UL 60730-1

STANDARD FOR SAFETY

Automatic Electrical Controls – Part 1: General Requirements

UL Standard for Safety for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1

Sixth Edition, Dated October 31, 2024

Summary of Topics

Adoption of IEC 60730-1, Automatic electrical controls – Part 1: General requirements, (Edition 6.0, issued by the IEC September 2022) as a new Sixth Edition IEC-based UL Standard, UL 60730-1, dated October 31, 2024 with US National Differences. Please note that the national difference document incorporates all of the U.S. National Differences for UL 60730-1.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated January 26, 2024 and April 19, 2024.

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October 31, 2024

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The most recent designation of ANSI/UL 60730-1 as an American National Standard (ANSI) occurred on October 31, 2024. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, or Preface. The National Difference Page and IEC Foreword are also excluded from the ANSI approval of IEC-based standards.

Comments or proposals for revisions on any part of the Standard may be submitted to ULSE at any time. Proposals should be submitted via a Proposal Request in the Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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Preface

This UL Standard is based on IEC Publication 60730-1: sixth edition, Automatic electrical controls – Part 1: General requirements. IEC publication 60730-1 is copyrighted by the IEC.

^^This edition has been issued to satisfy ULSE Standards policy [or state other reason, including an administrative new edition, or out of necessity to incorporate extensive revisions].

This is the UL Standard for Automatic electrical controls – Part 1: General requirements. This UL Part 1 is to be used in conjunction with the appropriate UL Part 2's , which contains clauses to supplement or modify the corresponding clauses in the Part 1, to provide relevant requirements for each type of product.

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

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NATIONAL DIFFERENCES

National Differences from the text of International Electrotechnical Commission (IEC) Publication 60730-1, Automatic Electrical Controls, Part 1: General Requirements, copyright 2022 are indicated by notations (differences) and are presented in bold text.

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

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

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

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

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

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

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

Addition / Add - An addition entails adding a complete new numbered clause, subclause, table, figure, or annex. Addition is not meant to include adding select words to the base IEC text.

Modification / Modify - A modification is an altering of the existing base IEC text such as the addition, replacement or deletion of certain words or the replacement of an entire clause, subclause, table, figure, or annex of the base IEC text.

Deletion / Delete - A deletion entails complete deletion of an entire numbered clause, subclause, table, figure, or annex without any replacement text.

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FOREWORD

INTERNATIONAL ELECTROTECHNICAL COMMISSION

AUTOMATIC ELECTRICAL CONTROLS – Part 1: General requirements

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

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

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

IEC 60730-1 has been prepared by IEC technical committee 72: Automatic electrical controls. It is an International Standard.

This sixth edition cancels and replaces the fifth edition published in 2013, Amendment 1:2015 and Amendment 2:2020. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) Structure of the main clauses	The clauses of the standard are grouped into two sections of requirements, where • the first section consists of the Clauses 5 to 13 that, in general, addresses the construction of the product. It is noted that certain construction requirements may have verification requirements integrated within the clause to facilitate usage of the standard, and

	• the second section consists of Clauses 14 to 26 that addresses the verification requirements;
b) Scope	Relocated and deleted clauses to better reflect the products covered under the part 1 and for easier reading;
c) Normative references	Updated references;
d) Terms and definitions	Revised text in certain clauses and relocated relevant Clause H.3 subclauses into Clause 3;
e) General requirements	General structure of the standard explained along with a figure to depict the intent;
f) General notes on tests	Reduced sample size from 3 to 1, yet requiring analysis; order of tests more flexible; relocation of battery requirements from Annex V;
g) Rating	Deleted – covered under the scope;
h) Classification	Deleted – covered under information;
i) Information	Updated Table 1 to reflect entries from the classification clause, and all cross-references;
j) Protection against electric shock	Revised Clause 8 to include Clause H.8 and Clause V.8 subclauses, revised clauses as appropriate to distinguish between a live part and a hazardous live part;
k) Provision for protective earthing	
l) Construction requirements	One Y1 capacitor allowed; relocated relevant requirements of Clause H.11 and Clause V.11 into Subclause 9.2.5 and Subclause 9.13.4.4 respectively;
m) Moisture and dust	Relocated IP table from classification to Clause 14; updated references;
n) Manufacturing deviation and drift	All clauses moved to Annex H since the requirements pertain to functional safety of controls;
o) EMC-Emissions	Moved Clause H.23 into Clause 23;
p) EMC-Immunity	New EMC requirements (performance) for all controls except incorporated/integrated controls with Class A control functions. Products intended for HBES/BACS are also subjected to these requirements;
q) Fault assessment on electronic circuits	Fault assessment moved from Annex H to Clause 13; deleted test abnormal voltage for electronic disconnection;
r) Annex H	Relocated all relevant requirements for electronics to the respective clauses within the body of the standard and retained requirements related to functional safety in this annex;
s) Annex T	Revised clauses for clarity in Annex P;
t) Annex U	Removed, the necessity of the annex was not seen anymore;
u) Annex V	Included in the main part of the standard.

The text of this International Standard is based on the following documents:

Draft	Report on voting
72/1307/FDIS	72/1320/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at https//www.iec.ch/publications.

A list of all parts of the IEC 60730 series, under the general title: *Automatic electrical controls*, can be found on the IEC website.

In the development of a fully international standard to cover automatic electrical controls, it has been necessary to take into consideration the differing requirements resulting from practical experience in various parts of the world and to recognize the variation in national electrical systems and wiring rules.

The "in some countries" clauses have been moved to the regional respectively national differences in Annex Q to Annex T.

It is envisaged that in the next edition of this document, it will be found possible to remove those differences that are covered by new IEC standards now being prepared by other technical committees.

This part 1 is to be used in conjunction with the appropriate part 2 for a particular type of control, or for controls for particular applications. This part 1 may also be applied, so far as reasonable, to controls not mentioned in a part 2, and to controls designed on new principles, in which cases additional requirements may be considered to be necessary.

Where, for a particular clause or subclause, the text of part 2 indicates:

Addition:	the part 1 text applies with the additional requirement indicated in a part 2;
Modification:	the part 1 text applies with a minor change as indicated in a part 2;
Replacement:	the part 2 text contains a change which replaces the part 1 text in its entirety.

Where no change is necessary, the part 2 indicates that the relevant clause or subclause applies.

NOTE In this document the following print types are used:

– Requirements proper: in roman type;

– *Test specifications: in italic type;*

– Explanatory matter: in smaller roman type;

– Defined terms: **bold type**.

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

• reconfirmed,

• withdrawn,

• replaced by a revised edition, or

• amended.

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

DV.1 ***Modification to the Notes:***

– Words in SMALL ROMAN CAPITALS in the text are defined in Clause 3.

DV.2 ***Addition:***

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

AUTOMATIC ELECTRICAL CONTROLS – Part 1: General requirements

1 Scope

This document applies to automatic electrical controls

• for use in, on, or in association with equipment for household appliance and similar use;

NOTE 1 Throughout this document, the word "equipment" means "appliance and equipment".

• for building automation within the scope of ISO 16484 series and IEC 63044 series (HBES/BACS);

EXAMPLE 1 Independently mounted water valves, controls in smart grid systems and controls for building automation systems within the scope of ISO 16484–2.

• for equipment that is used by the public, such as equipment intended to be used in shops, offices, hospitals, farms and commercial and industrial applications;

EXAMPLE 2 Controls for commercial catering, heating and air-conditioning equipment.

• that are SMART ENABLED CONTROLS;

EXAMPLE 3 Smart grid control, remote interfaces/control of energy-consuming equipment including computer or smart phone.

• that are AC or DC powered controls with a rated voltage not exceeding 690 V AC or 600 V DC where the DC source is provided by primary or secondary batteries;

• used in, on, or in association with equipment that use electricity, gas, oil, solid fuel, solar thermal energy, etc., or a combination thereof;

• utilized as part of a control system or controls which are mechanically integral with multifunctional controls having non-electrical outputs;

• using NTC or PTC THERMISTORS and to discrete THERMISTORS, requirements for which are contained in Annex J;

• that are mechanically or electrically operated, responsive to or controlling such characteristics as temperature, pressure, passage of time, humidity, light, electrostatic effects, flow, or liquid level, current, voltage, acceleration, or combinations thereof;

• as well as manual controls when such are electrically and/or mechanically integral with automatic controls.

NOTE 2 Requirements for manually actuated mechanical switches not forming part of an automatic control are contained in IEC 61058-1-1.

This document applies to

– the inherent safety of automatic electrical controls, and

– functional safety of automatic electrical controls and safety related systems,

– controls where the performance (for example the effect of EMC phenomena) of the product can impair the overall safety and performance of the controlled system,

– the operating values, operating times, and operating sequences where such are associated with equipment safety.

This document specifies the requirements for construction, operation and testing of automatic electrical controls used in, on, or in association with an equipment.

This document does not

• apply to automatic ELECTRONIC CONTROLS intended exclusively for industrial process applications unless explicitly mentioned in the relevant part 2 or the equipment standard. However, this document can be applied to evaluate automatic electrical controls intended specifically for industrial applications in cases where no relevant safety standard exists.

• take into account the response value of an automatic action of a control, if such a response value is dependent upon the method of mounting the control in the equipment. Where a response value is of significant purpose for the protection of the user, or surroundings, the value defined in the appropriate equipment standard or as determined by the manufacturer will apply.

• address the integrity of the output signal to the network devices, such as interoperability with other devices unless it has been evaluated as part of the control system.

1DV.1 D2 *Modification of Clause 1 by adding the following text:*

CONTROLS intended to be installed in air handling spaces or in other environmental air space (plenums) are covered under the scope of this standard.

CONTROLS intended to manage (monitor and/or control) energy consumption of components/systems (load management) or power sources are covered under the scope of this standard.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60038, *IEC standard voltages*

IEC 60065:2014, *Audio, video and similar electronic apparatus – Safety requirements*

IEC 60068-2-75, *Environmental testing – Part 2-75: Tests – Test Eh: Hammer tests*

IEC 60085, *Electrical insulation – Thermal evaluation and designation*

IEC 60099-1:1991, *Surge arresters – Part 1: Non-linear resistor type gapped surge arresters for a.c. systems*[1]

[1] Withdrawn.

IEC 60112:2020, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials*

IEC 60127 (all parts), *Miniature fuses*

IEC 60227-1, *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V – Part 1: General requirements*

IEC 60245-1, *Rubber insulated cables – Rated voltages up to and including 450/750 V – Part 1: General requirements*

IEC 60269 (all parts), *Low-voltage fuses*

IEC 60335-1:2020, *Household and similar electrical appliances – Safety – Part 1: General requirements*

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

IEC 60384-16, *Fixed capacitors for use in electronic equipment – Part 16: Sectional specification – Fixed metallized polypropylene film dielectric DC capacitors*

IEC 60384-17, *Fixed capacitors for use in electronic equipment – Part 17: Sectional specification – Fixed metallized polypropylene film dielectric AC and pulse capacitors*

IEC 60417, *Graphical symbols for use on equipment*

IEC 60423, *Conduit systems for cable management – Outside diameters of conduits for electrical installations and threads for conduits and fittings*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP code)*
IEC 60529:1989/AMD1:1999
IEC 60529:1989/AMD2:2013

IEC 60539 (all parts), *Directly heated negative temperature coefficient thermistors*

IEC 60664-1:2007[2], *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

[2] Withdrawn.

IEC TR 60664-2 (all parts), *Insulation coordination for equipment within low-voltage systems*

IEC 60664-3:2016, *Insulation coordination for equipment within low-voltage systems – Part 3: Use of coating, potting or moulding for protection against pollution*

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

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

IEC 60695-2-11:2021, *Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods – Glow-wire flammability test method for end-products (GWEPT)*

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

IEC 60738 (all parts), *Thermistors – Directly heated positive temperature coefficient*

IEC 60747-5-5, *Semiconductor devices – Part 5-5: Optoelectronic devices – Photocouplers*

IEC 60884-1, *Plugs and socket-outlets for household and similar purposes – Part 1: General requirements*

IEC 60884-2-5:2017, *Plugs and socket-outlets for household and similar purposes – Part 2-5: Particular requirements for adaptors*

IEC 60998-2-2, *Connecting devices for low-voltage circuits for household and similar purposes – Part 2-2: Particular requirements for connecting devices as separate entities with screwless-type clamping units*

IEC 60998-2-3, *Connecting devices for low-voltage circuits for household and similar purposes – Part 2-3: Particular requirements for connecting devices as separate entities with insulation-piercing clamping units*

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

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

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

IEC 61000-3-11, *Electromagnetic compatibility (EMC) – Part 3-11: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems – Equipment with rated current ≤ 75 A and subject to conditional connection*

IEC 61000-3-12, *Electromagnetic compatibility (EMC) – Part 3-12: Limits – Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current >16 A and ≤ 75 A per phase*

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

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

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

IEC 61000-4-5:2014, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*
IEC 61000-4-5:2014/AMD1:2017

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

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

IEC 61000-4-11, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests for equipment with current up to 16 A per phase*

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 61000-4-13:2002 /AMD1:2009
IEC 61000-4-13:2002 /AMD2:2015

IEC 61000-4-20, *Electromagnetic compatibility (EMC) – Part 4-20: Testing and measurement techniques – Emission and immunity testing in transverse electromagnetic (TEM) waveguides*

IEC 61000-4-21, *Electromagnetic compatibility (EMC) – Part 4-21: Testing and measurement techniques – Reverberation chamber test methods*

IEC 61000-4-22, *Electromagnetic compatibility (EMC) – Part 4-22: Testing and measurement techniques – Radiated emissions and immunity measurements in fully anechoic rooms (FARs)*

IEC 61000-4-28, *Electromagnetic compatibility (EMC) – Part 4-28: Testing and measurement techniques – Variation of power frequency, immunity test for equipment with input current not exceeding 16A per phase*

IEC 61000-6-1:2016, *Electromagnetic compatibility (EMC) – Part 6-1: Generic standards – Immunity standard for residential, commercial and light-industrial environments*

IEC 61000-6-2:2016, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity standard for industrial environments*

IEC 61000-6-3:2020, *Electromagnetic compatibility (EMC) – Part 6-3: Generic standards – Emission standard for equipment in residential environments*

IEC 61000-6-4:2018, *Electromagnetic compatibility (EMC) – Part 6-4: Generic standards – Emission standard for industrial environments*

IEC 61051-1, *Varistors for use in electronic equipment – Part 1: Generic specification*

IEC 61051-2, *Varistors for use in electronic equipment – Part 2: Sectional specification for surge suppression varistors*

IEC 61051-2-2, *Varistors for use in electronic equipment – Part 2: Blank detail specification for zinc oxide surge suppression varistors. Assessment level E*

IEC 61210, *Connecting devices – Flat quick-connect terminations for electrical copper conductors – Safety requirements*

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

IEC 61558-2-6, *Safety of transformers, reactors, power supply units and combinations thereof – Part 2-6: Particular requirements and tests for safety isolating transformers and power supply units incorporating safety isolating transformers for general applications*

IEC 61558-2-16, *Safety of transformers, reactors, power supply units and combinations thereof – Part 2-16: Particular requirements and tests for switch mode power supply units and transformers for switch mode power supply units for general applications*

IEC 61810-3, *Electromechanical elementary relays – Part 3: Replays with forcibly guided (mechanically linked) contacts*

IEC 62151, *Safety of equipment electrically connected to a telecommunication network*

IEC 62319 (all parts), *Polymeric thermistors – Directly heated positive step function temperature coefficient*

IEC 62326 (all parts), *Printed boards*

IEC 62368-1, *Audio/video, information and communication technology equipment – Part 1: Safety requirements*

IEC 63044 (all parts), *Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS)*

CISPR 11, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*

CISPR 14-1:2020, *Electromagnetic compatibility – Requirements for household appliances, electric tools and similar apparatus – Part 1: Emission*

CISPR 32:2015, *Electromagnetic compatibility of multimedia equipment – Emission requirements*
CISPR 32:2015/AMD1:2019

ISO 4046-4:2016, *Paper, board, pulps and related terms − Vocabulary – Part 4: Paper and board grades and converted products*

ISO 7637-2:2011, *Road vehicles – Electrical disturbances from conduction and coupling – Part 2: Electrical transient conduction along supply lines only*

ISO 7637-3:2016, *Road vehicles – Electrical disturbances from conduction and coupling – Part 3: Electrical transient transmission by capacitive and inductive coupling via lines other than supply lines*

ISO 16484 (all parts), *Building automation and control systems (BACS)*

2DV D2 *Modification of Clause 2 to add the following:*

The following UL Standards are referenced in this Standard:

UL 50, *Enclosures for Electrical Equipment, Non-Environmental Considerations*

UL 50E, *Enclosures for Electrical Equipment, Environmental Considerations*

UL 62, *Flexible Cords and Cables*

UL 94, *Tests for Flammability of Plastic Materials for Parts in Devices and Appliances*

UL 157, *Gaskets and Seals*

UL 248-14, *Low-Voltage Fuses – Part 14: Supplemental Fuses*

UL 310, *Electrical Quick-Connect Terminals*

UL 508, *Industrial Control Equipment*

UL 514A, *Metallic Outlet Boxes*

UL 514B, *Conduit, Tubing, and Cable Fittings*

UL 514C, *Nonmetallic Outlet Boxes, Flush-Device Boxes, and Covers*

UL 635, *Insulating Bushings*

UL 746C, *Polymeric Materials – Use in Electrical Equipment Evaluations*

UL 796, *Printed Wiring Boards*

UL 969, *Marking and Labeling Systems*

UL 1059, *Terminal Blocks*

UL 1434, *Thermistor-type Devices*

UL 4200A, *Products Incorporating Button Batteries or Coin Cell Batteries* (First edition including revisions through August 30, 2023)

UL 4248, *Fuseholders series*

UL 5085-1, *Low Voltage Transformers – Part 1: General Requirements*

UL 5085-2, *Low Voltage Transformers – Part 2: General Purpose Transformers*

UL 5085-3, *Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

• IEC Electropedia: available at http://www.electropedia.org/

• ISO Online browsing platform: available at http://www.iso.org/obp

NOTE Where the terms "voltage" and "current" are used, they imply the RMS values, unless otherwise specified.

3.1 Definitions relating to ratings, voltages, currents, frequencies, and wattages

3.1.1
RATED VOLTAGE, CURRENT, FREQUENCY OR WATTAGE
voltage, current, frequency or wattage assigned to a control by the manufacturer

Note 1 to entry: For three phase supply, the RATED VOLTAGE is the line-to-line voltage.

3.1.2
RATED VOLTAGE, CURRENT, FREQUENCY OR WATTAGE RANGE
voltage, current, frequency or wattage ranges assigned to the CONTROL by the manufacturer and expressed by lower and upper values

3.1.3
WORKING VOLTAGE
highest RMS value of the AC or DC voltage across any particular insulation which can occur when the equipment is supplied at RATED VOLTAGE

Note 1 to entry: TRANSIENT OVERVOLTAGES are disregarded.

Note 2 to entry: Open-circuit conditions and normal operating conditions are taken into account.

3.1.4
EXTRA-LOW VOLTAGE
ELV
voltage not exceeding the maximum values of 50 V AC (RMS), 70,7 V AC (peak) or 120 V DC (ripple-free) between conductors and between conductors and earth which is permitted to be maintained indefinitely under normal and single-FAULT conditions

Note 1 to entry: Ripple-free is conventionally defined as an RMS ripple voltage of not more than 10 % of the DC component.

Note 2 to entry: The use of ELV other than in SELV SYSTEM or PELV SYSTEM is not a protective measure against electric shock, this is in line with IEC 61140:2016.

3.1.5
SAFETY EXTRA-LOW VOLTAGE
PROTECTIVE EXTRA-LOW VOLTAGE
SELV/PELV
voltage for use in SELV SYSTEM or PELV SYSTEM between simultaneously ACCESSIBLE PART(S) and between any ACCESSIBLE PART and earth, not exceeding the limits of 30 V AC (RMS), 42,4 V AC (peak) or 60 V DC (ripple free) under normal and single-FAULT condition, which is provided by an independent source (such as motor generators, and batteries) or when obtained from higher voltage is obtained by a SAFETY ISOLATING TRANSFORMER or a converter with separate windings providing equivalent insulation

Note 1 to entry: The voltage limits are based on the assumption that the safety isolating transformer is supplied at its rated voltage. For the purpose of the output test in 12.2.1, the secondary output voltage limit shall be increased as specified in 19.2.2.

Note 2 to entry: Transformers used in converters that have separate windings and provide equivalent insulation are covered under IEC 61558-2-6 and IEC 61558-2-16.

Note 3 to entry: SELV/PELV limits are defined regardless of any special condition which may occur in installation. Different requirements may be specified in the relevant electrical installation standards (e.g. IEC 60364 series) or in the applicable local regulations.

Note 4 to entry: Ripple-free is conventionally defined as an RMS ripple voltage of not more than 10 % of the DC component.

Note 5 to entry: SELV/PELV limits may be different in other product or system standards. In case a control is declared exclusively for use in applications governed by a different standard, the limits set by the application standard apply (e.g. controls to be used

exclusively in household appliances according IEC 60335 set of standards or connected to HBES/BACS systems according to IEC 63044-3 accept different SELV voltage limits).

3.1.5DV D1 *Modification of Clause 3.1.5 NOTE 2 as follows:*

Replace "IEC 61558-2-6" with "UL 5085-1 and UL 5085-3. Transformers used in Switch-mode power supplies are evaluated to the applicable requirements of this standard."

3.1.6
SAFETY ISOLATING TRANSFORMER
transformer, the input winding of which is electrically separated from the output winding by an insulation at least equivalent to DOUBLE INSULATION or REINFORCED INSULATION, and which is intended to supply SAFETY EXTRA-LOW VOLTAGE circuits

3.1.6DV DR *Modification of 3.1.6 to add the following NOTE:*

NOTE DV1: A Class 2 transformer which is considered a safety isolating transformer is defined as a step-down transformer of the low-voltage secondary type in accordance with Article 725 of the National Electrical Code, NFPA 70.

3.1.7
ISOLATED LIMITED SECONDARY CIRCUIT
circuit from an isolated secondary winding of a transformer having a maximum capacity of 100 VA and an open-circuit secondary voltage rating not exceeding 1 000 V

3.1.8
PILOT DUTY
class of OPERATION in which the ultimate electrical load is controlled by an auxiliary means such as a relay or contactor

3.1.9
TRANSIENT OVERVOLTAGE
overvoltage with a duration of a few milliseconds or less, oscillatory or non-oscillatory, usually highly damped

Note 1 to entry: TRANSIENT OVERVOLTAGES may be immediately followed by temporary overvoltages. In such cases the two overvoltages are considered as separate events.

Note 2 to entry: IEC 60071-1 defines three types of TRANSIENT OVERVOLTAGES, namely slow-front overvoltages, fast-front overvoltages and very fast-front overvoltages according to their time to peak, tail or total duration, and possible superimposed oscillations.

[SOURCE: IEC 60050-614:2016, 614-03-14]

3.1.10
RATED IMPULSE VOLTAGE
impulse withstand voltage assigned by the manufacturer to the equipment or to a part of it, characterizing the specified withstand capability of its insulation against overvoltages

Note 1 to entry: The term rated impulse voltage is the same as impulse withstand voltage given in IEC 60664-1 overvoltage category.

3.1.11
OVERVOLTAGE CATEGORY
numeral defining a TRANSIENT OVERVOLTAGE condition

Note 1 to entry: Overvoltage categories I, II, III, and IV are used. See Annex D.

[SOURCE: IEC 60050-581:2008, 581-21-02, modified − Note 1 to entry has been added]

3.1.12
SELV SYSTEM
electrical system in which the voltage cannot exceed the values in 3.1.5:

– under normal conditions, and

– under single FAULT conditions, including protective earth FAULTS in other electric circuits

[SOURCE: IEC 60050-826:2004, 826-12-31; modified − "the value of extra-low voltage" has been changed to "the values in 3.1.5" and Note 1 to entry has been deleted]

3.1.13
PELV SYSTEM
electrical system in which the voltage cannot exceed the values in 3.1.5:

– under normal conditions, and

– under single FAULT conditions, except protective earth FAULTS in other electric circuits

[SOURCE: IEC 60050-826:2004, 826-12-32; modified − "the value of extra-low voltage" has been changed to "the values in 3.1.5" and Note 1 to entry has been deleted]

3.2 Definitions of types of control according to purpose

3.2.1
ELECTRICAL CONTROL
device used in, on or in association with an equipment for the purpose of varying or modifying the output from such equipment, and which embodies the aspects of INITIATION, TRANSMISSION and OPERATION

Note 1 to entry: Hereinafter, electrical control is referred to as "CONTROL".

Note 2 to entry: At least one of these aspects shall be electrical or electronic.

3.2.2
MANUAL CONTROL
control in which the INITIATION is by ACTUATION and in which the TRANSMISSION and the OPERATION are both direct and without any intentional time delay

3.2.3
AUTOMATIC CONTROL
CONTROL in which at least one aspect is non-manual

3.2.4
SENSING CONTROL
AUTOMATIC CONTROL in which INITIATION is by an element sensitive to the particular ACTIVATING QUANTITY declared, for example, temperature, current, humidity, light, liquid level, position, pressure or velocity

3.2.5
THERMOSTAT
cycling temperature SENSING CONTROL, which is intended to keep a temperature between two particular values under normal operating conditions and which can have provision for SETTING BY THE USER

Note 1 to entry: A THERMOSTAT will provide a TYPE 1 ACTION or a TYPE 2 ACTION as declared.

3.2.6
TEMPERATURE LIMITER
temperature SENSING CONTROL which is intended to keep a temperature below or above one particular value during normal operating conditions and which can have provision for SETTING BY THE USER

Note 1 to entry: A TEMPERATURE LIMITER may be of the automatic or of the manual reset type. It does not make the reverse OPERATION during the normal DUTY CYCLE of the appliance.

Note 2 to entry: A TEMPERATURE LIMITER will provide a TYPE 1 ACTION or a TYPE 2 ACTION as declared.

3.2.7
THERMAL CUT-OUT
temperature SENSING CONTROL intended to keep a temperature below or above one particular value during abnormal operating conditions and which has no provision for SETTING BY THE USER

Note 1 to entry: A THERMAL CUT-OUT may be of the automatic or of the manual reset type.

Note 2 to entry: A THERMAL CUT-OUT will provide a TYPE 2 ACTION.

3.2.8
ENERGY REGULATOR
self-cycling CONTROL which alters the energy to a load and which can incorporate means for SETTING BY THE USER to change the average energy supplied

Note 1 to entry: The ratio of the on-time, to the on-plus-off-time, determines the average energy supplied.

3.2.9
TIME-BASED CONTROL
automated CONTROL in which the TRANSMISSION is effected by a time-based PRIME MOVER or a time-based electrical circuit

3.2.10
ELECTRICALLY OPERATED CONTROL
AUTOMATIC CONTROL in which the TRANSMISSION is affected by an electrical PRIME MOVER and in which the OPERATION controls an electric circuit, and is without intentional significant time-delay

Note 1 to entry: An example is a relay.

Note 2 to entry: A slugged-relay may be either an ELECTRICALLY OPERATED CONTROL, or a TIME-BASED CONTROL by agreement between test house and manufacturer.

3.2.11
TIMER
TIME-BASED CONTROL which requires ACTUATION before the next cycle can take place

Note 1 to entry: During a cycle, it may require an external electrical or mechanical signal before moving from a rest position to allow the cycle to continue. An example is a programmer.

3.2.12
TIME SWITCH
TIME-BASED CONTROL which continues with a subsequent cycle when the preceding one has been completed

Note 1 to entry: An example is a 24 h CONTROL on a storage heater.

3.2.13
ELECTRICALLY OPERATED VALVE
AUTOMATIC CONTROL in which the TRANSMISSION is effected by an electrical PRIME MOVER and in which the OPERATION controls the flow of a liquid or a gas

3.2.14
ELECTRICALLY OPERATED MECHANISM
AUTOMATIC CONTROL in which the TRANSMISSION is effected by an electrical PRIME MOVER in which the OPERATION controls a mechanical device

Note 1 to entry: An example is an electrically operated interlock for a spin dryer lid.

Note 2 to entry: An electric motor is not included in this definition.

3.2.15
OPERATING CONTROL
CONTROL which starts or regulates the equipment during normal operation

Note 1 to entry: This operating control can provide CLASS A, CLASS B or CLASS C CONTROL FUNCTIONS.

3.2.16
PROTECTIVE CONTROL
CONTROL, the OPERATION of which is intended to prevent a hazardous situation during abnormal operation of the equipment

3.2.17
MULTIPURPOSE CONTROL
ELECTRICAL CONTROL that can be classified and used for more than one purpose

Note 1 to entry: An example of a MULTIPURPOSE CONTROL is a THERMOSTAT that can also be used as a TEMPERATURE LIMITER.

3.2.18
MULTIFUNCTIONAL CONTROL
ELECTRICAL CONTROL which incorporates more than one function

Note 1 to entry: An example of a MULTIFUNCTIONAL CONTROL is the combination of a THERMOSTAT and a humidistat.

3.2.19
SYSTEM
CONTROL and CONTROL sensors and actuators as applied to an application or processes

3.3 Definitions relating to the function of controls

3.3.1
INITIATION
alteration to that aspect of a CONTROL which is required to produce TRANSMISSION and OPERATION

3.3.2
TRANSMISSION
essential coupling between INITIATION and OPERATION which is required to enable the CONTROL to fulfil its purpose

Note 1 to entry: This includes, but is not limited to, the use of:

a) communication lines/protocols;

b) additional hardware and/or software;

c) IR/RF; or

all combinations of a) to c) via Internet using, for example, modems, portable telephones, etc.

3.3.3
OPERATION
change in that aspect of a CONTROL which modifies the input to the equipment or part of the equipment

3.3.4
AUTOMATIC ACTION
that action of an AUTOMATIC CONTROL in which the TRANSMISSION and OPERATION are produced by initiation which is not the result of ACTUATION

3.3.5
SLOW-MAKE SLOW-BREAK AUTOMATIC ACTION
mode of OPERATION where the rate of contact make and/or break is directly proportional to the rate of change of the ACTIVATING QUANTITY, or to the speed of movement of a PRIME MOVER

Note 1 to entry: This action may be applicable to either the make, or the break, or both.

