.

NOTE 2 Regarding the impacts of environmental conditions on the performance of products, reference is made to IEC 60068 series, IEC 60721 series and IEC Guide 106.

O.3 Terms and definitions

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

O.3.1
design and development
activities that take an idea or requirement and transform these into a product

NOTE The process of design and development usually follows a series of defined steps starting with an initial idea, transforming that into a formal specification, and resulting in the creation of a working prototype and whatever documentation is required to support production of the goods or provision of the service.

[IEC 62430:2009, 3.1]

O.3.2
environment
surroundings in which an organization operates, including air, water, land, natural resources, flora, fauna, humans and their interrelation

NOTE Surroundings in this context extend from within an organization to the global system.

[ISO 14001:2004, 3.5]

O.3.3
environmental aspect
element of an organization's activities or products that can interact with the environment

NOTE A significant environmental aspect has or can have a significant environmental impact.

[IEC 62430:2009, 3.3]

O.3.4
environmental impact
any change to the environment, whether adverse or beneficial, wholly or partly resulting from an organization's environmental aspects

[ISO 14001:2004, 3.7]

O.3.5
environmental parameter
quantifiable attribute of an environmental aspect

EXAMPLE Environmental parameters include the type and quantity of materials used (mass, volume), power consumption, emissions, rate of recyclability, etc.

[IEC 62430:2009, 3.5]

O.3.6
environmentally-conscious design
ECD
systematic approach which takes into account environmental aspects in the design and development process with the aim to reduce adverse environmental impacts

[IEC 62430:2009, 3.6]

O.3.7
environmentally conscious design tool
formalized method which facilitates qualitative or quantitative analysis, comparison and/or solution finding during the ECD process

[IEC 62430:2009, 3.7]

O.3.8
life cycle
consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to the final disposal

[ISO 14040:2006, 3.1]

O.3.9
life cycle assessment
LCA
compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle

[ISO 14040:2006, 3.2]

O.3.10
life cycle stage
element of a life cycle

NOTE 1 The phrase 'life cycle phase' is sometimes used interchangeably with 'life cycle stage'.

NOTE 2 Examples of life cycle stages are: Raw material acquisition and production; manufacturing; packaging and distribution; installation and use, maintenance and upgrading; and end of life.

[IEC 62430:2009, 3.10]

O.3.11
life cycle thinking
LCT
consideration of all relevant environmental aspects during the entire life cycle of products

[IEC 62430:2009, 3.11]

O.3.12
organization
group of people and facilities with an arrangement of responsibilities, authorities and relationships

[IEC 62430:2009, 3.12]

O.3.13
process
set of interrelated or interacting activities which transform inputs into outputs

NOTE 1 Inputs to a process are generally outputs of other processes.

NOTE 2 Processes in an organization are generally planned and carried out under controlled conditions to add value.

[IEC 62430:2009, 3.13]

O.3.14
product
any goods or service

NOTE This includes interconnected and / or interrelated goods or services.

[IEC 62430:2009, 3.14]

O.3.15
product category
group of technologically or functionally similar products where the environmental aspects can reasonably be expected to be similar or can be derived through a certain ratio over some functional aspect of the products (e.g. product weight or performance range)

[IEC 62430:2009, 3.15, modified]

O.3.16
stakeholder
individual, group or organization that has an interest in an organization or activity

NOTE Usually a stakeholder can affect or is affected by the organization or the activity.

[IEC 62430:2009, 3.16]

O.3.17
recycling
reprocessing in a production process of the waste materials for the original purpose or for other purposes but excluding energy recovery

[IEC Guide 109:2012, 3.16, modified]

O.3.18
recyclability
property of a substance or a material and parts/products made thereof that makes it possible for them to be recycled

NOTE The recyclability of a product is not only determined by the recyclability of the materials it contains. Product structure and logistics are also very important factors.

