IS/IEC 60947-1 (2007): Low-voltage switchgear and controlgear, Part 1: General rules [ETD 7: Low Voltage Switchgear and Controlgear]

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IS/IEC 60947-1 : 2004
[Superseding IS 13947 (Part 1) : 1993]

भारतीय मानक

निम्न-वोल्टता के स्विचगियर और नियंत्रणगियर

भाग 1 सामान्य नियम

Indian Standard

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR

PART 1 GENERAL RULES

ICS 29.130.20

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

December 2007

Price Rs. 1360.00

CONTENTS

Low-Voltage Switchgear and Controlgear Sectional Committee, ETD 07

NATIONAL FOREWORD

This Indian Standard (Part 1) which is identical with IEC 60947-1 : 2004 'Low-voltage switchgear and controlgear — Part 1: General rules' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Low-Voltage Switchgear and Controlgear Sectional Committee and approval of the Electrotechnical Division Council.

This standard supersedes IS 13947 (Part 1) : 1993 'Specification for low-voltage switchgear and controlgear: Part 1 General rules'.

The text of IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker, while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their respective places, are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60050 (151) (2001) International Electrotechnical Vocabulary (IEV) — Chapter 151: Electrical and magnetic devices	IS 1885 (Part 74) : 1979 Electrotechnical vocabulary: Part 74 Electrical and magnetic devices	Technically Equivalent
IEC 60050 (441) (1984) International Electrotechnical Vocabulary (IEV) — Chapter 441: Switchgear, controlgear and fuses	IS 1885 (Part 17) : 1979 Electrotechnical vocabulary: Part 17 Switchgear and controlgear (*first revision*)	do
IEC 60050 (604) (1987) International Electrotechnical Vocabulary (IEV) — Chapter 604: Generation, transmission and distribution of electricity — Operation	IS 1885 (Part 69) : 1979 Electrotechnical vocabulary: Part 69 Generation, transmission and distribution of electricity — Operation	do
IEC 60060-1 (1989) High-voltage test techniques — Part 1: General definitions and test requirements	IS 2071 (Part 1) : 1993 High-voltage test techniques: Part 1 General definitions and test requirements (*second revision*)	do
IEC 60071-1 (1993) Insulation co-ordination — Part 1: Definitions, principles and rules	IS 2165 (Part 1) : 1977 Insulation co-ordination: Part 1 Phase-to-earth insulation co-ordination principles and rules (*second revision*)	do
IEC 60085 (1984) Thermal evaluation and classification of electrical insulation	IS 1271 : 1985 Thermal evaluation and classification of electrical insulation (*first revision*)	do

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60112 (2003) Method for the determination of the proof and the comparative tracking indices of solid insulating materials	IS 2824 : 1975 Method for determining the comparative tracking index of solid insulating materials under moist conditions	Technically Equivalent
IEC 60216 (2001) Guide for the determination of thermal endurance properties of electrical insulating materials	IS 8504 (Part 1) : 1994 Guide for the determination of thermal endurance properties of electrical insulating materials: Part 1 General guidelines for ageing procedures and evaluation of test results (*first revision*)	do
IEC 60269-1 (1998) Low-voltage fuses — Part 1: General requirements	IS 13703 (Part 1) : 1993 Low-voltage fuses for voltages not exceeding 1 000 V ac or 1 500 V dc: Part 1 General requirements	do
IEC 60269-2 (1986) Low-voltage fuses — Part 2: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application)	IS 13703 (Part 2/Sec 1) : 1993 Low-voltage fuses for voltages not exceeding 1 000 V ac or 1 500 V dc: Part 2 Fuses for use by authorized persons, Section 1 Supplementary requirements	Identical
IEC 60439-1 (1999) Low-voltage switchgear and controlgear assemblies — Part 1: Type-tested and partially type-tested assemblies	IS 8623 (Part 1) : 1993 Specification for low-voltage switchgear and controlgear assemblies: Part 1 Requirements for type-tested and partially type-tested assemblies (*first revision*)	Technically Equivalent
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 for an alphanumeric system	IS 11353 : 1985 Guide for uniform system of marking and identification of conductors and apparatus terminals	do
IEC 60529 (1989) Degrees of protection provided by enclosures (IP code)	IS 12063 : 1987 Classification of degrees of protection provided by enclosures of electrical equipment	do
IEC 60617-7 (2001) Graphical symbols for diagrams	IS 12032 (Part 7) : 1987 Graphical symbols for diagrams in the field of electrotechnology: Part 7 Switchgear, controlgear and protective devices	do
IEC 60664-1 (1992) Insulation co-ordination for equipment within low-voltage systems — Part 1: Principles, requirements and tests	IS 15382 (Part 1) : 2003[1)] Insulation coordination for equipment within low-voltage systems: Part 1 Principles, requirements and tests	Identical
IEC 60695-2-2 (1991) Fire hazard testing — Part 2: Test methods — Section 2: Needle-flame test	IS 11000 (Part 2/Sec 2) : 1984 Fire hazard testing: Part 2 Test methods, Section 2 Needle-flame test	Technically Equivalent
IEC 60947-5-1 (1997) Low-voltage switchgear and controlgear — Part 5: Control circuit devices and switching elements — Section 1: Electromechanical control circuit devices	IS/IEC 60947-5-1 : 2003[2)] Low-voltage switchgear and controlgear: Part 5 Control circuit devices and switching elements, Section 1 Electromechanical control circuit devices	Identical

[1)] This standard is identical to IEC 60664-1 (2002).
[2)] This standard is identical to IEC 60947-5-1 (2003).

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 61000-3-2 (2000) Electromagnetic compatibility (EMC) — Part 3: Limits — Section 2: Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)	IS 14700 (Part 3/Sec 2) : 1999 Electromagnetic compatibility (EMC): Part 3 Limits, Section 2 Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)	Technically Equivalent
IEC 61000-3-3 (1994) Electromagnetic compatibility (EMC) — Part 3: Limits — Section 3: Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current ≤ 16 A	IS 14700 (Part 3/Sec 3) : 1999 Electromagnetic compatibility (EMC): Part 3 Limits, Section 3 Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current ≤ 16 A	Identical
IEC 61000-4-2 (1995) Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 2: Electrostatic discharge immunity test	IS 14700 (Part 4/Sec 2) : 1999 Electromagnetic compatibility (EMC): Part 4 Testing and measurement techniques, Section, 2 Electrostatic discharge immunity test	do
IEC 61000-4-3 (2002) Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 3: Radiated, radio-frequency, electromagnetic field immunity test	IS 14700 (Part 4/Sec 3) : 2005 Electromagnetic compatibility (EMC): Part 4 Testing and measurement techniques, Section 3 Radiated, radio-frequency, electromagnetic field immunity test	do
IEC 61000-4-4 (1995) Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 4: Electrical fast transient/burst immunity test	IS 14700 (Part 4/Sec 4) : 1999 Electromagnetic compatibility (EMC): Part 4 Testing and measurement techniques, Section 4 Electrical fast transient/burst immunity test	do
CISPR 11 (2003) Industrial, scientific and medical (ISM) radio-frequency equipment — Electromagnetic disturbance characteristics — Limits and methods of measurement	IS 6873 (Part 4) : 1999 Limits and methods of measurement of radio disturbance characteristics: Part 4 Industrial, scientific and medical (ISM) radio-frequency equipment (*first revision*)	Technically Equivalent

The technical committee responsible for the preparation of this standard has reviewed the provisions of the following International Standard referred in this adopted standard and has decided that they are acceptable for use in conjunction with this standard:

International Standard	*Title*
IEC 60050 (826) (1982)	International Electrotechnical Vocabulary (IEV) — Chapter 826: Electrical installations of buildings
IEC 60068-2-78 (2001)	Environmental testing — Part 2-78: Tests — Test cab: Damp heat, steady state
IEC 60073 (2002)	Basic and safety principles for man-machine interface, marking and identification — Coding principles for indicators and actuators
IEC 60364-4-44 (2001)	Electrical installations of buildings — Part 4-44: Protection for safety — Protection against voltage disturbances and electromagnetic disturbances
IEC 60417 (2002)	Graphical symbols for use on equipment

International Standard	*Title*
IEC 60447 (1993)	Basic and safety principles for man-machine interface (marking and identification) — Actuating principles
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 60695-11-10 (1999)	Fire hazard testing — Part 11-10: Test flames — 50 W horizontal and vertical flame test methods
IEC 60981 (1989)	Extra-heavy duty rigid steel conduits for electrical installations
IEC 61000-4-5 (1995)	Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 5: Surge immunity test
IEC 61000-4-6 (1996)	Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 6: Immunity to conducted disturbances, induced by radio frequency fields
IEC 61000-4-8 (1993)	Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 8: Power frequency magnetic field immunity test
IEC 61000-4-11 (1994)	Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 11: Voltage dips, short interruptions and voltage variations immunity tests
IEC 61000-4-13 (2002)	Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 13: Harmonics and interharmonics including mains signalling at a.c. power port, low-frequency immunity tests
IEC 61140 (2001)	Protection against electric shock — Common aspects for installation and equipment
IEC 61180 (all parts)	High-voltage test techniques for low-voltage equipment

Only the English text of the International Standard has been retained while adopting it as an Indian Standard, and as such the page numbers given here are not same as in the IEC Publication.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be same as that of the specified value in this standard.

Indian Standard

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 due to be part of the series of IEC standards covering low-voltage switchgear and controlgear are:

60947-2: Part 2: Circuit-breakers

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

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

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

60947-6: Part 6: Multiple function equipment

60947-7: Part 7: Ancillary equipment

1.1 Scope and object

This standard applies, when required by the relevant product standard, to switchgear and controlgear hereinafter referred to as "equipment" 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.

It does not apply to low-voltage switchgear and controlgear assemblies which are dealt with in IEC 60439.

NOTE In certain clauses or subclauses of this standard, the equipment covered by this standard is also referred to as "device", to be consistent with the text of such clauses or subclauses.

The object of this standard is to state those general rules and requirements which are common to low-voltage equipment as defined in 1.1, including for example:

- definitions;
- characteristics;
- information supplied with the equipment;
- normal service, mounting and transport conditions;
- constructional and performance requirements;
- verification of characteristics and performance.

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):1982, *International Electrotechnical Vocabulary (IEV) – Chapter 826: Electrical installations of buildings*
Amendment 1 (1990)
Amendment 2 (1995)
Amendment 3 (1999)

IEC 60060, *High-voltage test techniques*

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 60085:1984, *Thermal evaluation and classification of electrical insulation*

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 60269-1:1998, *Low-voltage fuses – Part 1: General requirements*

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 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*

IEC 60439-1:1999, *Low-voltage switchgear and controlgear assemblies – Part 1: Type-tested and partially type-tested assemblies*

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 60447:1993, *Man-machine interface (MM) – 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 60664-1:1992, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests* – Basic safety publication
Amendment 1 (2000)
Amendment 2 (2002)

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 60695-11-10:1999, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

IEC 60947-5-1:1997, *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*
Amendment 1 (1999)
Amendment 2 (1999)

IEC 60981:1989, *Extra-heavy duty rigid steel conduits for electrical installations*

IEC 61000-3-2:2000, *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤16 A per phase)*
Amendment 1 (2001)

IEC 61000-3-3:1994, *Electromagnetic compatibility (EMC) – Part 3: Limits – Section 3: Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current ≤16 A*
Amendment 1 (2001)

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

IEC 61000-4-2:1995, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 2: Electrostatic discharge immunity test* – Basic EMC publication
Amendment 1 (1998)
Amendment 2 (2000)

IEC 61000-4-3:2002, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*
Amendment 1:2002

IEC 61000-4-4:1995, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 4: Electrical test transient/burst immunity test* – Basic EMC publication
Amendment 1 (2000)
Amendment 2 (2001)

IEC 61000-4-5:1995, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 5: Surge immunity test*
Amendment 1 (2000)

IEC 61000-4-6:1996, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 6: Immunity to conducted disturbances, induced by radio-frequency fields*
Amendment 1 (2000)

IEC 61000-4-8:1993, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 8: Power frequency magnetic field immunity test* – Basic EMC Publication
Amendment 1 (2000)

IEC 61000-4-11:1994, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 11: Voltage dips, short interruptions and voltage variations immunity tests*

Amendment 1 (2000)

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

IEC 61140:2001, *Protection against electric shock – Common aspects for installation and equipment*

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

CISPR 11:2003, *Industrial, scientific and medical (ISM) radio-frequency equipment – Electromagnetic disturbance characteristics – Limits and methods of measurement*

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.

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 equipment 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 structures, 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]

2.1.15
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]

2.2 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-link
part 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]

2.3 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
terminal
conductive part of a device provided for electrical connection to external circuits

2.3.23
screw-type terminal
terminal intended for the connection and disconnection of conductors or for the interconnection 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.

2.3.24
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
clamping unit
part(s) of a terminal necessary for the mechanical clamping and the electrical connection of the conductor(s)

2.3.26
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.

2.3.27
prepared conductor
conductor, the strands of which are soldered or the end of which is fitted with a cable lug, eyelet, etc.

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 corresponding 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 discrimination
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

[441-17-15]

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

2.6 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

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
Rated breaking capacity	–	4.3.5.3
Rated conditional short-circuit current	–	4.3.6.4
Rated control circuit voltage	U_c	4.5.1
Rated control supply voltage	U_s	4.5.1
Rated current	I_n	[1]
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}	[1]
Rated rotor operational current	I_{er}	[1]
Rated rotor operational voltage	U_{er}	[1]
Rated service short-circuit breaking capacity	I_{cs}	[1]
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	–	[1]
Rated stator insulation voltage	U_{is}	[1]
Rated stator operational current	I_{es}	[1]
Rated stator operational voltage	U_{es}	[1]
Rated ultimate short-circuit breaking capacity	I_{cu}	4.3.2.4
Rated uninterrupted current	I_u	[1]
Rotor thermal current	I_{thr}	[1]
Selectivity limit current	I_s	[1]
Stator thermal current	I_{ths}	[1]
Take-over current	I_B	2.5.25
Temporary duty	–	4.3.4.4
Uninterrupted duty	–	4.3.4.2
Utilization category	–	4.4

[1] 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 2).

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.

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

NOTE 2 The conventional enclosed thermal current value may be for unventilated equipment in which case the enclosure used for the test shall be of the size stated by the manufacturer as being the smallest that is applicable in service. Alternatively, the value may be for a ventilated equipment according to the manufacturer's data.

NOTE 3 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 sha indicate, either in terms of the true cycle if this is known, or in terms of conventional cycle designated by him, the values of the rated operational currents which shall be such that:

$$\int_0^T i^2 dt \leq I_{th}^2 \times T \quad \text{or} \quad I_{the}^2 \times T$$

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 power-factors 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 withstand 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

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.

4.4 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 Electrical control circuits

The characteristics of electrical control circuits are:

- kind of current;
- rated frequency if a.c.;
- rated control circuit voltage U_c (nature, and frequency if a.c.);
- rated control supply voltage U_s (nature, and frequency if a.c.), where applicable.