3.3.6
MANUAL ACTION
that action of an AUTOMATIC CONTROL or of a MANUAL CONTROL in which the TRANSMISSION and OPERATION are produced by INITIATION which is the result of ACTUATION

3.3.7
ACTUATION
movement of the ACTUATING MEMBER of the CONTROL by the USER, by hand, by foot or by any other human activity

3.3.8
LOCATED POSITION
position of the ACTUATING MEMBER to which it will return if it is released after being moved slightly

3.3.9
INTERMEDIATE POSITION
any position of any ACTUATING MEMBER which is adjacent to a LOCATED POSITION, and in which the ACTUATING MEMBER will remain and in which the OPERATION of the CONTROL is intermediate

3.3.10
ACTIVATING QUANTITY
physical characteristic of a medium, the variation or stability of which is being sensed

3.3.11
OPERATING VALUE
value of the relevant temperature, pressure, current, etc. at which a SENSING CONTROL operates on a rise or fall of the ACTIVATING QUANTITY

3.3.12
OPERATING TIME
duration of time, or the difference of time, between any two functions, electrical or mechanical, occurring during the AUTOMATIC ACTION of a TIME-BASED CONTROL

3.3.13
OPERATING SEQUENCE
intended sequence, order or pattern in which the OPERATION of the electrical or mechanical functions of a CONTROL are intended to occur as a result of either an AUTOMATIC or a MANUAL ACTION of a CONTROL

Note 1 to entry: It includes the pattern of opened or closed contacts in any LOCATED POSITION, INTERMEDIATE POSITION or position of SETTING BY THE EQUIPMENT MANUFACTURER or SETTING BY THE USER.

3.3.14
RESPONSE VALUE
OPERATING VALUE, the OPERATING TIME or the OPERATING SEQUENCE which relates a CONTROL to a particular equipment

3.3.15
TRIP-FREE
AUTOMATIC ACTION, with a reset ACTUATING MEMBER, in which the AUTOMATIC ACTION is independent of manipulation or position of the reset mechanism

3.3.16
SETTING
mechanical positioning of a part of a control in order to select an OPERATING VALUE

3.3.17
SETTING BY THE CONTROL MANUFACTURER
any SETTING carried out by the CONTROL MANUFACTURER which is not intended to be altered by the EQUIPMENT MANUFACTURER, the INSTALLER or the USER

3.3.18
SETTING BY THE EQUIPMENT MANUFACTURER
any SETTING carried out by the EQUIPMENT MANUFACTURER which is not intended to be altered by the INSTALLER or the USER

3.3.19
SETTING BY THE INSTALLER
any SETTING carried out by the INSTALLER, as instructed by the EQUIPMENT MANUFACTURER or the CONTROL MANUFACTURER, and which is not intended to be altered by the USER

3.3.20
SETTING BY THE USER
any selection of an OPERATING VALUE by ACTUATION performed by the USER

3.3.21
SET POINT
value selected by SETTING

3.3.22
ADJUSTABLE SET POINT
multiple values, within a declared range of values, which can be selected by SETTING

3.3.23
DUTY CYCLE
all automatic and MANUAL ACTIONS involved in one start-to-finish OPERATION of the controlled equipment

3.3.24
CYCLE OF CONTACT OPERATION
one contact make and one subsequent contact break action, or one contact break and one subsequent contact make action

3.3.25
OPERATING DIFFERENTIAL
difference between the upper and lower values of the OPERATING VALUE

3.3.26
ADJUSTABLE DIFFERENTIAL
ability to change or alter the OPERATING DIFFERENTIAL within rated limits by OPERATION of a manually actuated mechanism

3.3.27
FIXED DIFFERENTIAL
OPERATING DIFFERENTIAL which cannot be changed from the manufacturer's SETTING

3.3.28
MAXIMUM WORKING PRESSURE
declared maximum line or SYSTEM working pressure to which the control or parts thereof can be subjected

3.3.29
MAXIMUM TEMPERATURE
T_{max}
declared maximum continuous ambient temperature to which the SWITCH HEAD is intended to be exposed during normal operation

3.3.30
REMOTELY ACTUATED CONTROL FUNCTION
function providing any OPERATION by CONTROL devices through external means

Note 1 to entry: This includes, but is not limited to, the use of:

a) communication lines/protocols;

b) additional hardware and/or software;

c) IR/RF TRANSMISSION; or

all combinations of a) to c) via Internet using, for example, modems, portable telephones, etc.

3.3.31
SAFETY SHUT-DOWN
change in the state of all electrical outputs so that all safety critical electrical outputs of the CONTROL will proceed to a safe condition including shut-down

3.3.32
MOUNTING SURFACE TEMPERATURE
$T_{s\ max}$
declared maximum temperature to which the mounting surface of the control is intended to be exposed including any likely overshoot once a control has operated

3.3.33
TOUCH CURRENT
electric current passing through a human body or through livestock when it touches one or more accessible parts of an installation or of equipment

Note 1 to entry: Touch current is often referred to as "leakage current" in many safety standards such as IEC 60335 series of standards.

[SOURCE: IEC 60050-195:2021, 195-05-21, modified – Note 1 to entry has been added]

3.4 Definitions relating to disconnection and interruption

Some CONTROLS can incorporate more than one form of circuit disconnection or interruption.

3.4.1
ALL-POLE DISCONNECTION
disconnection of all supply conductors, except the protective earthed (grounded) conductor, by a single switching action

Note 1 to entry: The protective earthing conductor is not considered to be a supply conductor.

3.4.2
FULL DISCONNECTION
contact separation in all supply poles other than protective earth so as to provide the equivalent of BASIC INSULATION between the supply mains and those parts intended to be disconnected

Note 1 to entry: There are electric strength and dimensional requirements.

Note 2 to entry: Where the number of poles on the CONTROL is equal to the number of supply poles of the appliance to which it is connected, FULL DISCONNECTION provides ALL-POLE DISCONNECTION.

Note 3 to entry: An ELECTRONIC DEVICE does not provide this disconnection.

3.4.3
MICRO-DISCONNECTION
adequate contact separation in at least one pole for functional disconnection

Note 1 to entry: There is a requirement for the electric strength of the contact gap but no dimensional requirement.

Note 2 to entry: MICRO-DISCONNECTION denotes that for non-SENSING CONTROLS the function controlled by the disconnection is secure, and that for SENSING CONTROLS is secure between the limits of ACTIVATING QUANTITY declared in Table 1, requirement 30.

Note 3 to entry: An ELECTRONIC DEVICE does not provide this disconnection.

3.4.4
MICRO-INTERRUPTION
interruption of a circuit by contact separation, by a cycling action or by a non-cycling action which does not provide FULL DISCONNECTION or MICRO-DISCONNECTION

Note 1 to entry: There are no electric strength or dimensional requirements for the contact gap.

Note 2 to entry: An ELECTRONIC DEVICE does not provide this disconnection.

3.4.5
OFF POSITION
position providing a visible or implied indication of a FULL DISCONNECTION or MICRO-DISCONNECTION

3.4.5DV D2 *Modification of Clause 3.4.5 definition as follows:*

Add "that is mechanically secured (see 9.4.4DV)." after "MICRO-DISCONNECTION"

3.4.6
ELECTRONIC DISCONNECTION
non-cycling interruption by an ELECTRONIC DEVICE of a circuit for functional disconnection and which provides a disconnection other than by means of an air gap by satisfying certain electrical requirements in at least one pole

Note 1 to entry: ELECTRONIC DISCONNECTION ensures that, for all non-SENSING CONTROLS, the function controlled by the disconnection is secure and that, for all SENSING CONTROLS, the function controlled is secure between the limits of the ACTIVATING QUANTITY declared in Table 1, requirement 30.

The disconnection may be obtained by an AUTOMATIC ACTION or a MANUAL ACTION.

Some CONTROLS may incorporate circuit disconnections of more than one form.

3.5 Definitions of types of control according to construction

3.5.1
INTEGRATED CONTROL
CONTROL which is dependent on its correct mounting and fixing in an equipment, and which can only be tested in combination with the relevant parts of the equipment

Note 1 to entry: INTEGRATED CONTROL also denotes a CONTROL which is part of a more complex CONTROL (electrical or non-electrical).

3.5.2
INCORPORATED CONTROL
CONTROL intended to be mounted in, or on, an equipment, but which can be tested separately

Note 1 to entry: The fact that an INCORPORATED CONTROL can be tested separately does not imply that it is not allowed to be tested in an equipment as specified in 4.3.4.1.1.

Note 2 to entry: INCORPORATED CONTROL also denotes a CONTROL intended for incorporation in or on a more complex CONTROL (electrical or non-electrical).

3.5.3
IN-LINE CORD CONTROL
separately cased CONTROL intended to be connected to the supply and to the equipment by means of flexible cords, equipment inlets or socket-outlets, and is intended to be manually actuated

Note 1 to entry: A fuse in the plug is not regarded as a part of the CONTROL.

3.5.3DV D2 *Modification of Clause 3.5.3 NOTE 1 as follows:*

NOTE 1DV: A fuse in the plug is regarded to be part of the CONTROL if the cord is non-detachable using attachment methods Y or Z.

3.5.4
FREE-STANDING CONTROL
IN-LINE CORD CONTROL intended to stand on a table or on the floor

Note 1 to entry: It may be actuated by hand, by foot or by other similar human activity.

3.5.5
INDEPENDENTLY MOUNTED CONTROL
CONTROL intended for permanent connection to FIXED WIRING, but intended to be mounted separately from the controlled equipment

Note 1 to entry: It may be either:

– for surface mounting such as on to a wall;

– for flush mounting, such as into a wall cavity, when installation shall be possible from the front;

– for panel mounting, such as onto or into a CONTROL panel, when installation may be from the rear.

3.5.6
PULL-CORD ACTUATED CONTROL
CONTROL intended to be mounted in, or on, an equipment and actuated by means of a PULL-CORD

3.5.7
ELECTRONIC CONTROL
CONTROL which incorporates at least one ELECTRONIC DEVICE

3.5.8
ELECTRONIC DEVICE
a device in which conduction is principally by electrons moving through a vacuum, gas or semi-conductor

[SOURCE: IEC 60050-531:1974, 531-11-01]

3.5.9
ELECTRONIC ASSEMBLY
group of components, at least one of which is an ELECTRONIC DEVICE, but in which individual parts can be replaced without damage to the assembly

Note 1 to entry: An example of this is a group of components mounted on a printed circuit board.

3.5.10
INTEGRATED CIRCUIT
microcircuit in which all or some of the circuit elements are inseparably associated and electrically interconnected so that it is considered to be indivisible for the purpose of construction and commerce

[SOURCE: IEC 60050-521:2002, 521-10-03]

3.5.11
HYBRID CIRCUIT
circuit produced on ceramic substrate by means of thick-film, thin-film or surface-mounted devices (SMD) technology, without accessible electrical connections except for I/O points, and with all internal connections constructed as part of a lead frame or other integral construction

3.5.12
TWO-STEP ACTUATION
sequential performance of two distinct movements of the ACTUATING MEMBER

3.6 Definitions of type of automatic action of a control

3.6.1
TYPE 1 ACTION
AUTOMATIC ACTION for which the MANUFACTURING DEVIATION and the DRIFT of its OPERATING VALUE, OPERATING TIME or OPERATING SEQUENCE have not been declared and tested under this document

3.6.2
TYPE 2 ACTION
AUTOMATIC ACTION for which the MANUFACTURING DEVIATION and the DRIFT of its OPERATING VALUE, OPERATING TIME or OPERATING SEQUENCE have been declared and tested under this document

3.7 Definitions relating to protection against electric shock and type of insulation

3.7.1
LIVE PART
conductor or conductive part intended to be energized in NORMAL USE, including a neutral conductor, but by convention not a PEN conductor or PEM conductor or PEL conductor

Note 1 to entry: Accessible parts complying with 6.1.1 are not considered to be LIVE PARTS.

Note 2 to entry: Definitions for PEN, PEM and PEL can be found in IEC 61140:2016.

3.7.2
HAZARDOUS LIVE PART
live part that, under certain conditions, can give a harmful electric shock

[SOURCE: IEC 60050-195:2021, 195-06-05, modified – Note 1 to entry not included.]

3.7.3
CLASS 0 CONTROL
CONTROL in which protection against electric shock relies upon BASIC INSULATION

Note 1 to entry: This implies that there are no means for the connection of accessible conductive parts, if any, to the PROTECTIVE CONDUCTOR in the FIXED WIRING of the installation; reliance in the event of a FAILURE of the BASIC INSULATION is placed upon the environment.

Note 2 to entry: An earthing terminal is only allowed if it is for continuity or functional (as distinct from protective) purposes.

3.7.4
CLASS 0I CONTROL
IN-LINE CORD CONTROL having at least BASIC INSULATION throughout and provided with a protective earthing terminal but with a NON-DETACHABLE CORD without protective earthing conductor, and a plug without protective earthing contact which cannot be introduced into a socket-outlet with protective earthing contact

Note 1 to entry: An earthing terminal is only allowed if it is for continuity (as distinct from protective) purposes.

3.7.4DV DR *Modification of Clause 3.7.4 by adding the following text after NOTE 1:*

CLASS 0I CONTROL is not applicable.

3.7.5
CLASS I CONTROL
CONTROL in which protection against shock does not rely on BASIC INSULATION only, but which includes an additional safety precaution in such a way that means are provided for the connection of accessible conductive parts to the protective earthing conductor in the FIXED WIRING of the installation in such a way that accessible conductive parts cannot become live in the event of a FAILURE of the BASIC INSULATION

Note 1 to entry: This provision includes a PROTECTIVE CONDUCTOR as part of the flexible cord or cable. When CLASS I CONTROLS are fitted with a two-core flexible cord or cable with a plug which cannot be introduced into a socket-outlet with earthing contact, the protection is then equivalent to that of class 0. However,the earthing provisions of the equipment in all other respects should fully comply with the requirements of class I.

Note 2 to entry: CLASS I CONTROLS may have parts with DOUBLE INSULATION or parts that provide protection against electric shock by SELV or PELV.

3.7.6
CLASS II CONTROL
CONTROL in which protection against electric shock does not rely on BASIC INSULATION only, but in which additional protective precautions, such as DOUBLE INSULATION or REINFORCED INSULATION, are provided, there being no provision for protective earthing or reliance upon installation conditions

Note 1 to entry: Such a CONTROL may be one of the types defined in 3.7.6.1 to 3.7.6.3.

Note 2 to entry: CLASS II CONTROLS may have parts that provide protection against electric shock by use of SELV.

Note 3 to entry: CLASS II CONTROLS cannot have parts that provide protection against electric shock by use of PELV, as such circuits require connection to an earthing terminal.

3.7.6.1
INSULATION-ENCASED CLASS II CONTROL
CONTROL having a durable and substantially continuous enclosure of insulation material which envelopes all metal parts, with the exception of small parts, such as name plates, screws and rivets, which are isolated from LIVE PARTS by insulation at least equivalent to REINFORCED INSULATION

3.7.6.2
METAL-ENCASED CLASS II CONTROL
CONTROL having a substantially continuous metal enclosure in which DOUBLE INSULATION is used throughout, except for those parts where REINFORCED INSULATION is used, because the application of DOUBLE INSULATION is manifestly impracticable

3.7.6.3
COMBINATION INSULATION-ENCASED/METAL-ENCASED CLASS II CONTROL
CONTROL which is a combination of the types described in 3.7.6.1 and 3.7.6.2

Note 1 to entry: The enclosure of an all-insulated CLASS II CONTROL may form a part or the whole of the supplementary insulation or of the REINFORCED INSULATION. If a CONTROL with DOUBLE INSULATION and/or REINFORCED INSULATION throughout has an earthing terminal or earthing contact, it is deemed to be of class 0I or class I construction.

3.7.7
CLASS III CONTROL
CONTROL relying on limitation of voltage in 3.1.5 values as provision against electric shock for basic protection and

• with no provision for FAULT protection;

• which for supply are only connected to a SELV SYSTEM or a PELV SYSTEM, to form part of that SYSTEM;

• where internal circuits do not operate at a higher level than ELV;

• where in case of a single FAULT within the CONTROL no steady state touch voltage can appear or be generated exceeding ELV level; and

• not provided with a means of connection for a PROTECTIVE CONDUCTOR

3.7.8
DETACHABLE PART
part that

• can be removed or opened without the aid of a tool, or

• can be removed or opened with a tool according to the NORMAL USE and user maintenance as declared by the control manufacturer, or

• does not fulfil the test of 9.11.1.3

3.7.9
ACCESSIBLE PART OR ACCESSIBLE SURFACE
part or surface which can be touched by the test finger of Figure 5, when the CONTROL is mounted as in NORMAL USE, and after DETACHABLE PARTS have been removed

3.7.9DV D2 *Modification of Clause 3.7.9 as follows:*

Replace "Figure 5" with "Figure R33DV.2".

3.7.10 Definitions relating to type of insulation

NOTE In 3.7.10.1 through 3.7.10.5, the following abbreviations are used:

L LIVE PART;

A ACCESSIBLE PART (either conductive or an insulating surface);

I intermediate part.

3.7.10.1
FUNCTIONAL INSULATION
insulation between LIVE PARTS which have a potential difference between them, and which insulation is necessary for the correct OPERATION of the CONTROL or controlled equipment (L-L)

3.7.10.2
BASIC INSULATION
insulation applied to LIVE PARTS to provide basic protection against electric shock (L-A or L-I)

Note 1 to entry: BASIC INSULATION includes insulation between LIVE PARTS and

– intermediate conductive parts or metal foil over intermediate insulating surfaces (class II situation);

– accessible conductive parts (class 0, 0I, I situations);

– conductive parts connected to accessible conductive parts (class 0, 0I, I situations);

– metal foil over accessible insulating surfaces (class 0 situation).

3.7.10.3
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 (I-A)

Note 1 to entry: It includes insulation between intermediate conductive parts, or metal foil over intermediate insulating surfaces and

– accessible conductive parts (class II situation);

– conductive parts connected to accessible conductive parts (class II situation);

– metal foil over accessible insulating surfaces (class II situation).

3.7.10.4
REINFORCED INSULATION
single insulation SYSTEM applied to LIVE PARTS, which provides a degree of protection against electric shock equivalent to DOUBLE INSULATION under the conditions specified in this document (L-A)

Note 1 to entry: It includes insulation between LIVE PARTS and

– accessible conductive parts;

– conductive parts connected to accessible conductive parts;

– metal foil over accessible insulating surfaces.

Note 2 to entry: The term "insulation system" does not imply that the insulation must be one homogeneous piece. It may comprise several layers which cannot be tested singly as SUPPLEMENTARY INSULATION or BASIC INSULATION.

3.7.10.5
DOUBLE INSULATION
insulation comprising both BASIC INSULATION and SUPPLEMENTARY INSULATION (L-I-A)

[SOURCE: IEC 60050-195:2021, 195-06-08]

3.7.11
PROTECTIVE IMPEDANCE
impedance connected between live parts and accessible conductive parts, of such value that the current, in normal use and under likely FAULT conditions in the equipment, is limited to a safe value

3.7.12
EQUIPOTENTIAL BONDING
set of electric connections intended to achieve equipotentiality between conductive parts

[SOURCE: IEC 60050-195:2021, 195-01-10]

3.7.12.1
PROTECTIVE EQUIPOTENTIAL BONDING
EQUIPOTENTIAL BONDING for the purposes of electrical safety

Note 1 to entry: Functional EQUIPOTENTIAL BONDING is defined in IEC 60050-195:2021,195-01-16].

[SOURCE: IEC 60050-195:2021, 195-01-15, modified – Note 1 to entry has been added.]

3.7.12.1DV DR *Modification of Clause 3.7.12.1 to replace Note 1 with the following:*

NOTE 1DV to entry: Requirements for EQUIPOTENTIAL BONDING can be found in the National Electrical Code (NEC), NFPA 70 for the installation of buildings.

3.7.13
EXPOSED CONDUCTIVE PART
conductive part of equipment that can be touched and that is not live under normal conditions, but that can become live when BASIC INSULATION fails

Note 1 to entry: A conductive part of a CONTROL which can only become live through contact with an EXPOSED CONDUCTIVE PART which has become live is not considered to be an EXPOSED CONDUCTIVE PART itself.

[SOURCE: IEC 60050-195:2021, 195-06-10, modified – Note 1 to entry has been added.]

3.7.14
CONDUCTIVE SCREEN
screen of conductive material intended to reduce the penetration of an electric field

[SOURCE: IEC 60050-195:2021, 195-02-38]

3.7.15
PROTECTIVE SCREEN, <ELECTRICALLY>
CONDUCTIVE SCREEN used to separate an electric circuit and/or conductors from hazardous-live-parts

[SOURCE: IEC 60050-195:2021, 195-06-17]

3.7.16
PROTECTIVE SCREENING, <ELECTRICALLY>
separation of electric circuits and/or conductors from HAZARDOUS LIVE PARTS by an ELECTRICALLY PROTECTIVE SCREEN connected to the PROTECTIVE EQUIPOTENTIAL BONDING SYSTEM and intended to provide protection against electric shock

[SOURCE: IEC 60050-195:2021, 195-06-18]

3.7.17
SIMPLE SEPARATION
separation between electric circuits or between an electric circuit and protective earth by means of BASIC INSULATION

[SOURCE: IEC 60050-826:2004, 826-12-28; modified by replacing "local" by "protective"]

3.7.18
PROTECTIVE SEPARATION,, <ELECTRICALLY>
separation of one electric circuit from another by means of basic protection and fault protection

[SOURCE: IEC 60050-195:2021, 195-06-19]

3.7.19
PROTECTIVE EARTHING
earthing for purposes of electrical safety

[SOURCE: IEC 60050-195:2021, 195-01-11]

3.7.20
FUNCTIONAL EARTHING
earthing for purposes other than electrical safety

[SOURCE: IEC 60050-195:2021, 195-01-13]

3.7.21DV D2 ***Add the following definitions to Clause 3:***

3.7.21DV.1
PROTECTIVE BONDING CONDUCTOR
a conductor in the equipment, or a combination of conductive parts in the equipment, connecting a main protective earthing terminal to a part of the equipment that is required to be earthed

3.7.21DV.2
PROTECTIVE EARTHING CONDUCTOR
a conductor connecting the main protective earthing terminal or lead in the equipment to the building earth, or in the power SUPPLY CORD, connecting a main protective earthing terminal in the equipment to an earth point in the building installation

3.8 Definitions relating to component parts of controls

3.8.1
SENSING ELEMENT
that part of the CONTROL which is intended to be exposed to the influences of the ACTIVATING QUANTITY to which the AUTOMATIC ACTION of a SENSING CONTROL responds

3.8.2
SWITCH HEAD
complete CONTROL, except for any SENSING ELEMENT

Note 1 to entry: If by construction it is impossible to distinguish between the SWITCH HEAD and the SENSING ELEMENT, then the whole control is considered to be the SENSING ELEMENT.

3.8.3
ACTUATING MEMBER
that part which is manually moved, pulled, pushed or turned to cause INITIATION of a CONTROL action, or for SETTING BY THE USER

Note 1 to entry: The term "ACTUATING MEMBER" does not include any device such as a set-screw used for SETTING BY THE CONTROL MANUFACTURER if such a device is adequately locked against further movement, or if a TOOL is required for such SETTING BY THE CONTROL MANUFACTURER.

3.8.4
ACTUATING MEANS
any part which connects the ACTUATING MEMBER to the mechanism of the CONTROL

3.8.5
PULL-CORD
flexible ACTUATING MEMBER which is pulled to cause ACTUATION

3.8.6
PRIME MOVER
any device used to produce the mechanical energy required to provide the TRANSMISSION for an AUTOMATIC CONTROL, such as an ELECTRICALLY OPERATED CONTROL, an ELECTRICALLY OPERATED VALVE, an ELECTRICALLY OPERATED MECHANISM or a TIME-BASED CONTROL

Note 1 to entry: It may be a mechanical storage device (for example, a clockwork spring), an electro-magnetic device (for example, an electric motor, or stepping solenoid), an electro-thermal device (for example, the heating element of an ENERGY REGULATOR) or any other mechanism producing mechanical energy.

3.8.7
CLUTCH
mechanical device by which an ACTUATING MEMBER can override either a PRIME MOVER or an ACTIVATING QUANTITY, causing or allowing the INITIATION or cancellation of an action

3.8.8
COVER
COVER PLATE
part which is accessible when the CONTROL is mounted as in NORMAL USE and which can be removed only with the aid of a TOOL

Note 1 to entry: It shall not require the use of a SPECIAL PURPOSE TOOL for its removal.

3.8.9
SCREWLESS FIXED PART (OR COMPONENT)
ACCESSIBLE PART (or component) which, after attachment, installation, mounting or assembly into or onto an equipment or another component, or to a specially prepared support, is retained in position by positive means which do not depend on screws

Note 1 to entry: Disassembly or removal may require the use of a tool, either applied directly to the part (or component), or to obtain access to the retaining means.

Note 2 to entry: The following are some examples of parts which are not regarded as SCREWLESS FIXED PARTS or COMPONENTS:

– parts of components fixed permanently by rivets, glueing or similar means;

– flat, push-on connectors;

– SCREWLESS TERMINALS;

– standard plugs and socket-outlets;

– standard appliance couplers, even if such have additional latching devices to prevent a single action uncoupling;

– the replacement of a lamp in a bayonet type lampholder;

– twist-lug construction;

– friction-fit construction.

3.9 Definitions of types of terminals and terminations of controls

3.9.1
PILLAR TERMINAL
terminal in which the conductor is inserted into a hole or cavity, where it is clamped under the shank of the screw or screws

Note 1 to entry: The clamping pressure may be applied directly by the shank of the screw, or through an intermediate clamping member to which pressure is applied by the shank of the screw (see Figure 12).

3.9.2
SCREW TERMINAL
terminal in which the conductor is clamped under the head of the screw

Note 1 to entry: The clamping pressure may be applied directly by the head of the screw, or through an intermediate part, such as a washer, a clamping plate or an anti-spread device (see Figure 11).

3.9.3
STUD TERMINAL
terminal in which the conductor is clamped under a nut

Note 1 to entry: The clamping pressure may be applied directly by a suitably shaped nut, or through an intermediate part, such as a washer, a clamping plate or an anti-spread device (see Figure 11).

3.9.4
SCREWLESS TERMINAL
terminal in which the connection of the conductor is achieved directly or indirectly by means of springs, wedges, eccentrics, cones or the like

Note 1 to entry: The following are not regarded as SCREWLESS TERMINALS:

– terminals requiring the fixing of special devices to the conductors before clamping them in the terminal, for example, FLAT PUSH-ON CONNECTORS;

– terminals requiring wrapping of the conductors, for example, those with wrapped joints;

– terminals providing direct contact to the conductors by means of edges or points penetrating the insulation.

3.9.5
FLAT PUSH-ON CONNECTOR
assembly of a TAB and a RECEPTACLE enabling the connection, at will, of a core or conductor to a CONTROL or to another core or conductor

3.9.6
RECEPTACLE
female part of a FLAT PUSH-ON CONNECTOR intended to be permanently attached to a core or conductor (see Figure 17)

3.9.7
TAB
male part of a FLAT PUSH-ON CONNECTOR (see Figure 15 and Figure 16)

3.9.8
IN-LINE TAB
TAB intended to be permanently attached to a core or conductor

3.9.9
TAB FORMING PART OF A CONTROL
TAB permanently attached to, or an integral part of, a CONTROL

3.9.10
TERMINATION
part by which a conductor can be connected to a CONTROL in such a way that its replacement requires either a SPECIAL PURPOSE TOOL, a special process or a specially prepared end of the conductor

Note 1 to entry: Soldering requires a SPECIAL PURPOSE TOOL. Welding requires a special process. A cable lug attached to a conductor is a specially prepared end.

3.9.11
SOLDER TERMINATION
TERMINATION in which the conductor is secured by a mechanical means, and the circuit continuity is assured by solder

3.9.12
SADDLE TERMINAL
terminal in which the conductor is clamped under a saddle by means of two or more screws or nuts (see Figure 14a)

3.9.13
LUG TERMINAL
SCREW TERMINAL or STUD TERMINAL, intended to clamp a cable lug or bar by means of a screw or nut (see Figure 14b)

3.9.14
MANTLE TERMINAL
terminal in which the conductor is clamped against the base of a slot in a threaded stud by means of a nut

Note 1 to entry: The conductor is clamped against the base of the slot by a suitably shaped washer under the nut, by a central peg if the nut is a cap nut or equally effective means for transmitting the pressure from the nut to the conductor within the slot (see Figure 13).

3.9.15
PROTECTIVE BONDING TERMINAL
terminal intended for PROTECTIVE EQUIPOTENTIAL BONDING purposes

Note 1 to entry: Examples are a PROTECTIVE SCREEN- or PE-terminal of a CONTROL or equipment.

3.9.16
PROTECTIVE CONDUCTOR
PE
conductor provided for purposes of electrical safety

[SOURCE: IEC 60050-195:2021, 195-02-09]

3.10 Definitions relating to the connections to controls

3.10.1
EXTERNAL CONDUCTOR
any cable, flexible cord, core or conductor, a part of which is external to an IN-LINE CORD CONTROL, an INDEPENDENTLY MOUNTED CONTROL or to an equipment in or on which a CONTROL is mounted

Note 1 to entry: Such a conductor may be a supply lead, a function cord or interconnecting cord between different parts of an equipment; or it may form part of the FIXED WIRING.

3.10.2
FIXED WIRING
any EXTERNAL CONDUCTOR which is permanently secured to the fabric of the building such that, in NORMAL USE at the point at which the conductor enters the equipment or CONTROL, there is no likelihood of any strain being applied to the conductor

Note 1 to entry: Such securing to the fabric of the building may be, for example, by the enclosing of conductors in conduit, burying cables in walls, adequately fixing cables or cords to walls or other surfaces, etc.

3.10.3
INTERNAL CONDUCTOR
any cable, flexible cord, core or conductor which is neither an EXTERNAL CONDUCTOR, nor an INTEGRATED CONDUCTOR

Note 1 to entry: An example is a conductor inside the equipment to interconnect the CONTROL and the equipment.

3.10.4
INTEGRATED CONDUCTOR
conductor which is inside a CONTROL, or is used to permanently interconnect terminals or TERMINATIONS of a CONTROL

3.10.5
DETACHABLE CORD
flexible external cord connected to a CONTROL or equipment by means of an equipment inlet, or plug and socket arrangement

3.10.6
NON-DETACHABLE CORD
flexible EXTERNAL CONDUCTOR connected to, or assembled to, a CONTROL according to one of the methods in 3.10.6.1 to 3.10.6.4

3.10.6.1
TYPE X ATTACHMENT
method of attachment such that the cord can be easily replaced without SPECIAL-PURPOSE TOOLS, using standard cords without any special preparation

3.10.6.2
TYPE M ATTACHMENT
method of attachment such that the cord can be easily replaced without SPECIAL PURPOSE TOOLS, but is intended to use only a special cord, such as one with a moulded-on cord guard, or one with special prepared ends

Note 1 to entry: This attachment method does not apply if it is possible to fit a standard cord during SERVICING unless such is permitted by a particular equipment standard.