[IEC Guide 109:2012, 3.15, modified]

O.3.19
end of life
EOL
state of a product when it is finally removed from its intended use or original purpose

[IEC Guide 109:2012, 3.1, modified]

O.3.20
energy recovery
use of combustible waste as a means to generate energy through direct incineration with or without other waste but with recovery of the heat

[IEC Guide 109:2012, 3.2, modified]

O.4 General considerations

It should be checked that consideration of the following points always leads to a reduction of the adverse environmental impact of the product throughout its life cycle:

• material conservation;

• efficient use of energy and resources;

• reduction of emissions and waste;

• minimum material content of product (including packaging material);

• decreasing the number of different materials;

• substitution or reduction in use of hazardous substances;

• re-use/refurbishing of subassemblies or components;

• possibility of technical upgrading;

• design for maintainability, disassembly and recyclability;

• surface coating or other material combinations enhancing recyclability;

• marking;

• adequate environmental instruction/information for the user.

This leads to the implementation of an adequate process for consideration of the environmental impact of the products. The process should reflect the standardized principle of environmental conscious design based on life cycle thinking.

Clause O.5 describes the fundamental requirements of ECD to be implemented by the organization. Clause O.6 describes the ECD process to be implemented on an operational basis.

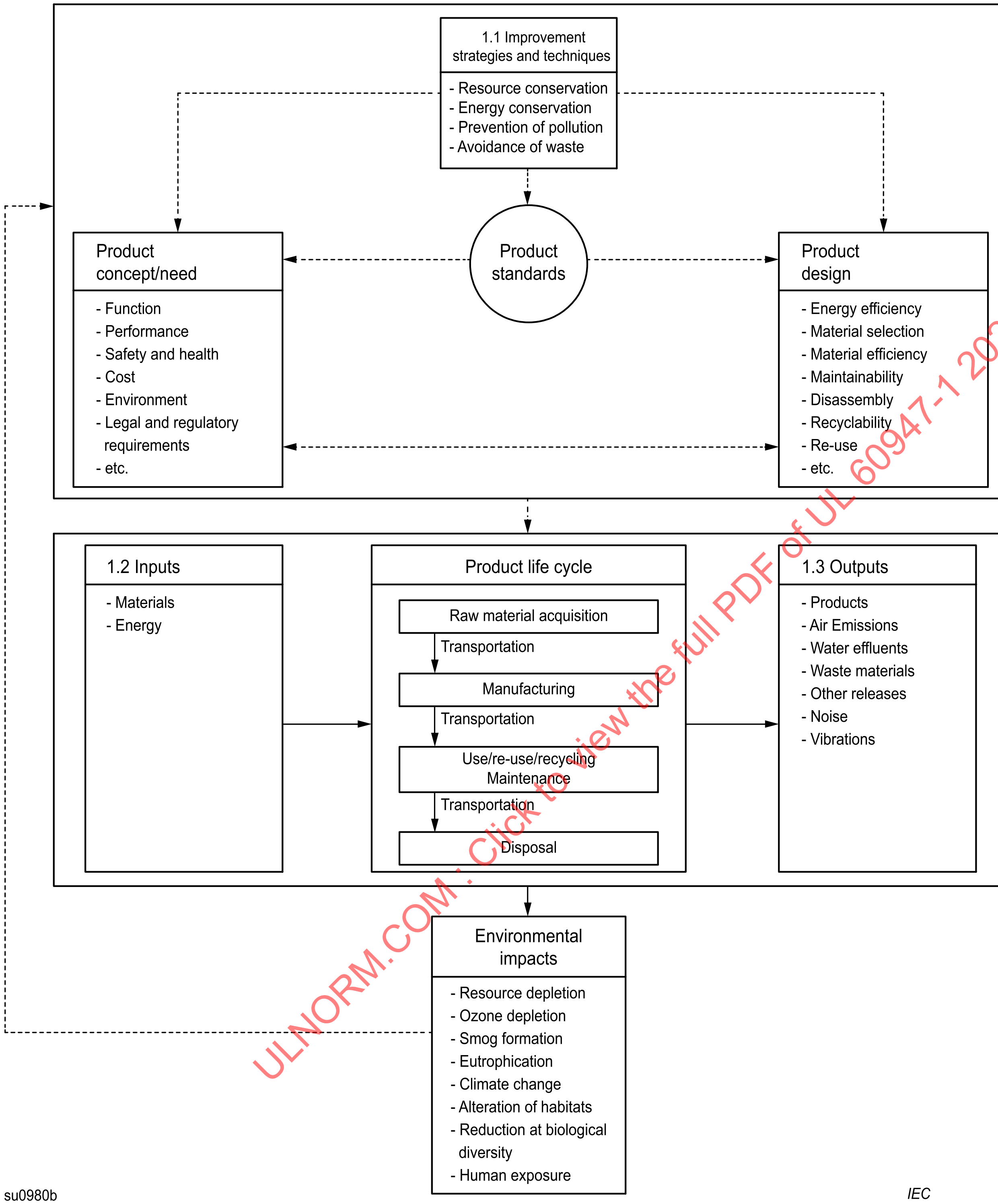

Figure O.1

Conceptual relationship between provisions in product standards and the environmental impacts associated with the product during its life cycle

O.5 Fundamentals requirements of environmentally conscious design (ECD)

Environmentally conscious design shall be based on the concept of life cycle thinking (LCT), which requires consideration during the design and development process of the significant environmental aspects of a product in all life cycle stages.

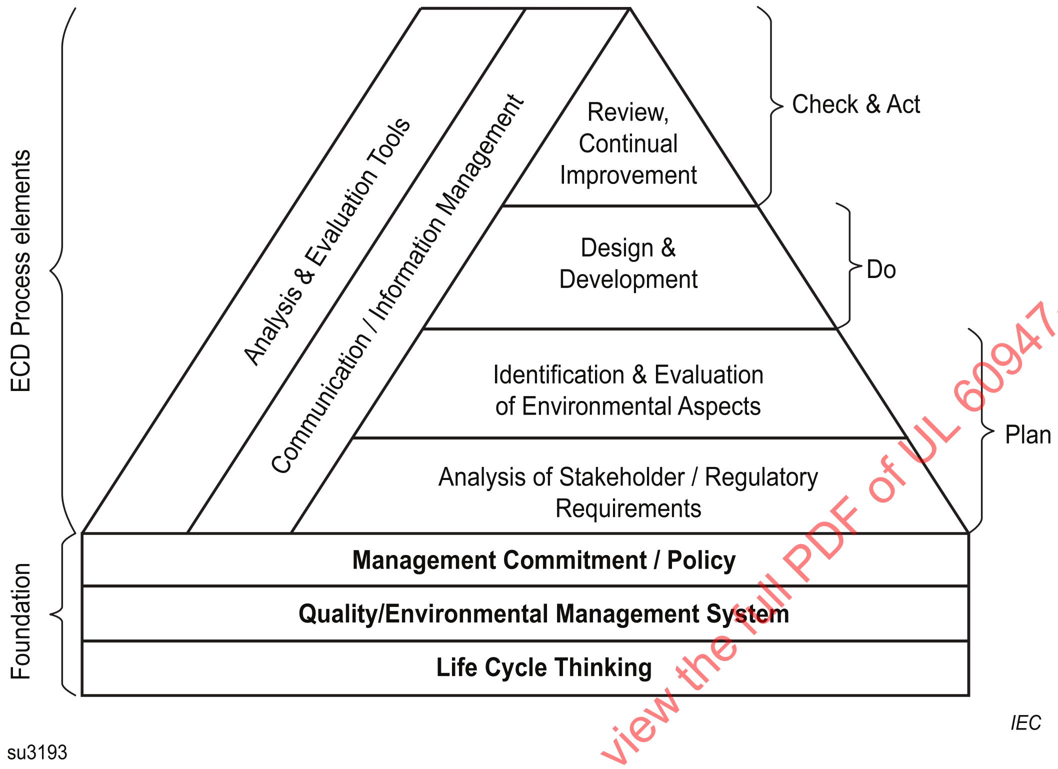

Figure O.2

Overview of ECD process

Key elements of life cycle thinking are:

a) having an objective to minimize the overall adverse environmental impact of the product;

b) identifying, qualifying and where feasible, quantifying the significant environmental aspects of the product;

c) considering the trade-offs between environmental aspects and life cycle stages.

The above shall be initiated as early as possible in the design and development process, when most opportunities exist to make changes and improvements to the product affecting its overall environmental performance throughout its life cycle.