NOTE 1 A distinction has been made above between the control circuit voltage, which is the voltage which would appear across the "a" contacts (see 2.3.12) in the control circuit, and the control supply voltage, which is the voltage applied to the input terminals of the control circuit of the equipment and may be different from the control circuit voltage, due to the presence of built-in transformers, rectified, resistors, etc.

The rated control circuit voltage and rated frequency, if any, are the values on which the operating and temperature-rise characteristics of the control circuit are based. The correct operating conditions are based upon a value of the control supply voltage not less than 85 % of its rated value, with the highest value of control circuit current flowing, nor more than 110 % of its rated value.

NOTE 2 The manufacturer should be prepared to state the value or values of the current taken by the control circuit(s) at the rated control supply voltage.

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.

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 It is recommended that the current be plotted as abscissa and the time as ordinate, using logarithmic scales. It is recommended that the current be plotted as a multiple of the current setting and the time in seconds on the standard graph sheet detailed in IEC 60269-1 (first edition, 5.6.4) and IEC 60269-2 (Figures 1 to 7).

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);
- 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;
- rated control 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.

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.

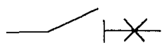
NOTE In the USA and Canada, the rated operational voltage U_e, may be marked as follows:

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 7.1.4.2), if applicable;
- indication of the position of the actuator (see also 7.1.5.1 and 7.1.5.2);
- approval or certification mark, if applicable;
- for miniaturized equipment, symbol, colour code or letter code;
- terminal identification and marking (see 7.1.7.4);
- 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.:



for a circuit-breaker suitable for isolation;

for a switch-disconnector.

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 7.1.10.

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

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 in the documentation the following notice:

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.

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 60439-1 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 Standard reference air temperature 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 Tables 13 and 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.

7 Constructional and performance requirements

7.1 Constructional requirements

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.

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.

7.1.1 Materials

The suitability of materials used is verified by making tests:

a) on the equipment; or

b) on sections taken from the equipment; or

c) on samples of identical material having representative cross-section.

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

The manufacturer shall indicate which tests, amongst a), b) and c), 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.

7.1.1.1 Resistance to abnormal heat and fire

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

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 to 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 60695-2-2). 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).

When tests on materials are used, they shall be made according to the tests for flammability classification, hot wire ignition and, where applicable, arc ignition, as specified in 8.2.1.1.2.

The relevant product standard shall specify the required flammability category of IEC 60695-11-10.

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's flammability category shall conform to Table M.1.

The manufacturer may provide data from the insulating material supplier to demonstrate compliance with this requirement.

7.1.2 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.

7.1.3 Clearances and creepage distances

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

Electrical requirements are given in 7.2.3.

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

7.1.4 Actuator

7.1.4.1 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.

7.1.4.2 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.

7.1.5 Indication of the contact position

7.1.5.1 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 | 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.

7.1.5.2 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.

7.1.6 Additional requirements for equipment suitable for isolation

7.1.6.1 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 the moving 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.

7.1.6.2 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.

7.1.6.3 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.

7.1.7 Terminals

7.1.7.1 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 conductors may be connected by means of screws, springs or other equivalent means so as to ensure that the necessary contact pressure is maintained.

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

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

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.

7.1.7.2 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.

7.1.7.3 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.

7.1.7.4 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 7.1.9.3.

7.1.8 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 7.1.7.4).

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.

7.1.9 Provisions for protective earthing

7.1.9.1 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.

7.1.9.2 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 2.1.1.5 – 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.

7.1.9.3 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 Enclosures for equipment

The following requirements are only applicable to enclosures supplied or intended to be used with the equipment.

7.1.10.1 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.

7.1.10.2 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.

7.1.11 Degrees of protection of enclosed equipment

Degrees of protection of enclosed equipment and relevant tests are given in Annex C.

7.1.12 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.

7.2 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 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 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.

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.

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 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 Tables 2 and 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.

7.2.2.1 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 Tables 2 and 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 Tables 2 and 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 Tables 2 and 3.

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 Tables 2 and 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 cause damage to current-carrying parts or adjacent parts of the equipment. In particular, for insulating materials, the manufacturer shall demonstrate compliance either 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.

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) Auxiliary and control circuits which operate directly from the main circuit at the rated operational voltage shall comply with the requirements of item 1) a) of 7.2.3.1 (see also the note of 7.2.3.1 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.

7.2.3.3 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 higher than the values given in Table 13 for case A (inhomogeneous field).

The method of measuring clearances is given in Annex G.

7.2.3.4 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.

7.2.3.5 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.

Dimensioning rules for solid insulation and d.c. test voltages are under consideration.

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.

7.3 Electromagnetic compatibility (EMC)

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 2 Environment B corresponds to equipment class B in CISPR 11.

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 purpose of this subclause, the term "electronic circuits" excludes circuits in which all components are passive (for example diodes, resistors, varistors, capacitors, surge suppressors, inductors).

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

For equipment not incorporating electronic circuits, electromagnetic disturbances can only be generated by equipment during occasional switching operations. The duration of the disturbances is of the order of milliseconds.

The frequency, the level and the consequences of these emissions are considered as part of the normal electromagnetic environment of low-voltage installations.

Therefore, the requirements for electromagnetic emissions are deemed to be satisfied, and no verification is necessary.

7.3.3.2 Equipment incorporating electronic circuits

7.3.3.2.1 Limits for high-frequency emissions

Equipment incorporating electronic circuits (such as switched mode power supply, circuits incorporating microprocessors with high-frequency clocks) may generate continuous electromagnetic disturbances.

For such emissions, these shall not exceed the limits specified in the relevant product standard, based on CISPR 11 for environment A and for environment B.

These tests are only required when the control and/or auxiliary circuits contain components with fundamental switching frequencies greater than 9 kHz.

The product standard shall detail the test methods.

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 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 clauses 4 to 10 of IEC 60695-2-10 and IEC 60695-2-11 under the conditions specified in 7.1.1.1.

For the purpose of this test, a protective conductor is not considered as a current-carrying part.

NOTE If the test has to be made at more than one place on the same sample, care will be taken to ensure that any deterioration caused by previous tests does not affect the test to be made.

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 properties of terminals

This subclause does not apply to aluminium terminals nor to terminals for connection of aluminium conductors.

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-sectional area.

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 smallest cross-section connected to the terminal;

b) the maximum number of conductors of the largest cross-section connected to the terminal;

c) the maximum number of conductors of the smallest and largest 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.

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 specified 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).

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.

8.2.5 Verification of the effectiveness of indication of the main contact position of equipment suitable for isolation

NOTE See note of 7.1.6.

To verify the effectiveness of the indication of the main contact position as required by 7.1.6, 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 normal operation force F required at the extremity of the actuator to operate the equipment into the open position shall first be determined.

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 3F 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.

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.

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.

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.

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 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.

8.2.7.1 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.

8.3 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 60439.

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.

NOTE An individual enclosure is an enclosure designed and dimensioned to contain one equipment only.

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.

8.3.2.2 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 power-frequency 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 system 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.

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 tests, the ambient air temperature shall be between +10 °C and +40 °C and shall not vary by more than 10 K.

However, if the variation of the ambient air temperature exceeds 3 K, an appropriate correction factor should be applied to the measured temperature of the parts, depending on the thermal time-constant of the equipment.

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.

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:

$$T_2 = \frac{R_2}{R_1}\left(T_1 + 234{,}5\right) - 234{,}5$$

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 7.1.8).

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 Tables 2 and 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 cross-sections 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 cross-sectional 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.

8.3.3.3.5 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).

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.

NOTE 2 Dielectric tests for semiconductor devices are under consideration.

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 class 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 note 2 of Table 12A).

b) Test voltage

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

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 %.

The test voltage applied shall be within ±3 %.

c) Application of test voltage

For the dielectric test between phases, all circuits between these phases may be disconnected for the test.

NOTE 1 The purpose of this test is to check the basic and supplementary 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 b) above, such devices shall be disconnected for the test.

For the dielectric test between phase and earth, all circuits shall be connected.

NOTE 2 The purpose of this test is to check both basic and supplementary insulation, and the ability to withstand temporary overvoltages.

The test voltage shall be applied to for 5 s in accordance with items i), ii) and iii) of 2) c) above.

In particular cases, for example equipment having more than one open position or solid state equipment, etc., the relevant product standard may specify detailed test requirements.

Printed circuit boards and modules with multi-point connectors may be withdrawn, 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.

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 short-circuit 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

Under consideration.

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.

8.3.3.4.2 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.

8.3.3.4.3 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) Figures 3, 4, 5 and 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 8.

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 Figures 8a and 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 Figures 3, 4, 5 or 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.

8.3.4 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 short-circuit 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) Figures 9, 10, 11 and 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 (Figures 9, 10, 11 and 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 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 Figures 9, 10, 11 or 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 $A_2/2\sqrt{2}$ 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 test 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 test 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

$$\int_0^{t_{test}} i_{test}^2 \, dt \geq I^2 \cdot t_{st}$$

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 under representative conditions, both operational and environmental, using the manufacturer's instructions for installation.

The tests shall be carried out in accordance with the reference EMC standard; however, the product standard shall specify any 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

Equipment utilizing circuits in which all components are passive (for example diodes, resistors, varistors, capacitors, surge suppressors, inductors) are not required to be tested.

Tests shall be made according to the values given in Table 23 except where a different test level is given and justified in the product standard.

Performance criteria shall be given in the product standard based on the acceptance criteria given in Table 24.

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 – Standard cross-sections of round copper conductors and approximate relationship between mm² and AWG/kcmil sizes
(see 7.1.7.2)

Rated 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 7.1.7.2).

Table 2 – Temperature-rise limits of terminals
(see 7.2.2.1 and 8.3.3.3.4)

Terminal material	Temperature-rise limits [1] [3] K
Bare copper	60
Bare brass	65
Tin plated copper or brass	65
Silver plated or nickel plated copper or brass	70
Other metals	[2]

[1] The use in service of connected conductors significantly smaller than those listed in Tables 9 and 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.

[2] Temperature-rise limits to be based on service experience or life tests but not to exceed 65 K.

[3] 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 [1] 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[2]:	
Exteriors of enclosures adjacent to cable entries:	40
Metallic	50
Non-metallic	200[2]
Exterior of enclosures for resistors	
Air issuing from ventilation openings of enclosures for resistors	200[2]

[1] 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.

[2] 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 8.3.2.1, 8.2.6 and 8.2.6.2)

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[1) 2)]	Height H [1)]	Mass	Pulling force
mm²	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
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

1) Tolerances: for height $H \pm 15$ mm, for diameter of the bushing hole ± 2 mm.

2) 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 / −0,05
2,5	4	A3	2,8	2,4	B3	2,7	
4	6	A4	3,6	3,1	B4	3,5	
6	10	A5	4,3	4,0	B5	4,4	0 / −0,06
10	16	A6	5,4	5,1	B6	5,3	
16	25	A7	7,1	6,3	B7	6,9	
25	35	A8	8,3	7,8	B8	8,2	0 / −0,07
35	50	A9	10,2	9,2	B9	10,0	
50	70	A10	12,3	11,0	B10	12,0	
70	95	A11	14,2	13,1	B11	14,0	0 / −0,08
95	120	A12	16,2	15,1	B12	16,0	
120	150	A13	18,2	17,0	B13	18,0	
150	185	A14	20,2	19,0	B14	20,0	
185	240	A15	22,2	21,0	B15	22,0	
240	300	A16	26,5	24,0	B16	26,0	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 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 $^{+5}_{0}$ %	– Power factor ± 0,05	– Power factor $^{0}_{-0,05}$
– Voltage $^{+5}_{0}$ % (including power frequency recovery voltage)	– Time-constant $^{+15}_{0}$ %	– Time-constant $^{+25}_{0}$ %
	– Frequency ±5 %	– 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 [1)]		Conductor size [2), 3), 4)]	
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

* See notes following Table 11.

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[1)] A		Conductors [2), 3), 4)]			
		Metric		kcmil	
		Number	Size mm²	Number	Size kcmil
400	500	2	150	2	250
500	630	2	185	2	350
630	800	2	240	3	300

* See notes following Table 11.

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 [1] A		Copper bars [2], [3], [4], [5], [6]		
		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

NOTES to Tables 9, 10 and 11

NOTE 1 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.

NOTE 2 For convenience of testing and with the manufacturer's consent, smaller conductors than those given for a stated test current may be used.

NOTE 3 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.

NOTE 4 Either of the two conductors specified for a given test current range may be used.

NOTE 5 Bars are assumed to be arranged with their long faces vertical. Arrangements with long faces horizontal may be used if specified by the manufacturer.

NOTE 6 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 [2), 3)] 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
$1\,000 < U_i \leq 1\,500$ [1)]	–	3 820

1) For d.c. only.

2) Test voltages based on 4.1.2.3.1, third paragraph of IEC 60664-1.

3) 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

<table>
<tr><th rowspan="4">Rated impulse withstand voltage
U_{imp}
kV</th><th colspan="8">Minimum clearances
mm</th></tr>
<tr><th colspan="4">Case A
Inhomogeneous field conditions
(see 2.5.63)</th><th colspan="4">Case B
Homogeneous field ideal conditions
(see 2.5.62)</th></tr>
<tr><th colspan="4">Pollution degree</th><th colspan="4">Pollution degree</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>1</th><th>2</th><th>3</th><th>4</th></tr>
<tr><td>0,33</td><td>0,01</td><td rowspan="3">0,2</td><td rowspan="4">0,8</td><td rowspan="5">1,6</td><td>0,01</td><td rowspan="3">0,2</td><td rowspan="5">0,8</td><td rowspan="6">1,6</td></tr>
<tr><td>0,5</td><td>0,04</td><td>0,04</td></tr>
<tr><td>0,8</td><td>0,1</td><td>0,1</td></tr>
<tr><td>1,5</td><td>0,5</td><td>0,5</td><td>0,3</td><td>0,3</td></tr>
<tr><td>2,5</td><td>1,5</td><td>1,5</td><td>1,5</td><td>0,6</td><td>0,6</td></tr>
<tr><td>4,0</td><td>3</td><td>3</td><td>3</td><td>3</td><td>1,2</td><td>1,2</td><td>1,2</td></tr>
<tr><td>6,0</td><td>5,5</td><td>5,5</td><td>5,5</td><td>5,5</td><td>2</td><td>2</td><td>2</td><td>2</td></tr>
<tr><td>8,0</td><td>8</td><td>8</td><td>8</td><td>8</td><td>3</td><td>3</td><td>3</td><td>3</td></tr>
<tr><td>12</td><td>14</td><td>14</td><td>14</td><td>14</td><td>4,5</td><td>4,5</td><td>4,5</td><td>4,5</td></tr>
<tr><td colspan="9">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.</td></tr>
</table>

Table 14 – Test voltages across the open contacts of equipment suitable for isolation

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	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. 4) V	Creepage distances for equipment subject to long term stress mm															
	Pollution degree			Pollution degree				Pollution degree				Pollution degree			
	1 5)	2 5)	1	2				3				4			
	Material group			Material group				Material group				Material group			
	1)	2)	1)	I	II	IIIa	IIIb	I	II	IIIa	IIIb	I	II	IIIa	IIIb
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	3)
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	3)	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	

1) Material groups I, II, IIIa, IIIb.