3.10.6.3
TYPE Y ATTACHMENT
method of attachment of the supply cord such that any replacement is intended to be made by the manufacturer, its service agent or a similar qualified person

3.10.6.4
TYPE Z ATTACHMENT
method of attachment such that the flexible cable or cord cannot be replaced without breaking or destroying a part of the CONTROL

3.10.7
PRIMARY BATTERY
CELL
any kind of electrochemical CELL in which the electrochemical reaction of interest is not reversible

Note 1 to entry: An example is an alkaline battery.

3.10.8
SECONDARY BATTERY
RECHARGEABLE CELL
any kind of electrochemical CELL in which the electrochemical reaction of interest is reversible

Note 1 to entry: A rechargeable battery is a group of two or more secondary CELLS.

Note 2 to entry: Examples of rechargeable batteries are nickel metal hydride (NiMH), lithium ion (Li-ion) etc.

3.11 Definitions relating to the performance of type 2 actions

3.11.1
MANUFACTURING DEVIATION
maximum difference of OPERATING VALUE, OPERATING TIME or OPERATING SEQUENCE which is claimed between any two CONTROLS, supplied by the manufacturer to a UNIQUE TYPE REFERENCE, when tested as submitted and in the same manner

Note 1 to entry: The difference may be related to an absolute value if permitted by the appropriate subclause of Clause 17.

3.11.2
DRIFT
maximum alteration of OPERATING VALUE, OPERATING TIME or OPERATING SEQUENCE of any one sample which can occur when it is tested under the conditions specified in this document

Note 1 to entry: The alteration may be related to an absolute value, or combined with the MANUFACTURING DEVIATION, if permitted by the appropriate subclause of Clause 17.

3.12 Definitions relating to the requirements for creepage distances and clearances

3.12.1
CLEARANCE
shortest distance through air between two conductive parts, or between a conductive part and a metal foil in contact with a surface of insulating material

Note 1 to entry: The method of measurement is detailed in Annex B and Figure 18.

3.12.2
CREEPAGE DISTANCE
shortest distance along the surface of the insulating material between two conductive parts, or between a conductive part and a metal foil in contact with any ACCESSIBLE SURFACE of insulating material

Note 1 to entry: The method of measurement is detailed in Annex B and Figure 18.

3.12.3
POLLUTION
any addition of foreign matter, solid, liquid, or gaseous that can result in a reduction of electric strength or surface resistivity of the insulation

3.12.4 Definitions relating to the environment

3.12.4.1
MACRO-ENVIRONMENT
environment of the room or other location in which the equipment is installed or used

3.12.4.2
MICRO-ENVIRONMENT
environment in the immediate surrounding of an insulation, which particularly influences the dimensioning of clearances and CREEPAGE DISTANCES

3.12.4.3
POLLUTION DEGREE
numeral characterizing the expected POLLUTION of the MICRO-ENVIRONMENT

Note 1 to entry: POLLUTION DEGREES 1, 2, 3, and 4 are used. See Annex F.

3.13 Miscellaneous definitions

3.13.1
UNIQUE TYPE REFERENCE
marking such that by quoting it in full to the manufacturer of the CONTROL, a replacement can be supplied which will be fully interchangeable with the original, electrically, mechanically, dimensionally and functionally

3.13.2
TOOL
screwdriver, a coin or any other object which can be used to operate a nut, a screw or similar part

3.13.3
SPECIAL-PURPOSE TOOL
TOOL which is unlikely to be readily available in a normal household, for example, a key for a hexagonal socket-headed screw

Note 1 to entry: TOOLS such as coins, screwdrivers and spanners intended to operate square, or hexagonal nuts, are not SPECIAL-PURPOSE TOOLS.

3.13.4
NORMAL USE
use of the CONTROL, or its associated equipment, for the purpose for which it was made, and in the manner intended by the manufacturer

Note 1 to entry: NORMAL USE includes any overload, or abnormal operating conditions specified in the equipment standard.

Note 2 to entry: NORMAL USE does not include any process which is necessary to maintain the CONTROL or equipment in good order, even though this may be carried out by the USER according to the manufacturer's instructions.

Note 3 to entry: NORMAL USE may include standby mode and one or more operating modes.

3.13.5
USER MAINTENANCE
any periodic process necessary to maintain the CONTROL, or equipment, in good order, for which details are given in the manufacturer's instructions to the USER

3.13.6
SERVICING
any process necessary to maintain a CONTROL, or equipment, in good order, that would be done by a competent person, such as in a workshop, by an electrician or by a service organization

Note 1 to entry: This includes replacing a flexible cord, thermal link or the like.

3.13.7
MANUFACTURER SERVICING
SERVICING which can only be done by the manufacturer, or his accredited serviceman

Note 1 to entry: This may be due to the need for SPECIAL PURPOSE TOOLS, or special instrumentation, and includes the SETTING BY THE CONTROL MANUFACTURER.

3.13.8
FAILURE
termination of the ability of an item to perform a required function

[SOURCE: IEC 60050-603:1986, 603-05-06]

3.13.9
FAULT
state of an item characterised by its inability to perform a required function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external resources

Note 1 to entry: "FAILURE" is an event, as distinguished from "FAULT", which is a state.

Note 2 to entry: After FAILURE, the item has a FAULT.

Note 3 to entry: This concept as defined does not apply to items consisting of software only.

Note 4 to entry: A FAULT is often the result of a FAILURE of the item itself, but may exist without prior FAILURE.

3.13.10
SMART GRID
INTELLIGENT GRID
electric power SYSTEM that utilizes information exchange and CONTROL technologies, distributed computing and associated sensors and actuators, for purposes such as:

– to integrate the behaviour and actions of the network USERS and other stakeholders,

– to efficiently deliver sustainable, economic and secure electricity supplies

[SOURCE: IEC 60050-617:2009+AMD1:2011, 617-04-13]

3.13.11
SMART ENABLED CONTROL
CONTROL that integrates or uses one or more of the following functionalities:

– power demand response from the smart grid,

– demand signals from energy-consuming equipment,

– communications technology IoT,

– data analytics,

– control functions to optimize energy efficiency and deliver on operational requirements.

Note 1 to entry: For example, smart grid control, remote interfaces/control of energy-consuming equipment including computer or smart phone.

3.13.12
INTENTIONALLY WEAK TRACE
printed circuit board trace intended to rupture under conditions of abnormal operation to prevent the occurrence of a condition which could impair compliance with this document

Note 1 to entry: See 9.1.4.

3.14 Definitions relating to manufacturer and user

3.14.1
CONTROL MANUFACTURER
manufacturer of the CONTROL

3.14.2
EQUIPMENT MANUFACTURER
manufacturer of equipment in which, on which, or together with which the CONTROL is used

3.14.2DV D2 *Modification of Clause 3.14.2 to add the following NOTE:*

Note DV1 to entry: In the USA, the EQUIPMENT MANUFACTURER is indicated as the OEM (original equipment manufacturer). The OEM receives CONTROLS from control manufacturers for integration or incorporation into equipment.

3.14.3
INSTALLER
person qualified to install the CONTROL and possibly the associated equipment

3.14.4
USER
one who uses the CONTROL with the aid of documentation (USER MAINTENANCE) during its normal life

Note 1 to entry: The USER is considered a layman.

3.15 Definitions pertaining to thermistors

See J.3.15.

3.16 Definitions relating to the structure of controls using software

See H.3.16.

3.17 Definitions relating to error avoidance in controls using software

See H.3.17.

3.18 Definitions relating to fault/error control techniques for controls using software

See H.3.18.

3.19 Definitions relating to memory tests for controls using software

See H.3.19.

3.20 Definitions of software terminology – General

See H.3.20.

3.21 Definitions relating to classes of control functions

See H.3.21.

3.22 Definitions relating to functional safety

See H.3.22.

3.23 Definitions related to access to data exchange

See H.3.23.

3.24 Definitions related to EMC performance

3.24.1
PORT
particular interface of the equipment which couples this equipment with or is influenced by the external electromagnetic environment

Note 1 to entry: See Figure 1.

Note 2 to entry added: I/O ports are input, output or bi-directional, measurement, control, or data ports.

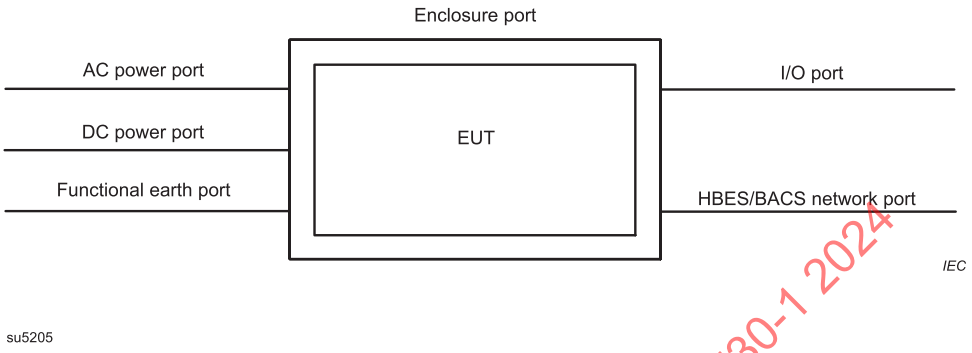


Figure 1

Example of ports

[SOURCE: IEC 61000-6-1:2016: 3.1, modified − Note 1 to entry, modified Figure 1]

3.24.2
ENCLOSURE PORT
physical boundary of the equipment through which electromagnetic fields can radiate or impinge

[SOURCE: IEC 61000-6-1:2016: 3.2, modified – "may" changed to "can"]

3.24.3
I/O PORT
port at which a conductor or cable intended to carry signals is connected to the equipment

EXAMPLE Analog/digital inputs, outputs and control lines, data buses, communication networks other than HBES/BACS networks (3.24.10), etc

[SOURCE: IEC 61000-6-1:2016: 3.3; modified – "signal/control port" changed to "I/O port", example added with digital inputs/outputs and the exclusion for HBES/BACS networks]

3.24.4
DC POWER PORT
port used to connect to a low voltage DC power generating SYSTEM, energy storage or DC distribution network to power the equipment

[SOURCE: IEC 61000-6-3:2020, 3.1.13, modified – Note 1 to entry is removed]

3.24.5
DC DISTRIBUTION NETWORK
local DC electricity supply network in the infrastructure of a certain site or building intended for flexible use by one or more different types of equipment and ensuring continuous power supply independently from the conditions of the public mains network

Note 1 to entry: Connection to a remote local battery is not regarded as a DC distribution network, if such a link comprises only supply for a single piece of equipment

[SOURCE: IEC 61000-6-1:2016, 3.10]

3.24.6
EUT
equipment under test

3.24.7
RESIDENTIAL ELECTROMAGNETIC ENVIRONMENT
electromagnetic environment at a location including commercial, public and light-industrial locations where there is a level of electromagnetic interference normally expected in houses, shops, and business premises, cinemas, sports centres, workshops and laboratories for example

EXAMPLE 1 of residential locations are: houses, apartments, farm buildings used for living.

EXAMPLE 2 of commercial, public or light industrial are:

• retail outlets, for example shops, supermarkets;

• business premises, for example offices, banks, hotels, data centres;

• areas of public entertainment, for example cinemas, public bars, dance halls;

• places of worship;

• general public locations, for example parks, amusement facilities, public offices;

• hospitals, educational institutions, for example schools, universities, colleges;

• public traffic area, railway stations, and public areas of an airport;

• light-industrial locations, for example workshops, laboratories, service centres.

3.24.8
INDUSTRIAL ELECTROMAGNETIC ENVIRONMENT
location where the totality of electromagnetic phenomena is characterized by a separate power network, supplied from a high- or medium-voltage transformer, dedicated for the supply of the installation

EXAMPLE Metalworking, pulp and paper, chemical plants, car production, farm building, high-voltage areas of airports.

Note 1 to entry: Industrial locations can generally be described by the existence of an installation with one or more of the following characteristics:

– items of equipment installed and connected together and working simultaneously;

– significant amount of electrical power generated, transmitted and/or consumed;

– frequent switching of heavy inductive or capacitive loads;

– high currents and associated magnetic fields;

– presence of industrial, high power scientific and medical (ISM) equipment (for example, welding machines).

The electromagnetic environment at an industrial location is predominantly produced by the equipment and installation present at the location. There are types of industrial locations where some of the electromagnetic phenomena appear in a more severe degree than in other installations.

Note 2 to entry: In general, the electromagnetic environment is time-dependent and its description may need a statistical approach.

Note 3 to entry: It is very important not to confuse the electromagnetic environment and the location itself.

[SOURCE: IEC 61000-6-2:2016, 3.7 and 3.8 combined and modified to one definition]

3.24.9
LONG-DISTANCE LINES
lines within a building which are longer than 30 m, or which leave the building (including lines of outdoor installations)

[SOURCE: IEC 61000-6-1:2016, 3.6, modified – definition extended to all lines instead of lines connected to signal/control ports]

3.24.10
HBES/BACS NETWORK PORT
port at which a conductor or cable intended to carry communication signals between the different devices of the HBES/BACS network is connected to the apparatus

Note 1 to entry: For test purposes, the HBES/BACS network port is equivalent to the telecommunications/network port according to IEC 61000-6-3.

Note 2 to entry: (HBES) Home and Building Electronic Systems and (BACS) Building Automation and Control Systems

[SOURCE: IEC 63044-5-1:2017, 3.1.5, modified – Note 2 to entry has been added]

4 General

4.1 General structure of the document

The clauses of this document are grouped into two sections of requirements, where

• the first section consists of Clauses 5 to 13 that, in general, addresses the construction of the product. It is noted that certain construction requirements have verification requirements integrated within the clause to facilitate usage of the document, and

• the second section consists of the of Clauses 14 to 26 that addresses the verification requirements.

NOTE For explanation of the word "Verification", see IEC 60050-192:2015,192-01-17.

The above structure is also applied to Annex H, Annex I and Annex J.

The requirements of this document have been structured based on two basic safety principles – inherent safety and functional safety.

Inherent safety is related to the potential risk of electric shock, fire and personal injury that exists within the design of the control, under normal and abnormal operation of the control and independent of any declaration to output functions. All controls, independent of their classification, shall comply with the requirements for inherent safety.

Requirements that relate to the inherent safety of all products covered under the scope of this document are located in the main body of the document.

Functional safety is related to the correct operation of the declared safety related function(s), failure or malfunction of which can cause a hazard. The hazard could result from a loss of protective function (output function) leading to a risk of explosion, excessive temperature, electric shock, fire and/or personal injury,

etc. The requirements for functional safety, which are relevant for a control, depend on the classification of the output function.

Requirements that relate to functional safety are specified in Annex H of this document and shall be used in conjunction with the requirements of the main part, when applicable. Since some requirements are applicable for both inherent and functional safety, e.g. Table 14 showing the FAULT modes for electronic components used for the FAULT assessment, the place for those requirements were chosen as appropriate.

A pictorial representation of the document structure and applicable requirements are noted below in Figure 2:

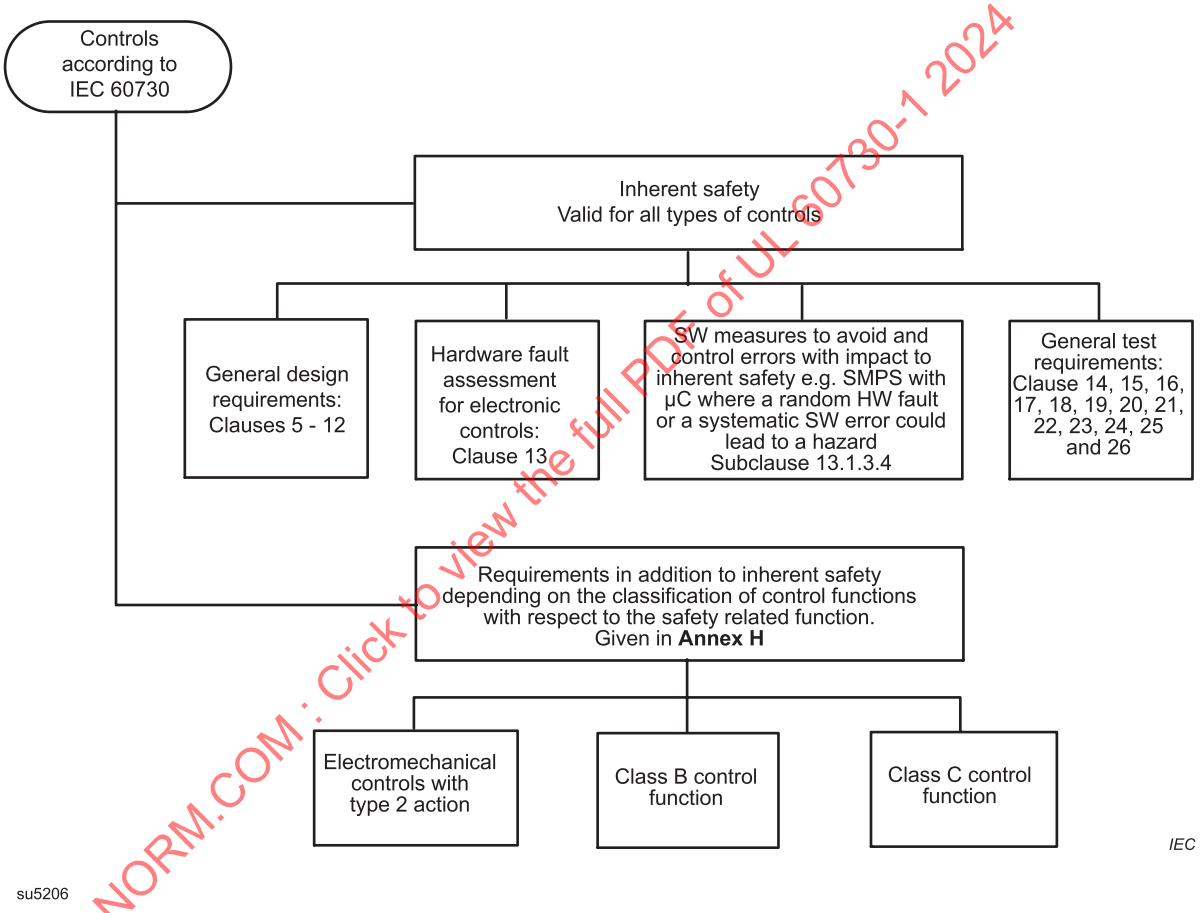


Figure 2

Structure of the document with respect to inherent safety and functional safety

4.2 General requirements

CONTROLS shall be so designed and constructed that in NORMAL USE, they function so as not to cause injury to persons or damage to surrounding property, even in the event of such carelessness as can occur in NORMAL USE.

In general, compliance is checked by carrying out the relevant tests specified in this document and the appropriate part 2, if any.

4.2DV DR *Modification of Clause 4.2 by adding the following after "the appropriate part 2, if any.":*

In addition, controls shall be constructed so as to be installable in accordance with the National Electrical Code, NFPA 70.

4.3 General notes on tests

4.3.1 General

Tests according to this document are type tests.

NOTE If the results of any of the prescribed tests can be determined beyond doubt by assessment, then the test or tests need not be performed.

4.3.2 Conditions of test

4.3.2.1 Unless otherwise specified in this document, the samples are tested as delivered, having been mounted as declared by the manufacturer, but, when significant, in the most unfavourable position.

4.3.2.2 If the test results are influenced by the room temperature, this shall be maintained at (20 ± 5) °C, except that in cases of doubt, it shall be maintained at (23 ± 2) °C, unless otherwise specified in a particular clause.

4.3.2.3 ACTUATING MEMBERS are placed in the most unfavourably LOCATED POSITION, INTERMEDIATE POSITION or position of SETTING BY THE USER, unless other instructions are given in a particular clause.

4.3.2.4 Unless otherwise specified in this document or evident from the construction of the control (in general for ELECTRONIC CONTROLS), the tests are carried out in the order of the clauses of this document.

For ELECTRONIC CONTROLS, the tests of Clauses 24.1, 25 and 13.1 are carried out before the tests of Clause 21.

4.3.2.5 During the tests of this document, actuation is performed by test equipment if so desired, except for the high-speed tests of 19.12.

4.3.2.6 During and for the purpose of the tests of this document, other than for the tests of 19.12, the actuating means can be used to actuate the control, if an actuating member is not supplied by the manufacturer.

4.3.2.7 The rates of temperature change declared in 5.2 and used in Clause 19 (that are α_1, β_1, α_2 and β_2) shall have test tolerances of ±12 K/h.

For other activating quantities, the minimum and/or maximum rates of change declared in Table 1, requirement 31 and used in Clause 19 (that is α_1, β_1, α_2 and β_2) shall have test tolerances as specified in the appropriate part 2.

4.3.2.7DV D2 *Modification of Clause 4.3.2.7 to add the following:*

Throughout the standard, the symbol K used to denote temperature values represents the Kelvin scale ($T_K = T_c + 273$). Therefore, when the Fahrenheit scale is used in tests or measurements, the values shall be converted to °F such that the thermal energy of the entity under consideration is the same irrespective of the temperature scale used in the test or measurement.

4.3.2.8 In all tests, the measuring instruments or the measuring means shall be such as not to affect appreciably the value being measured.

NOTE Principles for uncertainty of measurements can be found in various sources, e.g. in OD-5014 under IECEE.

4.3.3 Samples required

4.3.3.1 Unless otherwise specified, one sample is used for the tests in Clauses 6 to 26, including the relevant annexes. For electromechanical controls, one sample shall be used for verification of Clauses 5 to 13 and another sample for Clauses 14 to 26, while for ELECTRONIC CONTROLS different samples can be used unless tests are required to be carried out on the same sample.

If the sample does not comply with one or more of the tests, the cause of the non-compliance shall be identified and corrective action shall be taken. The test which caused the non-compliance, and those preceding which could have influenced the result of that test, are repeated on two other sets of identical samples, all of which shall then comply with the repeated tests. Also any tests where the corrective action has influence on the initial test result shall be repeated.

4.3.3.2 Additional samples can be required for some destructive tests of this document.

4.3.3.3 Controls which are intended to meet the requirements of more than one part 2 document shall, in general, be tested to each part 2 separately.

NOTE By agreement between manufacturer and test house, requirements and tests which are common to more than one part 2, need only be checked once, unless the common tests can influence the results of any specific tests.

4.3.4 Instructions for test

4.3.4.1 According to submission

4.3.4.1.1 Controls for use in or with an equipment can either be tested with the equipment or separately. When tested in or with an equipment, the type of load controlled is classified as for declared specific load. When tested separately as an individual control, the type of load controlled is classified for the declared specific load, resistive load or resistive and inductive load. In both cases, the current in the appropriate circuit when the equipment is operating under normal load is regarded as the rated current of the circuit.

4.3.4.1.2 For all controls submitted, in, on or with an equipment, all other relevant information as required by 5.2 can be obtained by inspection and measurement of the submitted equipment.

4.3.4.1.3 Integrated controls are classified as for declared specific load and are tested in the equipment, or part thereof, for which they are intended.

4.3.4.1.4 Controls not submitted in or with an equipment are tested separately.

4.3.4.1.5 Controls for use with non-detachable cords are tested with the appropriate cord connected.

4.3.4.2 According to rating

4.3.4.2.1 Controls for AC only are tested with AC at rated frequency if declared; those for DC only are tested with DC and those for AC/DC at the more unfavourable supply.

4.3.4.2.2 Controls for AC only, which are not declared for a rated frequency, are tested at either 50 Hz or 60 Hz, whichever is the more unfavourable. Controls with a rated frequency within a declared range other than 50 Hz to 60 Hz are tested at the most unfavourable frequency within the marked or declared range.

4.3.4.2.3 When testing controls intended for DC only, the possible influence of polarity on the operation of the control is taken into consideration.

4.3.4.2.4 For controls with different AC and DC ratings, the tests for Clauses 14, 15, 16 and 19, are made on two sets of samples, one being tested according to the AC rating, and the other according to the DC rating.

NOTE At the option of the test house, a reduced number of tests can be made to cover the various ratings.

4.3.4.2.5 Unless otherwise specified, controls declared for one or more voltage ranges shall be tested at the most unfavourable voltage within the declared range, and this voltage being multiplied by the factor indicated in the appropriate clause (see 4.3.4.2.7).

4.3.4.2.6 For controls marked or declared for more than one rated voltage or rated current, the tests of Clause 19 are made on sets of samples for each combination of RATED VOLTAGE and rated current.

NOTE At the option of the test house, a reduced number of tests can be made to cover the various ratings.

4.3.4.2.7 For controls declared for a voltage range, tests are made on one set of samples at each limit of the range, unless the difference between the limits does not exceed 10 % of the mean value of the range, in which case the tests are made on one set of samples at the upper limit of the range.

4.3.4.2.8 Controls intended to be operated from a specific supply are tested with that specific supply.

4.3.4.2.9 A circuit for connection to the DC mains supply is classified as either a SELV/PELV circuit, ELV circuit or mains voltage circuit depending on the maximum operating voltage of the supply. This maximum operating voltage shall include consideration of the battery charging "float voltage" associated with the intended supply SYSTEM, regardless of the marked voltage rating of the equipment.

NOTE Float voltage is the constant voltage that is applied continuously to a voltaic CELL to maintain the CELL in a fully charged condition. Float voltage varies significantly with the chemistry and construction of the battery and ambient temperature.

4.3.4.2.10 Operation of the control powered by secondary batteries (rechargeable) is under the following conditions:

– the CONTROL, supplied by its fully charged battery, is operated as specified in this document;

– if possible, the CONTROL is supplied from the supply mains through its battery charger, the battery being initially discharged to such an extent that the CONTROL cannot operate;

– if the CONTROL incorporates inductive coupling between two parts that are detachable from each other, the CONTROL is supplied from the supply mains with the DETACHABLE PART removed.

4.3.4.2.11 See J.4.3.4.2.11.

4.3.4.3 According to protection against electric shock

4.3.4.3.1 If in class 0 control, class 0I control or class I control, or in controls for class 0, class 0I or class I equipment, it is necessary to have parts with double insulation or REINFORCED INSULATION, such parts are checked for compliance with the appropriate requirements specified for class II controls.

4.3.4.3.2 In any class I control, and in any control used in a class I equipment, unearthed accessible metal or accessible insulating surfaces shall be provided with insulation complying with the requirements for a class II control (see 7.1.1).

4.3.4.3.3 If in class 0 control, class 0I control, class I control or class II controls, or controls for class 0, class 0I, class I or class II equipment, it is necessary to have parts using SELV-circuits, such parts are also checked for compliance with the appropriate requirements specified for protection by use of SELV in 9.2.6.

If in CLASS I CONTROLS or CONTROLS for class I equipment it is necessary to have parts using PELV-circuits, such parts are also checked for compliance with the appropriate requirements specified for protection by use of PELV in 9.2.6.

NOTE By definition (3.7.6) CLASS II CONTROLS cannot use PELV-circuits.

4.3.4.4 According to manufacturing variants

4.3.4.4.1 Controls which are otherwise identical but which can produce varying operating values, operating times or operating sequences due to the setting by the manufacturer or inclusion of alternate components or parts at the manufacturing stage, are treated as a single submission. Normally, controls set to the most arduous condition will be sufficient. However, the test house may require extra samples, set to other values, where it can be clearly shown that these are necessary to allow approval of the whole range.

4.3.4.4.2 In these cases, due attention shall be paid to possible variations in manufacturing deviation and drift of any operating value, operating time or operating sequence, and, for sensing controls, to the minimum and maximum acceptable rates of rise and fall of the appropriate activating quantity which could be applicable to different parts of the range.

4.3.4.5 According to purpose

4.3.4.5.1 Multi-purpose controls shall, in general be tested for each purpose separately. During the tests for any one purpose, the activating quantities and prime movers applicable to all other purposes, shall be maintained constant at the most arduous value or position within the declared range or ranges.

4.3.4.5.2 Such controls without an appropriate section of Clause 19 shall be tested in a manner agreed between the manufacturer and the test house so that the essential intended operating values, operating times and operating sequences are tested.

4.3.4.5.3 Any control with a purpose not defined in 3.2, or in the appropriate part 2, can be tested and approved to this document, except for Clause 19. A test schedule for Clause 19 shall be based, wherever possible, on the intent of that clause and shall be agreed between the manufacturer and the test house.

4.3.4.5.4 See J.4.3.4.5.

5 Required technical information

5.1 General requirements

The CONTROL MANUFACTURER shall provide adequate information to confirm:

– that a suitable CONTROL can be selected;

– that the CONTROL can be mounted and used in a manner that will enable it to meet the requirements of this document; and

– that the relevant tests can be performed to determine compliance with this document.

5.2 Methods of providing technical information

5.2.1 Information shall be provided using one or more of the following methods. The information required for CONTROLS and the appropriate method for providing this information shall be as declared in Table 1.

NOTE It is not intended that Table 1 itself necessarily be the actual form used to communicate between manufacturer and test house.

– By marking (C) – this information shall be provided by marking on the CONTROL itself, except that, in the case of an INTEGRATED CONTROL, such marking can be on an adjacent part of the equipment, provided that it is clear that it refers to the CONTROL.

– By documentation on hard copy (D) – this information shall be provided for the USER or INSTALLER of the CONTROL, and shall consist of legible instructions. Each CONTROL shall be accompanied by such instructions. Instruction sheets and other texts required by this document shall be written in the official language(s) of the country in which the CONTROL is to be sold.

– For CONTROLS intended to be exclusively delivered to the EQUIPMENT MANUFACTURER, the instruction sheet is replaced by a leaflet, letter or drawing, etc. It is not necessary for each CONTROL to be accompanied by such a document.

– By documentation on electronic media on internal or external memory or on web pages (e.g. by QR code) (E) – this information is as alternative to (D).

– By declaration (X) – this information shall be provided for the test house for purposes of test and in a manner agreed between test house and manufacturer. It can, for example, be provided by a marking on the CONTROL, by a leaflet, letter or drawing or, in the case of a CONTROL submitted in, on or with an equipment, by measurement or inspection of the submitted equipment. This information should also be provided to the EQUIPMENT MANUFACTURER, as appropriate.

5.2.2 Information which is indicated as being required by marking (C) or by documentation (D,E) shall also be provided for the test house in an agreed manner if so requested by the test house.

5.2.3 For CONTROLS submitted in, on or with an equipment, the requirement for documentation (D,E) is replaced by declaration (X).

5.2.4 For an INTEGRATED CONTROL forming part of a more complex CONTROL, the marking relating to the INTEGRATED CONTROL can be included in the marking of the more complex CONTROL.

5.2.5 The requirement for documentation (D,E) is considered to be met if such information has been provided by marking (C).

5.2.6 The requirement for declaration (X) is considered to be met if such information has been provided by either documentation (D,E) or by marking (C).