Environmentally conscious design is performed within the boundaries set by regulatory and stakeholders' requirements. Such requirements shall be regularly reviewed so that relevant changes are understood by the organization undertaking the ECD.

Environmentally conscious design and its objective of minimizing the overall adverse impact of the product shall be reflected in the policies and strategies of the organization. If an organization has a management system which includes the product design and development function, the ECD process shall be an integral part of that documented system.

NOTE 1 As a first step in LCT, the intended function of the product should be determined. In subsequent design and development stages the influence of any applied business model should be recognized.

NOTE 2 When a product is part of a system, the environmental performance of one product during one or more life cycle stages can be altered by other products in that system.

NOTE 3 ECD requires collaboration and contributions of all stakeholders along the supply chain.

NOTE 4 Communication regarding the ECD process and its objectives is performed within an organization so that the affected departments understand the rationale for the initiative, leading to their cooperation and collaboration.

NOTE 5 The detailed description of the fundamental requirements of ECD can be found in IEC 62430.

O.6 Environmentally conscious design process (ECD process)

O.6.1 General

Organizations performing environmentally conscious design (ECD) shall establish, document, implement and maintain an ECD process as an integral part of the product design and development process. This ECD process includes the following steps, which are further described in O.6.2:

d) analysis of the regulatory and stakeholders' environmental requirements;

e) identification and evaluation of environmental aspects and corresponding impacts;

f) design and development;

g) review and continual improvement.

The organization shall, while following the above steps, document the relevant results and the subsequent conclusions and responsibilities assigned.

NOTE The above process from a) to d) corresponds to PDCA cycle as follows:

steps a) and b) to Plan,

step c) to Do, and

step d) to Check and Act.

O.6.2 Process steps of ECD

As an initial step of ECD, to be carried out in conjunction with the identification of environmental aspects, the organization shall understand the relevant regulatory and stakeholders' requirements, both at horizontal and sector specific level. These requirements set the basic framework within which a product is developed.

The organization shall then establish a procedure to identify environmental aspects and corresponding impacts of the product.

NOTE 1 The identification of environmental aspects could be done for a product category.

The choice of a design solution should achieve a balance between the various environmental aspects and other relevant considerations, such as function, technical requirements, quality, performance, business risks and economic aspects. Where certain attributes are required for compliance with regulations (e.g. health and safety, electromagnetic compatibility) these shall be met while taking into account the environmental targets. These considerations also apply to research and development of new technologies.

A procedure for review and continual improvement of the significant environmental aspects of products throughout the entire life cycle shall be established, implemented and maintained.

As part of the ECD process, organizations in the supply chain shall disclose information of their product or product category to organizations involved in design and development to enable them to achieve ECD objectives.

Information on the environmental impact of the products or product categories should be made available to the stakeholders in adequate, standardized form, e.g. compliant to the ISO 14020 series standards – environmental product declarations.

NOTE 2 The detailed description of the ECD process can be found in IEC 62430.

O.7 Tools for including ECD in product design and development

Identification and assessment of how environmental impacts are influenced by products are complex and need careful consideration; they may also require consultation with experts. Certain tools and techniques are evolving to encourage the inclusion of environmental aspects in product design and development. These can assist in the development of key design items, decision-making, and integration with business and economic factors. Examples of such tools are:

a) analysis of a product’s environmental aspects; for example, LCA (Life Cycle Assessment), ECD checklists and ECD benchmarking based on physical metrics (for example, weight, energy consumption, volume);

b) determination of a product’s environmental strategy: qualitative decision-making tools, for example, Eco-matrices, checklists, Pareto diagrams, SWOT analysis (Strengths, Weaknesses, Opportunities, Threats), spider’s-web diagrams and portfolio diagrams;

c) transfer of environmental aspects into product properties; for example, QFD (Quality Function Deployment) and FMEA (Failure Mode and Effects Analysis) techniques.

When selecting which tools to use, it is helpful to consider the basic product-related concepts for integrating environmental aspects into product design and development.

NOTE Proper tools and tool categories and implementation strategies are described in IEC 62430:2009, Annex C.