2) Material groups I, II, IIIa.

3) 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.

4) 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.

5) The values given in these two columns apply to creepage distances of printed circuit materials.

6) 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*
$I \leq$ 1 500	0,95	5	1,41
1 500 < $I \leq$ 3 000	0,9	5	1,42
3 000 < $I \leq$ 4 500	0,8	5	1,47
4 500 < $I \leq$ 6 000	0,7	5	1,53
6 000 < $I \leq$ 10 000	0,5	5	1,7
10 000 < $I \leq$ 20 000	0,3	10	2,0
20 000 < $I \leq$ 50 000	0,25	15	2,1
50 000 < I	0,2	15	2,2

Table 17 – Limits of actuator test force for given types of actuator
(see 8.2.5.2.1)

Type of actuator*	Lower limit force N	Upper limit force N
Push-button (a)	50	150
One-finger operated (b)	50	150
Two-finger operated (c)	100	200
One-hand operated (d and e)	150	400
Two-hand operated (f and g)	200	600
* See 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 Inside mm	Outside mm	Bending moment N·m
12 H	12,5	17,1	35 [1)]
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

1) 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 Inside mm	Outside mm	Torque 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
Electrical fast transient/burst immunity test IEC 61000-4-4	2 kV on power ports [1)] 1 kV on signal ports [2)]
1,2/50 μs – 8/20 μs surge immunity test IEC 61000-4-5 [3)]	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 IEC 61000-4-8 [4)]	30 A/m
Voltage dips and interruptions immunity test IEC 61000-4-11	30 % reduction for 0,5 cycle 60 % reduction for 5 and 50 cycles 100 % reduction for 250 cycles
Immunity to harmonics in the supply IEC 61000-4-13	No requirements [5)]

1) Power port: the point at which a conductor or cable carrying the primary electrical power needed for the operation of an equipment or associated equipment is connected.

2) Signal port: the point at which a conductor or cable carrying information for transferring data or signals is connected to the equipment. The applicable ports are stated in the product standard.

3) Not applicable for ports with a rated voltage of 24 V d.c. or less.

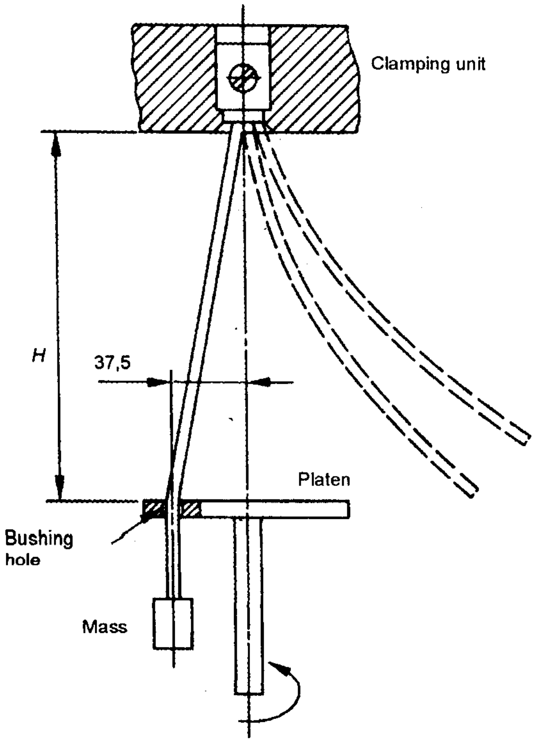
4) Applicable only to equipment containing devices susceptible to power frequency magnetic fields.

5) Requirements are under study for the future.

Table 24 – Acceptance criteria when EM disturbances are present

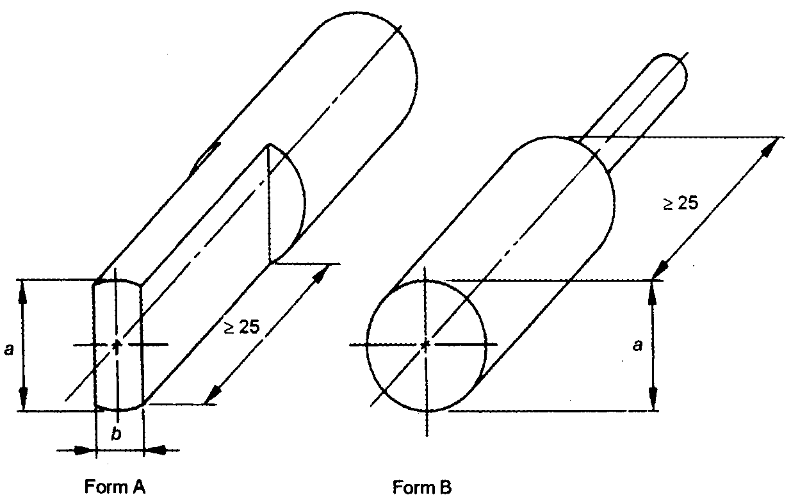
Item	Acceptance criteria (performance criteria during tests)		
	A	B	C
Overall performance	No noticeable changes of the operating characteristic. Operating as intended	Temporary degradation or loss of performance which is self-recoverable	Temporary degradation or loss of performance which requires operator intervention or system reset [1]
Operation of power and control circuits	No maloperation	Temporary degradation or loss of performance which is self-recoverable [1]	Temporary degradation or loss of performance which requires operator intervention or system reset [1]
Operation of displays and control panels	No changes to 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 error reports of the internal and external devices [1]	Erroneous processing of information. Loss of data and/or information. Errors in communication. Not self-recoverable

[1] Specific requirements shall be detailed in the product standard.



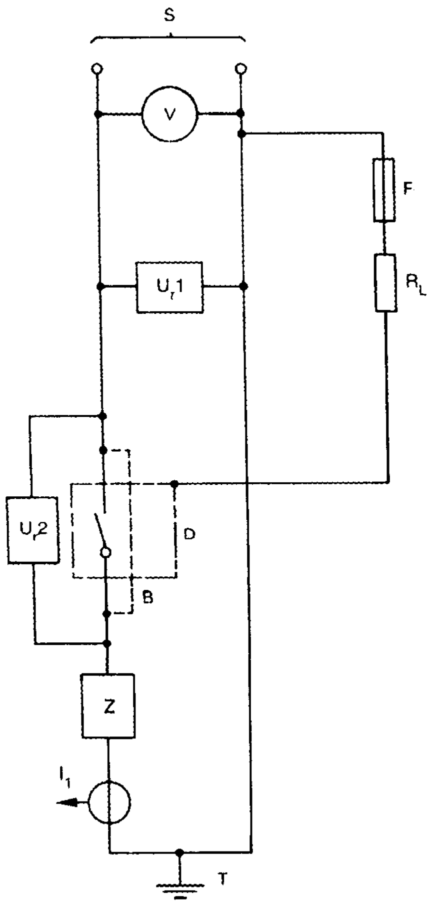
Dimensions in millimetres

Figure 1 – Test equipment for flexion test
(see 8.2.4.3 and Table 5)



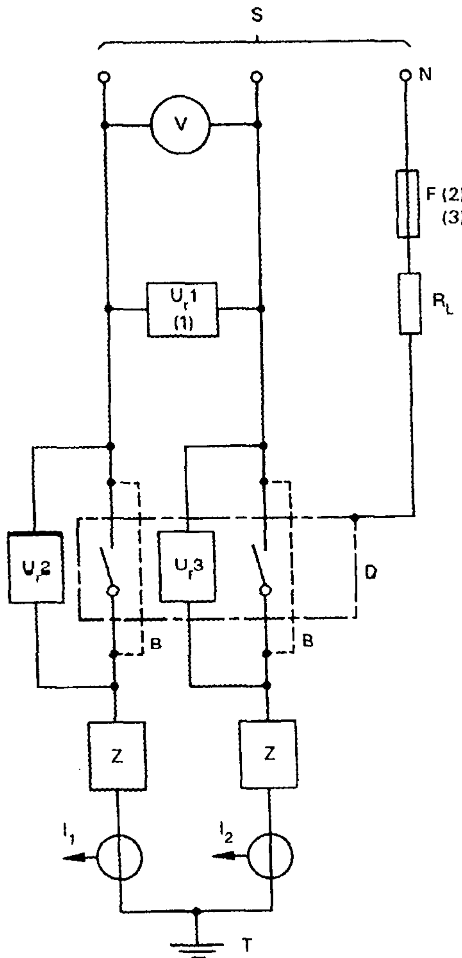
Dimensions in millimetres

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 calibration
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.

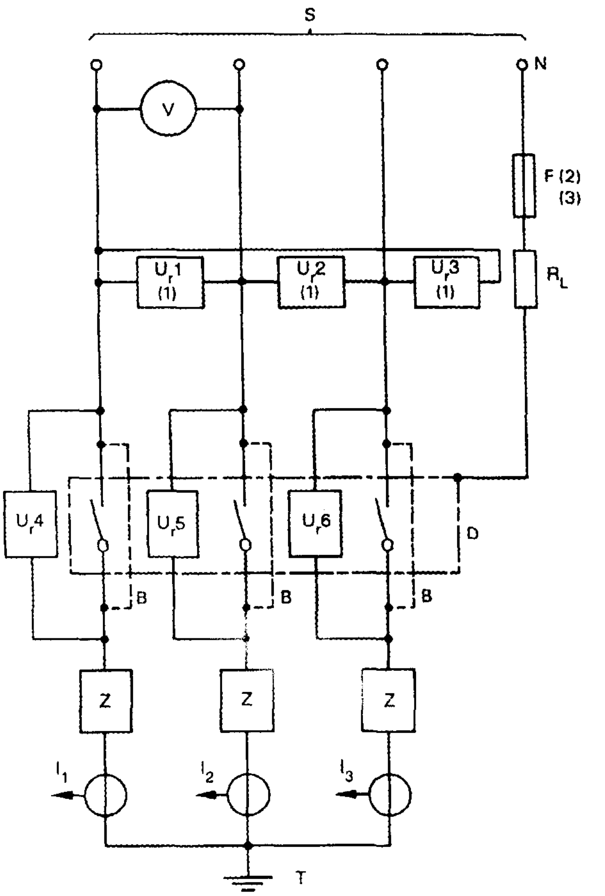
NOTE 2 In the case of equipment intended for use in phase-earthed systems or if this diagram is used for the test of the neutral and adjacent poles of a 4-pole equipment, F shall be connected to one phase of the supply.

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)



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.

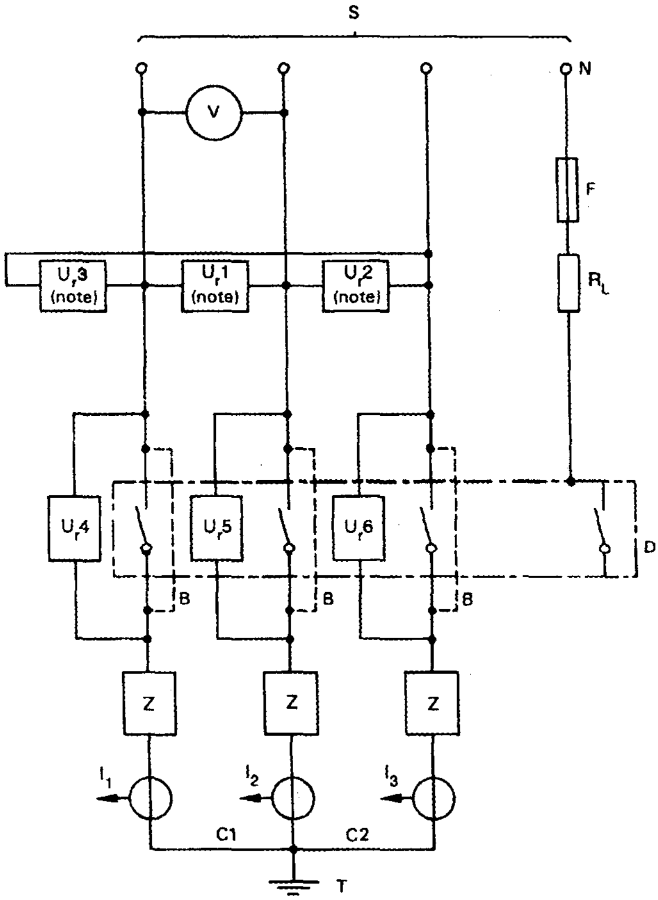
In the case of d.c., F shall be connected to the negative of the supply.

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)

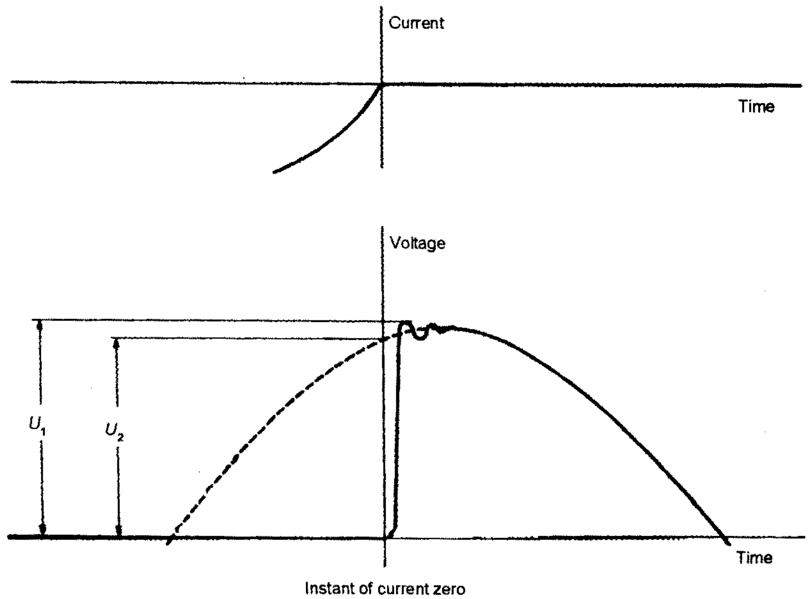
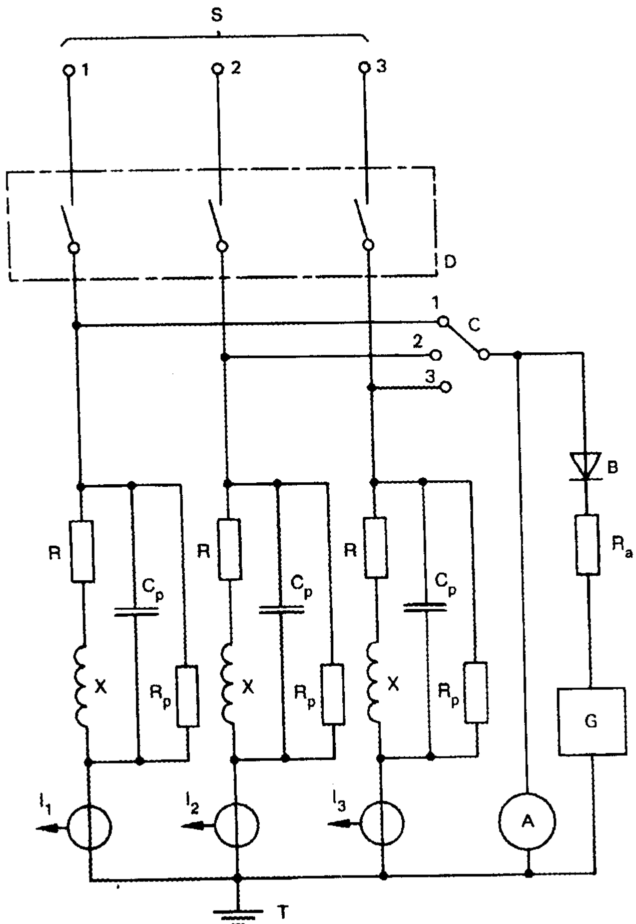