5.2.7 Except as indicated in 5.4, for INTEGRATED CONTROLS all information is provided by means of declaration (X). Unless otherwise indicated in a part 2, for INCORPORATED CONTROLS, the only marking required is the manufacturer's name or trade mark and the UNIQUE TYPE REFERENCE, if other required marking is provided by documentation (D,E). For INCORPORATED CONTROLS as declared in Table 1, requirement 45, see the explanation of documentation (D,E) contained in 5.2.1.

5.2.8 For CONTROLS that are neither integrated nor incorporated, where lack of space prevents legible marking as specified, the CONTROL shall be marked with the manufacturer's name (or trade mark) and the UNIQUE TYPE REFERENCE only. The other marking required shall be included in documentation (D,E).

5.2.9 Additional marking or information is allowed, provided that it does not give rise to misunderstanding.

5.2.10 When symbols are used, they shall be as follows:

Amperes	A
Volts	V
Watts	W
Volts-amperes	VA
Alternating current (single-phase)	~ IEC 60417-5032 (2002-10)
Alternating current (three-phase)	3~ IEC 60417-5032-1 (2002-10)
Alternating current (three-phase with neutral)	3N~ IEC 60417-5032-2 (2002-10)
Direct current	⎓ IEC 60417-5031 (2002-10)
CLASS II CONTROL	⧈ IEC 60417-5172 (2003-02)
CLASS III CONTROL	⋄ IEC 60417-5180 (2003-02)
Ambient temperature limits of SWITCH HEAD	T (The letter T preceded by a minus sign and the numerical value of the lower temperature if T_{min} less than 0 °C, or followed by the numerical value of the higher temperature if T_{max} other than 55 °C.)
Rated current of the appropriate fuse in amperes	▭ IEC 60417-5016 (2002-10)
Frequency	Hz
Protective earth	⏚ IEC 60417-5019 (2006-08)
FUNCTIONAL EARTHING	⏚ IEC 60417-5018 (2011-07)
Caution	⚠ ISO 7000-0434B (2004-01)
Read operator's manual	🕮 ISO 7000-0790 (2004-01)

For identification of the degree of protection provided by enclosures, the symbols shown in Table 1, requirement 9 shall be used.

NOTE 1 Information about rated current and rated voltage can be provided by using figures alone, the figure for the rated current preceding or above that for the rated voltage and separated from it by a line. For circuits for resistive load and inductive loads, the rated current for inductive load is placed between parentheses and immediately following the rated current for resistive load. The symbol for the nature of the supply is placed after the current and voltage.

Current, voltage and nature of supply can be indicated as follows:

$$16\,(3)\text{A}\ 240\text{V}\sim \text{or}\ 16\,(3)\ /\ 240\sim \text{or}\frac{16\,(3)}{240}\sim$$

NOTE 2 The following are examples of ways to provide information about the temperature limits of a CONTROL:

– 20T 30 (meaning minus 20 °C up to plus 30 °C);

– T85 (meaning 0 °C up to plus 85 °C).

NOTE 3 Information concerning declared specific loads can be given by reference to drawings or to types, for example:

"Electric motor, drawing No. ..., part list No. ..., made by..." or "5 × 80 W fluorescent".

5.2.10DV.1 D2 *Modification of Clause 5.2.10 by adding the following to the list of symbols:*

Alternating current (single phase) ..... ∿ "or a.c."

Direct current..... ⎓ "or d.c."

5.2.10DV.2 D2 *Modification of Clause 5.2.10 by adding the following paragraphs:*

5.2.10DV.2.1 Symbols for alternating current (single phase), alternating current (three phase), alternating current (three phase with neutral) and ambient temperature limits of SWITCH HEAD are not applicable.

5.2.10DV.2.2 Letter type abbreviations (FLA for full load amperes, HP for horsepower) which clearly convey the assigned rating may be used.

5.2.10DV.2.3 For INDEPENDENTLY-MOUNTED, FREE STANDING and IN-LINE CONTROLS, information regarding the connection of specific loads shall be on a wiring diagram or label attached to the control.

Table 1
Required technical information and methods of providing these information

	Information	Clause or subclause	Method
1	Manufacturer's name or trade mark	5.2.7	C
2	UNIQUE TYPE REFERENCE [a]	3.13.1, 5.2.7	C
3	Rated voltage or rated voltage range in volts (V)	3.1.2, 4.3.4.2 16.4,	C

Table 1 Continued on Next Page

Table 1 Continued

	Information	Clause or subclause	Method
4	Nature of supply AC, DC, both AC and DC, battery powered, specific supplies or multiple supplies	4.3.4.2	C
5	Frequency if other than for range 50 Hz to 60 Hz inclusive	4.3.4.2	C
6	Purpose of CONTROL	3.2, 4.3.4.2, 4.3.4.5, 19.15	D or E
7	Type of CONTROL according to construction and whether the CONTROL is electronic	3.5, 3.5.7	X
8	The type of load controlled by each circuit[b] such as substantially resistive, resistive or inductive, declared specific load, 20 mA load, declared motor load and PILOT DUTY load	16, 19, Table 18, Table 19, Table 20, 23.2.2 26.2.3	C
9	Degree of protection provided by enclosure [c] (IP classification according IEC 60529)	9.5, 14.1	C
10	Marking of terminals for external connections	5.4.2	C
11	Which of the terminals for EXTERNAL CONDUCTORS are for a wider range of conductor sizes than those indicated in Table 2.	8.1	D or E
12	For SCREWLESS TERMINALS, the method of connection and disconnection [d], if not readily identifiable	8	D
13	Details of any special conductors which are intended to be connected to the terminals for INTERNAL CONDUCTORS	8.2.1	D or E
14	Maximum temperature of terminals for INTERNAL CONDUCTORS and terminals for EXTERNAL CONDUCTORS of INCORPORATED and INTEGRATED CONTROLS, if higher than 85 °C	16	X
15	Temperature limits of the SWITCH HEAD, if the minimum value (T_{min}) lower than 0 °C or the maximum value (T_{max}) other than 55 °C Preferred values of T_{max} are 30 °C, 55 °C, 70 °C, 85 °C, 105 °C, 125 °C, 150 °C. Preferred values of T_{min} are 0 °C, −10 °C, −20 °C, −30 °C, and −40 °C	16.5 16.7, 19.3	C
16	Temperature limits of mounting surfaces (T_s) Maximum temperature of mounting surface ($T_{s\,max}$) if it is more than 20K above T_{max}	16.5 a), 19.3	C
17	Type of CONTROL according to protection against electric shock	3.7.3, 3.7.4, 3.7.5, 3.7.6, 3.7.7, 6, 7	X
18	For CLASS II CONTROLS, the symbol for Class II construction	5.3	C
19	Number of cycles of ACTUATION (M) for each MANUAL ACTION Preferred values are: 100 000 cycles; 30 000 cycles; 10 000 cycles; 6 000 cycles; 3 000 cycles [j]; 300 cycles [j]; 30 cycles [j] NOTE For controls with more than one manual action, a different value can be declared for each. If a control has more than one intended "OFF" position, then a cycle of actuation is regarded as a movement from one "OFF" position to the next "OFF" position.	19.10, 19.11	X
20	Number of automatic cycles (A) for each automatic action.	13.1.3.3, Table 14,	X

Table 1 Continued on Next Page

Table 1 Continued

	Information	Clause or subclause	Method
	Preferred values are: 300 000 cycles; 200 000 cycles; 100 000 cycles; 30 000 cycles; 20 000 cycles; 10 000 cycles; 6 000 cycles; 3 000 cycles[1]); 1 000 cycles[1]); 300 cycles[2]); 30 cycles[2)4)]; 1 cycle[3]). [1)] Not applicable to thermostats or to other fast cycling actions. [2)] Applicable only to manual reset. [3)] Applicable only to actions which require the replacement of a part after each operation. [4)] Can only be reset during manufacturer servicing. NOTE For controls having more than one automatic action, a different value can be declared for each.	19.7.6, 19.8.4,	
21	Ageing period (Y) for CONTROLS with type 1.M or 2.M action Preferred values are: 60 000 h; 30 000 h; 10 000 h; 3 000 h; 300 h; 15 h	19.6	X
22	Type of disconnection or interruption provided by each circuit	3.4.1, 3.4.2, 3.4.3, 3.4.4	X
23	PTI of materials used for insulation	11.3.1, Table 12, Footnote [c], Table 13, Footnote [d], 21.2.9	X
24	Method of mounting CONTROL [d]	9.6, 9.11, 10.1, 16, 19 and 20	D
25	Marking and method of providing earthing of CONTROL	5.4.2.3, 7, 7.1.1, 7.1.2	D
26	Method of attachment for NON-DETACHABLE CORDS [e]	8.1, 9.7	D or E
27	Range of allowed outer diameter for cords used in controls with type X attachment method when relevant for the compliance with Clause 14	14.1.4	D or E
28	Intended transportation condition of CONTROL [f]	18.1	X
29	Details of any limitation of OPERATING TIME [g]	16, 19	D or E
30	Limits of ACTIVATING QUANTITY for any SENSING ELEMENT over which MICRO-DISCONNECTION or ELECTRONIC DISCONNECTION is secure	9.3.2, 9.4.16, 19.14, 20.1.5, 13.1.1	X
31	Minimum and/or maximum rates of change of activating quantity, or minimum and/or maximum cycling rates for a SENSING CONTROL [h]	4.3.2.7, H.17, 19	X
32	Values of overshoot of ACTIVATING QUANTITY for SENSING CONTROLS which are necessary for correct action, or which can be used for test purposes	19	X
33	TYPE 1 ACTION or TYPE 2 ACTION	3.6	D or E
34	Additional features of TYPE 1 ACTION or TYPE 2 ACTIONS	9.4	D or E

Table 1 Continued on Next Page

Table 1 Continued

	Information	Clause or subclause	Method
35	MANUFACTURING DEVIATION and condition of test (electrical, mechanical and thermal) appropriate to deviation	3.11.1, 9.4.3, H.17, 19.14	X
36	DRIFT	3.11.2, 9.4.3, H.17, 18.2.4	X
37	Reset characteristics for cut-out action [i]	9.4.11, 9.4.12,	D or E
38	If a CONTROL is either to be hand-held or is intended for a hand-held equipment	21, 9.12.4.4.1	X
39	Any limitation to the number or distribution of flat push-on RECEPTACLES which can be fitted	8.2.4.4	D or E
40	For any TYPE 2 ACTION the MANUFACTURING DEVIATION and DRIFT of its OPERATING VALUE, OPERATING TIME or OPERATING SEQUENCE (declared in Table 1, requirement 35, and requirement 36)	9.4.3	D or E
41	Extent of any SENSING ELEMENT	3.8.1	X
42	OPERATING VALUE (or values) or OPERATING TIME	3.3.11, 3.3.12, 9, 16, H.17.6, 19	D
43	Installation class (surge immunity) and operating modes	12.2 H.25.8.1 H.25.8.3 Annex N	X
44	Intended POLLUTION DEGREE of the CONTROL	Annex F	D or E
45	CONTROL intended to be delivered exclusively to the EQUIPMENT MANUFACTURER	5.2.1, 5.2.7	X
46	Glow wire test temperatures	21.2.5, 21.2.6, 21.2.7, and 21.2.8	X
47	The minimum parameters of any heat dissipator (for example, heat sink) not provided with an ELECTRONIC CONTROL but essential to its correct OPERATION	16	D
48	Type of output waveform if other than sinusoidal	24.1	X
49	Details of the TOUCH CURRENT waveform produced after FAILURE of the BASIC INSULATION	13.1	X
50	The relevant parameters of those ELECTRONIC DEVICES or other circuit components considered as unlikely to fail (see paragraph 1 of 13.1.3.1)	13.1	X
51	Type of output waveform(s) produced after FAILURE of an ELECTRONIC DEVICE or other circuit component (see item g) of 13.1.3.8)	13.1	X
52	The effect on controlled output(s) after electronic circuit component FAILURE if relevant (item c) of 13.1.3.8)	13.1	X
53	Any component on which reliance is placed for ELECTRONIC DISCONNECTION which is disconnected as required by footnote n to Table 16	15.2 13.1	X
54	External load and emission control measures to be used for test purposes	23.3	X
55	RATED IMPULSE VOLTAGE	3.1.10, 11.2	D or E
56	Type of printed circuit board protection	Annex L or	X

Table 1 Continued on Next Page

Table 1 Continued

	Information	Clause or subclause	Method
		Annex M	
57	Temperature for the ball pressure test	21.2.5, 21.2.6 and 21.2.7	X
58	Maximum declared torque on single bush mounting using thermoplastic material	Table 9, Footnote [a]	D or E
59	POLLUTION DEGREE in the MICRO-ENVIRONMENT of the CREEPAGE DISTANCE or CLEARANCE if cleaner than that of the CONTROL, and how this is designed	Table 14	X
60	RATED IMPULSE VOLTAGE for the CREEPAGE DISTANCE or CLEARANCE if different from that of the CONTROL, and how this is ensured	Table 14	D or E
61	The values designed for tolerances of distances for which the exclusion from FAULT mode "short" is claimed	13.1.3.3, Table 14, 13.1.3.5	X
62	For CLASS III CONTROLS, the symbol for Class III construction	5.4.2.5	C
63	For SELV or PELV circuits, the ELV limits realized	3.1.5, 6.1.1, P.3.2	X
64	Value of accessible voltage of SELV/PELV circuit, if different from 6.1.1, and the product standard(s) referred to for the application of the CONTROL, in which the accessible SELV/PELV level(s) is (are) given	3.1.4, 6.1.1	X
65	Emission tests and groups as declared according to CISPR 11	23.2	X
66	Immunity tests for PROTECTIVE CONTROLS for use in accordance with IEC 60335 appliances	Table H.12	X
67	Maximum short circuit current as declared	9.3.5.2.1 b)	X
68	Overcurrent protective device external to the CONTROL	9.2.8, 26.2	D or E
69	Marking for the type of replaceable battery	5.4.3.3	C
70	For INCORPORATED CONTROLS or INTEGRATED CONTROLS, whether the overload test shall be done at control level	26.2.2	X
71	Maximum altitude at which the CONTROL can be used if greater than 2 000 m	11.2	X
72	Maximum number of RESET actions within a time period	9.12.4.4.5	D
73	Number of remote RESET actions	19.1.6.5	X
74	Resistance to heat and fire for controls intended for use in IEC 60335 appliances	21.2.4	X
75	Type of electromagnetic environment of one of the two EMC emission limits RESIDENTIAL ELECTROMAGNETIC ENVIRONMENT or INDUSTRIAL ELECTROMAGNETIC ENVIRONMENT	23, Table 23 or Table 24	D or E
76	Type of electromagnetic environment of one of the two EMC immunity levels	25.3.2	D or E
77	RESIDENTIAL ELECTROMAGNETIC ENVIRONMENT	Table 26 or	
78	INDUSTRIAL ELECTROMAGNETIC ENVIRONMENT	Table 27	
79	Cable length up to or equal to 30 m (if not for LONG-DISTANCE LINES)	25.3.2, Table 26 or Table 27	D or E
80	Cable length up to or equal to 3 m (if not for LONG-DISTANCE LINES)	25.3.2, Table 26 or Table 27	D or E
81	Applicable of test and frequency	25.3.2, Table 26 or Table 27	D or E

Table 1 Continued on Next Page

Table 1 Continued

	Information	Clause or subclause	Method
82	Additional requirements for HBES/BACS [k] controls in RESIDENTIAL ELECTROMAGNETIC ENVIRONMENT according to IEC 63044-5-2 or INDUSTRIAL ELECTROMAGNETIC ENVIRONMENT according to IEC 63044-5-3	25.3.2, Table 26 or Table 27	D or E
83	Control susceptible to magnetic fields (see footnote e in both tables)	25.3.2, Table 26 or Table 27	D or E
84	Controls declared for EMC performance	25.1, Table 25	D
85	Minimum and maximum battery voltage	24.2	X
86	ELECTRONIC CONTROLS of class A control function, which are additionally complying with 25.7 to 25.10	25.1, Table 25	D
87	Type of DC supply for non-stationary applications	Annex I, I.1	D

[a] The UNIQUE TYPE REFERENCE shall be such that, when it is quoted in full, the manufacturer of the CONTROL can supply a replacement which will be fully interchangeable with the original electrically, mechanically, dimensionally, and functionally.

It may comprise a series type reference with other marking, such as voltage rating or an ambient temperature marking, which together provide a unique type reference.

[b] For CONTROLS with more than one circuit, the current applicable to each circuit and to each terminal. If these are different from each other, then it shall be made clear to which circuit or terminal the information applies. For circuits for resistive and inductive loads, the rated current, or the rated load in VA, at power factors as indicated in the appropriate table of 19.2.

[c] The marking (C) requirement does not apply to CONTROLS or parts thereof classified as IP00, IP10, IP20, IP30 and IP40.

[d] If, for INDEPENDENTLY MOUNTED CONTROLS, it is necessary to take special precautions when installing or using the CONTROL, these details shall be given in an instruction sheet accompanying the CONTROL.

Special precautions may be necessary, for example, for flush mounting INDEPENDENTLY MOUNTED CONTROLS. In order to ensure that, after building-in, the conditions necessary to meet the requirements of this document are achieved, the instruction sheet for such CONTROLS shall include clear information concerning:

– the dimensions of the space to be provided for the CONTROL;

– the dimensions and position of the means for supporting and fixing the CONTROL within this space;

– a minimum clearance between the various parts of the CONTROL and the surrounding parts of the fitment;

– the minimum dimensions of ventilating openings and their correct arrangements;

– the connection of the CONTROL to the supply and the interconnection of separate components, if any.

If the supply conductors of a CONTROL can come into contact with parts of a terminal block or a compartment for FIXED WIRING, and these parts have, under conditions of NORMAL USE, a temperature exceeding that specified in Table 17, the instruction sheet shall also state that the CONTROL shall be connected by means of conductors having the appropriate T rating (see Footnote h of Table 17).

For CONTROLS with wiring between a sensor, sensing or actuating element and the rest of the CONTROL where part of this wiring is, or is intended to be, also part of the fixed installation, the manufacturer shall give in the documentation the relevant information for proper installation and the appropriate type of cable or cord required for that part of the fixed installation.

[e] IN-LINE CORD, FREE-STANDING and INDEPENDENTLY MOUNTED CONTROLS, if fitted with NON-DETACHABLE CORDS using TYPE Y ATTACHMENTS or TYPE Z ATTACHMENTS, shall have documentation (D) containing the substance of one of the following statements, whichever is appropriate:

– "The supply cord of this control cannot be replaced; if the cord is damaged, the control should be discarded" (Z)

or

– "The supply cord of this control can be replaced only by the manufacturer or his accredited service agent" (Y).

[f] The method of packaging does not have to be declared.

[g] For IN-LINE CORD, FREE-STANDING and INDEPENDENTLY MOUNTED CONTROLS, this information shall be provided by method C.

[h] α_1 = minimum rising rate

Table 1 Continued on Next Page

Table 1 Continued

	Information	Clause or subclause	Method
β_1 = minimum falling rate The rate of change (α_1 and β_1) of the ACTIVATING QUANTITY are those applicable to NORMAL USE. α_2 = maximum rising rate (for TYPE 2 ACTIONS only) β_2 = maximum falling rate (for TYPE 2 ACTIONS only) For test purposes, α_1 and β_1 shall be as declared but not lower than the limit(s) indicated in the appropriate part 2 standards for TYPE 1 ACTIONS and/or TYPE 2 ACTIONS. The values α_2 and β_2 are for test purposes only, and may alternatively be declared as a maximum cycling rate. The rates of change for the purpose of this document shall be expressed in the units as shown in the following table*:			

Activating quantity	Unit for rate of change
Pressure	Pa/s
Temperature	K/h
Position	mm/s
Illumination	lux/s
Velocity	mm/s^2
Liquid level	mm/s
Current	A/s
Humidity	%/s
Air flow	m^3/s^2

* When using other activating quantities, the units shall be expressed in SI-units.

[i] The manufacturer may declare a time before which, or a specific value of ACTIVATING QUANTITY above which, manual reset shall not occur.

[j] Applicable only to actions of CONTROLS for specific equipment and applications such as voltage-tap CONTROLS, summer/winter CONTROLS for water heaters and where permitted by the appropriate equipment standard.

[k] Home and Building Automation and Control (HBES/BACS) products.

Table 1DV.1 D2 *Modification of Table 1 as follows:*

1) Add row 2ADV and row 4ADV:

Table 1DV
Required technical information and methods of providing these information

	Information	Clause or subclause	Method
2ADV	Date code of manufacturing	R31DV.1.5	C
4ADV	Class 2 power source or circuit	R32DV.1	C

2) Modify row 11 column 3 by adding "R31DV.1.1.21".

3) Modify row 65 by replacing "CISPR 11" with "FCC Part 15 and/or 18."

4) Replace note (e) with the following, "This note does not apply. Attachment or replacement of NON-DETACHABLE CORDS is not considered a user function."

5) Replace note (b) with the following, "Motor load and PILOT DUTY load ratings are established as indicated in Annex R, R30DV.1 and R31DV.1 respectively, and marked accordingly."

6) Add the following three paragraphs to note (c):

Control enclosures shall be marked either using the IP system of marking or in accordance with the environmental enclosure requirements of UL 50E.

A control enclosure which has been evaluated against the ingress of water only by the Rain Test shall be marked "Raintight" if so constructed that exposure to beating rain will not result in the entrance of water; "Rainproof" if so constructed, protected, or treated as to prevent beating rain from interfering with successful OPERATION of the control.

Control enclosures are not required to be marked to indicate the degree of protection against the entrance of solid objects.

7) Add the following paragraph at the end of the notes:

A switch having one or more push-in (SCREWLESS) TERMINALS shall be marked:

a) With instructions for connecting acceptably sized wire where readily visible during installation,

b) With instructions for disconnecting a wire from the terminal where readily visible during wiring and rewiring,

c) To specify use with "solid wire only" unless the terminal is intended for both solid and stranded wire, and

d) With instruction to strip the insulation from conductors a specific length, where readily visible during installation.

Marking (C) is required for the method of connection and disconnection of SCREWLESS TERMINALS for field wiring.

5.3 Class II symbol

5.3.1 The symbol for class II construction shall be used only for CONTROLS of class II. The symbol for class II construction is not required for INCORPORATED CONTROLS and INTEGRATED CONTROLS.

5.3.2 The dimension of the symbol for class II construction shall be such that the length of the sides of the outer square is about twice the length of the sides of the inner square.

5.3.2.1 The length of the sides of the outer square of the symbol shall be not less than 5 mm, unless the largest dimension of the CONTROL is 15 mm in length or less, in which case the dimension of the symbol can be reduced but the length of the sides of its outer square shall be not less than 3 mm.

5.3.2.2 CONTROLS providing protection against electric shock as required for class II but that include terminals for earthing continuity for functional purposes shall not be marked with the symbol for class II construction, IEC 60417-5172 (2003-02), but shall be regarded as CLASS I CONTROLS.

5.4 Additional requirements for marking

5.4.1 General

Required marking on a CONTROL shall not be placed on DETACHABLE PARTS.

Required markings shall be legible and durable.

Compliance is checked by inspection and by the tests of Annex A.

5.4.1DV D2 *Modification of Clause 5.4.1 to add the following:*

Tests to determine the legibility and durability of markings placed on labels are in the Standard for Marking and Labeling Systems, UL 969. Markings, other than those placed on labels, are tested in accordance with Annex A.

5.4.2 Marking of terminals for external connections

5.4.2.1 Terminals of CONTROLS intended for the connection of supply conductors shall be indicated by an arrow pointing towards the terminal, unless the method of connection to the supply mains is of no importance or is self-evident.

Compliance is checked by inspection.

5.4.2.2 Terminals intended exclusively for a neutral EXTERNAL CONDUCTOR shall be indicated by the letter "N".

5.4.2.3 Earthing terminals for external protective earthing conductors or earthing continuity, and terminals for earthing for functional purposes (as opposed to purposes of protection against electric shock) shall be indicated

– for protective earth, by the earth symbol for protective earth, IEC 60417-5019 (2006-08);

– or functional earth, by the earth symbol for functional earthing, IEC 60417-5018 (2011-07).

5.4.2.4 All other terminals shall be suitably identified, their purpose self-evident or the CONTROL circuitry visually apparent. The arrow, the letter "N" or the earth symbol shall not be used except as indicated above.

Compliance is checked by inspection.

5.4.2.4DV D2 *Modification of Clause 5.4.2.4 to add the following 3 NOTES:*

NOTE 1DV A terminal intended for connection of a grounded supply conductor shall be finished to show a white or grey colour and shall be distinguishable from the other parts.

NOTE 2DV A wire-binding screw intended for the connection of an equipment earthing conductor shall have a slotted or hexagonal green-coloured head. A pressure wire connector intended for connection of such a conductor shall be identified by being marked GROUND, GROUNDING, EARTH by a marking on a wiring diagram provided on the CONTROL L. The wire-binding screw or pressure wire connector shall be so located that it is unlikely to be removed during SERVICING of the CONTROL L.

NOTE 3DV With respect to 5.3.2 to 5.4.2.2 inclusive, additional or alternative markings are required in the wiring rules.

5.4.2.5 In-line cord controls, free-standing controls and independently mounted controls intended to be connected only to SELV SYSTEMS or PELV SYSTEMS shall be marked with the graphic symbol IEC 60417-5180 (2003-02). This requirement does not apply where the means of connection to the supply is so shaped that it can only mate with a particularly designed SELV or PELV arrangement.

CONTROLS providing protection against electric shock as required for CLASS III CONTROLS but that carry terminals for functional earthing purposes or for external earthing continuity shall be marked with the symbol for class III construction.

NOTE The symbol for functional earth is IEC 60417-5018 (2011-07).

5.4.2.5DV D2 *Modification of Clause 5.4.2.5 to add the following:*

See Annex R, R31DV.1.

5.4.3 Markings for installation and servicing

5.4.3.1 CONTROLS intended to be set by the USER or by the EQUIPMENT MANUFACTURER during installation shall be provided with an indication of the direction to increase or decrease the RESPONSE VALUE.

NOTE An indication of "+" or "–" is sufficient.

CONTROLS intended to be set by the EQUIPMENT MANUFACTURER or the INSTALLER shall be accompanied by documentation (D) indicating the proper method for securing the SETTING.

5.4.3.2 Parts destroyed during the normal OPERATION of the CONTROL and which have to be replaced shall be marked so as to enable them to be identified from a catalogue or the like, even after they have operated, unless they are intended to be replaced only during MANUFACTURER SERVICING.

5.4.3.3 If an equipment is provided with a replaceable battery, and if replacement by an incorrect type could result in an explosion (for example, with some lithium batteries), the following applies:

– if the battery is intended to be replaced by the USER, there shall be a marking close to the battery or a statement in both the instructions for use and the service instructions;

– if the battery is not intended to be replaced by the USER, there shall be a marking close to the battery or a statement in the service instructions.

This marking or statement shall include the following or similar text:

CAUTION
RISK OF EXPLOSION IF BATTERY IS REPLACED BY AN INCORRECT TYPE
DISPOSE OF USED BATTERIES ACCORDING TO THE INSTRUCTIONS

5.4.3.4 The battery compartment of CONTROLS incorporating batteries that are intended to be replaced by the USER shall be marked with the battery voltage and the polarity of the terminals.

If colours are used, the positive terminal is to be identified in red and the negative terminal in black.

Colour is not to be used as the only indication of polarity.

5.4.3.5 The instructions for CONTROLS incorporating batteries that are intended to be replaced by the USER shall include the following:

– the type reference of the battery;

– the orientation of the battery with regard to polarity;

– the method of replacing batteries;

– warning against using incorrect type batteries;

– how to deal with leaking batteries.

The instructions for CONTROLS incorporating a battery that contains materials which are hazardous to the environment shall give details on how to remove the battery and shall state that:

– the battery must be removed from the CONTROL before it is scrapped;

– the CONTROL must be disconnected from the supply mains when removing the battery;

– the battery is to be disposed of safely.

5.4.3.6 For controls powered by secondary batteries (rechargeable), the instructions shall give information regarding charging of batteries.

5.5 Warning or cautionary markings

Warnings or cautions shall be written in the manufacturer's instructions (D or E) provided that the symbol ISO 7000-0434B (2004-01) is marked on the product.

6 Protection against electric shock

6.1 General requirements

6.1.1 CONTROLS shall be so constructed that there is adequate protection against accidental contact with LIVE PARTS, in any unfavourable position which can occur in NORMAL USE, and after any accessible DETACHABLE PARTS, other than lamps located behind a detachable COVER have been removed. However, during the insertion and removal of lamps, protection against accidental contact with LIVE PARTS of the lamp cap shall be ensured.

Unless otherwise specified, ACCESSIBLE PARTS connected to SELV SYSTEMS or PELV SYSTEMS where the voltage does not exceed the SELV limits of 3.1.5 are not considered to be HAZARDOUS LIVE PARTS.

SELV/PELV circuits are not considered HAZARDOUS LIVE PARTS if:

– the CONTROL is intended only to be used in an application governed by another product standard where the limit value of the voltage for accessible bare conductors of SELV/PELV is different

and

– the manufacturer declares the application, product standard governing the application and level of voltage for accessible SELV/PELV circuits considered to be non-hazardous by the application standard (declared in Table 1, requirement 64)

For accessible parts connected to a SELV SYSTEMor a PELV SYSTEM where the voltage exceeds the limits of 3.1.5, or is higher than the values declared in Table 1, requirement 64, the current between the simultaneously accessible parts and between the ACCESSIBLE PART(S) and earth shall not exceed the limits in 6.1.10 under FAULT-free (normal) and single-FAULT conditions.

6.1.2 The insulating properties of lacquer, enamel, paper, cotton, oxide film on metal parts, beads and sealing compounds shall not be relied upon to give the required protection against accidental contact with HAZARDOUS LIVE PARTS. Sealing compounds of the self-hardening types can be touched, provided that the sealing compound fulfils requirements of Clauses 15 and 11.

6.1.2DV D2 *Modification of Clause 6.1.2 to add the following:*

Sealing compounds shall comply with the requirements of the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

6.1.3 For those CLASS II CONTROLS and CONTROLS for class II equipment which are connected in NORMAL USE to the gas supply mains or to the water supply mains, any metal parts conductively connected to the gas pipes or in electrical contact with the water SYSTEM shall be separated from HAZARDOUS LIVE PARTS by DOUBLE INSULATION or REINFORCED INSULATION.

6.1.4 Those CLASS II CONTROLS and CONTROLS for class II equipment which are intended to be permanently connected to FIXED WIRING shall be so designed that the required degree of protection against electric shock is not impaired by the installation of the CONTROL.

NOTE The protection against electric shock of CLASS II INDEPENDENTLY MOUNTED CONTROLS can be affected, for example, by the installation of metal conduits or of cables provided with a metal sheath.