O.8 Relevant ISO technical committees

TC 61 Plastics

TC 79 Light metals and their alloys

TC 122 Packaging

TC 146 Air quality

TC 147 Water quality

TC 190 Soil quality

TC 200 Solid wastes

TC 203 Technical energy systems

TC 205 Building environment design

TC 207 Environmental management

SC 1 Environmental management systems

SC 2 Environmental auditing and related environmental investigations

SC 3 Environmental labelling

SC 4 Environmental performance evaluation

SC 5 Life cycle assessment

SC 6 Terms and definitions

WG 1 Environmental aspects in product standards

O.9 Reference documents for environmental conscious design

IEC 62430, *Environmentally conscious design for electrical and electronic products*

IEC 62474, *Material declaration for products of and for the electrotechnical industry*

IEC Guide 109, *Environmental aspects – Inclusion in electrotechnical product standards*

ISO/IEC Guide 73, *Risk management – Vocabulary*

ISO 9000, *Quality management systems – Fundamentals and vocabulary*

ISO 9001, *Quality management systems – Requirements*

ISO 14001, *Environmental management systems – Requirements with guidance for use*

ISO 14020, *Environmental labels and declarations – General principles*

ISO 14040, *Environmental management – Life cycle assessment – Principles and framework*

ISO/TR 14062, *Environmental management – Integrating environmental aspects into product design and development*

ISO 14063, *Environmental management – Environmental communication – Guidelines and examples*

ISO Guide 64, *Guide for addressing environmental issues in product standards*

ECODESIGN – *a promising approach to sustainable production and consumption: 1997, United Nations Environmental Programme*

Annex P
(informative)

Terminal lugs for low voltage switchgear and controlgear connected to copper conductors

Table P.1
Examples of terminal lugs for low voltage switchgear and controlgear connected to copper conductors

Conductor cross-sectional area mm²		Dimensions (see Figure P.1) mm						Clearance hole for mounting bolt
Flexible	Solid or stranded	L max.	N max.	W max.	W Gauge	Z max.	M min.	H
6	10	22	6	10		12	6	M5
10	16	26	6	10		12	6	M5
16	25	28	6	10		12	6	M5
25	35	33	7	12	12, 5	17	7	M6
35	50	38	7	12	12, 5	17	7	M6
50	70	41	7	12	12, 5	17	7	M6
70	95	48	8, 5	16	16, 5	20	8, 5	M8
95	120	51	10, 5	20	20, 5	25	10, 5	M10
120	150	60	10, 5	20	20, 5	25	10, 5	M10
150	185	72	11	25	25, 5	25	11	M10
185	240	78	12, 5	31	32, 5	31	12, 5	M12
240	300	89	12, 5	31	32, 5	31	12, 5	M12
300	400	105	17	40	40, 5	40	17	M16
400	500	110	17	40	40, 5	40	17	M16
NOTE Other different dimensions of cables lugs are available.								

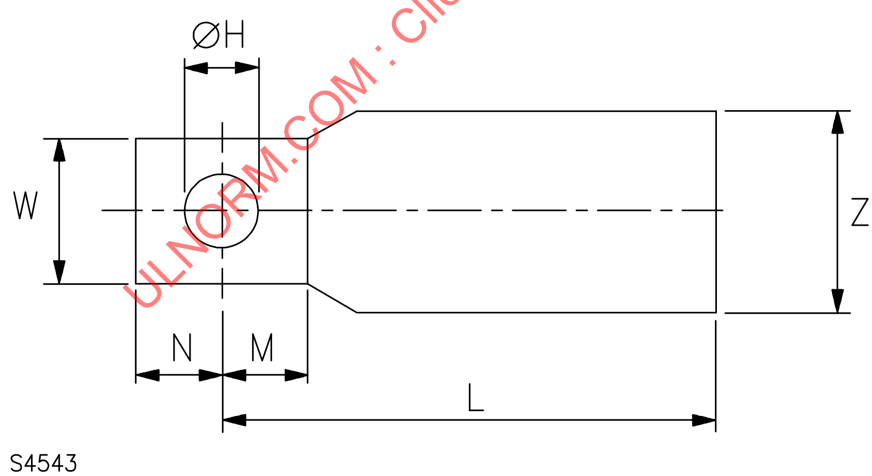

Figure P.1

Dimensions

Annex Q
(normative)

Special tests – Damp heat, salt mist, vibration and shock

Q.1 General

The purpose of this annex is to define the requirements allowing to assess the ability of switchgear and controlgear to perform its function where intended to be used under certain climatic conditions different from normal service conditions as described in 6.1.