Figure 7 – Schematic illustration of the recovery voltage across contacts of the first phase to clear under ideal conditions
(see 8.3.3.5.2, item e))



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))

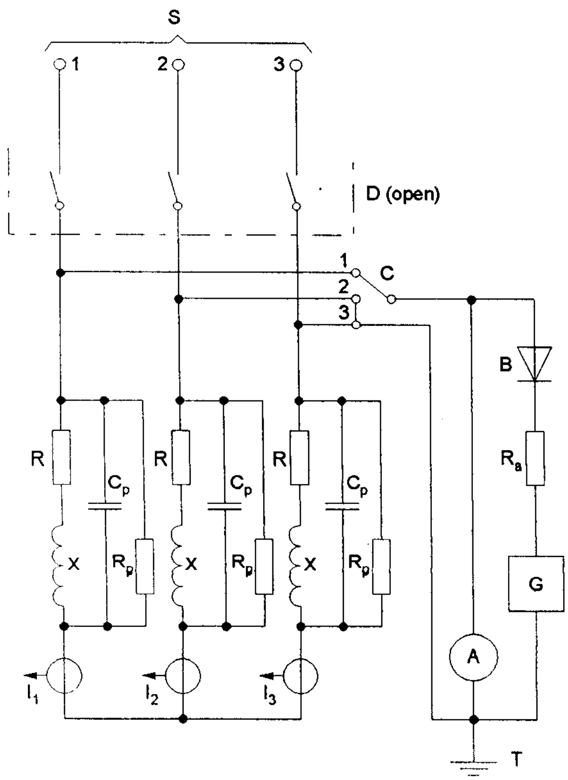
R_p = Resistor in parallel

C_p = Capacitor in parallel

I_1, I_2, I_3 = Current sensors

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

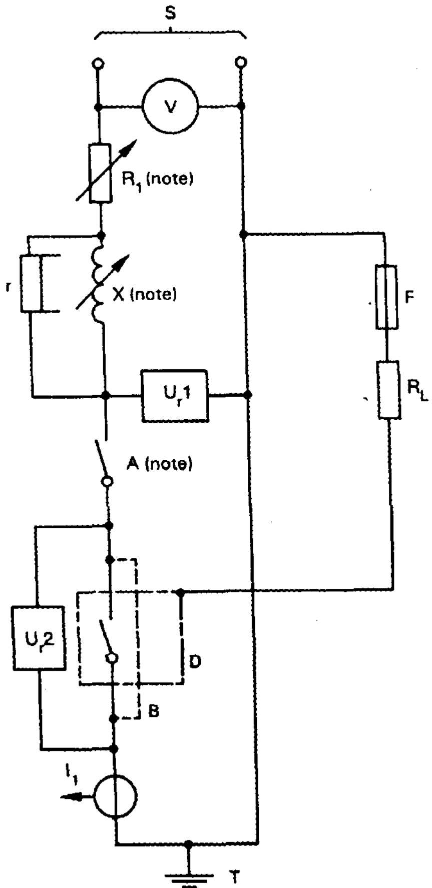


S = Supply
D = Equipment under test
C = Phase adjustment selector switch
B = Diode
A = Recorder
R_a = Resistor
G = High-frequency generator
R = Load circuit resistor
X = Load circuit reactor (8.3.3.5.2 d))
R_p = Resistor in parallel
C_p = Capacitor in parallel
I_1, I_2, I_3 = Currents sensors

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.

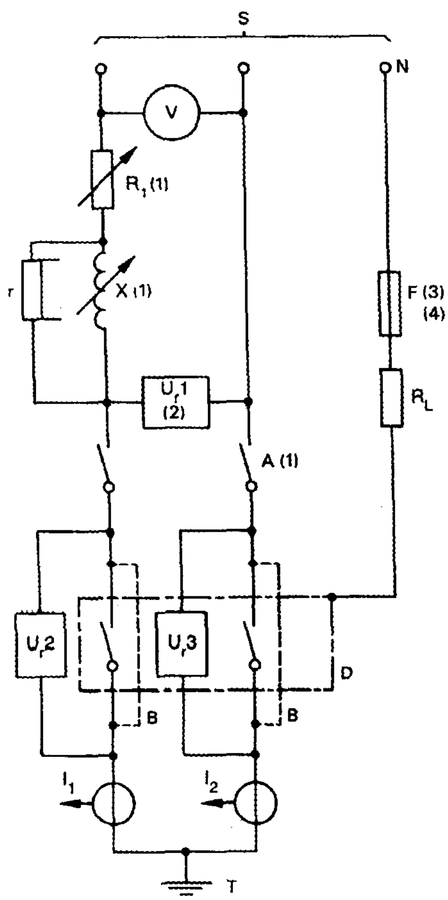
Figure 8b – Diagram of a load circuit adjustment method: supply star-point earthed



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, the closing device A being located on the low-voltage side.

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 metallic 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, the closing device A being located on the low-voltage side.

NOTE 2 U_r1 may, alternatively, be connected between phase and neutral.

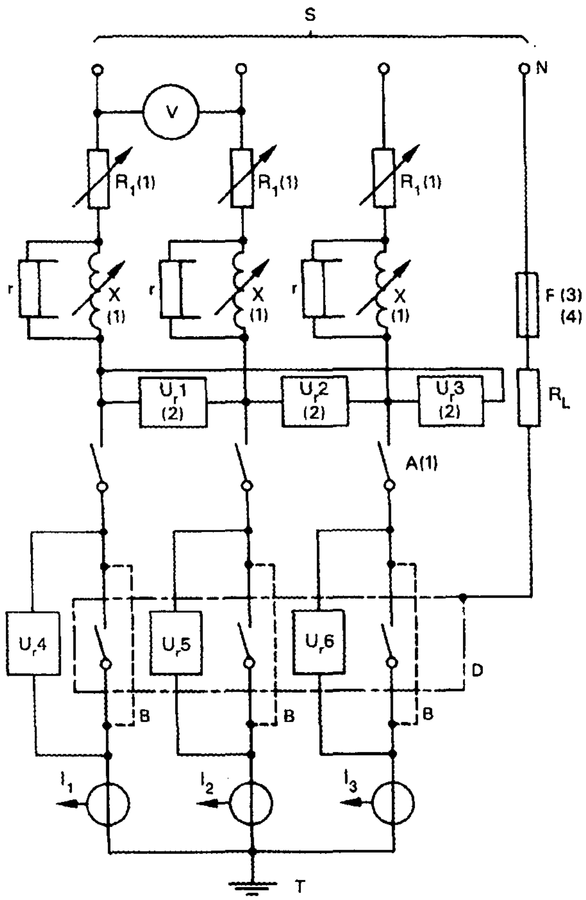
NOTE 3 In the case of equipment intended for use in phase-earthed systems or if this diagram is used for the test of the neutral and adjacent pole of a four-pole equipment, F shall be connected to one phase of the supply.

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)



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 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, the closing device A being located on the low-voltage side.

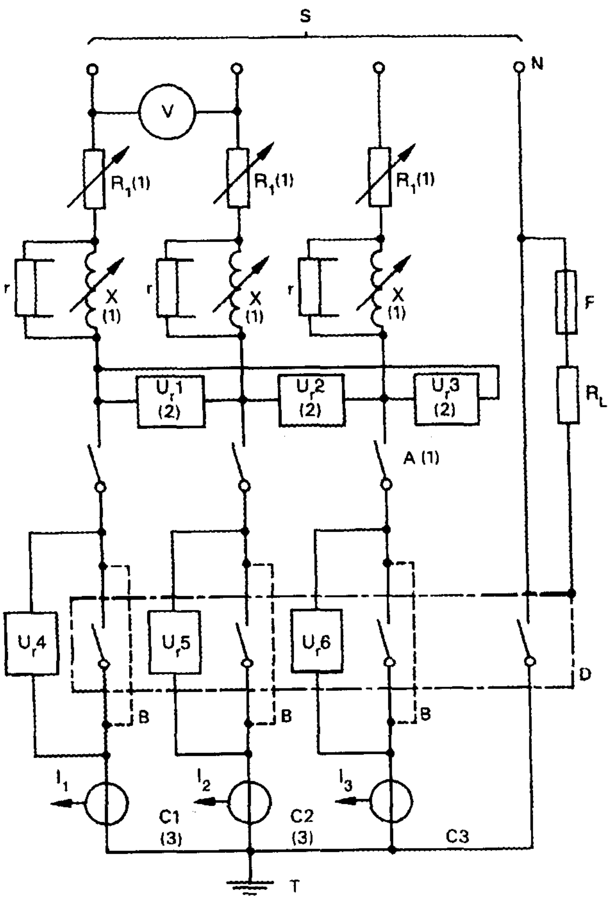
NOTE 2 U_r1, U_r2, U_r3 may, alternatively, be connected between phase and neutral.

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)



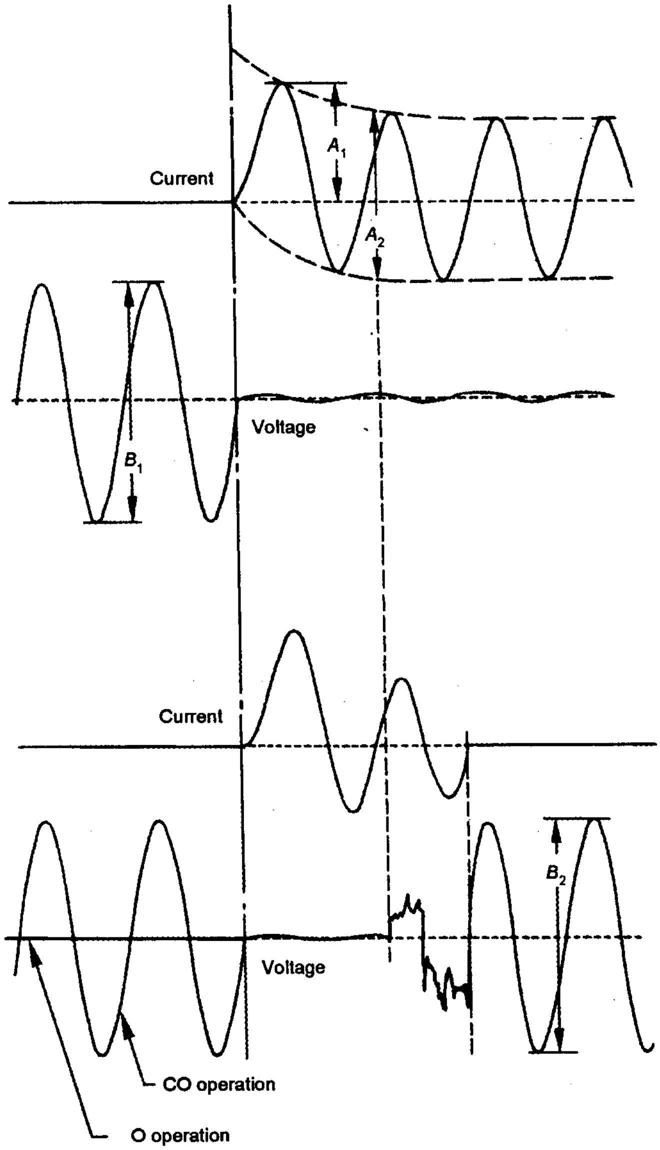
S	= Supply
U_r1, U_r2, U_r3, U_r4, U_r5, U_r6,	= Voltage sensors
V	= Voltage measuring device
R_1	= Adjustable resistor
N	= Neutral of supply
F	= Fusible element (8.3.4.1.2, item d))
X	= Adjustable reactors
R_L	= Fault current limiting resistor
A	= Closing device
D	= Equipment under test (including connecting 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, the closing device A being located on the low-voltage side.

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)



a) = Calibration of circuit

A_1 = Prospective peak making current

$\frac{A_2}{2\sqrt{2}}$ = Prospective symmetrical breaking current (r.m.s. value)

$\frac{B_1}{2\sqrt{2}}$ = Applied voltage (r.m.s. value)

b) = O or CO operation

$\frac{B_2}{2\sqrt{2}}$ = Supply voltage, (r.m.s. value)

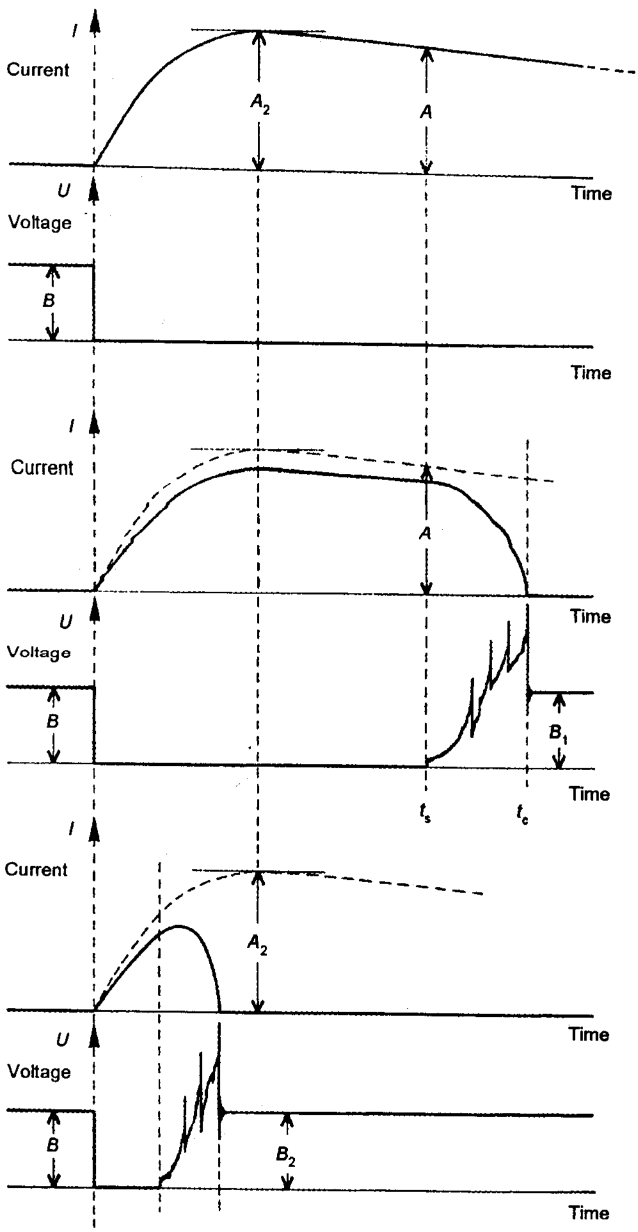
Making capacity (peak value) = A_1 (see 8.3.4.1.8, items b) and c))