6.1.5 For INTEGRATED and INCORPORATED CONTROLS, the tests of 6.1.8 are only applied to those parts of the CONTROL which are accessible when they are mounted in any position in accordance with the manufacturer's declarations and after removal of DETACHABLE PARTS.

6.1.6 For IN-LINE CORD CONTROLS and FREE-STANDING CONTROLS, the tests of 6.1.8 are made when the CONTROL is fitted with flexible cords either of the smallest, or of the largest nominal cross-sectional area used in 8.1.5, whichever is more unfavourable. DETACHABLE PARTS are removed, and hinged COVERS which can be opened without the use of a TOOL are opened.

6.1.7 For INDEPENDENTLY MOUNTED CONTROLS, the test is made when the CONTROL is mounted as in normal use, fitted with cable of the smallest or of the largest nominal cross-sectional area used in 8.1.5, whichever is more unfavourable, or with a rigid, pliable or flexible conduit. DETACHABLE PARTS are removed, and hinged covers which can be opened without the use of a TOOL are opened.

6.1.8 *Compliance with 6.1.1 to 6.1.7 inclusive is checked by inspection and by the following tests:*

a) The test finger shown in Figure 5 is applied without force in every possible position. Apertures preventing the entry of the finger are further tested by means of a straight unjointed test finger of the same dimensions which is applied with a force of 20 N; if this finger enters, the test with the test finger shown in Figure 5 is repeated, the finger being pushed through the aperture if necessary. If the unjointed test finger does not enter, the force applied is increased to 30 N. If then the guard is so displaced or the aperture so distorted that the test finger shown in Figure 5 can be inserted without force, the test with the latter finger is repeated. An electrical contact indicator is used to show contact.

NOTE A lamp can be used for the indication of contact, with the voltage not less than 40 V.

b) The test finger shown in Figure 5 shall be so designed that each of the jointed sections can be turned through an angle of 90° with respect to the axis of the finger in the same direction only.

c) In addition, openings in insulating material and in unearthed metal shall be tested by applying the test pin shown in Figure 4 without force in every possible position.

d) It shall not be possible, with either the standard test finger or the test pin, to touch HAZARDOUS LIVE PARTS.

e) For CONTROLS which have any parts of DOUBLE INSULATION construction, it shall not be possible to touch metal parts with the test finger shown in Figure 5 which are only separated from HAZARDOUS LIVE PARTS by BASIC INSULATION.

f) If there is an instruction to remove a part during NORMAL USE or USER MAINTENANCE and if there is no warning on the part which indicates: "Disconnect from supply before removing", that part is regarded as a DETACHABLE PART for compliance with 6.1.5, 6.1.6 and 6.1.7 only, even if a TOOL has to be used for its removal. If there is such a warning on the part, it is permissible, after removal, to touch parts separated from HAZARDOUS LIVE PARTS by BASIC INSULATION.

6.1.8DV D2 *Modification of Clause 6.1.8 to add the following:*

The requirements of 6.1.8 inclusive are replaced by the requirements of Annex R, R33DV.1.

6.1.9 Accessible conductive parts shall not be considered as hazardous live parts if separated from the supply by protective impedance.

6.1.10 For PROTECTIVE IMPEDANCE, the current between the part or parts and either pole of the supply source shall not exceed 0,7 mA (peak value) AC or 2 mA DC:

– for frequencies exceeding 1 kHz, the limit of 0,7 mA (peak value) is multiplied by the value of the frequency in kHz but shall not exceed 70 mA (peak value);

– for voltages over 42,4 V (peak value) and up to and including 450 V (peak value), the capacitance shall not exceed 0,1 µF;

– for voltages over 450 V (peak value) and up to and including 15 kV (peak value), the product of the capacitance in farads times the potential in volts shall not exceed 45 µC;

– for voltages over 15 kV (peak value), the product of the capacitance in farads times the square of the potential in volts shall not exceed 350 mJ.

Compliance is checked by measurement.

Voltages and currents are measured between a single accessible conductive part (or any combination of such parts) and the protective earth conductor. Measurements shall be taken in normal supply configuration, and with supply poles interchanged.

Details of the measuring circuit are shown in Figure K.1 of Annex K.

6.1.11 Between class III circuits and circuits connected to the mains or earth, insulation external to the SAFETY ISOLATING TRANSFORMER shall comply with all requirements for class II insulation.

NOTE Where a circuit is not specifically required to be class III, class II requirements are not applicable between the class III circuit and earth.

Compliance is checked by inspection and measurement.

6.1.12 CONTROLS having battery compartments that can be opened without the aid of a TOOL, or that according to the instructions for use can be replaced by the USER need only have BASIC INSULATION between LIVE PARTS and the inner surface of the battery compartment. If the CONTROL can be energized without the batteries, DOUBLE INSULATION or REINFORCED INSULATION is required.

NOTE If a part has to be removed in order to discard the battery before scrapping the CONTROL, this part is not considered to be detachable even if the instructions state that it is to be removed.

Compliance is checked by inspection and measurement.

6.2 Actuating members and actuating means

6.2.1 An actuating member shall not be a LIVE PART.

6.2.2 An ACTUATING MEANS shall not be a LIVE PART, unless either it is provided with an insulated ACTUATING MEMBER which is adequately fixed or the ACTUATING MEANS is not accessible when the ACTUATING MEMBER is removed.

Compliance with 6.2.1 and 6.2.2 is checked by inspection and by the tests of 6.1.

NOTE An insulated ACTUATING MEMBER is considered to be adequately fixed if it can be removed only by breaking, cutting, or after being seriously damaged.

6.2.3 For CONTROLS other than class III or CONTROLS for equipment other than those of class III, ACTUATING MEMBERS and handles held in NORMAL USE shall be either of insulating material, or adequately covered by insulating material, or, if of metal, their ACCESSIBLE PARTS shall be separated from their ACTUATING MEANS, or from their fixings by SUPPLEMENTARY INSULATION, if such parts would be likely to become live in the event of an insulation FAULT.

For CONTROLS for connection to FIXED WIRING, or for CONTROLS for stationary equipment, this requirement does not apply provided that such parts are either:

– reliably connected to a PROTECTIVE EARTHING terminal or a protective earthing contact of a plug; or

– shielded from hazardous live parts by PROTECTIVE SCREENING.

Compliance is checked by inspection.

NOTE Parts separated from HAZARDOUS LIVE PARTS by DOUBLE INSULATION or REINFORCED INSULATION are not regarded as likely to become live in the event of an insulation FAULT.

6.3 Capacitors

6.3.1 For class II IN-LINE CORD CONTROLS and INDEPENDENTLY MOUNTED CONTROLS, capacitors shall not be connected to accessible metal parts, unless they comply with 6.1.10 and 9.2.5. For INCORPORATED CONTROLS and INTEGRATED CONTROLS used in class II equipment, capacitors shall not be connected to metal likely to be connected to accessible metal when the CONTROL is mounted in accordance with the manufacturer's declarations.

Compliance is checked by inspection.

6.3.2 CONTROLS intended to be connected to the supply by means of a plug shall be so designed that in NORMAL USE, there is no RISK of electric shock from charged capacitors when touching the pins of the plug after disconnecting from the supply.

Compliance is checked by the following tests, which are made 10 times.

a) The CONTROL is supplied at rated voltage or at the upper limit of the rated voltage range.

b) The ACTUATING MEMBER, if any, is then moved to the "OFF" position if one exists and the CONTROL is disconnected from the supply by removing the plug from the socket-outlet.

c) One second after disconnection, the voltage between the pins of the plug is measured.

d) The voltage shall not exceed 42,4 V peak. The test is only performed if the capacitor exceeds 0,1 µF.

6.4 Covers and uninsulated live or hazardous parts

CONTROLS provided with a COVER or COVER PLATE of non-metallic material shall be so designed that the COVER fixing screws are not accessible, unless they are either protective earthed or separated from HAZARDOUS LIVE PARTS by DOUBLE INSULATION or REINFORCED INSULATION or not accessible after mounting in the equipment.

Compliance is checked by inspection.

6.4DV D2 *Modification of Clause 6.4 to add the following NOTES:*

NOTE 1DV HAZARDOUS LIVE PARTS are required to be so arranged, and the COVER so located, that persons are not likely to be exposed to shock HAZARD while removing and replacing the COVER .

NOTE 2DV HAZARDOUS LIVE PARTS or hazardous moving parts are required to be so located, guarded or enclosed so as to reduce the likelihood of contact of such parts by persons while changing lamps, electron tubes or fuses; lubricating parts, or during other operations carried out during USER MAINTENANCE or SERVICING.

6.5 Battery operated controls provided with a user accessible mains supply input connector

Battery operated CONTROLS provided with a USER accessible mains supply input connector shall be so designed that 1 s after disconnection of the mains supply connector, the voltage between any two accessible mains supply input terminals is less than or equal to the limits given in 6.1.1. The test shall be conducted using a fully charged battery or batteries.

7 Provision for protective earthing

7.1 Class 0I and Class I controls

7.1.1 Accessible metal parts, other than ACTUATING MEMBERS, of

– IN-LINE CORD, FREE-STANDING and INDEPENDENTLY MOUNTED CONTROLS of class 0I and class I which can become live in the event of an insulation FAULT, shall be permanently and reliably connected to an earthing terminal or TERMINATION within the CONTROL, or to the earthing contact of an equipment inlet.

– INTEGRATED CONTROLS and INCORPORATED CONTROLS for class 0I and class I equipment which can become live in the event of an insulation FAULT shall have provision for earthing.

NOTE 1 Parts separated from LIVE PARTS by DOUBLE INSULATION or REINFORCED INSULATION and parts screened from LIVE PARTS by metal parts connected to an earthing terminal, earthing TERMINATION or earthing contact are not regarded as likely to become live in the event of an insulation FAULT.

NOTE 2 Requirements for ACTUATING MEMBERS are specified in 6.2.3.

INTEGRATED CONTROLS and INCORPORATED CONTROLS can be connected to earth through their fixing means, provided that provision is made for clean metallic surfaces. This also applies, for example, to CONTROLS with metallic SENSING ELEMENTS which are connected reliably to the metal parts of the equipment if the manufacturer has declared this to be a method of earthing.

7.1.1DV.1 D2 *Modification of Clause 7.1.1 to add the following:*

A splice shall not be employed in a wire used for bonding purposes.

7.1.1DV.2 D2 *Modification of Clause 7.1.1 to add paragraphs 7.1.1DV.2.1 – 7.1.1DV.2.3 as follows:*

7.1.1DV.2.1 Individually covered or insulated grounding conductors shall have a continuous outer finish that is either green, or green with one or more yellow stripes and no other conductors visible to the INSTALLER in a field wiring compartment shall be so identified.

7.1.1DV.2.2 Additional requirements related to Grounding and Bonding of electrical installations and systems are specified in Article 250 of the National Electrical Code (NEC), NFPA 70.

7.1.1DV.2.3 A PELV circuit supplied from a transformer where the supply system is less than 150 V to ground may be earthed for functional reasons, and are used in applications where SELV is not required. A PELV circuit that is supplied from a transformer where the supply system exceeds 150 V to ground, the PELV circuit shall be grounded.

NOTE: Examples of common electrical supply systems covered in the 0 to 150 volts-to-ground group are: 120/240-volt, single phase, 3-wire and 208Y/120-volt, 3-phase, 4-wire systems.

7.1.2 Earthing terminals, earthing TERMINATIONS and earthing contacts shall not be electrically connected to any neutral terminal.

Compliance with 7.1.1 and 7.1.2 inclusive is checked by inspection.

7.1.2DV D2 *Modification of Clause 7.1.2 to add the following:*

A grounding connection shall reliably penetrate a nonconductive coating, such as paint or vitreous enamel.

Compliance is checked by the test of 7.3.1.

7.2 Class II and class III controls

Class II and class III controls shall have no provision for protective earthing.

Compliance is checked by inspection.

7.3 Adequacy of earth connections

7.3.1 General requirements

The connection between an earthing terminal or TERMINATION or earthing contact, and parts required to be connected thereto, shall be of low resistance.

Compliance is checked by the following test:

– A current of 1,5 times the rated current, but not less than 25 A, and derived from an AC or DC source with a no-load voltage not exceeding 12 V, is passed between the earthing terminal, earthing TERMINATION or earthing contact, and each of the parts, in turn.

– The voltage drop between the earthing terminal, earthing TERMINATION or earthing contact and the part is measured, and the resistance calculated from the current and this voltage drop. In no case shall the resistance exceed 0,1 Ω. The test is continued until steady conditions have been established.

NOTE 1 The contact resistance between the tip of the measuring probe and the metal part under test is such that it does not influence the test results.

NOTE 2 The resistance of any EXTERNAL CONDUCTOR or INTERNAL CONDUCTOR is not included in the resistance measurement, but the resistance of any INTEGRATED CONDUCTOR is included.

7.3.2 Fixed wiring and methods X and M

Earthing terminals for the connection of FIXED WIRING or for NON-DETACHABLE CORDS shall comply using methods X and M

Compliance is checked by requirements of 8.1.

7.3.2DV D2 *Modification of Clause 7.3.2 to add paragraphs 7.3.2DV.1 – 7.3.2DV.3 and Table 7.3.2DV.1 as follows:*

7.3.2DV.1 A quick connect terminal having the dimensions indicated in Table 7.3.2DV.1 may be employed as a non-accessible earthing terminal provided it has additional means for preventing displacement in use and it is used on a circuit having a protective device as specified in the table.

7.3.2DV.2 An earthing conductor in FIXED WIRING or in a supply cord shall not be terminated by means of a quick-connect terminal.

7.3.2DV.3 Earthing terminals for the connection of non-detachable cords using methods X and M shall comply with the requirements of 8.2.

Table 7.3.2DV.1
Quick Connect Terminal Dimensions

Nominal sizes mm			Rating of circuit protective device A
Width	Thickness	Length	
4,8	0,5	6,4	20 or less
4,8	0,8	6,4	20 or less
5,2	0,8	6,4	20 or less
6,3	0,8	8,0	60 or less

7.3.3 External conductors

Earthing connections for EXTERNAL CONDUCTORS shall not be made using SCREWLESS TERMINALS, however for TYPE Y ATTACHMENT and TYPE Z ATTACHMENT, screwless-type clamping units complying with IEC 60998-2-2 or 60998-2-3 or screwless-type clamping units according to IEC 60999-1 are allowed.

7.3.4 Size of accessible earthing terminals

Earthing terminals which are accessible in NORMAL USE shall allow the connection of conductors having nominal cross-sectional areas of 2,5 mm^2 to 6 mm^2 inclusive and it shall not be possible to loosen them without the aid of a TOOL.

7.3.4DV D2 ***Modification of Clause 7.3.4 by adding the following NOTE 1DV, paragraphs 7.3.4DV.1 – 7.3.4DV.9 and Tables 7.3.4DV.1 and 7.3.4DV.2:***

NOTE 1DV Conductors of other nominal cross-sectional area are permitted.

7.3.4DV.1 A flying lead for connection to an external earthing conductor shall have a free length of 6 inch (152 mm) and shall have the free end insulated – for example, shall have the end folded back and taped to the lead – unless the lead is located so that it cannot contact live parts in the event that the lead is not used in the field. It shall be not smaller than the size specified in Table 7.3.2DV.1 but in no case shall they be required to be larger than the circuit conductors supplying the equipment.

7.3.4DV.2 PROTECTIVE EARTHING CONDUCTORS shall not be smaller than shown in Table 7.3.4DV.1 but in no case shall they be required to be larger than the supply conductors supplying the circuit

7.3.4DV.3 ***Compliance is checked by inspection and measurement.***

Table 7.3.4DV.1
Minimum size of earthing and bonding conductors

Rated current of the equipment under consideration	Minimum conductor sizes AWG (mm^2)	
	A	B
Amperes	PROTECTIVE EARTHING CONDUCTOR AWG (mm^2)	PROTECTIVE BONDING CONDUCTOR AWG (mm^2)
Up to and including 10	18 (0,82)[1)]	20 (0,52)[1)]
Over 10 up to and including 13	16 (1,31)[2)]	18 (0,82)[2)]
Over 13 up to and including 18	14 (2,08)	16 (1,31)
Over 18 up to and including 25	12 (3,31)	14 (2,08)
Over 25 up to and including 30	10 (5,26)	12 (3,31)
Over 30 up to and including 40	8 (8,36)	10 (5,26)
Over 40 up to and including 55	6 (13,29)	8 (8,36)
Over 55 up to and including 70	4 (21,14)	6 (13,29)
Over 70 up to and including 95	2 (33,61)	4 (21,14)

Smaller conductors may be used provided that footnotes 1) or 2) are implemented and controlled via markings and installation instructions during installation.

1)

1. Continuous loads do not exceed 5.6 amperes.
2. Overcurrent protection is provided by one of the following:
   a) Branch-circuit-rated circuit breakers listed and marked for use with 18 AWG copper wire
   b) Branch-circuit-rated fuses listed and marked for use with 18 AWG copper wire
   c) Class CC, Class J, or Class T fuses

2)

1. Continuous loads do not exceed 8 amperes.
2. Overcurrent protection is provided by one of the following:
   a) Branch-circuit-rated circuit breakers listed and marked for use with 16 AWG copper wire
   b) Branch-circuit-rated fuses listed and marked for use with 16 AWG copper wire
   c) Class CC, Class J, or Class T fuses

7.3.4DV.4 PROTECTIVE BONDING CONDUCTORS shall comply with the following:

a) Shall pass the resistance test of 7.3.1; and

b) Shall be no smaller than the minimum conductor sizes in column B of Table 7.3.4DV.1; or for components only, be no smaller than the conductors that supply power to the component.

7.3.4DV.5 If the PROTECTIVE BONDING CONDUCTOR is smaller than the conductor supplying power to the component, or smaller than the conductor size in column B of Table 7.3.4DV.1, or a printed conductor on a printed circuit board, the protective bonding path shall demonstrate the ability to withstand a limited short circuit.

7.3.4DV.6 Compliance is determined by conducting the limited short circuit test specified in 7.3.4DV.7 and 7.3.4DV.9.

7.3.4DV.7 The protective earthing path shall be connected to the supply circuit having a capacity in accordance with Table 7.3.4DV.2. The capacity shall be determined without the protective earthing path in the circuit. The supply voltage shall be the nominal voltage of the a.c. mains supply. The specified over-current protective device rated no less than specified in 7.3.4DV.9 shall be connected in series with the protective earthing path.

Table 7.3.4DV.2
Short circuit capacity for the limited short circuit test

Maximum rating of the appliance			Wattage (hp)	Volts	Circuit capacity in A
Volt-A single-phase	Volt-A 3-phase	Volt-A direct current			
0 – 1 176	0 – 832	0 – 648	373 max (0,5)	0 – 250	200
0 – 1 176	0 – 832	0 – 648	373 max (0,5)	251 – 480	1 000
1 177 – 1 920	833 – 1 496	649 – 1 140	>373 (0,5) to 746 (1.0)	0 – 480	1 000
1 921 – 4 080	1 497 – 3 990	1 141 – 3 000	>746 (1.0) to 2 200 (3.0)	0 – 250	2 000
4 081 – 9 600	3 991 – 9 145	3 001 – 6 960	>2 200 (3.0) to 5 600 (7,5)	0 – 250	3 500
9 601 or higher	9 146 or higher	6 961 or higher	>5 600 (7,5)	0 – 250	5 000
1 921 or higher	1 497 or higher	1 141 or higher	>746 (1.0)	251 – 480	5 000

7.3.4DV.8 During the test, the protective earthing path shall not open, and there shall be no damage to any insulation, the failure of which would result in contact between the earth path and a LIVE PART. The integrity of the insulation shall be checked by the electric strength test of 15.2 by applying the test between LIVE PART and earthed parts.

7.3.4DV.9 The current rating of the overcurrent protective device shall be the smallest of the following:

a) The current rating of the attachment plug but not less than 20 A;

b) The rating of an overcurrent protective device which is specified by the manufacturer for installation in the field to protect the equipment; or

c) The rating of an overcurrent protective device in the equipment that protects the circuit or part required to be earthed.

7.3.5 Size of non-accessible earthing terminals

Earthing terminals which are not accessible in NORMAL USE for EXTERNAL CONDUCTORS shall be of a size equal to or larger than that required for the corresponding current-carrying terminal.

7.3.6 Locking of earthing terminals

Clamping means of earthing terminals for EXTERNAL CONDUCTORS shall be adequately locked against accidental loosening.

Compliance with 7.3.2 to 7.3.6 inclusive is checked by inspection, by manual test and by the appropriate tests of 8.1.

NOTE In general, the designs commonly used for current-carrying terminals provide sufficient resilience to comply with the requirement for adequate locking against accidental loosening, provided that there is no excessive vibration or temperature cycling. If the terminal is subjected to excessive vibration or temperature cycling, special provision such as the use of an adequately resilient part, for example, a pressure plate which is not likely to be removed inadvertently, can be necessary when PILLAR TERMINALS are used.

Screwless clamping units for TYPE Y ATTACHMENT and TYPE Z ATTACHMENT in accordance with 7.3.3 are considered to provide adequate resilience against vibrations and thermal cycling.

7.3.6DV D2 *Modification of Clause 7.3.6 to add 7.3.6DV.1 and 7.3.6DV.2 as follows:*

7.3.6DV.1 An equipment-grounding terminal or lead grounding point shall be connected to the frame or enclosure by a positive means, such as by a bolted or screwed connection.

7.3.6DV.2 A grounding point shall be located so that it is unlikely that the grounding means will be removed during normal servicing.

7.4 Corrosion resistance

7.4.1 General

All parts of an earthing terminal shall be resistant to corrosion resulting from contact between those parts and the copper of the earthing conductor or any other metal that is in contact with those parts.

7.4.2 Materials

The body of an earthing terminal shall be of brass, or other metal no less resistant to corrosion, unless it is a part of the metal frame or enclosure. Then any screws or nuts shall be of brass, plated steel or other metal complying with Clause 22, or other metal no less resistant to corrosion.

7.4.3 Frames or enclosures of aluminium

If the body of an earthing terminal is a part of a frame or enclosure of aluminium or aluminium alloy, precautions shall be taken to avoid the RISK of corrosion due to electrochemical action resulting from contact between copper and aluminium or its alloys.

Compliance with 7.4, 7.4.2, and 7.4.3 is checked by inspection, and in cases of doubt by an analysis of the materials and their coatings.

NOTE Corrosion resistance can be achieved by plating or similar process.

7.5 Other requirements

7.5.1 Detachable parts

If a DETACHABLE PART of a CONTROL has an earth connection, this connection shall be made before any current-carrying connections are established when placing the part in position, and any current-carrying connections shall be separated before the earth connection is broken when removing the part.

Compliance is checked by inspection.

7.5.2 Incorporated control

If an INCORPORATED CONTROL is likely to be separated from its normal earthing means after mounting in the equipment for purposes of testing, SETTING or SERVICING while the equipment is energized, it shall be provided with an earthing connection or with an earthing conductor which does not require removal from the CONTROL for such testing, SETTING or SERVICING.

Compliance is checked by inspection.

NOTE Refrigerator temperature SENSING CONTROLS and defrost CONTROLS are examples.

7.6 Protective equipotential bonding

The requirements for PROTECTIVE EQUIPOTENTIAL BONDING are those for PROTECTIVE EARTHING as given in 7.1 to 7.5.

For the installation of controls which consist of several component parts (sensing component, transmitters, central control unit, receivers, actuators, interface units) and where such component parts are parts of the fixed electrical installation of a building, the requirements for protective bonding in IEC standards for installation of buildings apply.

8 Terminals and terminations

8.1 Terminals and terminations for external copper conductors

8.1.1 Terminals for FIXED WIRING and for NON-DETACHABLE CORDS using TYPE X ATTACHMENT and TYPE M ATTACHMENT, except as specified in 8.1.3, shall be such that connection is made by means of screws, nuts or equally effective devices or methods, but without requiring a SPECIAL PURPOSE TOOL for connection or disconnection.

8.1.1DV D2 *Modification of Clause 8.1.1 to add paragraphs 8.1.1DV.1 and 8.1.1DV.2 as follows:*

8.1.1DV.1 Terminals for fixed wiring shall comply with the requirements contained in the Standard for Terminal Blocks, UL 1059. Methods X and M are not allowed. The attachment of a power supply cord may be made by the methods specified for external, internal, or INTEGRATED CONDUCTORS.

8.1.1DV.2 Flat quick connect terminals may be employed for limited energy, safety extra low voltage circuits. Such connections shall:

a) Have both engagement parts shipped with the control;

b) Have engagement parts provided with a means to permit interlocking; and

c) Be accompanied by instructions for proper installation.

8.1.2 Terminals or TERMINATIONS for NON-DETACHABLE CORDS using TYPE Y ATTACHMENT and TYPE Z ATTACHMENT shall satisfy the appropriate requirements for terminals and TERMINATIONS for INTERNAL CONDUCTORS and can require the use of SPECIAL PURPOSE TOOLS for connection or disconnection.

Compliance with 8.1.1 and 8.1.2 is checked by inspection and test.

NOTE 1 Screw type terminals in accordance with IEC 60998-2-1, SCREWLESS TERMINALS in accordance with IEC 60998-2-2 or IEC 60998-2-3 and clamping units in accordance with IEC 60999-1 are considered to be effective devices.

NOTE 2 Flat push-on terminals are deemed to require a SPECIAL PURPOSE TOOL for effecting the crimp.

8.1.3 Screws and nuts which clamp EXTERNAL CONDUCTORS shall have a metric ISO thread or a thread of equivalent effectiveness. They shall not serve to fix any other component, except that they can also clamp INTERNAL CONDUCTORS if these are so arranged that they are unlikely to be displaced when fitting the EXTERNAL CONDUCTORS.

Compliance is checked by inspection.

NOTE SI, BA and Unified threads are deemed to be of equal effectiveness to metric ISO thread.

8.1.4 Soldered, welded, crimped or similar TERMINATIONS shall not be used for the connection of NON-DETACHABLE CORDS using TYPE X ATTACHMENT and TYPE M ATTACHMENT unless such is permitted by the appropriate equipment standard. When such TERMINATIONS are used for EXTERNAL CONDUCTORS, they shall also comply with the requirements of 8.2.2 and 8.2.3.

Compliance is checked by inspection.

NOTE The application standards restrict the use of such connections.

8.1.5 Terminals for FIXED WIRING or NON-DETACHABLE CORDS using TYPE X ATTACHMENT or TYPE M ATTACHMENT shall allow at least the connection of conductors having nominal cross-sectional areas as shown in Table 2.

Compliance is checked by inspection, by measurement and by fitting conductors of the smallest and largest cross-sectional areas specified or declared.

Table 2
Cross-sectional area of conductors

Current carried by terminal [a] A	Nominal cross-sectional area mm^2	
	Flexible cord conductor	Fixed wiring conductors
Up to 6 and including [b]	0,5 to 1	1 to 1,5
Over 6 up to and including 10	0,75 to 1,5	1 to 2,5
Over 10 up to and including 16	1 to 2,5	1,5 to 4
Over 16 up to and including 25	1,5 to 4	2,5 to 6
Over 25 up to and including 32	2,5 to 6	4 to 10
Over 32 up to and including 40	4 to 10	6 to 16
Over 40 up to and including 63	6 to 16	10 to 25

[a] Requirements for applications greater than 63 A are under consideration.

[b] The nominal cross-sectional areas specified do not apply to terminals in SELV-circuits or PELV-circuits carrying a current not exceeding 3 A.

If a terminal is designed to accommodate a wider range of FIXED WIRING or flexible cord conductor sizes than those indicated in columns 2 and 3 of Table 2, then this shall be declared in Table 1, requirement 11.

Table 2DV DR *Modification of Table 2 to replace with the following text:*

The nominal cross-sectional area of a conductor is related to the current being carried and shall be sized in accordance with Article 310 and Article 400 of the National Electrical Code, NFPA 70.

NOTE 1DV The measurements of CREEPAGE DISTANCE and CLEARANCES at terminals are made twice, once with conductors of the largest cross-sectional area to be used and once without conductors fitted

8.1.6 Terminals for FIXED WIRING or NON-DETACHABLE CORDS using TYPE X ATTACHMENT or TYPE M ATTACHMENT shall be so fixed that, when the clamping means is tightened or loosened, the terminal does not work loose, INTERNAL CONDUCTORS are not subjected to stress, and CREEPAGE DISTANCES and CLEARANCES are not reduced below the values specified in Clause 11.

Compliance is checked by inspection and by measurement after fastening and loosening a conductor of the largest cross-sectional area used in 8.1.5 10 times, the conductor being moved each time it is loosened. For threaded parts, the full torque applied is either that shown in Table 9, or the torque specified in the relevant figure (see Figure 11 to Figure 14), whichever is greater.

During the test, terminals shall not work loose and there shall be no damage, such as breakage of screws or damage to the head slots, threads, washers, stirrups or other parts, that will impair the further use of the terminal.

NOTE 1 This requirement does not imply that the terminal must be so designed that rotation or displacement is prevented, provided that its movement does not bring about non-compliance with the other requirements of this document.

NOTE 2 Terminals can be prevented from working loose by fixing with two screws, by fixing with one screw in a recess or by other suitable means.

NOTE 3 Covering with sealing compound, or with resins, is only considered to be a sufficient means for preventing a terminal from working loose if

– the seal is not subject to mechanical strain as a result of connection or disconnection of the conductor or use of the equipment; and

– the effectiveness of the sealing compound is not impaired by the temperature which is attained by the terminal under the most unfavourable conditions required by this document.

8.1.7 Terminals for FIXED WIRING or NON-DETACHABLE CORDS using TYPE X ATTACHMENT or TYPE M ATTACHMENT shall be so designed that they clamp the conductor between metal surfaces with sufficient contact pressure and without undue damage to the conductor, except that for SCREWLESS TERMINALS intended for circuits carrying a current not exceeding 2 A, one of the surfaces can be of non-metallic material.

Compliance is checked by inspection of the terminal and of the conductors after the test of 8.1.6.

NOTE Conductors are considered to be unduly damaged if they show sharp or deep indentations.

8.1.8 Terminals for FIXED WIRING and NON-DETACHABLE CORDS using TYPE X ATTACHMENT shall not require special preparation of the conductor in order to effect correct connection.

Terminals for TYPE X ATTACHMENT can also have alternative means of connection if at least one of the means conforms to this requirement, even if the original factory-made connection uses another means. In this case, the original factory-made connection shall comply with the requirements for terminals and TERMINATIONS for INTERNAL CONDUCTORS.

Compliance is checked by inspection.

NOTE The term "special preparation of the conductor" covers soldering of the strands, use of cable lugs, formation of eyelets, etc., but not the reshaping of the conductor before its introduction into the terminal or the twisting of a stranded conductor to consolidate its end.