This annex states the test conditions and sequences and the results to be obtained.

The following special tests shall be made either at the discretion of the manufacturer or according to an agreement between manufacturer and user (see 2.6.4). As special tests, these additional tests are not mandatory, and it is not necessary for an equipment to satisfy any of these tests to conform to this standard.

Q.2 Classification of equipment

Equipment classification is defined according to six sets of environmental tests, resulting from a combination of different parameter classes (temperature and humidity, vibration, shock, salt mist):

− Temperature and humidity test ranges:

CC1: −5 °C to +55 °C (first range: dry heat test at +55 °C / damp heat test at +40 °C / cold test at −5 °C)

CC2: −25 °C to +70 °C (second range: dry heat test at +70 °C / damp heat test at +55 °C / cold test at −25 °C)

− Vibration and shock levels:

MC1: no vibration

MC2: vibration

MC3: vibration plus shock

− Salt mist:

SC1: no salt mist

SC2: salt mist (test according to IEC 60068-2-52)

The combination of these environmental tests results in the following six categories A, B, C, D, E and F:

− A: controlled environment subject to temperature and humidity (temperature test range −5 °C to +55 °C) = MC1+CC1+SC1

NOTE 1 These environmental conditions may be described as “humid atmosphere”.

− B: environment subject to temperature and humidity (temperature test range −25 °C to +70 °C) = MC1+CC2+SC1

NOTE 2 These environmental conditions may be described as “humid and cold atmosphere”.

− C: environment subject to temperature, humidity and salt mist = MC1+CC2+SC2

NOTE 3 These environmental conditions may be described as “humid and salty atmosphere” or “marinas”.

− D: environment subject to temperature, humidity and vibration = MC2+CC2+SC1

NOTE 4 These environmental conditions may be described as “humid and cold atmosphere on board ship, with vibrations”.

− E: environment subject to temperature, humidity, vibration and shock = MC3+CC2+SC1

NOTE 5 These environmental conditions may be described as “open deck, humid and cold atmosphere, without salt mist” or “onerous (severe) conditions other than at sea”.

− F: environment subject to temperature, humidity, vibration, shock and salt mist = MC3+CC2+SC2

NOTE 6 These environmental conditions may be described as “open deck, humid, cold and salty atmosphere” or “onerous (severe), sea conditions”.

Q.3 Tests

Q.3.1 General test conditions

Unless otherwise specified, 8.3.2 applies with the following additions.

These tests demonstrate the ability of the equipment to function as intended under the specified testing conditions. The intended function is defined in the test sequence.

The equipment shall be tested (if applicable) in the open position, this equipment having previously been under a normal atmospheric condition for a minimum time of 24 h. Normal atmospheric condition means:

− temperature: 25 °C ±10 °C;

− relative humidity: 60 % ±30 %;

− air pressure: 96 kPa ±10 kPa.

During the tests inside the climatic oven, the cables shall have at least 5 cm length and, in case of equipment with enclosure, at least 5 cm length outside of the enclosure, and the passage through the enclosure shall be made according the manufacturer's instructions.

With the manufacturer's agreement, it is permitted to use cables with a cross-section lower than those given in Table 9, Table 10 and Table 11 of 8.3.3.3.4. For devices with high current rating, where space is limited in the climatic chamber, it is permissible to omit cable connections.

NOTE As the Subclause 6.1.4 “Shock and vibrations” for normal conditions, is still under consideration, this annex does not prejudge what will be finally considered as normal conditions of shock and vibrations, and may consequently be revised when the Subclause 6.1.4 is completed.

Q.3.2 Test sequences

After selecting the required environment, the relevant tests are to be performed as a test sequence according to Table Q.1. See also footnote f of Table Q.1.