Breaking capacity (r.m.s. value) = $\frac{A_2}{2\sqrt{2}}$ (see 8.3.4.1.8, items b) and c))

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)



a) Calibration of the circuit

Prospective peak making current = A_2

b) Oscillogram corresponding to a break after the current has passed its maximum value

Short-circuit breaking capacity:
Current $I = A$ at voltage $U = B_1$

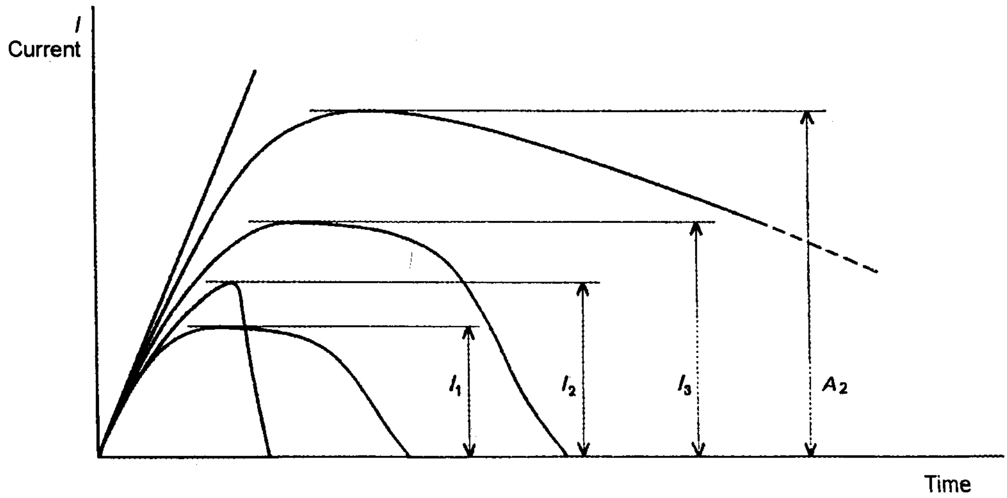
Short-circuit making capacity:
Current $I = A_2$ at voltage $U = B$

c) Oscillogram corresponding to a break before the current has reached its maximum value

Short-circuit breaking capacity:
Current $I = A_2$ at voltage $U = B_2$

Short-circuit making capacity:
Current $I = A_2$ at voltage $U = B$

Figure 14 – Verification of short-circuit making and breaking capacities on d.c.
(see 8.3.4.1.8)



I_1 First calibration

I_2 Actual breaking current

I_3 Second calibration

A_2 Breaking capacity

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))

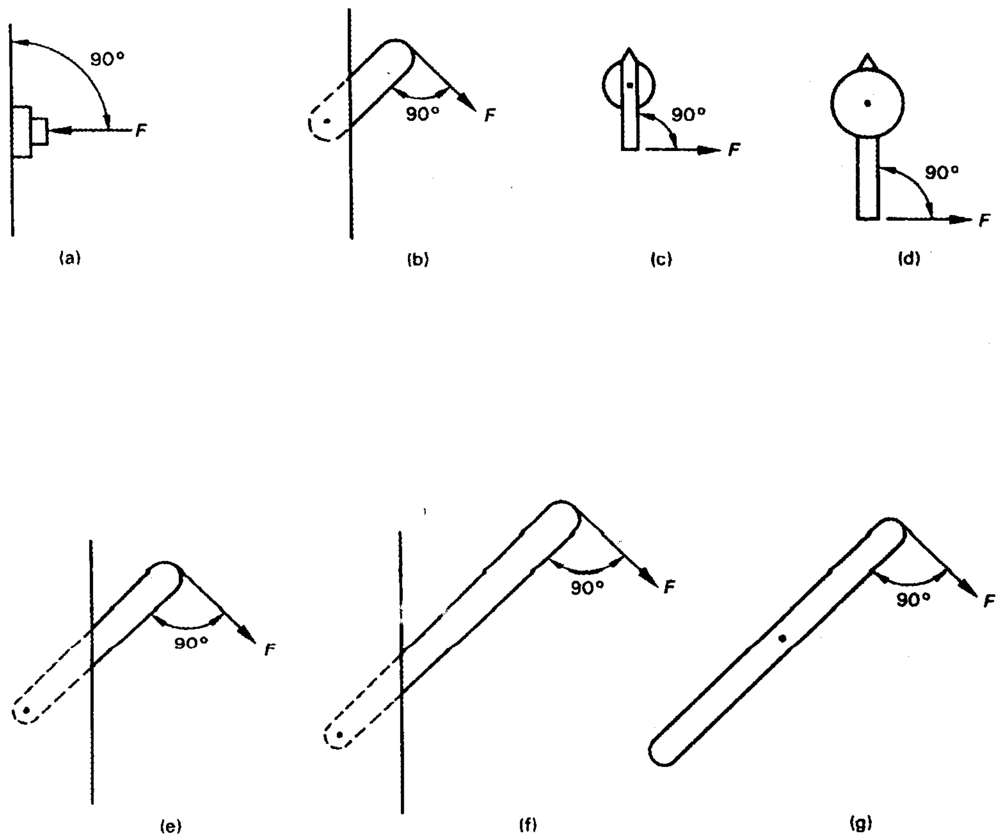


Figure 16 – Actuator test force
(see 8.2.5.2.1 and Table 17)

Annex A
(informative)

Examples of utilization categories for low-voltage switchgear and controlgear

Nature of current	Category	Typical applications	Relevant IEC product standard
a.c.	AC-20	Connecting and disconnecting under no-load conditions	60947-3
	AC-21	Switching of resistive loads, including moderate overloads	
	AC-22	Switching of mixed resistive and inductive loads, including moderate overloads	
	AC-23	Switching of motor loads or other highly inductive loads	
	AC-1	Non-inductive or slightly inductive loads, resistance furnaces	60947-4-1
	AC-2	Slip-ring motors: starting, switching off	
	AC-3	Squirrel-cage motors: starting, switching off motors during running	
	AC-4	Squirrel-cage motors: starting, plugging[1], inching[2]	
	AC-5a	Switching of electric discharge lamp controls	
	AC-5b	Switching of incandescent lamps	
	AC-6a	Switching of transformers	
	AC-6b	Switching of capacitor banks	
	AC-8a	Hermetic refrigerant compressor motor control with manual resetting of overload releases	
	AC-8b	Hermetic refrigerant compressor motor control with automatic resetting of overload releases	
	AC-52a	Control of slip ring motor stators: 8 h duty with on-load currents for start, acceleration, run	60947-4-2
	AC-52b	Control of slip ring motor stators: intermittent duty	
	AC-53a	Control of squirrel-cage motors: 8 h duty with on-load currents for start, acceleration, run	
	AC-53b	Control of squirrel-cage motors: intermittent duty	
	AC-58a	Control of hermetic refrigerant compressor motors with automatic resetting of overload releases: 8 h duty with on-load currents for start, acceleration, run	
	AC-58b	Control of hermetic refrigerant compressor motors with automatic resetting of overload releases: intermittent duty	
	AC-51	Non-inductive or slightly inductive loads, resistance furnaces	60947-4-3
	AC-55a	Switching of electric discharge lamp controls	
	AC-55b	Switching of incandescent lamps	
	AC-56a	Switching of transformers	
	AC-56b	Switching of capacitor banks	
	AC-12	Control of resistive loads and solid-state loads with isolation by optocouplers	60947-5-1
	AC-13	Control of solid-state loads with transformer isolation	
	AC-14	Control of small electromagnetic loads	
	AC-15	Control of a.c. electromagnetic loads	

Nature of current	Category	Typical applications	Relevant IEC product standard
	AC-12	Control of resistive loads and solid state loads with optical isolation	60947-5-2
	AC-140	Control of small electromagnetic loads with holding (closed) current ≤ 0,2 A, e.g. contactor relays	
	AC-31	Non inductive or slightly inductive loads	60947-6-1
	AC-33	Motor loads or mixed loads including motors, resistive loads and up to 30 % incandescent lamp loads	
	AC-35	Electric discharge lamp loads	
	AC-36	Incandescent lamp loads	
	AC-40	Distribution circuits comprising mixed resistive and reactive loads having a resultant inductive reactance	60947-6-2
	AC-41	Non-inductive or slightly inductive loads, resistance furnaces	
	AC-42	Slip-ring motors; starting, switching off	
	AC-43	Squirrel-cage motors: starting, switching off motors during running	
	AC-44	Squirrel-cage motors: starting, plugging[1], inching[2]	
	AC-45a	Switching of electric discharge lamp controls	
	AC-45b	Switching of incandescent lamps	
	AC-7a	Slightly inductive loads for household appliances and similar applications	61095
	AC-7b	Motor-loads for household applications	
a.c. and d.c.	A	Protection of circuits, with no rated short-time withstand current	60947-2
	B	Protection of circuits, with a rated short-time withstand current	
d.c.	DC-20	Connecting and disconnecting under no-load conditions	60947-3
	DC-21	Switching of resistive loads, including moderate overloads	
	DC-22	Switching of mixed resistive and inductive loads, including moderate overloads (e.g. shunt motors)	
	DC-23	Switching of highly inductive loads (e.g. series motors)	
	DC-1	Non-inductive or slightly inductive loads, resistance furnaces	60947-4-1
	DC-3	Shunt-motors, starting, plugging[1], inching[2]. Dynamic breaking of motors	
	DC-5	Series-motors, starting, plugging[1], inching[2]. Dynamic breaking of motors	
	DC-6	Switching of incandescent lamps	
	DC-12	Control of resistive loads and solid-state loads with isolation by optocouplers	60947-5-1
	DC-13	Control of electromagnets	
	DC-14	Control of electromagnetic loads having economy resistors in circuit	
	DC-12	Control of resistive loads and solid state loads with optical isolation	60947-5-2
	DC-13	Control of electromagnets	
	DC-31	Resistive loads	60947-6-1
	DC-33	Motor loads or mixed loads including motors	
	DC-36	Incandescent lamp loads	

Nature of current	Category	Typical applications	Relevant IEC product standard
	DC-40	Distribution circuits comprising mixed resistive and reactive loads having a resultant inductive reactance	60947-6-2
	DC-41	Non-inductive or slightly inductive loads, resistance furnaces	
	DC-43	Shunt-motors: starting, plugging[1], inching[2]. Dynamic breaking of d.c. motors	
	DC-45	Series-motors: starting, plugging[1], inching[2]. Dynamic breaking of d.c. motors	
	DC-46	Switching of incandescent lamps	

[1] By plugging is understood stopping or reversing the motor rapidly by reversing motor primary connections while the motor is running.

[2] By inching (jogging) is understood energizing a motor once or repeatedly for short periods to obtain small movements of the driven mechanism.

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:

C.11 General requirements for tests

C.11.1 Clause 11.1 of IEC 60529 applies.

C.11.2 Clause 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 Clause 11.4 of IEC 60529 applies.

C.11.5 Where an empty enclosure is used as a component of an enclosed equipment, clause 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.

C.14 Tests for protection against water indicated by second characteristic numeral

C.14.1 Subclause 14.1 of IEC 60529 applies.

C.14.2 Subclause 14.2 of IEC 60529 applies.

C.14.3 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.

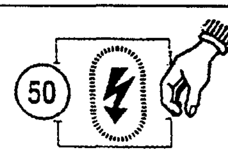
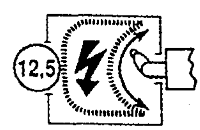
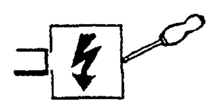
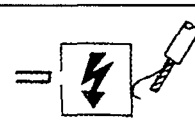
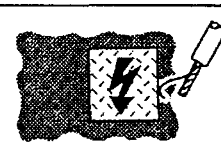
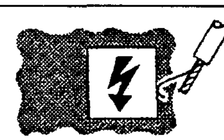
C.15 Tests for protection against access to hazardous parts indicated by additional letter

Clause 15 of IEC 60529 applies.

C.16 Summary of responsibilities of relevant technical committees

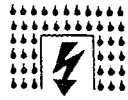
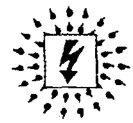
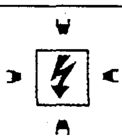
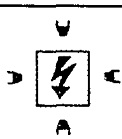
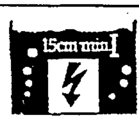
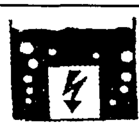
The relevant product standards specify the detailed information listed, as a guide, in Annex B of IEC 60529, taking into account the supplements specified above in this Annex C.

Further illustrations are included to facilitate the understanding of the IP Codes (see Figure C.1).