8.1.9 Terminals for FIXED WIRING and NON-DETACHABLE CORDS using TYPE X ATTACHMENT or TYPE M ATTACHMENT shall be so designed or placed that neither the conductor nor a wire of a stranded conductor can slip out while any clamping screws or nuts are being tightened, or while any equally effective device is being operated.

Compliance is checked by the following tests.

a) Terminals are fitted with conductors according to the use of the terminal, in accordance with Table 3. The wires of fixed wiring conductors are straightened before inserting into the terminal.

b) The wires of flexible cables and cords are twisted so that there is an even twist of one complete turn in 20 mm. The conductor is inserted into the terminal for the minimum distance prescribed, or where no distance is prescribed, until it just projects from the far side of the terminal. The conductor is inserted into the terminal in the position most likely to assist a wire to escape and then the screw is tightened with a torque equal to two-thirds of the torque specified in Table 9.

c) For flexible cords, the test is repeated using a new conductor which is twisted as before, but in the opposite direction. After the test, no wire of the conductor shall have escaped into the gap between the clamping means and the retaining device.

8.1.9DV D2 *Modification of Clause 8.1.9 item (a) to replace with the following:*

a) Terminals are fitted with conductors according to the use of the terminal and in accordance with Article 400 of the National Electrical Code, NFPA 70. The wires of FIXED WIRING conductors are straightened before inserting into the terminal.

Table 3
Terminal conductors

Current carried by terminal a A		Conductor to be fitted (number of wires and nominal diameter of each wire in millimetres)	
Flexible cord conductors	Fixed wiring conductors	For flexible cord conductors	For fixed wiring conductors
0 to 6	–	32 × 0,20	–
6 to 10	0 to 6	40 × 0,25	7 × 0,52
10 to 16	6 to 10	50 × 0,25	7 × 0,67
16 to 25	10 to 16	56 × 0,30	7 × 0,85
25 to 32	16 to 25	84 × 0,30	7 × 1,04
–	25 to 32	94 × 0,30	7 × 1,35
32 to 40	32 to 40	80 × 0,40	7 × 1,70
40 to 63	40 to 63	126 × 0,40	7 × 2,14

[a] Requirements for applications greater than 63 A are under consideration.

8.1.10 Terminals shall be so designed that they clamp the conductor reliably.

Compliance is checked by the following tests.

a) The terminals are fitted with conductors of the smallest and largest nominal cross-sectional areas used in 8.1.5, fixed or flexible, whichever is appropriate, or the more unfavourable and the terminal screws are tightened, the torque applied being equal to two-thirds of the torque specified in Table 9. Each conductor is subjected to a pull of the value shown in Table 4. The pull is applied without jerks for 1 min, in the direction of the axis of the conductor space.

b) This pull test is normally applied directly to the conductor adjacent to where it enters the terminal. If, however, an additional crimping or clamping device holding the conductor or the insulation around the conductor exists not more than 30 mm from the entry point for the conductor into the terminal and measured along the length of the conductor, this test should apply to the crimping or clamping device, and not to the actual terminal.

c) During the test, the conductor shall not move by more than 1,6 mm in the terminal.

Table 4
Conductor pull test values

Current carried by terminal A	Pull N	
	Terminals for flexible cord conductors	Terminals for fixed wiring conductors
Up to and including 3	20	20
Over 3 up to and including 6	30	30
Over 6 up to and including 10	30	50
Over 10 up to and including 16	50	50
Over 16 up to and including 25	50	60
Over 25 up to and including 32	60	80
Over 32 up to and including 40	90	90
Over 40 up to and including 63	100	100

8.1.11 Terminals shall be so designed that they do not attain temperature in NORMAL USE, so as to damage the material of the supporting insulation, or the insulating covering of the clamped conductors.

Compliance is checked during the heating tests of Clause 16.

8.1.12 Terminals shall be so located that each core contained within any FIXED WIRING sheath or flexible cord sheath can be terminated in reasonable proximity to the other cores within the same sheath, unless there is a good technical reason for the contrary.

Compliance is checked by inspection.

8.1.13 Terminals for NON-DETACHABLE CORDS using TYPE X ATTACHMENT or TYPE M ATTACHMENT shall be so located or shielded, that should a wire escape when the conductors are fitted, there is no RISK of accidental contact between LIVE PARTS and accessible metal parts, and for CLASS II CONTROLS and CONTROLS for class II equipment, between LIVE PARTS and metal parts separated from accessible metal parts by SUPPLEMENTARY INSULATION only. Furthermore, there shall be no RISK of short-circuiting a declared action providing a FULL DISCONNECTION or a MICRO-DISCONNECTION.

Compliance is checked by inspection and by the following test:

– An 8 mm length of insulation is removed from the end of a stranded conductor having a nominal cross-sectional area equal to the minimum size used during the test of 8.1.5. One wire of the stranded conductor is left free, and the other wires are fully inserted into and clamped in the terminal. The free wire is bent, without tearing the insulation back, in every direction, but without making sharp bends around barriers.

– The free wire of a conductor connected to a live terminal shall not touch any metal part which is accessible or is connected to an accessible metal part, or for CLASS II CONTROLS and CONTROLS of class II equipment, any metal part which is separated from accessible metal parts by SUPPLEMENTARY INSULATION only.

– The free wire of a conductor connected to an earthing terminal shall not touch any LIVE PART.

– The free wire of a conductor connected to a live terminal shall not become accessible, nor shall it short-circuit a declared action providing a FULL DISCONNECTION or a MICRO-DISCONNECTION.

8.1.14 Terminals shall be so designed that circuit continuity is not maintained by pressure transmitted through insulating material other than ceramic, or other insulating material with characteristics no less suitable, unless there is sufficient resilience in the appropriate metal parts to compensate for any shrinkage or distortion.

Compliance is checked by initial inspection and by further examination of the terminals when the samples have completed the test of Clause 19.

NOTE The suitability of the material is considered in respect to the stability of the dimensions within the temperature range applicable to the CONTROL.

8.1.15 Screws and threaded parts of terminals shall be of metal.

Compliance is checked by inspection.

8.1.15DV.1 D2 *Modification of Clause 8.1.15 to add a NOTE 1DV and 8.1.15DV.1.1 as follows:*

NOTE 1DV National standards require that when screws are used for conductors of 2,5 mm or smaller diameter, the connection shall consist of clamps or binding screws with terminal plates having upturned lugs, or equivalent, to hold the wires in position. Terminal plate thicknesses are 1,27 mm (0,050 in) for wire size of more than 1,6 mm diameter (14 AWG); and 0,76 mm thickness minimum (0,030 in) for wire sizes of 1,6 mm or smaller diameter. The terminal screws shall not be smaller than No. 8 Unified, except that No. 6 Unified screw may be used for connection of a 1,29 mm (AWG 16) wire or a 1,02 mm (AWG 18) wire or a single 1,6 mm (AWG 14) wire.

8.1.15DV.1.1 A terminal plate tapped for a wire binding screw shall have two or more full threads which may be extruded to provide two full threads.

8.1.16 TERMINALS of the pillar type and the mantle type shall be so designed as to allow an adequate length of conductor to be introduced into, and pass beyond the edge of the screw, to ensure that the conductor does not fall out.

Compliance is checked for PILLAR TERMINALS by measurement of dimension "g" in Figure 12 and for MANTLE TERMINALS by the minimum distance specified in Figure 13.

8.1.16DV D2 *Modification of Clause 8.1.16 to add 8.1.16DV.1 and 8.1.16DV.2 as follows:*

8.1.16DV.1 Flying Leads (pig tails)

Flying leads (pig tails) may be used for wiring connections of INDEPENDENTLY MOUNTED CONTROLS. The lead wires shall not be smaller than 0,82 mm^2. The insulation shall be at least 0,8 mm thick, if thermoplastic, or at least 0,8 mm thick rubber, with a braid of 0,8 mm thick thermoplastic.

The leads shall have a minimum length of 150 mm and shall be arranged so that they are inaccessible when installed in accordance with national wiring practices. Additionally, the CONTROL end connection of such a lead, if located in the same wiring compartment, shall not be to a threaded terminal construction unless the means of connection is rendered unusable for connection of an EXTERNAL CONDUCTOR.

The threaded terminal construction need not be rendered unusable if the lead is insulated at the connection end, and a marking on the device clearly indicates the intended use of the lead.

Compliance is checked by inspection.

8.1.16DV.2 Flying leads shall be provided with strain relief to prevent mechanical stress from being transmitted to terminal, splices (for example, twist-on connections) or internal wiring.

Compliance is checked by inspection and by applying a pull of 44 N on the leads for 1 min.

During this test, the lead shall not be damaged and shall not be displaced longitudinally by more than 2 mm.

8.2 Terminals and terminations for internal conductors

8.2.1 Connection of conductors

Terminals and TERMINATIONS shall allow the connection of conductors having nominal cross-sectional areas as shown in Table 5.

Table 5
Nominal cross-sectional areas of conductors

Current carried by terminal or terminations [a] A	Minimum nominal cross-sectional area of conductor mm^2
Up to and including 3	– [b]
Over 3 up to and including 6	0,75
Over 6 up to and including 10	1
Over 10 up to and including 16	1,5
Over 16 up to and including 25	2,5
Over 25 up to and including 32	4
Over 32 up to and including 40	6
Over 40 up to and including 63	10

[a] Requirements for applications greater than 63 A are under consideration.

[b] No minimum specified, but the manufacturer shall declare the conductor size for test purposes.

The requirements of 8.2.1 do not apply to terminals which are not intended to accept standard conductors without special preparation, or which, by their design and application, cannot accept standard conductors; or which are deliberately designed to accept conductors of a different size and which are for use only in particular types of equipment.

NOTE An example is a thermostat intended for use within the fabric of an electric blanket.

8.2.1DV D2 *Modification of Clause 8.2.1 to add the following:*

In the USA, other sizes of conductors apply. Also, see 8.1.9DV.

8.2.2 Suitability for purpose

Terminals and TERMINATIONS shall be suitable for their purpose. TERMINATIONS for making soldered, crimped and welded connections shall be capable of withstanding the stresses which occur in normal service.

Compliance is checked by inspection.

8.2.3 Soldered terminals

When soldered terminals are used, the conductor shall be so positioned or fixed that reliance is not placed upon the soldering alone to maintain the conductor in position, unless barriers are provided such that CREEPAGE DISTANCES and CLEARANCES between LIVE PARTS and other metal parts cannot be reduced to less than 50 % of the values specified in Clause 11 should the conductor break away at the soldered joint.

Compliance is checked by inspection.

NOTE In general, "hooking-in" before soldering is considered to be a suitable means for maintaining a conductor in position, provided the hole through which the conductor is passed is not unduly large, and provided that the conductor is not part of a flat-twin tinsel cord.

Other methods of maintaining a conductor in position, such as waisting the sides of a solder tag, are also considered acceptable.

8.2.4 Flat push-on connectors

8.2.4.1 TABS forming part of a CONTROL shall comply with the dimensional requirements of Figure 15 or Figure 16.

Compliance is checked by measurement.

TABS with dimensions other than those shown in Figure 15 or Figure 16 can be used, if the dimensions and shapes are so different as to prevent any possible mismating with a standard RECEPTACLE (see Figure 17).

For the dimensions of Figure 15, Figure 16 and Figure 17, the physical dimensions of IEC 61210 can alternatively be used. The performance requirements of IEC 61210 do not apply.

TABS allowing the polarized acceptance of RECEPTACLES can be used (see Figure 17).

8.2.4.2 TABS forming part of a control shall consist of material and plating having electrical, thermal and mechanical characteristics appropriate for the application; particularly, with regard to resistance to corrosion and mechanical strength. The maximum temperature of the TABS shall be within the manufacturer's specifications.

Compliance is checked by tests of this document.

8.2.4.3 TABS forming part of a CONTROL shall have adequate strength to allow the insertion and withdrawal of RECEPTACLES without damage to the CONTROL such as to impair compliance with this document.

Compliance is checked by applying, without jerks, axial forces equal to those shown in Table 6. No significant displacement or damage shall occur.

Table 6
Axial force values for tab insertion and withdrawal

Tab size (see Figure 17)	Push [a] N	Pull [a] N
2,8	50	40
4,8	60	50
6,3	80	70
9,5	100	100

[a] The values in the table are the maximum allowed for the insertion and the withdrawal of a receptacle from a tab.

8.2.4.4 TABS forming part of a CONTROL shall be adequately spaced to allow the connection of the appropriate RECEPTACLES.

For the dimensions of Figure 15, Figure 16 and Figure 17, the physical dimensions of IEC 61210 can alternatively be used. The performance requirements of IEC 61210 do not apply.

Compliance is checked by applying an appropriate receptacle on each TAB unless otherwise declared in 7.2. During this application, no strain nor distortion shall occur to any of the tabs nor to their adjacent parts, nor shall the creepage distance or clearance values be reduced below those specified in Clause 11.

NOTE For TABS complying with Figure 15 or Figure 16, the appropriate RECEPTACLE is shown in Figure 17.

8.3 Terminals and terminations for integrated conductors

There are no specific requirements or tests for terminals or terminations for INTEGRATED CONDUCTORS under Clause 8, but the relevant requirements of the other clauses can apply.

9 Constructional requirements

9.1 Materials

9.1.1 Insulating materials – Impregnated

Wood, cotton, silk, ordinary paper and similar fibrous or hygroscopic material shall not be used as insulation unless impregnated.

Compliance is checked by inspection.

NOTE Insulating material is considered to be impregnated if the interstices between the fibres of the materials are substantially filled with a suitable insulant.

9.1.1DV D2 *Modification of Clause 9.1.1 to add the following:*

Requirements for insulating materials and polymeric enclosures are contained in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

9.1.2 Current-carrying parts

If brass is used for current carrying parts other than threaded parts of terminals, it shall contain at least 50 % copper if the part is cast or made from bar, or at least 58 % if the part is made from rolled sheet.

Compliance is checked by inspection, comparing the requirement with the manufacturer's specification or by analysis of the material

9.1.3 Non-detachable cords

9.1.3.1 NON-DETACHABLE CORDS of CLASS I CONTROLS shall have a green/yellow insulated conductor which is connected to the earthing terminal or TERMINATION of the CONTROL, or to the earthing contact of any equipment inlet or socket-outlet, if provided.

9.1.3.1DV D2 *Modification of Clause 9.1.3.1 to add the following:*

Individually covered or insulated grounding conductors shall have a continuous outer finish that is either green, or green with one or more yellow stripes.

9.1.3.2 Conductor with insulation identified by the colour combination green/yellow shall not be connected to terminals or TERMINATIONS other than earthing terminals or TERMINATIONS.

Compliance with 9.1.3.1 and 9.1.3.2 is checked by inspection.

9.1.3.2DV D2 *Modification of Clause 9.1.3.2 to add the following:*

All individually covered or insulated conductors other than grounding conductors shall not use a continuous outer finish that is either green, or green with one or more yellow stripes.

9.1.4 Intentionally weak traces

INTENTIONALLY WEAK TRACES shall be used only to protect against hazards caused by failure of components included in Table 14.

9.2 Protection against electric shock

9.2.1 Double insulation

When DOUBLE INSULATION is employed, the design shall be such that the BASIC INSULATION and the SUPPLEMENTARY INSULATION can be tested separately unless satisfaction with regard to the properties of both insulations is provided in another way.

If the BASIC INSULATION and the SUPPLEMENTARY INSULATION cannot be tested separately, or if satisfaction with regard to the properties of both insulations cannot be obtained in another way, the insulation is regarded as REINFORCED INSULATION.

Compliance is checked by inspection and by test.

NOTE Specially prepared samples, or samples of the insulating parts, are regarded as ways of providing satisfaction.

9.2.2 Infringement of double insulation or reinforced insulation

CLASS II CONTROLS and CONTROLS for use in class II equipment shall be so designed that CREEPAGE DISTANCES and CLEARANCES over SUPPLEMENTARY INSULATION or REINFORCED INSULATION cannot, as a result of wear, be reduced below the values specified in Clause 11. They shall be so constructed that if any wire, screw, nut, washer, spring, flat push-on RECEPTACLE or similar part becomes loose and falls out of position, it cannot in NORMAL USE become so disposed that CREEPAGE DISTANCES or CLEARANCES over SUPPLEMENTARY INSULATION or REINFORCED INSULATION are reduced to less than 50 % of the value specified in Clause 11.

For the purpose of this requirement:

– it is not to be expected that two independent fixings will become loose at the same time;

– parts fixed by screws or nuts provided with a locking washer are regarded as not liable to become loose, provided these screws or nuts are not required to be removed during USER MAINTENANCE or SERVICING;

– springs and spring parts that do not become loose or fall out of position during the tests of Clauses 19 and 20 are deemed to comply;

– wires connected by soldering are considered to be not adequately fixed unless they are mechanically fixed in place near to the TERMINATION, independently of the solder;

– wires connected to terminals are considered to be not adequately secured unless an additional fixing is provided near to the terminal. This additional fixing, in the case of stranded conductors, shall clamp the insulation and not the conductor;

– short rigid wires are regarded as not liable to come away from a terminal if they remain in position when any one terminal screw or nut is loosened.

Compliance is checked by inspection, by measurement and/or by manual test.

9.2.3 Integrated conductors

9.2.3.1 INTEGRATED CONDUCTORS shall be so rigid, so fixed or so insulated that in NORMAL USE CREEPAGE DISTANCES and CLEARANCES cannot be reduced below the values specified in Clause 11.

9.2.3.2 Insulation, if any, shall be such that it cannot be damaged during mounting or in NORMAL USE.

Compliance with 9.2.3.1 and 9.2.3.2 is checked by inspection, by measurement and by manual test.

NOTE If the insulation on a conductor is not at least electrically equivalent to that of cables and flexible cords complying with the appropriate IEC standard, or alternatively does not comply with the electric strength test made between the conductor and metal foil wrapped around the insulation under the conditions specified in Clause 15, the conductor is considered to be a bare conductor.

9.2.3DV D2 *Modification of Clause 9.2.3 to add 9.2.3.3DV.1 to 9.2.3.3DV.4 as follows:*

9.2.3.3DV.1 A 18 AWG or 16 AWG (0,82 or 1,3 mm^2) rubber-covered wire in other than a low-voltage circuit as described in 3.1.5 shall be at least Type RFH-1 with impregnated

braid, for a potential of 300 V or less; and shall be at least Type RFH-2 with impregnated braid and shall be acceptable for the application for a potential of 301 – 600 V.

9.2.3.3DV.2 A 14 AWG (2,1 mm^2) or larger conductor shall be Type TW, RH, or RHW wire.

9.2.3.3DV.3 Other types of conductors that have been found to be acceptable may also be employed; Type TF wire may be used wherever Type RFH-1 or RFH-2 wire is acceptable.

9.2.3.3DV.4 Tubing shall not be subjected to sharp bends, tension, compression, or repeated flexing, and shall not contact sharp edges, projections, or corners. Tubing may be used in dry or damp locations but is not acceptable in wet locations.

9.2.4 Flexible cord sheaths

Inside a CONTROL, the sheath (jacket) of a flexible cable or cord shall be used as SUPPLEMENTARY INSULATION only where it is not subject to undue mechanical or thermal stresses, and if its insulating properties are not less than those specified in IEC 60227-1 or IEC 60245-1.

Compliance is checked by inspection, and, if necessary, by testing the sheaths of the flexible cords according to IEC 60227-1 or IEC 60245-1.

9.2.4DV D2 *Modification of Clause 9.2.4 to add the following:*

The tests for insulating properties of a cord's sheath shall be in accordance with UL 62.

9.2.5 Protective impedance

PROTECTIVE IMPEDANCE shall consist of two or more impedance components of equivalent resistance values in series, which are connected between LIVE PARTS and ACCESSIBLE PARTS. It shall consist of components in which the probability of a reduction in impedance during life can be ignored and the possibility of a short circuit is negligible.

Such components are

– Resistors detailed in Table 14, footnote c.

Alternatively, the resistors shall comply with the requirements of IEC 60065:2014, 14.2.

– Capacitors.

Capacitors shall comply with IEC 60384-14, class Y.

The use of only one Y1 capacitor is permitted where the capacitor complies with IEC 60384-14 appropriate to the WORKING VOLTAGE of application where it is used.

Compliance is checked by

a) open-circuiting each impedance component in turn;

b) short-circuiting of those impedance components which are likely to fail by a short circuit (according to 13.1);

c) applying a FAULT condition according to 13.1 to any part of the circuit which might influence the maximum TOUCH CURRENT with the PROTECTIVE IMPEDANCE intact.

Operation of a protective device or loss of one pole of the supply shall also be considered as FAULTS.

Under these conditions, the equipment shall still comply with the requirements of 6.1.9.

9.2.6 Protection against electric shock by use of SELV or PELV

See Annex P.

9.2.7 Connections between internal and external SELV/PELV circuits

Adequate measures shall be provided to prevent the interconnection of an integrated SELV circuit to an external PELV circuit and vice versa.

The supply of a CLASS III CONTROL from an external SELV source by means of a separable connection shall only be possible by means of a dedicated plug and socket SYSTEM which cannot be fitted or interconnected with other connecting SYSTEMS.

Compliance is checked by inspection.

9.2.8 Overcurrent protection

CONTROLS shall be capable of carrying the currents likely to flow in abnormal conditions for such periods of time as are determined by the characteristics of the overcurrent protective device. For INTEGRATED CONTROLS or INCORPORATED CONTROLS, if the overcurrent protective device is external to the control, it shall be declared in Table 1, requirement 68.

Compliance is checked by the test of 26.2.

9.3 Actuation and operation

9.3.1 Full disconnection

Controls with positions declared as FULL DISCONNECTION shall be so designed that in the declared positions there is contact separation in all supply poles other than earth, at least equal to the relevant values specified in Clause 11. The contact separation can be obtained by automatic action or by manual action, but any subsequent automatic action shall not cause any contact separation to be reduced below the specified minimum.

If the disconnection is also declared to provide ALL-POLE DISCONNECTION, the contact OPERATION in each supply pole shall be practically simultaneous.

Compliance is checked by inspection and by the tests of Clauses 15 and 11, where necessary.

9.3.2 Micro-disconnection

CONTROLS with positions declared as MICRO-DISCONNECTION shall be so designed that in the declared positions there is contact separation in at least one supply pole to meet the electric strength requirements of Clause 15 but no CLEARANCE dimension is specified. The contact separation can be obtained by AUTOMATIC ACTION or by MANUAL ACTION, but any subsequent change of ACTIVATING QUANTITY between the limits declared in Table 1, requirement 30, or at any SWITCH HEAD temperature between the limits declared

in Table 1, requirement 15, shall not cause an OPERATION which would reduce the contact separation such that the requirements of Clause 15 are no longer met.

Compliance is checked by inspection and, where necessary, by the tests of Clause 15 carried out at the temperature limits declared.

9.3.3 Reset buttons

Reset buttons of CONTROLS shall be so located or protected that they are not likely to be accidentally reset.

This requirement does not apply to manual reset CONTROLS with TRIP-FREE actions.

Compliance is checked by inspection.

NOTE This requirement precludes, for example, reset buttons mounted in such a position that they can be reset by pushing the CONTROL against a wall, or by pushing a piece of furniture against the CONTROL.

9.3.4 Setting by the manufacturer

Parts used for the SETTING of CONTROLS by the manufacturer shall be secured to prevent accidental shifting after SETTING.

Compliance is checked by inspection.

9.3.5 Contacts

9.3.5.1 General

Contacts with a DC rating greater than 0,1 A, which can be operated by ACTUATION, shall be so designed that the speeds of approach and separation of the contact surfaces are independent of the speed of ACTUATION.

Compliance is checked by inspection.

NOTE This requirement does not apply to contacts excluded by 9.3.7.

9.3.5.1DV D2 ***Modification of Clause 9.3.5.1 to add the following after the note:***

A component, such as a resistor, capacitor, diode, and the like, shall not be connected across the contacts of a safety CONTROL or a protective device unless it can be validated through a failure assessment that a single component fault will not result in a loss of protective function.

9.3.5.2 Systems of class C control functions

9.3.5.2.1 SYSTEMS of CLASS C CONTROL FUNCTIONS shall include at least two switching elements to directly de-energize the safety relevant terminals.

NOTE A single relay operating two independent contacts is considered to be only one switching element.

– To prevent common cause errors, measures shall be taken to protect against FAILURE of two (or more) switching elements, due to a common cause, by an external short circuit that would prevent the CONTROL from performing a SAFETY SHUT-DOWN.

Acceptable methods are, for example,

– overcurrent protection device,

– current limitation or

– internal FAULT detecting means.

The suitability of measures to maintain the capability to interrupt the energization of the safety related output terminals by means of at least one switching element or the interruption of an overcurrent protection device shall be verified by the following test.

The safety related output terminals of the control are connected to a switch that is intended to switch the short-circuit current. With this switch opened, the control is connected as described in 13.1.3 with the outputs energized to simulate normal operation (contacts of the internal switching elements closed).

The test equipment shall have the following characteristics:

a) when overcurrent protection devices are used as the protective measure, the power supply to the CONTROL shall have the capability of supplying a short-circuit current of at least 500 A.

b) when current limitation techniques are used as the protective measure (for example, transformer), the power supply to the CONTROL shall not limit the declared (Table 1, requirement 67) short-circuit current.

9.3.5.2.2 A short-circuit is applied between the safety related output terminals of the CONTROL by closing the switch.

The test is operated for 1 h or until there is no current flow through the switch, whichever occurs first.

If an overcurrent protection device is replaceable and has operated during the test, it shall be replaced and the test is repeated a further two times by attempting to restart the CONTROL keeping the switch closed.

The test is repeated using either the same or a separate sample with the switch maintained in the closed position prior to the first start-up sequence.

9.3.5.2.3 If an internal FAULT detecting function of the CONTROL either opens the switching elements or initiates a SAFETY SHUT-DOWN, the test is repeated two times by attempting to restart the control while maintaining the external short circuit.

Compliance is checked in accordance with 13.1.3.8 and Clause H.17.

After the test, at least one switching element of the CONTROL shall be able to de-energize the safety related output terminals, or a non-replaceable overcurrent protection device has permanently interrupted the supply to the safety related output terminals.

9.3.6 Contacts for full disconnection and micro-disconnection

Contacts for FULL DISCONNECTION and contacts for MICRO-DISCONNECTION, having either a DC rating not greater than 0,1 A, or an AC rating, and which can be operated by ACTUATION, shall be so designed that they can come to rest only in a closed position or in an open position.

Compliance is checked by inspection, and for a closed position by the temperature requirements of Clause 16, and for open position by the requirements of Clause 15, as specified for MICRO-DISCONNECTION. However, where an INTERMEDIATE POSITION of the ACTUATING MEMBER occurs adjacent to a LOCATED POSITION declared as FULL DISCONNECTION, then the tests of Clauses 15 and 11, as specified for FULL DISCONNECTION, are made for this INTERMEDIATE POSITION.

9.3.7 Exclusions for 9.3.5.1 and 9.3.6

9.3.7.1 The requirements of 9.3.5.1 and 9.3.6 shall not apply to contacts where inspection shows they cannot be operated on-load or are not intended to be operated on-load, nor to contacts which do not arc under conditions of NORMAL USE.

Compliance is checked by inspection, and if necessary by the test of 9.3.7.2.

9.3.7.2 *A DC voltage equal to the maximum WORKING VOLTAGE is applied to the contacts in series with a resistor such that the current occurring in NORMAL USE is obtained. It shall not be possible to maintain an arc by slowly opening the contacts.*

9.3.8 Contacts rest position

Contacts shall, in any rest position of the ACTUATING MEMBER, be either open or closed as intended, or such that no HAZARD can occur within the control or equipment.

Compliance is checked by inspection.

NOTE 1 The term "rest position of the ACTUATING MEMBER" includes located, intermediate and position of SETTING BY THE USER.

NOTE 2 For the purposes of trying to obtain an INTERMEDIATE POSITION of an ACTUATING MEMBER, between any indexed, marked, or intended rest positions, the ACTUATING MEMBER can be actuated as in NORMAL USE. Holding the ACTUATING MEMBER in position is not ACTUATION.

9.3.9 Pull-cord actuated control

A PULL-CORD ACTUATED CONTROL shall be so designed that when the PULL-CORD is released after actuating the CONTROL, the relevant parts of the mechanism normally cannot fail to return to a position from which they allow the immediate performance of the next movement in the cycle of ACTUATION of the CONTROL.

Compliance is checked by inspection and by the following test.

PULL-CORD ACTUATED CONTROLS can be actuated from any LOCATED POSITION to the next LOCATED POSITION by the application and removal of a steady pull not exceeding 45 N vertically downwards, or 70 N at 45° to the vertical, with the CONTROL mounted in any declared manner.

NOTE The actuating forces for CONTROLS actuated by other than PULL-CORDS, are not specified. Attention is drawn to the relevant equipment standard where such requirements are given.

9.3.10 See J.9.3.10.

9.4 Actions

9.4.1 Combined actions

A CONTROL having more than one action, with one of the actions designed to operate after the FAILURE of the other action(s), shall be so constructed that this action remains operative after FAILURE of any portion unique to the other action(s).

Compliance is checked by inspection and, if necessary, by tests after making all of the other action(s) inoperative.

9.4.2 Setting by the manufacturer

TYPE 2 ACTION which has provision for setting by the manufacturer of its operating value, operating time or operating sequence, shall be designed such that it is clearly discernible if any subsequent interference with the setting has been made.

Compliance is checked by inspection.

9.4.3 Type 2 action

Any TYPE 2 ACTION shall be so designed that the MANUFACTURING DEVIATION and DRIFT of its OPERATING VALUE, OPERATING TIME or OPERATING SEQUENCE is within the limit declared in Table 1, requirements 35 and requirement 36.

Compliance is checked by the tests of Clauses 17 to 19 inclusive.

9.4.4 Type 1.A or 2.A action (Full disconnection on operation)

Type 1.A or 2.A action shall operate to provide the CLEARANCES and electric strength requirements specified for FULL DISCONNECTION.

Compliance is checked by the tests of Clause 15 and the relevant requirements of Clause 11.

9.4.4DV D2 *Modification of Clause 9.4.4 to add the following:*

A Type 1.AY or 2.AY action (OFF POSITION) shall be so designed that it provides a FULL DISCONNECTION that is prevented from reclosing automatically when in the OFF POSITION by positive mechanical means.

9.4.5 Type 1.B or 2.B action (Micro-disconnection on operation)

A Type 1.B or 2.B action shall operate to provide the electric strength requirements specified for MICRO-DISCONNECTION.

Compliance is checked by the test of Clause 15 and the relevant requirements of Clause 11.

9.4.6 Type 1.C or 2.C action (Micro-interruption on operation)

A Type 1.C or 2.C action shall operate to provide circuit interruption by MICRO-INTERRUPTION.

Compliance is checked by the relevant requirements of Clause 11.