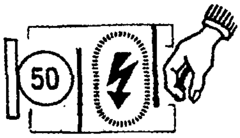
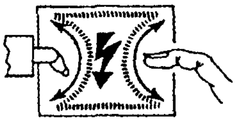
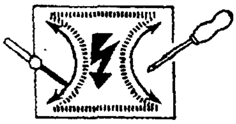
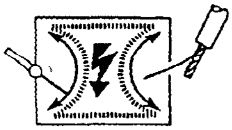
C.1a – FIRST NUMERAL			
Protection against ingress of solid objects			**Protection of persons against access to hazardous parts with:**
IP	**Requirements**	**Example**	
0	No protection		Non-protected
1	Full penetration of 50 mm diameter sphere not allowed. Contact with hazardous parts not permitted		Back of hand
2	Full penetration of 12,5 mm diameter sphere not allowed. The jointed test finger 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

(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

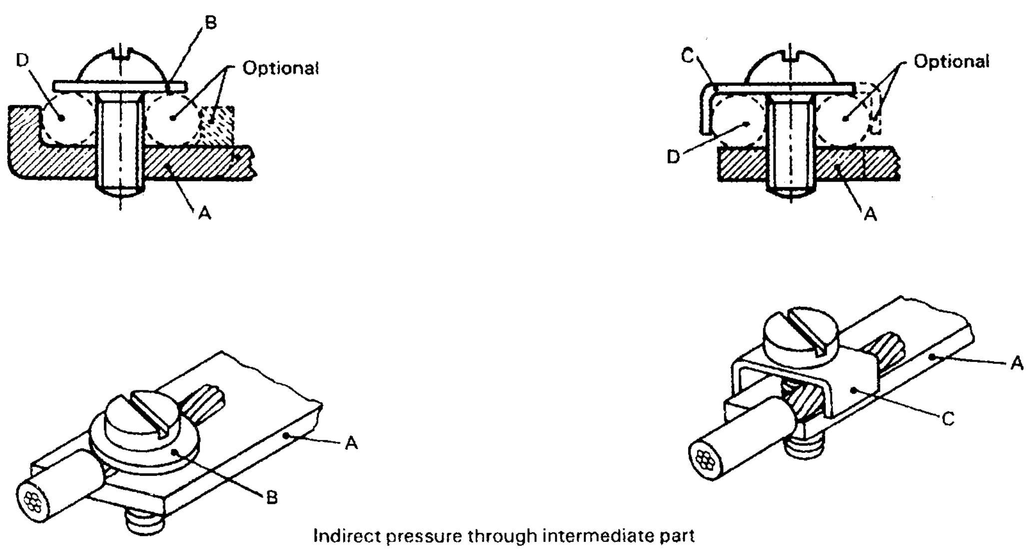
(continued)

C.1c – ADDITIONAL LETTER (optional)			
IP	Requirements	Example	Protection of persons against access to hazard-ous 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 × 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 × 100 mm long must not contact hazardous parts when spherical stop face is partially entered		Wire

Annex D
(informative)

Examples of terminals

Direct pressure through screw head



Indirect pressure through intermediate part

A Fixed part

B Washer or clamping plate

C Anti-spread device

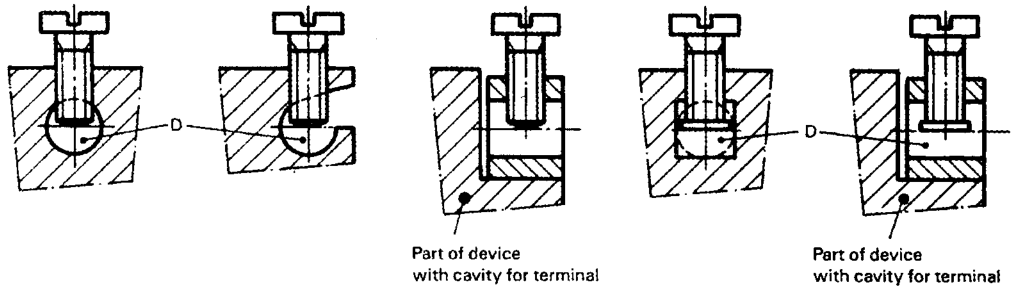
D Conductor space

NOTE Examples shown here do not prohibit the conductor being divided either side of the screw.

Screw terminal

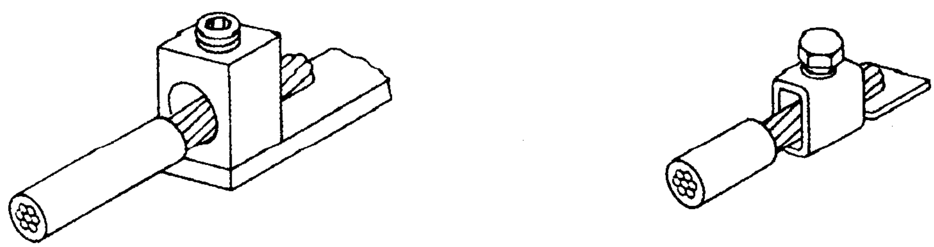
Screw-type terminal in which the conductor is clamped under the head of one or more screws. The clamping pressure may be applied directly by the head of the screw or through an intermediate part, such as a washer, clamping plate or anti-spread device.

Figure D.1 – Screw terminals

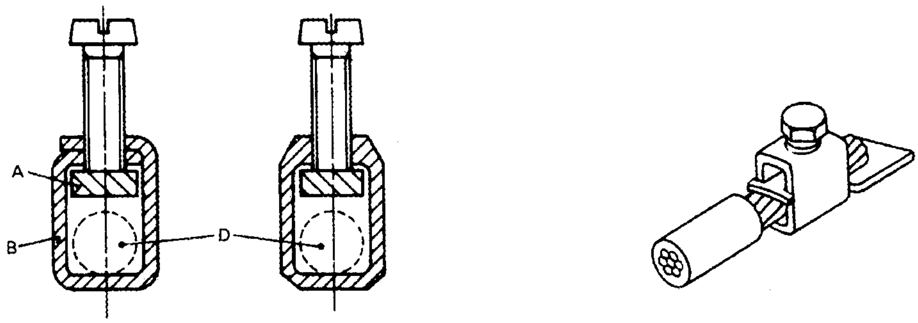


Terminals without pressure plate

Terminals with pressure plate



Terminals with direct pressure



Terminals with indirect pressure

A Fixed part

B Body of the clamping unit

D Conductor space

Pillar terminal

Screw-type terminal 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 terminals

A Fixed part
B Washer or clamping plate
C Anti-spread device
D Conductor space
E Stud

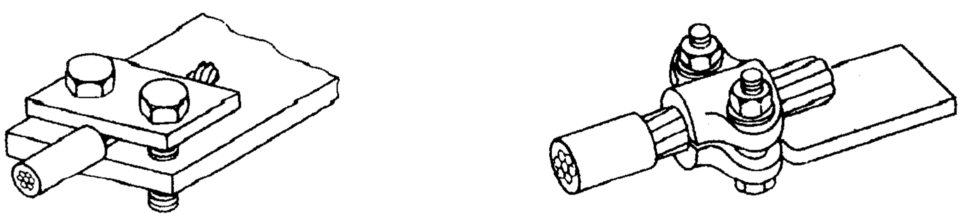
NOTE The part which retains the conductor in position may be of insulating material, provided the pressure necessary to clamp the conductor is not transmitted through the insulating material.

Stud terminal

Screw-type terminal 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 terminals

A Saddle
B Fixed part
C Stud
D Conductor space

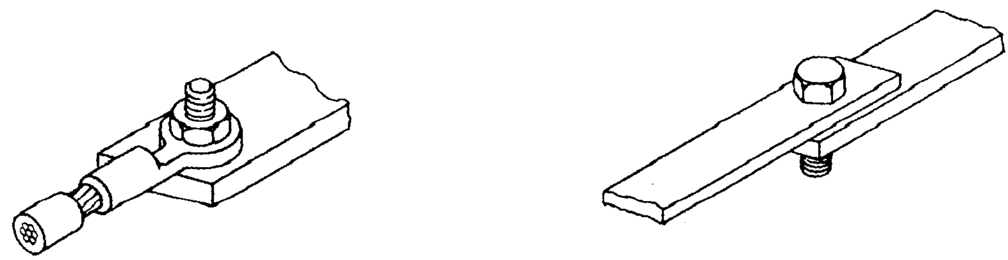


Saddle terminal

Screw-type terminal in which the conductor is clamped under a saddle by means of two or more screws or nuts.

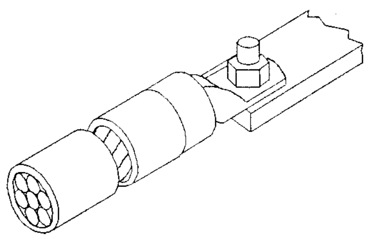
Figure D.4 – Saddle terminals

A Locking means
B Cable lug or bar
E Fixed part
F Stud



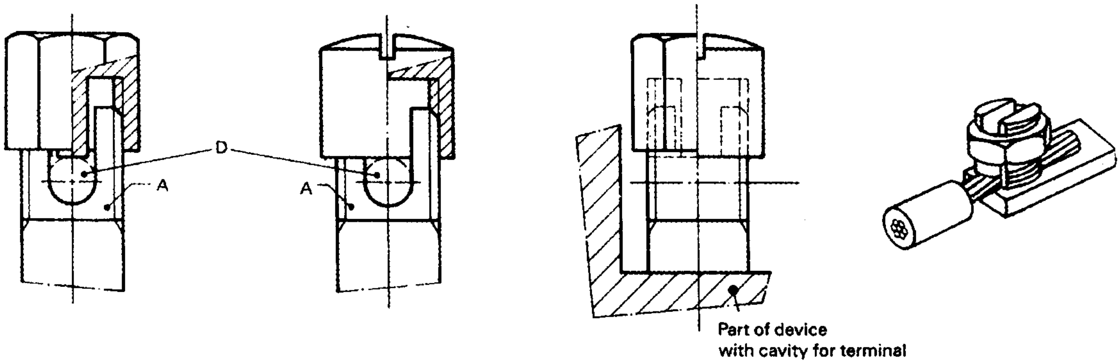
Lug terminal

Screw terminal or stud terminal designed for clamping a cable lug or bar by means of a screw or nut.



NOTE Examples of overall dimensions of cable lugs are given in Annex P.

Figure D.5 – Lug terminals



A Fixed part

D Conductor space

Mantle terminal

Screw-type terminal 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 terminals

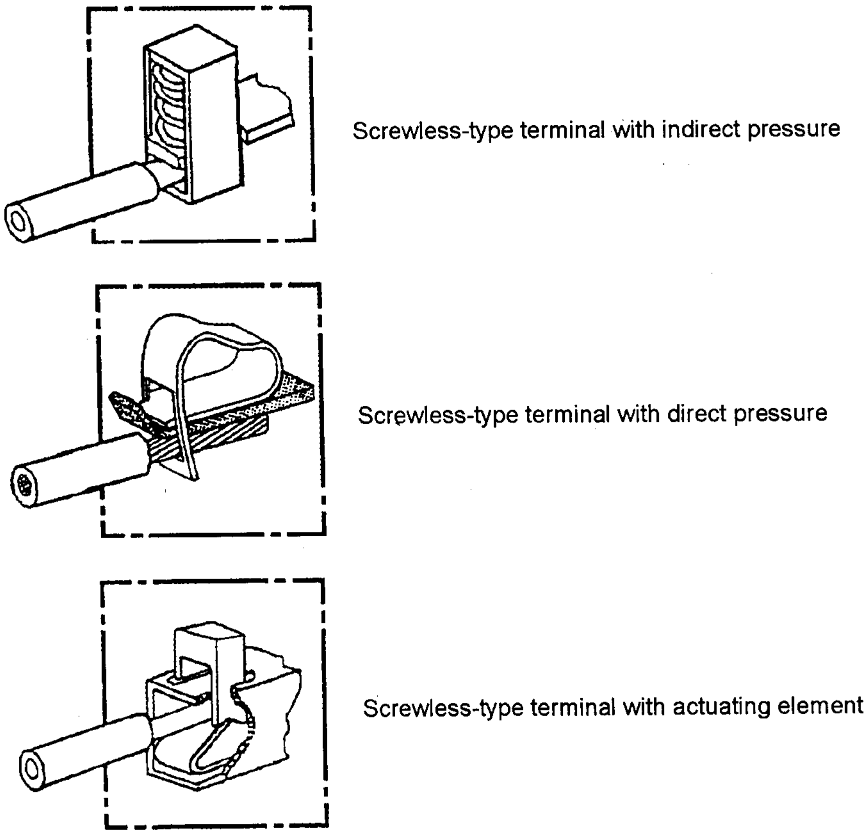


Figure D.7 – Screwless-type terminals

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 8.

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 $\omega = 2\ \pi.\ 2\ 000\ s^{-1}$ or $2\ \pi.\ 4\ 000\ s^{-1}$) 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.

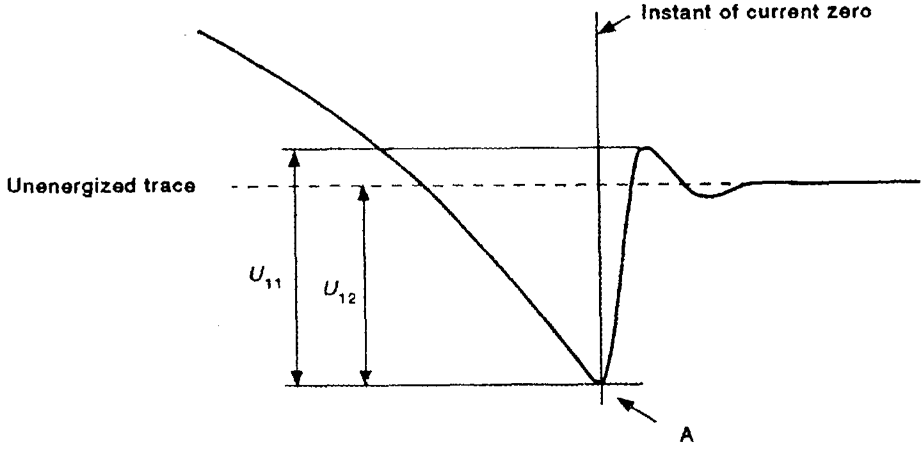


Figure E.1 – Determination of the actual value of the factor γ

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

$$i_d = I_{do}\, e^{-Rt/L}$$

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 $-\chi$ corresponding to the ratio i_d/I_{do}, from a table of values of $e^{-\chi}$;

The value χ 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.

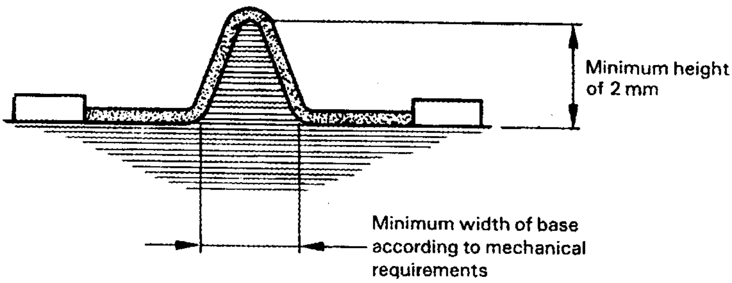


Figure G.1 – Measurement of ribs

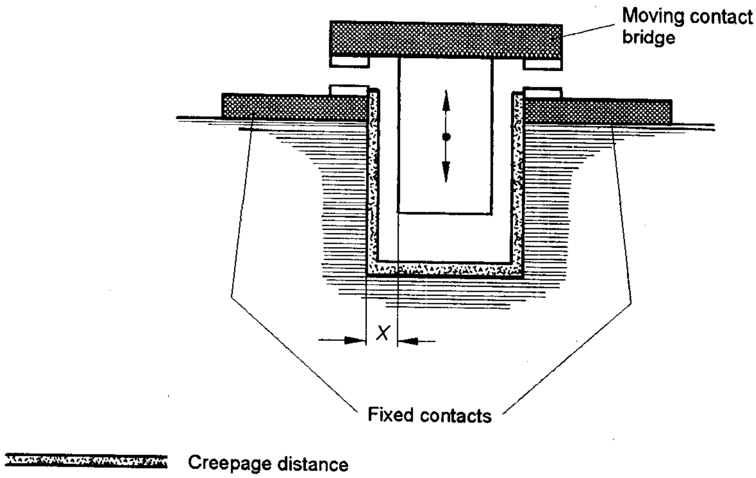
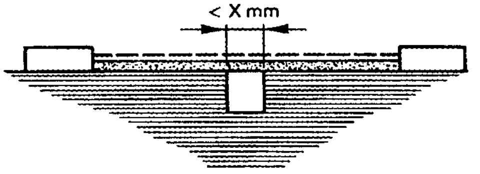


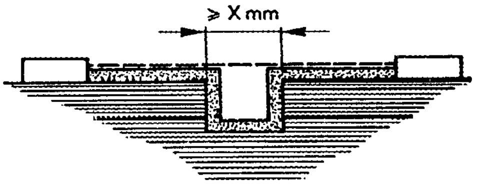
Figure G.2 – Creepage distance across the fixed and moving insulation of contact carriers

Example 1



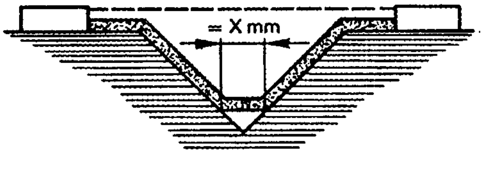
Condition:	This creepage distance path includes a parallel- or converging-sided groove of any depth with a width less than X mm.	Rule: Creepage distance and clearance are measured directly across the groove as shown.

Example 2



Condition:	This creepage distance path includes a parallel-sided groove of any depth and equal to or more than X mm.	Rule: Clearance is the "line-of-sight" distance. Creepage distance path follows the contour of the groove.

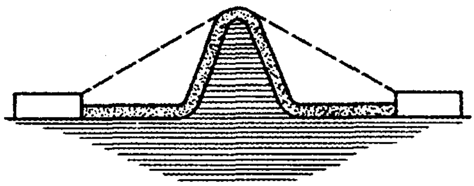
Example 3



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

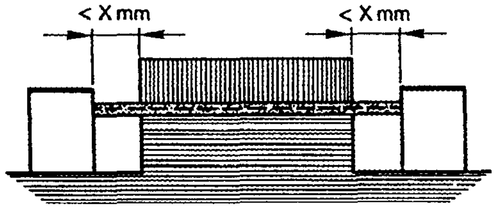
Example 4



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.

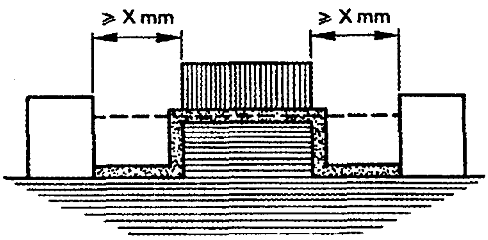
Example 5



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



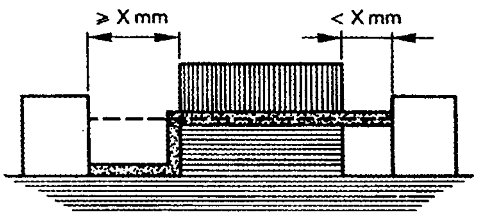
Condition: This creepage distance path includes an uncemented joint with grooves equal to or more than X mm wide on each side.

Rule: Clearance is the "line-of-sight" distance. Creepage distance path follows the contour of the grooves.

– – – – – Clearance

Creepage distance

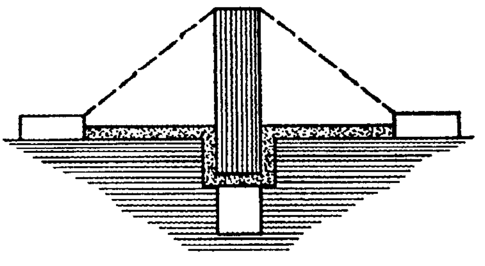
Example 7



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.

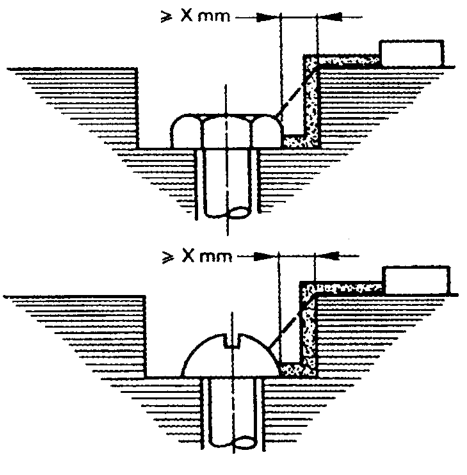
Example 8



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

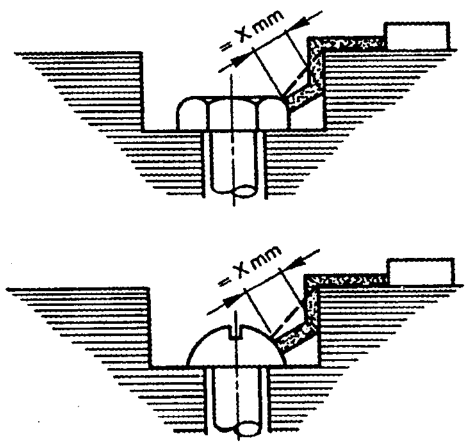


Condition: Gap between head of screw and wall of recess wide enough to be taken into account.

Rule: Clearance and creepage distance paths are as shown.

– – – – – Clearance   Creepage distance

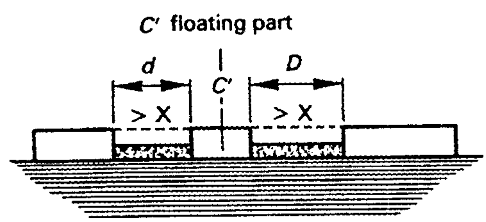
Example 10



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

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.

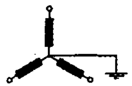
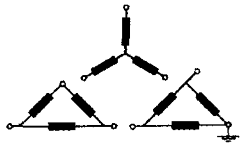
Table H.1 provides examples of the correlation between nominal supply system voltages and the corresponding rated impulse withstand voltage of equipment.

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	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			
					Overvoltage category			
					IV	III	II	I
a.c. r.m.s. or d.c. V	 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	Origin of installation (service entrance) level	Distribution circuit level	Load (appliance, equipment) level	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

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 Tables 9 and 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 Tables 9, 10 and 11 (subject to manufacturer's agreement). See note 2 of note to Tables 9, 10 and 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 9, 10, 11 or 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 L
(normative)

Terminal marking and distinctive number

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).

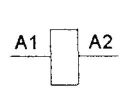
NOTE 1 The equipment dealt with in the following clauses L.2 and L.3 is also illustrated by graphical symbols in accordance with IEC 60617-7. It should be understood, however, that these symbols are not intended to be used for terminal marking on the equipment.

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.

L.2 Terminal marking of impedances (alphanumerical)

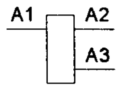
L.2.1 Coils

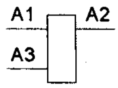
L.2.1.1 The two terminals of a coil for an electromagnetically operated drive shall be marked by A1 and A2.



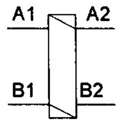
L.2.1.2 For a coil with tappings, the terminals of the tappings are marked in sequential order A3, A4, etc.

Examples:





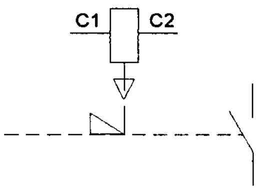
L.2.1.3 For a coil having two windings, the terminals of the first winding shall be marked A1, A2 and of the second winding B1, B2.



L.2.2 Electromagnetic releases

L.2.2.1 Shunt release

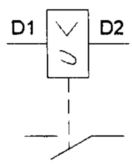
The two terminals of a shunt release shall be marked C1 and C2.



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

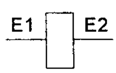
The two terminals of a coil intended to be used exclusively as an under-voltage release shall be marked D1 and D2.



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

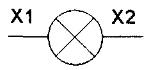
The two terminals of an interlocking electromagnet shall be marked E1 and E2.

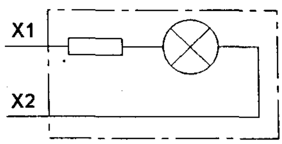


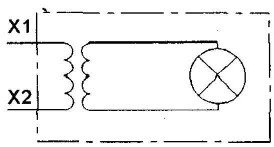
L.2.4 Indicating light devices

The two terminals of an indicating light device shall be marked X1 and X2.

Examples:







NOTE The term "indicating light devices" includes any incorporated resistor or transformer.

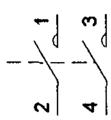
L.3 Terminal marking of contact elements for switching devices with two positions (numerical)

L.3.1 Contact elements for main circuits (main contact elements)

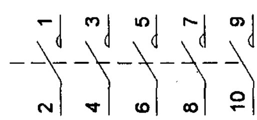
The terminals of main switching elements are identified by single figure numbers.

Each terminal marked by an odd number is associated with that terminal marked by the following even number.

Examples:



Two main contact elements



Five main contact elements

When a switching device has more than five main contact elements, alphanumerical marking shall be chosen, according to IEC 60445.

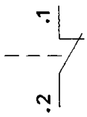
L.3.2 Contact elements for auxiliary circuit (auxiliary contact elements)

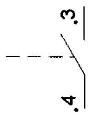
The terminals of auxiliary contact elements are identified by two-figure numbers:

- the figure of the units is a function number;
- the figure of the tens is a sequence number.

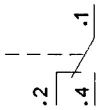
L.3.2.1 Function number

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)).





The terminals of change-over contact elements are marked by the function numbers 1, 2 and 4.

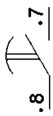


L.3.2.1.2 Auxiliary contact elements with special functions, such as time-delayed auxiliary contact elements, are identified by the function numbers 5 and 6, 7 and 8 for break-contact elements and make-contact elements respectively.

Examples:

Break-contact delayed on closing

Make-contact delayed on closing



The terminals of change-over contact elements with special functions are marked by the function numbers 5, 6 and 8.

Example:

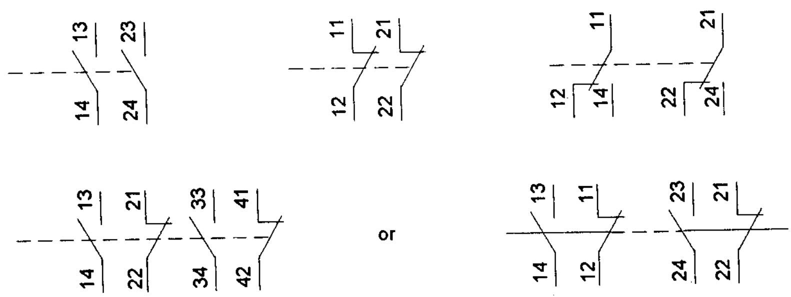
Change-over contact delayed in both directions

L.3.2.2 Sequence number

Terminals belonging to the same contact elements are marked with the same sequence numbers.

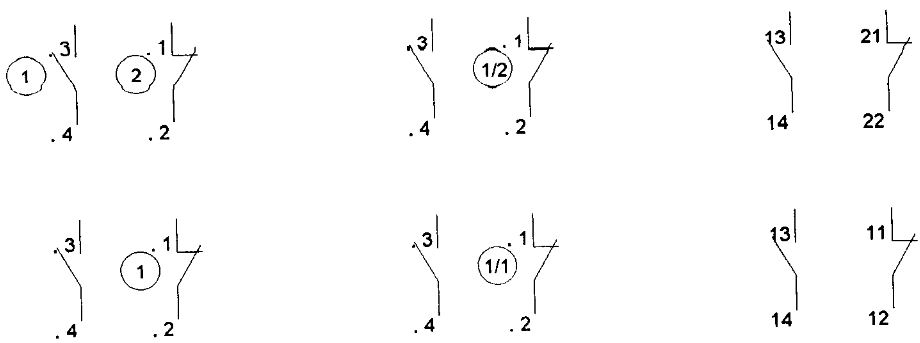
All contact elements having the same function shall have different sequence numbers.

Examples:



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:



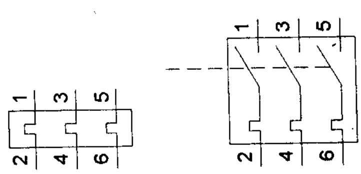
Device Device Diagram

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.

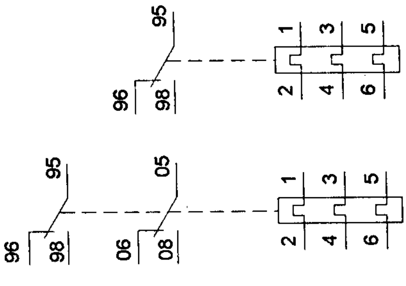
Examples:



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:

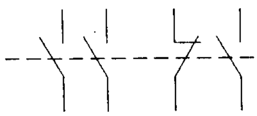


L.5 Distinctive number

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.

Distinctive number 31



Annex M
(normative)

Flammability test

M.1 Hot wire ignition test

M.1.1 Five samples of each material shall be tested. The samples shall be 150 mm long by 13 mm wide, and of uniform thickness stated by the material manufacturer.

Edges shall be free from burrs, fins, etc.

M.1.2 A (250 ± 5) mm length of nichrome wire (80 % nickel, 20 % chromium, iron free) approximately 0,5 mm diameter and having a cold resistance of approximately 5,28 Ω/m shall be used. 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 mm apart.

M.1.3 The wrapped sample shall be supported in a horizontal position and the ends of the wire connected to the variable power source, which is again adjusted to dissipate 0,26 W/mm in the wire (see Figure M.1).

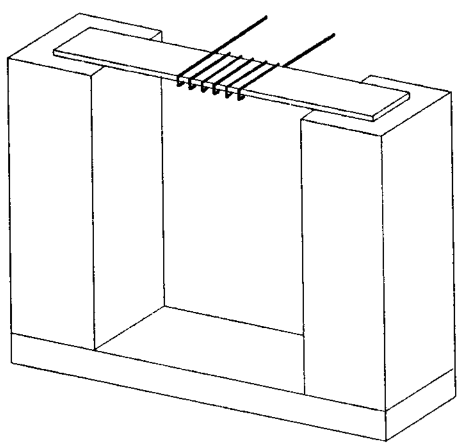


Figure M.1 – Test fixture for hot wire ignition test

M.1.4 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.

M.1.5 Continue heating until the test specimen ignites. When ignition occurs, shut off power and record time to ignite.

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.

M.1.6 The test shall be repeated on the remaining samples.

M.1.7 The average ignition time and the thickness of each set of specimens shall be recorded.

M.2 Arc ignition test

M.2.1 Three samples of each material shall be tested. The samples shall be 150 mm long by 13 mm wide and of uniform thickness stated by the material manufacturer. Edges shall be free from burrs, fins, etc.

M.2.2 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).

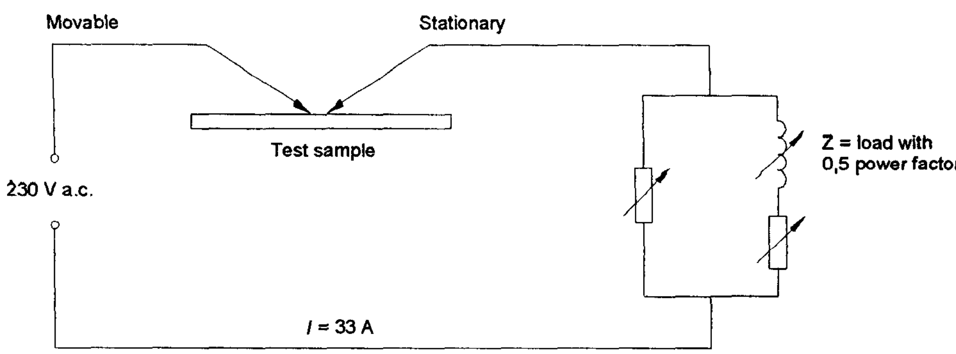


Figure M.2 – Circuit for arc ignition test

M.2.3 One electrode shall be stationary and the other movable. The stationary electrode shall consist of a 8 mm^2 to 10 mm^2 solid copper conductor having a horizontal chisel point with a total angle of 30°. The movable electrode shall be a 3 mm diameter stainless steel rod 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 the 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. With the electrodes short-circuited, the variable inductive impedance load shall be adjusted until the current is 33 A at a power factor of 0,5.