9.4.7 Type 1.D or 2.D action (a trip-free mechanism which cannot even momentarily be reclosed against the fault)

A Type 1.D or 2.D action shall be so designed that disconnection can neither be prevented nor inhibited, by any reset mechanism and so that after disconnection, it is not possible to reclose the circuit even momentarily while the excess or FAULT condition persists.

Compliance is checked by inspection and by test.

9.4.8 Type 1.E or 2.E action (a trip-free mechanism in which the contacts cannot be prevented from opening or maintained closed against a continuation of the fault)

A Type 1.E or 2.E action shall be designed so that disconnection can neither be prevented, nor inhibited by any reset mechanism and so that the contacts can neither be prevented from opening nor be maintained closed against a continuation of the excess or FAULT condition.

EXAMPLE A current-SENSING CONTROL which has to be reclosed or can be reclosed momentarily to detect that the excess current FAULT still exists.

Compliance is checked by inspection and by test.

9.4.9 Type 1.F or 2.F action (an action which can only be reset by the use of a tool)

A Type 1.F or 2.F action shall be designed so that after the CONTROL has been mounted in accordance with the manufacturer's instructions, it can only be reset with the aid of a TOOL.

Compliance is checked by inspection.

NOTE Mounting within an equipment such that a TOOL is required to gain access to the CONTROL is deemed to satisfy this requirement.

9.4.10 Type 1.G or 2.G action (an action which is not intended to be reset under electrically loaded conditions)

A Type 1.G or 2.G action shall be designed so that after the CONTROL has operated, it is possible to reset the CONTROL (although not intended) under electrically loaded conditions.

Compliance is checked by inspection and by resetting once at rated voltage and rated current.

9.4.11 Type 1.H or 2.H action (a trip-free mechanism in which the contacts cannot be prevented from opening and which can automatically be reset to the "closed" position after normal operation conditions have been restored if the reset means is held in the "reset" position)

A Type 1.H or 2.H action shall be so designed that the contacts cannot be prevented from opening and which can automatically reset to the closed position if the reset means is held in the reset position. The CONTROL shall not reset automatically at any temperature above –35 °C with the reset mechanism in the normal position.

Compliance is checked by inspection and by test.

NOTE The test is given in the relevant part 2.

9.4.12 Type 1.J or 2.J action (a trip-free mechanism in which the contacts cannot be prevented from opening and the control is not permitted to function as an automatic reset device if the reset means is held in the "reset" or "on" position)

A Type 1.J or 2.J action shall be so designed that the contacts cannot be prevented from opening, and the CONTROL is not permitted to function as an automatic reset device if the reset means is held in the reset position. The CONTROL shall not reset automatically at any temperature above 0 °C or –35 °C.

Compliance is checked by inspection and by test.

NOTE The test is given in the relevant part 2.

9.4.13 Type 1.K or 2.K action (for sensing actions, no increase in the operating value as the result of a breakage in the sensing element, or in parts connecting the sensing element to the switch head)

A Type 1.K or 2.K action shall be so designed that in the event of a break in the SENSING ELEMENT, or in any other part between the SENSING ELEMENT and the SWITCH HEAD, the declared disconnection is provided before the declared OPERATING VALUE, OPERATING TIME or OPERATING SEQUENCE is exceeded.

NOTE The test is given in the relevant part 2.

9.4.14 Type 1.L or 2.L action (an action that does not require any external auxiliary energy source of electrical supply for its intended operation)

A Type 1.L or 2.L action shall be so designed that in the case of FAILURE of the electrical supply, it performs its intended function independently of any external auxiliary energy source or electrical supply.

Compliance is checked by inspection.

NOTE A simple direct acting spring or weight is not regarded as an auxiliary energy source or electrical supply.

9.4.15 Type 1.M or 2.M action (an action which operates after a declared ageing period)

A Type 1.M or 2.M action shall be so designed that it operates in its intended manner after the declared ageing procedure.

Compliance is checked by the test of 19.6.

9.4.16 Type 1.Y or 2.Y (electronic disconnection on operation)

9.4.16.1 Type 1.Y or 2.Y action shall operate to provide ELECTRONIC DISCONNECTION.

Compliance is checked according to 9.4.16.2 and 9.4.16.3.

9.4.16.2 The test is carried out with the CONTROL connected to its declared maximum load, supplied with rated voltage, and at temperature T_{max}.

9.4.16.3 The current through the ELECTRONIC DISCONNECTION shall not exceed 5 mA or 10 % of the rated current, whichever is the lower.

9.4.17 See J.9.4.17.

9.5 Openings in enclosures

Drain holes, if any, shall have a minimum area of 20 mm^2, a maximum area of 40 mm^2 and minimum dimension of 3 mm.

Compliance is checked by inspection.

NOTE 1 Additional requirements for moisture resistance are contained in Clause 14.

NOTE 2 CONTROLS classified as IPX7 can have a facility for opening a drain hole.

9.5DV D2 *Modification of Clause 9.5 to add 9.5DV.1 to 9.5DV.3 as follows:*

9.5DV.1 In-line cord, free-standing and independently mounted controls shall meet the applicable requirements of R33DV.1.

9.5DV.2 A nonmetallic part such as a reset knob, lever, or button that protrudes through an opening in the enclosure that is not larger than 650 mm^2 (1 in^2) in area shall be made of a material classified as 5VA, 5VB, V-0, V-1, or V-2 in accordance with UL 94.

9.5DV.3 A nonmetallic part that protrudes through an opening in the enclosure that is larger than 650 mm^2 (1 in^2) in area shall be made of a material classified 5VA or 5VB and complies with the requirements for polymeric materials and enclosures in this standard.

9.6 Mounting of controls

9.6.1 CONTROLS shall be so designed that the methods of mounting in accordance with the manufacturer's declaration do not adversely affect compliance with this document.

9.6.2 Declared methods of mounting shall be such that the CONTROL cannot rotate or be otherwise displaced, and cannot be removed from an equipment without the aid of a TOOL, if such movement or removal could adversely affect compliance with this document. If removal or partial removal is necessary for correct use of the CONTROL, then the requirements of Clauses 6, 15 and 11 shall be satisfied before and after removal.

Compliance with 9.6.1 and 9.6.2 is checked by inspection and by manual test.

NOTE CONTROLS, other than those with rotary ACTUATION, fixed by a nut and single bushing concentric with the ACTUATING MEANS, are deemed to comply with this requirement, provided that the tightening of the nut requires the use of a TOOL, and that the parts have adequate mechanical strength. An INCORPORATED CONTROL mounted by screwless fixing is deemed to comply with this requirement if the use of a TOOL is required before the CONTROL can be removed from the equipment.

9.6.3 Mounting of independently mounted controls

9.6.3.1 INDEPENDENTLY MOUNTED CONTROLS other than those declared for panel mounting shall either:

– fit a standard box as declared;

– be supplied with a conduit box if a special conduit box is required; or

– be suitable for surface mounting on a plane surface.

9.6.3.2 If a special conduit box is required, it shall be delivered together with the control and the box shall be provided with the entries for conduit specified in IEC 60423.

9.6.3.2DV D2 *Modification of Clause 9.6.3.2 to add the following:*

The special conduit box provided with the CONTROL shall comply with the appropriate requirements of the Standard for Enclosures for Electrical Equipment, UL 50 or UL 514 series.

9.6.3.3 INDEPENDENTLY MOUNTED CONTROLS for surface mounting used with buried installation (concealed wiring) not using an outlet box shall be provided with suitable holes on the back of the CONTROL allowing easy installation and connection to the terminals.

9.6.3.4 INDEPENDENTLY MOUNTED CONTROLS for surface mounting used with exposed wiring shall be provided with cable or conduit entries, knock-outs, or glands, which allow connection of the appropriate type of cable or conduit complying with the relevant IEC standard.

9.6.3.4DV D2 *Modification of Clause 9.6.3.4 to add the following:*

INDEPENDENTLY MOUNTED CONTROLS for surface mounting used with exposed wiring shall be provided with cable or conduit entries, knock-outs, or glands, which allow connection of the appropriate type of cable or conduit complying with the National Electrical Code (NEC), NFPA 70, and relevant UL standards.

9.6.3.5 INDEPENDENTLY MOUNTED CONTROLS for surface mounting or the sub-bases for such controls shall be constructed in such a manner that the terminals for EXTERNAL CONDUCTORS are accessible and can be used when the control or the sub-base is correctly fixed to its support and its COVER (or the CONTROL) is removed.

9.6.3.6 CONTROLS intended for mounting on an outlet box or similar enclosure shall have wiring terminals, other LIVE PARTS and sharp-edged metal parts, earthed or not, located or protected so that they will not be forced against wiring in the box or enclosure during installation of the CONTROL.

9.6.3.7 Where back wiring terminals are used, they shall be recessed or be protected by close-fitting barriers or insulating materials or the equivalent that will prevent contact with wiring installed in the box.

9.6.3.8 *Compliance with 9.6.3.1 to 9.6.3.7, inclusive is checked by inspection.*

Terminals that do not project into the box beyond the plane of the front edge of the box are acceptable.

Guards provided alongside terminals and extending at least 6,5 mm beyond the terminals before wiring, with a corresponding guard between double pole mechanism, are acceptable.

9.7 Attachment of cords

9.7.1 Flexible cords

9.7.1.1 The flexible cords of IN-LINE CORD and FREE-STANDING CONTROLS shall be capable of withstanding the flexing likely to occur in NORMAL USE. If a cord-guard is provided to meet this requirement, it shall not be integral with the flexible cord if TYPE X ATTACHMENT is used.

9.7.1.2 *Compliance is checked by subjecting the* CONTROL, *fitted with the flexible cord or range of flexible cords for which it is designed, to the test of* 20.8.

9.7.2 Cord anchorages

9.7.2.1 CONTROLS other than those INTEGRATED and INCORPORATED, intended to be connected by means of a NON-DETACHABLE CORD, shall have cord anchorages such that the conductors are relieved from strain, including twisting, where they are connected to the terminals, and that their covering is protected from abrasion. It shall be clear how the relief from strain and the prevention of twisting is intended to be effected.

9.7.2.1DV D2 *Modification of Clause 9.7.2.1 to replace with the following:*

Polymeric strain relief used in controls other than integrated and incorporated, intended to be connected by means of a NON-DETACHABLE CORD, shall comply with the requirements of the Standard for Insulating Bushings, UL 635 and be suitable for the application with respect to the hole size and shape, maximum use temperature and wire size/type. To ensure that the hole size and shape is suitable for the bushing, the test noted in 20.9.3DV shall be conducted.

9.7.2.2 Cord anchorages of CLASS II CONTROLS shall be of insulating material or, if of metal, be insulated from accessible metal parts or metal foil over accessible non-metallic surfaces by insulation complying with the requirements for SUPPLEMENTARY INSULATION.

9.7.2.3 Cord anchorages of CONTROLS other than those of class II shall be of insulating material or be provided with an insulating lining, if otherwise an insulation FAULT on the cord could make accessible metal parts live. This lining, if any, shall be fixed to the cord anchorage, unless it is a bushing which forms part of a cord guard provided to meet the requirements of 9.7.1.

9.7.2.4 Cord anchorages shall be so designed that:

– the cord cannot touch clamping screws of the cord anchorage, if these screws are accessible metal parts;

– the cord is not clamped by a metal screw which bears directly on the cord;

– for TYPE X ATTACHMENT or TYPE M ATTACHMENT, at least one part is securely fixed to the CONTROL;

– for TYPE X ATTACHMENT or TYPE M ATTACHMENT, replacement of the flexible cord does not require the use of a SPECIAL PURPOSE TOOL;

– for TYPE X ATTACHMENT, they are suitable for the different types of flexible cord which can be connected;

– for TYPE X ATTACHMENT, the design and location make replacement of the flexible cord easily possible.

9.7.2.5 For other than TYPE Z ATTACHMENT, makeshift methods such as tying the cord into a knot, or tying the ends with string, shall not be used.

9.7.2.6 Glands shall not be used as cord anchorages in IN-LINE CORD CONTROLS using TYPE X ATTACHMENT unless they make provision for clamping all types and sizes of cords used in 10.1.4.

9.7.2.7 Screws, if any, which have to be operated when replacing the cord, shall not serve to fix any other component, unless either the CONTROL is rendered inoperable or manifestly incomplete if they are omitted or incorrectly replaced, or the component intended to be fixed cannot be removed without the aid of a TOOL when replacing the flexible cord.

9.7.2.8 *Compliance with 9.7.2.1 to 9.7.2.7 inclusive is checked by inspection and by the tests of 20.9 inclusive. Integrated and INCORPORATED CONTROLS, intended for the connection of flexible cords, are tested according to the relevant standard for the equipment in which they are integrated or incorporated.*

9.8 Size of cords – non-detachable

9.8.1 NON-DETACHABLE CORDS shall be at least those of ordinary tough rubber sheathed flexible cord, designated 60245 IEC 53, or ordinary polyvinyl chloride sheathed flexible cord, designated 60227 IEC 53. The use of a flexible cord other than specified above is permissible if allowed in a particular equipment standard or for connection to external SELV devices (sensors/units).

Compliance is checked by inspection.

9.8.2 CONTROLS fitted with NON-DETACHABLE CORDS shall have a cord with conductors of a size not less than that shown in Table 7.

Table 7
Minimum cord conductor sizes

Current in relevant circuit[a] A	Nominal cross-sectional area mm^2
Up to and including 6 [b]	0,75
Over 6 up to and including 10	1
Over 10 up to and including 16	1,5
Over 16 up to and including 25	2,5
Over 25 up to and including 32	4
Over 32 up to and including 40	6
Over 40 up to and including 63	10

[a] Requirements for applications greater than 63 A are under consideration.

[b] Lower values than 0,75 mm^2 are permitted for CLASS III CONTROLS or if permitted in a particular equipment or installation standard.

Compliance is checked by inspection.

9.8.2DV DR *Modification of Clause 9.8.2 to add the following:*

Cord conductors shall comply with the size requirements in the National Electrical Code, NFPA 70.

9.8.3 The space for the flexible cord inside the CONTROL shall be adequate to allow the conductors to be easily introduced and connected, and the COVER, if any, fitted without RISK of damage to the conductors or their insulation. It shall be possible to check that the conductors are correctly connected and positioned before the COVER is fitted.

Compliance is checked by inspection and by connecting cords of the largest cross-sectional area used in 8.1.5.

9.9 Inlet openings

9.9DV D2 *Modification of Clause 9.9 to add Clause 9.9DV.1 as follows:*

9.9DV.1 Independently mounted controls

9.9DV.1.1 CONTROLS intended to be permanently connected to fixed wiring shall allow the connection of the supply wires after the control has been fixed to its support, and shall be provided with:

a) A set of terminals allowing the connection of cables for fixed wiring of the nominal cross-sectional areas specified in Clause 8 or

b) A set of supply leads accommodated in a suitable compartment and

c) Cable entries, conduit entries, knockouts or glands which allow the connection of the appropriate types of cable or conduit.

d) Such a CONTROL may be provided with a plug and flexible cord if the following conditions are met:

1) The cord connection of the equipment facilitates frequent interchange;

2) Reduction of the TRANSMISSION of noise or vibration is accomplished; or

3) The fastening means or mechanical connections are intended to permit removal for maintenance and repair.

9.9.1 Inlet openings for flexible external cords shall be so designed and shaped, or shall be provided with an inlet bushing, so that the covering of the cord can be introduced without RISK of damage.

Compliance is checked by inspection.

9.9.2 Conduit entries and knock-outs of INDEPENDENTLY MOUNTED CONTROLS shall be so designed or located that introduction of the conduit or conduit fitting does not affect the protection against electric shock or reduce CREEPAGE DISTANCES and CLEARANCES below the values specified in Clause 11.

Compliance is checked by inspection.

9.9.3 If an inlet bushing is not provided, then the inlet opening shall be of insulating material.

9.9.4 If an inlet bushing is provided, then it shall be of insulating material, and

– shall be so shaped as to prevent damage to the cord,

– shall be reliably fixed,

– shall not be removable without the aid of a TOOL,

– shall, if TYPE X ATTACHMENT is used, not be integral with the cord.

9.9.5 An inlet bushing shall not be of rubber, with the exception that for TYPE M ATTACHMENT, TYPE Y ATTACHMENT and TYPE Z ATTACHMENT for CLASS 0 CONTROL, CLASS 0I CONTROL or CLASS I CONTROL, rubber is allowed if the bushing is integral with the sheath of a cord of rubber.

Compliance with 9.9.1 to 9.9.5 inclusive is checked by inspection and manual test.

9.9.5DV D2 *Modification of Clause 9.9.5 to add the following:*

A soft-rubber bushing shall not be less than 3/64 inch (1,2 mm) thick and shall be located so that it will not be exposed to oil, grease, oily vapor, or other substance having a deleterious effect on rubber.

9.9.6 Enclosures of INDEPENDENTLY MOUNTED CONTROLS intended to be permanently connected to FIXED WIRING shall have cable entries, conduit entries, knockouts or glands which permit the connection of the appropriate conduit, cable or cord, as applicable.

Compliance is checked by inspection.

9.9.6DV.1 DE *Modification of Clause 9.9.6 as follows:*

Replace "cable or cord" to "or EXTERNAL CONDUCTOR".

9.9.6DV.2 D2 *Modification of Clause 9.9.6 to add the following:*

A terminal box or compartment on equipment that is to be permanently connected electrically shall be located so that wire connections therein will be accessible for inspection, without disturbing either line-voltage or safety-circuit wiring after the equipment is installed in the intended manner. However, wire connections to equipment intended to be mounted on an outlet box may be accessible upon removal of the equipment from the box. A device which is acceptable for use with a fitting for only one type of wiring system shall be supplied with such a fitting.

9.10 Equipment inlets and socket-outlets

9.10.1 The design of equipment inlets and socket-outlets intended for use by the USER for the interconnection of CONTROLS and equipment shall be such as to render unlikely their engagement with each other or with equipment inlets or socket-outlets intended for other SYSTEMS if such engagement could result in fire, or injury or electric shock to persons or damage to equipment or surroundings.

Compliance is checked by inspection.

9.10.2 IN-LINE CORD CONTROLS provided with an equipment inlet or socket-outlet shall be so rated, or so protected, that unintentional overloading of either the CONTROL, equipment inlet or socket-outlet cannot occur in NORMAL USE.

Compliance is checked by inspection and test of 26.2.1.

9.10.3 CONTROLS provided with pins, blades, or other connecting/adapting means, in order to be introduced into fixed socket outlets shall comply with the requirements of the appropriate socket-outlet SYSTEM.

In IN-LINE CORD CONTROLS provided with a plug and a socket outlet, where the plug can be connected to a socket outlet rated for a higher load current than the CONTROL, the CONTROL shall be provided with an incorporated fuse or a protective device to limit the current to the CONTROL's rating. The testing of the protective function is done in the sequence of tests according to 26.2.

The plug and socket outlet part of the CONTROL shall comply with IEC 60884-1 and IEC 60884-2-5 or the appropriate standard for the plug and socket SYSTEM. In addition, the CONTROL part shall comply with this document.

Compliance is checked by inspection and by carrying out tests based on those prescribed for the socket-outlet SYSTEM.

9.10.3DV D2 *Modification of Clause 9.10.3 to add the following:*

CONTROLS designed for fixed socket-outlets as shown in Figure R33DV.3 shall have a weight of 0,79 kg or less and the design shall be suitable for the application. The maximum acceptable moment, center of gravity and dimensions of the CONTROL shall be within the limits given in Figure R33DV.3 for plug-in TIME SWITCHES featuring two or three integral blades or pins.

9.11 Requirements during mounting, use, maintenance and servicing

9.11.1 Covers and their fixing

9.11.1.1 For other than INTEGRATED CONTROLS, the removal of a COVER or COVER PLATE, including battery compartment COVER, which is intended to be removed during mounting, USER MAINTENANCE or SERVICING of the CONTROL or equipment, shall not affect the SETTING of the CONTROL if this might impair compliance with this document.

9.11.1.2 The fixing of COVERS shall be such that they cannot be displaced, nor replaced incorrectly if this could mislead the USER or would impair compliance with this document. The fixing of COVERS which need to be removed for mounting shall not serve to fix any parts, other than ACTUATING MEMBERS or gaskets.

Compliance with 9.11.1.1 and 9.11.1.2 is checked by inspection.

9.11.1.2DV D2 *Modification of Clause 9.11.1 by adding 9.11.1.2DV.1 to 9.11.1.2DV.10 as follows:*

9.11.1.2DV.1 A screwless fixed cover which gives access to bare live parts and which does not require a tool for its removal shall withstand the following tests:

A cover shall not become disengaged from the case when a direct pull of 60 N is applied. For this test, the COVER is to be gripped at any two convenient points. The test shall be performed before and after 10 removal and replacement operations.

A COVER shall be capable of withstanding an impact of 1,35 Nm applied to the accessible faces of the cover (one blow per face) without being displaced, and there shall be no damage to internal parts nor malfunction of the control as a result of this test. The radius of the ball used for this test shall be not less than 25,4 mm.

The continuity of the earthing means for a screwless fixed COVER shall comply with the requirements of 7.3 and 7.5.

9.11.1.2DV.2 A polymeric COVER attached by screws shall comply with the requirements of 11.11.19.11.1.2DV.1 with the screws loosened one full turn.

9.11.1.2DV.3 To reduce the risk of injury due to button or coin cell battery ingestion, the battery compartment of a control or any accessory, such as a wireless control, incorporating one or more button batteries or coin cell batteries shall comply with the Standard for Products Incorporating Button Batteries or Coin Cell Batteries, UL 4200A.

NOTE Applies to one or more single cell batteries having a diameter of 32 mm (1.25 in) maximum with a diameter greater than its height.

9.11.1.2DV.4 An enclosure COVER shall be hinged if it gives access to fuses, thermal cutouts, or any other overload-protective device, the functioning of which requires renewal, or if it is necessary to open the COVER in connection with normal OPERATION of the device.

9.11.1.2DV.5 A COVER hinged to comply with 9.11.1.2DV.6 and 9.11.1.2DV.7, shall not depend solely upon screws or other similar means requiring the use of a tool to hold it closed, but shall be provided with a spring latch or catch.

9.11.1.2DV.6 A door or cover giving access to a fuse or thermal cutout in other than a low-voltage circuit shall:

a) Shut closely against a 1/4 inch rabbet or the equivalent;

b) Have turned flanges for the full length of four edges; or

c) Have angle strips fastened to it.

9.11.1.2DV.7 A strip used to provide a rabbet and an angle strip fastened to the edges of a door shall be secured at not less than two points, not more than 1-1/2 inch (38,1 mm) from each end of each strip and at points between these end fastenings not more than 6 inch (152,4 mm) apart.

9.11.1.2DV.8 Glass covering an observation opening shall be reliably secured in place so that it cannot be readily displaced in service and shall provide mechanical protection for the enclosed parts.

9.11.1.2DV.9 Glass for an opening not more than 4 inches (102 mm) in any dimension shall not be less than 1/16 inch (1.6 mm) thick, and glass for a larger opening, but not more than 144 inches^2 (929 cm^2) in area and having no dimension greater than 12 inches (305 mm), shall not be less than 1/8 inch (3.2 mm) thick. Glass that covers a larger area shall not be less than 1/8 inch thick and shall conform to one of the following:

a) The glass shall be of a nonshattering or tempered type that, when broken, shall conform to the performance specifications in the Safety Performance Specifications and Methods of Test for Safety Glazing Material Used in Buildings, ANSI Z97.1-1984; or

b) Shall withstand a 2-1/2 foot-pound (2.41 J) impact from a 2-inch (50.8-mm) diameter, 1.18 pound (535 g) steel sphere without cracking or breaking to the extent that a piece is released or dropped from its intended position.

9.11.1.2DV.10 A transparent material other than glass employed as a covering over an opening in an enclosure shall be investigated to determine if it has adequate mechanical strength and is otherwise acceptable for the purpose.

Compliance is checked by the applicable requirements and tests of UL 746C.

9.11.1.3 Non-detachable parts

9.11.1.3.1 Non-detachable parts which provide the necessary degree of protection against electric shock, moisture or contact with moving parts shall be fixed in a reliable manner and shall withstand the mechanical stress occurring in NORMAL USE.

Snap-in devices used for fixing non-detachable parts shall have an obvious locked position. The fixing properties of snap-in devices used in parts which are likely to be removed for installation or during SERVICING shall not deteriorate.

Compliance is checked by the tests of 9.11.1.3.2 to 9.11.1.3.4.

9.11.1.3.2 Parts which are likely to be removed for installation or during SERVICING are disassembled and assembled 10 times before the test is carried out.

NOTE SERVICING includes replacement of the supply cord.

9.11.1.3.3 For the tests of 9.11.1.3.4, the CONTROL shall be at room temperature. However, in cases where compliance can be affected by temperature, the test is also carried out immediately after the CONTROL has been operated under the conditions specified in Clause 16.

9.11.1.3.4 A force is applied for 10 s, without jerks, in the most unfavourable direction, to those areas of the COVER or part which are likely to be weak. The force to be used shall be as follows:

–	*Push force*	*50 N*
–	*Pull force, as follows:*	
	a) If the shape of the part is such that the fingertips cannot easily slip off	*50 N*
	b) If the projection of the part which is gripped is less than 10 mm in the direction of removal	*30 N*

The push force is applied by means of a rigid test finger similar in dimensions to the standard test finger shown in Figure 5.

The pull force is applied by any suitable means (for example, a suction cup) so that the test results are not affected.

While the pull test of a) or b) is being applied, the test fingernail shown in Figure 6 is inserted in any aperture or joint with a force of 10 N. The fingernail is then slid sideways with a force of 10 N; it is not twisted or used as a lever.

If the shape of the part is such that an axial pull is unlikely, no pull force is applied but the test fingernail shown in Figure 6 is inserted in any aperture or joint with a force of 10 N and is then pulled for 10 s by means of the loop with a force of 30 N in the direction or removal.

If the COVER or part is likely to be subjected to a twisting force, a torque as detailed below shall be applied at the same time as the pull or push force:

– for major dimensions up to and including 50 mm 2 Nm

– for major dimensions over 50 mm 4 Nm

This torque is also applied when the test fingernail is pulled by means of the loop.

If the projection of the part which is gripped is less than 10 mm, the above torque is reduced to 50 % of the value.

9.11.1.3.5 During and after the tests of 9.11.1.3.4, parts shall not become detached and they shall remain in the locked position, otherwise they are deemed to be DETACHABLE PARTS.

9.11.1.4 A COVER, which can be removed with one hand, shall not be released when a squeezing force of up to 45 N combined with up to 15 N for the pull test is applied at any two points, the distance between which does not exceed 125 mm, as measured by a tape stretched tightly over that portion of the surface of the COVER which would be encompassed by the palm of the hand. The test is performed before and after 10 removal and replacement OPERATIONS.

9.11.2 Cover fixing means

Fixing screws of COVERS or COVER PLATES which need to be removed during mounting, USER MAINTENANCE or SERVICING shall be captive.

Compliance is checked by inspection.

NOTE The use of tight-fitting washers of cardboard or similar material is deemed to meet this requirement. See 10.1.5.

9.11.3 Actuating member

9.11.3.1 A CONTROL shall not be damaged when its ACTUATING MEMBER is mounted or removed in the intended manner.

9.11.3.2 If the maximum or minimum SETTING by the manufacturer or SETTING BY THE USER of a TYPE 2 ACTION is limited by mechanical means associated with an ACTUATING MEMBER, such ACTUATING MEMBER shall not be removable without the use of a TOOL.

9.11.3.3 If an ACTUATING MEMBER of a CONTROL with a TYPE 1 ACTION providing an "OFF" position or the ACTUATING MEMBER of any CONTROL with a TYPE 2 ACTION is used to indicate the condition of the CONTROL, it shall not be possible to fix the ACTUATING MEMBER in an incorrect position.

Compliance with 9.11.3.1 to 9.11.3.3 inclusive is checked by inspection and, for ACTUATING MEMBERS which do not require a TOOL for their removal, by the test of 20.7.

NOTE In certain equipment standards, an ACTUATING MEMBER that is used to indicate the condition of a CONTROL is not permitted to have the capability of being fixed in an incorrect position.

9.11.4 Parts forming supplementary insulation or reinforced insulation

Parts of CONTROLS which serve as SUPPLEMENTARY INSULATION or REINFORCED INSULATION and which might be omitted during reassembly after USER MAINTENANCE or SERVICING, shall either be fixed in such a way that they cannot be removed without being seriously damaged, or be so designed that they cannot be replaced in an incorrect position, and that, if they are omitted, the CONTROL is rendered inoperable or manifestly incomplete.

Compliance is checked by inspection.

NOTE Lining metal enclosures with a coating of lacquer, or with other material in the form of a coating which can be easily removed by scraping, is not deemed to meet this requirement.

9.11.5 Sleeving as supplementary insulation

Sleeving used as SUPPLEMENTARY INSULATION on INTEGRATED CONDUCTORS shall be retained in position by a positive means.

Compliance is checked by inspection and by manual test.

NOTE A sleeve is considered to be fixed by a positive means if it can only be removed by breaking or cutting, or if it is clamped.

9.11.6 Pull-cords

PULL-CORDS shall be insulated from LIVE PARTS and the CONTROL shall be so designed that it is possible to fit or to replace the PULL-CORD without LIVE PARTS becoming accessible.

Compliance is checked by inspection.

9.11.7 Insulating linings

Insulating linings, barriers and the like shall have adequate mechanical strength and shall be secured in a reliable manner.

Compliance is checked by inspection.

9.12 Controls using software

See H.9.12.

9.12.1 Requirements for the architecture

See H.9.12.1.

9.12.2 Measures to control faults/error

See H.9.12.2.

9.12.3 Measures to avoid errors

See H.9.12.3.

9.12.4 Remotely actuated control functions

9.12.4.1 Remotely actuated control functions can be connected to separate, independent devices, which can themselves contain control functions or provide other information. Remotely actuated control functions can either be safety critical or non-safety critical based on the application as listed below.

a) The following conditions are considered safety critical since they can impair the safety of the control or appliance:

1) If software is downloaded or data exchanged that are part of a CLASS B or CLASS C CONTROL FUNCTION.

2) If software is downloaded or data exchanged, that includes parametric changes (e.g. constants, algorithms, timing used for normal operation) that can impair the compliance criteria of the document due to unauthorized modification or transmission errors.

EXAMPLE A downloaded software or parameter set which regulates or limits the maximum normal temperature rises in Clause 16.