M.2.4 The sample under test shall be supported horizontally in air 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 (250 ± 25) mm/s.

M.2.5 The test is to be continued until ignition of the sample occurs, a hole is burned through the sample, or a total of 200 cycles has elapsed.

M.2.6 The average number of arcs to ignition and the thickness of each set of specimen shall be recorded.

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.

Each column represents HWI and AI minimum characteristics related to the flammability category.

Table M.1 – HWI and AI characteristics

Flammability category	FV 0	FV 1	FV 2	FH1	FH3	FH3
					≤ 40 mm/min	≤ 75 mm/min
Part thickness mm	Any	Any	Any	Any	≥ 3	< 3
HWI time to ignite, minimum s	7	15	30	30	30	30
AI minimum number of arcs to ignite	15	30	30	60	60	60

Example: A material with flammability category FV1 of any thickness must have a HWI value of at least 15 s and, if applicable, an AI value of at least 30 arcs.

Annex N
(normative)

Requirements and tests for equipment with protective separation

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 Protective separation

Separation between circuits by means of

- basic protection (basic insulation) and
- fault protection (supplementary insulation or protective screening), or
- by an equivalent protective provision (e.g. reinforced insulation).

N.2.7 SELV circuit

An electrical circuit:

- in which the voltage cannot exceed ELV; and
- with protective separation from circuits other than SELV; and
- with no provision for earthing of the SELV circuit nor of its exposed conductive parts; and
- with simple separation from earth.

N.2.8 PELV circuit

An electrical circuit

- in which the voltage cannot exceed ELV; and
- with protective separation from circuits other than PELV; and
- with provisions for earthing of the PELV circuit, or of its exposed conductive parts, or both.

N.3 Requirements

General

Unless otherwise specified in the relevant product standard:

- the only 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;
- 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.

N.3.1 Dielectric requirements

N.3.1.1 Creepages

It shall be verified that the creepage distances between SELV (PELV) circuit and other circuits is equal or higher than twice those given for basic insulation in Table 15 and corresponding to the determined SELV (PELV) rated voltage value (following the principles given in 3.2.3 of IEC 60664-1).

The creepage distances shall be verified in accordance with N.4.2.1.

N.3.1.2 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 3.1.5 of IEC 60664-1. The test conditions are given in N.4.2.2.

N.3.2 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.3.1.2.

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 three 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.

Annex O
(informative)

Environmental aspects

Introduction

The need to reduce the impact on the natural environment of a product during all phases of its life – from acquiring materials to manufacturing, distribution, use, re-use, recycling and disposal – is recognized in most countries around the world. The choices made largely decide what those impacts will be during each phase of that product's life. There are, however, considerable obstacles that make the task of selecting the best environmental options very difficult. For example, selecting design options to minimize environmental impact can involve difficult trade-off such as less recyclability for more energy efficiency.

The continuous introduction of new products and materials can make evaluation increasingly difficult, since additional data must be developed to assess the life cycle impacts of such new products and materials. Moreover, there is currently very little data available on the environmental impacts of existing materials. However, those which exist can be used as a basis for improvement of the products with respect to environmental impact. Environmental impact assessment (EIA) and design for environment (DFE) principles provide additional instruments that may be useful in this respect. This annex details some EIA principles to give background information on these issues.

Until more data are available, manufacturers can document more extensively, through the use of environmental impact assessments (EIAs), the specific design choices and the reasons behind them. This expands the knowledge based on such options and choices, and it may also assist in the recycling and disposal of the product at the end of life (EOL).

It should be noted that this annex can assist only insofar as the state of the art has been developed. As more studies and analyses are completed, more life-cycle data will be accumulated and better environmentally sound choices will be possible. Until then, the recommendation is to use this annex with care, professional judgement and a sound critical ability.

O.1 Scope

This annex is intended to give assistance in the consideration of environmental aspects relating to the impacts on the "natural" environment of products of the IEC 60947 series.

The term environment, as used in this annex, differs from the term used in the IEC standards dealing with the impact of environmental conditions on electrotechnical products.

NOTE As regards the impact of environmental conditions on the performance of products, reference is made to the IEC 60068 and IEC 60721 series and to IEC Guide 106.

O.2 Definitions

For the purpose of this annex, the following definitions apply.

O.2.1
"natural" environment (hereinafter referred to as environment)
attributes which affect the quality of life, such as water, air, and soil quality, conservation of energy and materials and avoidance of waste

O.2.2
life cycle
consecutive and interlinked stages, and all directly associated significant inputs and outputs, of a system from the extraction or exploitation of natural resources to the final disposal of all materials as irretrievable wastes or dissipated energy

O.2.3
life cycle assessment (LCA)
systematic set of procedures for compiling and examining the inputs and outputs of materials and energy and associated environmental impacts directly attributable to the functioning of an economic system throughout its life cycle

O.2.4
environmental burden
any change to the environment which, permanently or temporarily, results in loss of natural resources or deterioration of the natural quality of air, water or soil

O.2.5
environmental impact
consequences for human health, for the well-being of flora and fauna or for the future availability of natural resources, attributable to the input and output streams of a system

O.2.6
environmental impact assessment (EIA)
process to determine the magnitude and significance of environmental impacts within the confines of the goals, scope and objectives defined in the life cycle assessment

O.2.7
recycling
set of processes for diverting materials that would otherwise be disposed of as wastes, into an economic system where they contribute to the production of useful material

O.2.8
recyclability
property of a substance or a material and parts made thereof that makes it possible to be recycled

O.2.9
end of life
state of a product when it is finally removed from use

O.2.10
design for environment (DFE)
set of procedures for designing a product to optimize ecological features of the product under existing technical and economical conditions

O.3 General considerations

It should be checked that consideration of the following points always leads to minimizing the environmental impacts of the product throughout its life cycle:

- material conservation for preservation of resources;
- 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;
- design for easy maintainability, disassembly and recyclability if applicable;
- surface coating or other material combinations impeding recyclability;
- adequate environmental instruction/information for the user.

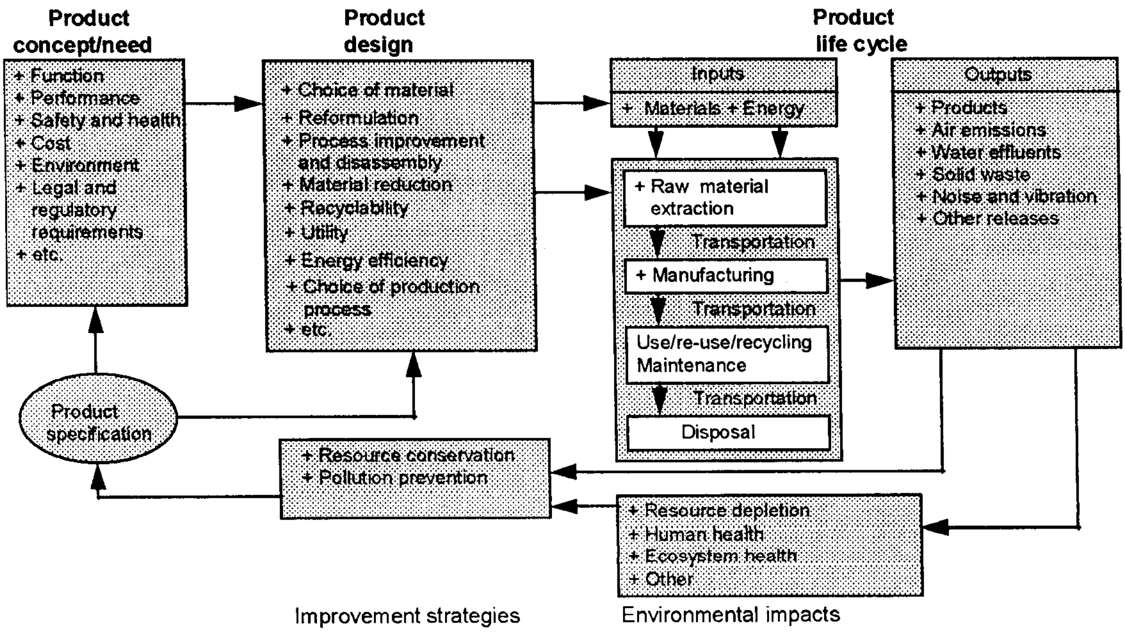
O.4 Inputs and outputs to be considered

O.4.1 General

Figure O.1, based on the work of ISO/TC 207/WG1, presents the correlation between principal steps in the environmental life cycle of a product, the product's function, its design, performance and other external considerations. The major objectives of environmental standards are also listed, namely consumption of material and energy, environmental emissions, recyclability, disassembly. At each step of a product's life cycle the materials and energy balance should be considered. When data are available, the study will cover the span of the life cycle from "cradle to grave". Figure O.1 also illustrates a product improvement cycle that leads to pollution prevention and resource conservation.

O.4.2 Inputs and outputs

Products environmental impacts are largely determined by the inputs that are used and the outputs that are generated at all stages of the products life cycle. Changing any single input, either to alter the materials and energy used, or to influence a single output, may affect other inputs and outputs (see Figure O.1).



NOTE 1 This figure is based on the work of ISO/TC 207.

NOTE 2 For the electrotechnical sector, "other releases" means electromagnetic emissions, ionizing and non-ionizing radiation and emissions to soil.

Figure O.1 – Environmental aspects for products related to the life cycle

O.4.3 Inputs: materials and energy

O.4.3.1 Material inputs used in product development should also be considered. These impacts can include depletion of renewable and non-renewable resources, detrimental land use, and environmental or human exposure to hazardous materials. Material inputs can also contribute to the generation of waste, emissions to air, effluents to water, and other releases. Material inputs associated with raw material acquisition, manufacturing, transportation (including packaging and storage), use/maintenance, re-use/recycling, and disposal of products can produce a variety of environmental impacts.

O.4.3.2 Energy inputs are required at most stages of a product's life cycle. Energy sources include fossil fuels, nuclear, recovered waste, hydroelectric, geothermal, solar and wind energy, and other sources. Each energy source has its own set of environmental impacts.

O.4.4 Outputs

O.4.4.1 Outputs generated during a product's life cycle generally comprise the product itself, intermediates and by-products, air emissions, water effluents, waste materials and other releases.

O.4.4.2 Air emissions comprise releases of gases, vapours or particulate matter into the air. Releases of toxic, corrosive, flammable, explosive, acidic or odorous substances may adversely affect flora, fauna, human beings, buildings, etc., or contribute to other environmental impacts such as depletion of stratospheric ozone or formation of smog. Air emissions include releases from point as well as diffuse sources, treated as well as untreated releases, and releases from normal operation as well as accidental releases.

O.4.4.3 Water effluents comprise the discharge of substances to a watercourse, either surface or ground water. The discharge of nutrients or toxic, corrosive, radioactive, persistent, accumulating or oxygen-depleting substances may give rise to adverse environmental impacts, including various pollution effects on aquatic ecosystems and undesirable eutrophication of natural waters. Water effluents include discharges from point as well as diffuse sources, treated as well as untreated discharges, and discharges from normal operation as well as accidental discharges.

O.4.4.4 Waste materials comprise solid or liquid materials and products which are disposed of. Waste materials may be produced at all stages of a product's life cycle. Waste materials are subject to recycling, treatment, recovery or disposal techniques associated with further inputs and outputs which may contribute to adverse environmental impacts.

O.4.4.5 Other releases may encompass emissions to soil, noise and vibration, radiation and waste heat.

O.5 Techniques for identifying and assessing environmental impacts

O.5.1 Accurate identification and assessment of how environmental impacts are influenced by products are complex and require careful consideration and may involve the need for consultation with experts. Certain techniques are evolving to guide the identification and assessment of a product's environmental impacts. Although a complete understanding of these techniques and their limitations requires extensive experience and study of the environmental sciences, awareness of them offers some general understanding of how products may affect the environment.

O.5.2 One example of such techniques, life cycle assessment (LCA), is the subject of standardization by ISO/TC 207/SC 5 and in ISO 14040.

LCA is a technique for assessing the environmental aspects and potential impacts associated with a product and comprises a three-phase series of analyses.

Phase 1: the inventory analyses, also known as life cycle inventory (LCI) – identifying and quantifying energy and materials used and the resultant environmental releases/burdens that occur during the entire life cycle

Phase 2: the impact assessment – assessing the environmental impacts of the energy and materials used, as well as those of the final product itself, plus any and all environmental releases/burdens over the entire life cycle.

Phase 3: the improvement assessment – evaluating the opportunities to improve environmental performance and then implementing the changes that will achieve improvements.

LCA studies the environmental aspects and potential impacts throughout a product's life ("cradle-to-grave") from raw material acquisition through production, use and disposal. The general categories of environmental impacts needing consideration include resource use, human health, and ecological consequences.

LCA can assist in:

- identifying opportunities to improve the environmental aspects of products at various points in their life cycle;
- decision-making in industry, governmental or non-governmental organizations (e.g. strategic planning, priority setting, product or process design or redesign);
- selection of relevant indicators of environmental performance, including measurement techniques;
- marketing (e.g. an environmental claim, ecolabelling scheme or environmental product declaration).

In addition to LCA, manufacturers should be aware of the emerging field of design for environment (DFE).

O.6 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 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.7 Guidance on environmental impact assessment (EIA) principles

Under consideration.

O.8 Guidance on design for environment (DFE) principles

Under consideration.

O.9 Reference documents

IEC Guide 106, *Guide for specifying environmental conditions for equipment performance rating*

IEC 60068 (all parts), *Environmental testing*

IEC 60721 (all parts), *Classification of environmental conditions*

ISO 14040:1997, *Environmental management – Life cycle assessment – Principles and framework*

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.								

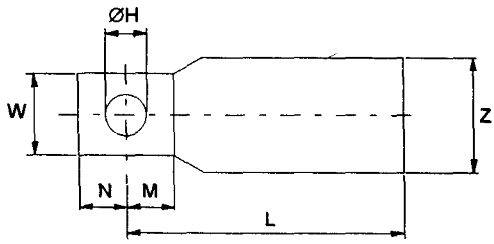


Figure P.1 – Dimensions

Bureau of Indian Standards

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Review of Indian Standards

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This Indian Standard has been developed from Doc: No. ETD 07 (5581).

Amendments Issued Since Publication

Amendment No.	Date of Issue	Text Affected

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