3) If software is downloaded, which only affects that part of the software which is not covered by the above cases 1) or 2), but where compliance with the document can be impaired due to improper separation or partitioning from the software or data as it relates to conditions 1) or 2).

b) Any downloaded software or data that meets the criteria of any item in a) shall comply with H.9.12.4.

c) Types of remote communication (software download or data exchange) not listed in a) are considered not to impair compliance with the document, therefore no additional requirements are specified. Examples are lised below:

– controls providing REMOTE COMMUNICATION and/or REMOTE OPERATION, where all measures to comply with the document are independent of software,

– controls using REMOTE COMMUNICATION through PUBLIC NETWORKS for the send only transmission of data,

– controls which only provide event driven or push remote monitoring.

9.12.4.2 Data exchange

9.12.4.2.1 General

REMOTELY ACTUATED CONTROL FUNCTIONS can be connected to separate, independent devices, which can themselves contain CONTROL functions or provide other information. Any data exchange between these devices shall not compromise the integrity of CLASS B CONTROL FUNCTION or CLASS C CONTROL FUNCTION.

9.12.4.2.2 Type of data

Message types for data exchange in a CONTROL function or functions shall be allocated to CLASS A CONTROL FUNCTION, CLASS B CONTROL FUNCTION or CLASS C CONTROL FUNCTION. Regarding the safety or protective relevance or influence, message types or data exchange shall be allocated only to CLASS B CONTROL FUNCTION or CLASS C CONTROL FUNCTIONS, see Table 8.

Table 8
Data exchange

Data	Safety relevant	Non safety relevant
Operating data	Messages such as "RESET from safe state"	Messages such as on/off instructions, room temperature information
Configuration parameters	Messages modifying parameters that determine related CLASS B CONTROL FUNCTION or CLASS C CONTROL FUNCTION	Messages modifying parameters that determine performance related functions
Software modules	Modules downloaded into a SYSTEM, that determine related CLASS B CONTROL FUNCTION or CLASS C CONTROL FUNCTION	Modules downloaded into a SYSTEM, that determine performance related functions

9.12.4.2.3 Communication of safety related data

See H.9.12.4.2.3.

9.12.4.2.4 Duration or limits of operation

For the operation of REMOTELY ACTUATED CONTROL FUNCTION, the duration or limits of operation shall be set before switching on, unless an automatic switching off is realized at the end of a cycle or the SYSTEM is designed for permanent operation (operation for longer than 24 h without interruption or new cycle).

Compliance is checked by software INSPECTION.

9.12.4.3 Priority of control functions

Care shall be taken that priority over CONTROL functions shall not lead to a hazardous condition.

Compliance is checked by INSPECTION.

9.12.4.4 Remote reset action

9.12.4.4.1 The remote reset action shall be manually initiated. When the reset function is initiated by a hand-held device, at least two manual actions are required to activate a reset.

NOTE The two MANUAL ACTIONS are considered to be discrete and separate.

9.12.4.4.2 RESET functions shall be capable of resetting the SYSTEM as intended.

9.12.4.4.3 Unintended resets from safe state shall not occur.

9.12.4.4.4 Any FAULT of the RESET function shall not cause the CONTROL or controlled function to result in a hazardous condition. In such a case, the RESET function shall comply with the class B requirements, see H.13.2.2.

9.12.4.4.5 For RESET functions initiated by manual action not in visible sight of the appliance, the following additional requirements apply:

– the actual status and relevant information of the process under control shall be visible to the USER before, during and after the reset action;

– the maximum number of reset actions within a time period shall be declared (for example, 5 actions within a time span of 15 min). Following this, any further reset shall be denied unless the appliance is physically checked.

9.12.4.4.6 For INTEGRATED CONTROLS and INCORPORATED CONTROLS, the reset function shall be evaluated in the final application.

NOTE 1 Remote RESET requirements are dictated by the end product requirements (example – the boiler standard).

NOTE 2 Not all types of remote RESET functions will be suitable for some applications.

If the reset is activated by manual switching of a device, this function shall be specified by the manufacturer and be suitable in the final application.

9.12.4.4.7 INDEPENDENTLY MOUNTED CONTROLS performing remote RESET functions shall be tested for a minimum 1 000 reset actions. For integrated and incorporated devices, unless otherwise specified, the minimum reset cycles shall be declared by the manufacturer. After the test, the reset device shall be capable to reset the SYSTEM as intended. Unintended RESETS shall not occur.

9.13 Protective controls and components of protective control systems

9.13.1 Protective controls

PROTECTIVE CONTROLS shall

– be so designed and constructed as to be reliable and suitable for their intended duty and take into account the maintenance and testing requirements of the devices, where applicable,

– be independent of other functions, unless their safety function cannot be affected by such other functions,

– comply with appropriate design principles in order to obtain suitable and reliable protection.

These principles include, in particular, fail-safe modes, redundancy, diversity, and self-diagnosis.

Compliance is checked by carrying out the relevant tests specified in this document and the appropriate part 2.

9.13.1DV D2 *Modification of Clause 9.13.1 to add the following:*

9.13.1DV.1 If an electronic circuit/component is relied upon to prevent a hazard under normal or abnormal operation of the product, that electronic circuit/component is considered to be providing a protective function. Such components/circuits shall comply with the relevant requirements for PROTECTIVE CONTROLS unless it can be shown through a fault assessment and tests of Clause 13 that failure or malfunction of the protective circuit/component will not lead to a hazardous condition of the control i.e., loss of the protective function.

NOTE Examples of such circuits could be zero cross circuits, power regulation circuits, overcurrent protection etc.

9.13.1DV.2 With respect to 9.13.1DV.1, when a programmable component, software module/library(s) or embedded firmware is separately evaluated to the relevant requirements of H.9.12, only a limited assessment may be required on the programmable component, software module/library(s) or embedded firmware.

9.13.2 Pressure limiting devices

These devices shall be so designed that the pressure will not permanently exceed the maximum allowable pressure of the controlled application; however, a short duration pressure surge of no more than 10 % of the maximum allowable pressure is acceptable, where appropriate, or where not specified in the relevant standard for the controlled application.

9.13.3 Temperature monitoring devices

These devices shall have an adequate response time on safety grounds, consistent with measurement function.

9.13.4 Batteries

9.13.4.1 CONTROLS containing batteries shall be designed to reduce the RISK of fire, explosion and chemical leaks under normal conditions and after a single FAULT in the CONTROL. For USER-replaceable batteries, the design shall reduce the likelihood of reverse polarity installation if this would create a HAZARD.

9.13.4.2 Battery circuits designed for a total battery capacity > 1 000 mAh shall be designed so that

– the output characteristics of a battery charging circuit are compatible with its rechargeable battery; and

– for non-rechargeable batteries, discharging at a rate exceeding the battery manufacturer's recommendations, and unintentional charging, are prevented; and

– for rechargeable batteries, charging and discharging at a rate exceeding the battery manufacturer's recommendations, and reversed charging, are prevented; and

– replaceable batteries shall either

- have contacts that cannot be shorted with the test finger (Figure 5); or
- be inherently protected to avoid creating a HAZARD within the meaning of the document.

NOTE Reversed charging of a rechargeable battery occurs when the polarity of the charging circuit is reversed, aiding the discharge of the battery.

9.13.4.3 If a battery with a capacity > 1 000 mAh contains liquid or gel electrolyte, a battery tray shall be provided that is capable of retaining any liquid that could leak as a result of internal pressure build-up in the battery. The requirement to provide a battery tray does not apply if the construction of the battery is such that leakage of the electrolyte from the battery is unlikely.

NOTE An example of a battery construction where leakage of the electrolyte is considered to be unlikely is the sealed CELL valve-regulated type.

If battery tray is required, its capacity shall be at least equal to the volume of electrolyte of all the CELLS of the battery, or the volume of a single CELL if the design of the battery is such that simultaneous leakage from multiple CELLS is unlikely.

NOTE If several CELLS (for example, the six CELLS in a 12 V lead-acid battery) are in a single casing, its fracture could lead to a greater volume of leakage than from a single CELL.

9.13.4.4 *Compliance with 9.13.4.1 to 9.13.4.3 is checked by inspection and by evaluation of the data provided by the EQUIPMENT MANUFACTURER and battery manufacturer.*

When appropriate data is not available, compliance is checked by the test of a) to e) and 9.13.4.5. However, batteries that are inherently safe for the conditions given are not tested under those conditions. Consumer grade, non-rechargeable carbon-zinc or alkaline batteries are considered safe under short-circuiting conditions and therefore are not tested for discharge; nor are such batteries tested for leakage under storage conditions.

Non-rechargeable batteries are subjected to the tests of a) and d). The battery used for the tests shall be a new non-rechargeable battery as provided with, or recommended by the manufacturer for use with, the CONTROL.

Rechargeable batteries are subjected to the tests of b) to d). The battery used for the tests shall be a new fully charged rechargeable battery as provided with, or recommended by the manufacturer for use with, the CONTROL.

NOTE Some of the tests specified can be hazardous to the persons carrying them out; it is suggested that all appropriate measures to protect personnel against possible chemical or explosion HAZARDS be taken.

a) Unintentional charging of a non-rechargeable battery: The battery is charged while briefly subjected to the simulation of any single component FAILURE that is likely to occur in the charging circuit and that would result in unintentional charging of the battery. To minimize testing time, the FAILURE is chosen that causes the highest charging current. The battery is then charged for a single period of 7 h with that simulated FAILURE in place.

b) Overcharging of a rechargeable battery: The battery is charged under each of the following conditions in turn.

1) The battery charging circuit is adjusted with the battery disconnected to give 106 % of the rated output voltage of the charger, or the maximum charging voltage available from the charger (without simulation of FAULTS), whichever is the higher attainable value. The battery is then charged for 7 h.

2) The battery charging circuit is adjusted, with the battery disconnected, to 100 % of the rated output voltage of the charger. The battery is charged while briefly subjected to the simulation of any single component FAILURE that is likely to occur in the charging circuit and that results in overcharging of the battery. To minimize testing time, the FAILURE is chosen that causes the highest overcharging current. The battery is then charged for a single period of 7 h with that simulated FAILURE in place.

c) Reverse charging of a rechargeable battery: The battery is reverse charged while briefly subjected to the simulation of any single component FAILURE that is likely to occur in the charging circuit and that would result in reverse charging of the battery. To minimize testing time, the FAILURE is chosen that causes the highest reverse charging current. The battery is then reverse charged for a single period of 7 h with that simulated FAILURE in place.

d) Excessive discharging rate of a rechargeable or non-rechargeable battery: The battery is subjected to rapid discharge by open-circuiting or short-circuiting any current-limiting or voltage-limiting components in the load circuit of the battery under test.

e) Compliance with the tests of a) to d) shall not result in any of the following:

– chemical leaks caused by cracking, rupturing or bursting of the battery jacket, if such leakage could adversely affect required insulation; or

– spillage of liquid from any pressure relief device in the battery, unless such spillage is contained by the CONTROL without RISK of damage to the insulation or HARM to the USER; or

– explosion of the battery, if such explosion could result in injury to a USER; or

– emission of flame or expulsion of molten metal to the outside of the CONTROL enclosure.

9.13.4.5 After completion of the tests of 9.13.4.4 a) to 9.13.4.4 d), the equipment is subjected to the electric strength tests of 15.2.

9.13.5 Smart enabled controls

9.13.5.1 A SMART ENABLED CONTROL shall be so designed that the external communication signals (data or power demand) do not unintentionally override the operating parameters of a TYPE 2 ACTION CONTROL nor interfere with any protective function of the CONTROL.

A SMART ENABLED CONTROL is permitted to alter the operating parameters of a CONTROL with TYPE 2 ACTION within defined limits so long as the protective functions remain intact.

9.13.5.2 A SMART ENABLED CONTROL that integrates operating and protective functions shall be evaluated as a PROTECTIVE CONTROL.

9.13.5.3 Any transmitter or communication module that is external to the CONTROL and acts as the interface between the CONTROL and the telecommunication network shall comply with IEC 62151 or IEC 62368-1. Nevertheless, the measures to ensure protection against electric shock in this document (e.g. Annex P) shall be met.

9.13.5.4 Any transmitter or communication module that is part of the SMART ENABLED CONTROL shall comply with the requirements of this document.

9.13.5.5 Compliance of 9.13.5 is checked by evaluating the CONTROL in accordance with the requirements of 13.1 and other relevant requirements of this document.

10 Threaded parts and connections

10.1 Threaded parts moved during mounting or servicing

10.1.1 Threaded parts, electrical or otherwise which are likely to be operated while the CONTROL is being mounted or during SERVICING shall withstand the mechanical stresses occurring in NORMAL USE.

NOTE Threaded parts which are operated while the CONTROL is being mounted, or during SERVICING, include items such as terminal screws, cord anchorage screws, fixing and mounting screws, nuts, threaded rings and COVER PLATE screws.

10.1.2 Such parts shall be easily replaceable if completely removed.

NOTE Constructions which restrict the complete removal of a threaded part are deemed to meet this requirement.

10.1.3 Such threaded parts shall have a metric ISO thread or a thread of equivalent effectiveness.

NOTE SI, BA and Unified threads are deemed to be of equivalent effectiveness to a metric ISO thread.

10.1.4 If such a threaded part is a screw and if it generates a thread in another part, it shall not be of the thread cutting type. It can be of the thread forming (swaging) type. There is no requirement for the type of thread so produced.

10.1.5 Such screws can be of the space threaded type (sheet metal), if they are provided with a suitable means to prevent loosening.

NOTE Suitable means to prevent loosening of space threaded screws include a spring nut, or other component of similar resilience, or a thread of resilient material.

10.1.6 Such threaded parts shall not be of non-metallic material if their replacement by a dimensionally similar metal screw could impair compliance with Clause 15 or 11.

10.1.7 Such screws shall not be of metal which is soft or liable to creep such as zinc or aluminium.

This requirement is not applicable to parts used either as a COVER to limit access to SETTING means, or as SETTING means such as flow or pressure adjusters in gas CONTROLS.

10.1.8 Such screws operating in a thread of non-metallic material shall be such that the correct introduction of the screw into its counterpart shall be ensured.

NOTE The requirement for the correct introduction of a metal screw into a thread of non-metallic material can be met if the introduction of the screw in a slanting manner is prevented, for example, by guiding the screw or part to be fixed by a recess in the female thread, or by the use of a screw with the leading thread removed.

10.1.9 Such threaded parts transmitting contact pressure and having a nominal diameter less than 3 mm, shall screw into metal. If they are of non-metallic material, they shall have a nominal diameter of at least 3 mm, and shall not be used for any electrical connection.

10.1.10 Compliance with 10.1.1 to 10.1.9 inclusive is checked by inspection and by the test of 10.1.11 to 10.1.15, inclusive.

10.1.10DV D2 *Modification of Clause 10.1.10 to add the following:*

The tests of 10.1.11 to 10.1.15 are not applicable to metal screws in engagement with a thread of metallic material.

10.1.11 Threaded parts are tightened and loosened:

– 10 times if one of the threaded parts is of non-metallic material, or

– five times if both parts are of metallic material.

10.1.12 *Screws in engagement with a thread of non-metallic material are completely removed and reinserted each time. When testing terminal screws and nuts, a conductor of the largest cross-sectional area used in 8.1.5 or of the minimum cross-sectional area specified in 8.2.1 is placed in the terminal.*

10.1.13 *The shape of the screwdriver should suit the head of the screw to be tested.*

10.1.14 *The conductor is moved each time the threaded part is loosened. During the test, no damage impairing the further use of the threaded parts shall occur, such as breakage of screws or damage to the slot head or washers.*

10.1.15 *The test is made by means of a suitable test screwdriver, spanner or key, applying a torque, without jerks, as shown in Table 9.*

Table 9
Threaded parts torque test values

Nominal diameter of thread mm	Torque Nm		
	I	II	III
Up to and including 1,7	0,1	0,2	0,2
Over 1,7 up to and including 2,2	0,15	0,3	0,3
Over 2,2 up to and including 2,8	0,2	0,4	0,4
Over 2,8 up to and including 3,0	0,25	0,5	0,5
Over 3,0 up to and including 3,2	0,3	0,6	0,6
Over 3,2 up to and including 3,6	0,4	0,8	0,6
Over 3,6 up to and including 4,1	0,7	1,2	0,6
Over 4,1 up to and including 4,7	0,8	1,8	0,9
Over 4,7 up to and including 5,3 [a]	0,8	2,0	1,0
Over 5,3 [a]	–	2,5	1,25

Use column I – for metal screws without heads if the screw when tightened does not protrude from the hole, or if the screwdriver access is limited to the major diameter of the screw.

Use column II – for other metal screws and for nuts:

- with a cylindrical head and a socket for a SPECIAL PURPOSE TOOL, the socket having a cross corner dimension exceeding the overall thread diameter;
- with a head having a slot or slots, the length of which exceeds 1,5 times the overall thread diameter.

– for screws of non metallic material having a hexagonal head with the dimension across flats exceeding the overall thread diameter.

Use column III – for other screws of non metallic material.

[a] Nuts and threaded rings of greater than 4,7 mm in diameter which are used for single-bush mounting are tested with a torque of 1,8 Nm, except that, for CONTROLS for single bush mounting using thermoplastic materials and where there is no torque effected on the mounting for SETTING or resetting (i.e. for THERMAL CUT-OUTS), the thread for mounting is tested with the maximum torque as declared by the manufacturer, which in no case shall be less than 0,5 Nm.

10.2 Current-carrying connections and connections providing protective earthing continuity

10.2.1 Current-carrying connections and connections providing protective earthing continuity which are not disturbed during mounting or SERVICING and the efficiency or security of which is maintained by the pressure of a screw, threaded part, rivet or the like shall withstand the mechanical, thermal and electrical stresses occurring in NORMAL USE.

10.2.2 Such current-carrying connections which are also subject to torsion in NORMAL USE, (that is, having parts integral with or connected rigidly to SCREW TERMINALS, etc.) shall be locked against any movement which could impair compliance with Clauses 15 or 11.

NOTE 1 The requirement regarding being locked against movement does not imply that the current-carrying connection shall be so designed that rotation or displacement is prevented, provided that any movement is appropriately limited and does not bring about non-compliance with this document.

NOTE 2 Connections made with one screw, rivet or the like are sufficient if the parts are themselves prevented from making such movement by mechanical interaction between parts or by the provision of spring washers or the like.

NOTE 3 Connections made with one rivet with a non-circular or notched shank corresponding to appropriately shaped holes in the current-carrying parts are considered to meet this requirement. Connections made with two or more screws or rivets also meet this requirement.

NOTE 4 Sealing compound can be used if the parts so sealed are not subjected to stress during NORMAL USE.

10.2.3 Such current-carrying connections shall be so designed that contact pressure is not transmitted through non-metallic material other than ceramic or other non-metallic material having characteristics no less suitable, unless there is sufficient resilience in the corresponding metal parts to compensate for any shrinkage or distortion of the non-metallic material.

NOTE The suitability of non-metallic material is considered with respect to the stability of the dimensions within the temperature range applicable to the CONTROL.

10.2.4 Such current-carrying connections shall not make use of space threaded screws, unless the screws clamp the current-carrying parts directly in contact with each other, and are provided with a suitable means of locking.

Space threaded screws can be used to provide protective earthing continuity if at least two such screws are used for each connection.

10.2.4DV D2 *Modification of Clause 10.2.4 to add the following NOTE:*

NOTE 1DV: To provide earthing continuity (bonding), the use of one screw is permitted if at least two full threads are engaged. If two screws are used, each screw shall engage at least one full thread.

10.2.5 Such current-carrying connections can make use of thread cutting screws if these produce a full-form standard machine screw thread.

Thread cutting screws can be used to provide protective earthing continuity if at least two such screws are used for each connection.

10.2.5DV D2 *Modification of Clause 10.2.5 to add the following NOTE:*

NOTE 1DV: To provide earthing continuity (bonding), the use of one screw is permitted if at least two full threads are engaged. If two screws are used, each screw shall engage at least one full thread.

10.2.6 Such current-carrying connections, whose parts rely on pressure for their correct function, shall have resistance to corrosion over the area of contact not inferior to that of brass. This requirement does not apply to parts whose essential characteristics can be adversely affected by plating such as bimetallic blades, which if not plated shall be clamped into contact with parts which have adequate resistance to corrosion. Suitable corrosion resistance can be achieved by plating or a similar process.

10.2.7 Compliance with 10.2.1 to 10.2.6 inclusive is checked by inspection. In addition, compliance with 10.2.3 and 10.2.6 is checked by an inspection of the metallic resilient parts after the tests of Clause 19 have been completed.

11 Creepage distances, clearances and distances through solid insulation

11.1 General

CONTROLS shall be constructed so that the CLEARANCES, CREEPAGE DISTANCES and distances through solid insulation are adequate to withstand the electrical stresses that can be expected.

Printed wiring boards conforming with all of the requirements for type 2 protection as specified in IEC 60664-3 shall comply with the minimum requirements of 11.4 for solid insulation. The spacing between the conductors before the protection is applied shall not be less than the values as specified IEC 60664-3. See also Annex M.

CREEPAGE DISTANCES and CLEARANCES between terminals for the connection of EXTERNAL CONDUCTORS shall be not less than 2 mm, or the specified limit, whichever is the highest. This requirement does not apply to such terminals if they are only used for factory attachment of conductors or if they are used for connection in ELV circuits.

CREEPAGE DISTANCES, CLEARANCES and distances through solid insulation in switch mode power supplies and other high frequency switching circuits where the fundamental frequency is above 30 kHz and less than 10 MHz shall be dimensioned in accordance with IEC 60664-4.

The tabulated values of Clause 11 are absolute minimum values that shall be maintained for all manufacturing conditions and through the lifetime of the equipment.

A creepage distance shall not be less than the associated clearance. The shortest creepage distance possible is equal to the required clearance.

Compliance is checked by inspection, by measurement and by the tests of this clause.

NOTE 1 The requirements and tests are based on IEC 60664-1 from which further information can be obtained.

NOTE 2 See Annex O for guidance.

CREEPAGE DISTANCES, CLEARANCES and distances through insulation shall comply

– across PROTECTIVE IMPEDANCE with the requirements for DOUBLE INSULATION or REINFORCED INSULATION;

– across each separate component of PROTECTIVE IMPEDANCE with the requirements for SUPPLEMENTARY INSULATION.

11.2 Clearances

11.2.1 CLEARANCES shall not be less than the values shown in Table 11 for case A, taking into account the POLLUTION DEGREE and the RATED IMPULSE VOLTAGE required to serve the overvoltage categories of Table 10, except that, for BASIC INSULATION and FUNCTIONAL INSULATION, smaller distances can be used if the CONTROL meets the impulse withstand test of 11.2.14 and the parts are rigid or held by mouldings, or if the construction is such that there is no likelihood of the distances being reduced by distortion or by movement of the parts (for example, during OPERATION or during assembly), but in no case shall the CLEARANCES be less than the values shown in Table 11 for case B.

Compliance is checked by inspection, by measurement and, if necessary, by the test of 11.2.14.

NOTE CONTROLS normally are expected to comply with the requirements for the OVERVOLTAGE CATEGORY of equipment in which they are used unless special circumstances determine other categories to be appropriate. Annex D provides guidance.

DETACHABLE PARTS are removed. CLEARANCES are measured with movable parts and parts such as hexagon nuts which can be assembled in different orientations placed in the most unfavourable position.

A force is applied to bare conductors and ACCESSIBLE SURFACES in order to attempt to reduce CLEARANCES when making the measurement.

The force is: *2 N for bare conductors;*

30 N for ACCESSIBLE SURFACES.

The force is applied by means of the test finger of Figure 5. Apertures are assumed to be covered by a piece of flat metal.

After application of the force, the clearances are measured according to methods and assumptions given in Annex B.

Table 10
Rated impulse voltage for equipment energized directly from the supply mains
(from IEC 60664-1:2007, Table F.1)

Nominal voltage of the supply based on IEC 60038 [a] [b] V		Voltage line-to-neutral derived from nominal voltages AC or DC up to and including V	Rated impulse voltage required according to overvoltage category [c] V			
Three-phase four-wire systems [a]	Single-phase [d] systems		I	II	III	IV
		50	330	500	800	1 500
		100	500	800	1 500	2 500
	120/240	150	800	1 500	2 500	4 000
230/400 277/480		300	1 500	2 500	4 000	6 000
400/690		600	2 500	4 000	6 000	8 000

[a] The first value listed is the line-to-neutral or the line-to-earth voltage and the second value listed is the line-to-line voltage.

[b] For CONTROLS capable of generating an overvoltage at the CONTROL terminals, for example, switching devices, the RATED IMPULSE VOLTAGE implies that the CONTROL shall not generate overvoltage in excess of this value when used in accordance with the relevant standard and instructions of the manufacturer.

[c] See Annex D for an explanation of OVERVOLTAGE CATEGORIES and Annex E for application guidance. OVERVOLTAGE CATEGORY may be specified in a part 2 or in the final equipment standard.

[d] See Annex C for other supply SYSTEMS (for example, note that some three-phase, three-wire SYSTEMS require higher RATED IMPULSE VOLTAGE than three-phase four-wire SYSTEMS of similar voltage).

Table 11
Clearances for insulation co-ordination
(from IEC 60664-1:2007, Table F.2)

Rated impulse voltage from Table 10 [a]	Clearances in air up to 2 000 m above sea-level [b] mm							
	Case A				Case B (impulse test required – see 11.2.14)			
	Pollution degree [c]				Pollution degree [c]			
kV	1	2	3	4	1	2	3	4
0,33	0,01	0,20	0,8	1,6	0,01	0,2	0,8	1,6
0,50	0,04				0,04			
0,80	0,10				0,1			
1,5	0,5	0,5			0,3	0,3		
2,5	1,5	1,5	1,5		0,6	0,6		
4,0	3	3	3	3	1,2	1,2	1,2	
6,0	5,5	5,5	5,5	5,5	2	2	2	2
8,0	8	8	8	8	3	3	3	3

Table 11 Continued on Next Page

Table 11 Continued

Rated impulse voltage from Table 10 [a]	Clearances in air up to 2 000 m above sea-level [b] mm							
	Case A				Case B (impulse test required – see 11.2.14)			
	Pollution degree [c]				Pollution degree [c]			
kV	1	2	3	4	1	2	3	4
NOTE For small values of CLEARANCES, the uniformity of the electric field can deteriorate in the presence of POLLUTION, making it necessary to increase the CLEARANCE values above the values of case B.								
[a] For FUNCTIONAL INSULATION, the RATED IMPULSE VOLTAGE is derived from the value in column III of Table 10 which covers the measured voltage across the CLEARANCE, unless otherwise declared and justified by the manufacturer. If the secondary winding of the stepdown transformer is earthed, or if there is an earthed screen between the primary and secondary windings, the reference for the RATED IMPULSE VOLTAGE for the CLEARANCES of BASIC INSULATION on the secondary side shall be one step lower than that which covers the rated input voltage of the primary side of the transformer. The use of an isolating transformer without an earthed PROTECTIVE SCREEN does not allow a reduction in the RATED IMPULSE VOLTAGE. [b] For altitudes of more than 2 000 m above sea-level, the values for CLEARANCES shall be multiplied with the correction factor specified in IEC 60664-1:2007, Table A.2. [c] An explanation of POLLUTION DEGREE is given in Annex F.								

11.2.2 The CLEARANCES of BASIC INSULATION shall be sufficient to withstand the overvoltages that can be expected in use, taking into account the RATED IMPULSE VOLTAGE. The values of Table 11, case A apply except as permitted by 11.2.9.

Compliance is checked by measurement.

11.2.3 If the CONTROL is supplied from a dedicated battery which has no provision for charging from an external mains supply, the RATED IMPULSE VOLTAGE shall be assumed to be 71 V peak.

11.2.4 For FUNCTIONAL INSULATION, Table 11, case A applies

– except as permitted by 11.2.9;

or

– except that CLEARANCES for ELECTRONIC CONTROLS are not specified if the requirements of 13.1.3.8 are met with the CLEARANCES short-circuited.

11.2.5 Compliance with 11.2 is checked by measurement using the methods of measurement as given in Annex B and Figure 18.

11.2.5.1 For CONTROLS provided with an equipment inlet or socket-outlet, the measurements are made twice, once with an appropriate connector or plug inserted, and once without a connector or plug inserted.

11.2.5.2 For terminals intended for the connection of EXTERNAL CONDUCTORS, the measurements of such terminals are made twice, once with conductors of the largest cross-sectional area used in 8.1.5 fitted, and once without conductors fitted.

11.2.5.3 For terminals intended for the connection of INTERNAL CONDUCTORS, the measurements of such terminals are made twice, once with conductors of the minimum cross-sectional area used in 8.2.1 fitted, and once without conductors fitted.

11.2.6 Distances through slots or openings in surfaces of insulating material are measured to metal foil in contact with the surface. The foil is pushed into corners and the like by means of the test finger shown in Figure 5, but is not pressed into openings.

11.2.7 The test finger shown in Figure 5 is applied to apertures as specified in 6.1, the distance through insulation between LIVE PARTS and the metal foil shall then not be reduced below the values specified.

11.2.8 If necessary, a force is applied to any point on bare LIVE PARTS which are accessible before the CONTROL is mounted, and to the outside of surfaces which are accessible after the CONTROL is mounted, in an endeavour to reduce the CREEPAGE DISTANCES, CLEARANCES and distances through insulation while taking the measurements.

The force is applied by means of the test finger shown in Figure 5 and has a value of:

– 2 N for bare LIVE PARTS;

– 30 N for ACCESSIBLE SURFACES.

Compliance is checked by measurement and by test if necessary.

11.2.9 For BASIC INSULATION and FUNCTIONAL INSULATION, smaller distances are permitted if the CONTROL meets the impulse withstand test of 11.2.14 and the parts are rigid or held by mouldings, or if the construction is such that there is no likelihood of the distances being reduced by distortion, by movement of the parts, or during assembly, but in no case shall the CLEARANCES be less than the values for case B.

Compliance is checked by the test of 11.2.14.

When testing FUNCTIONAL INSULATION, the impulse voltage is applied across the CLEARANCE.

NOTE When carrying out the impulse test, parts or components of the CONTROL can be disconnected if necessary.

a) For MICRO-DISCONNECTION and MICRO-INTERRUPTION, there is no specified minimum distance for the clearance between the contacts and between those current-carrying parts where the clearance varies with the movement of the contacts.

b) For FULL DISCONNECTION, the values specified in Table 11, case A apply to parts separated by the switching element including the contacts, when the contacts are in the fully open position.

11.2.9DV D2 *Modification of Clause 11.2.9 to add the following:*

The use of varistors and Gas Discharge Tube (GDT) are permitted and may be relied upon to reduce the overvoltage category downstream from these protective devices provided that the devices have been evaluated in accordance with 12.5.2DV and suitable for the application.

The nominal discharge current rating of the varistor or GDT shall be determined by dividing the rated impulse withstand voltage peak of Table 10 for the applicable overvoltage category by 2 ohms which represents the upstream impedance. This value shall be less than or equal to the rated discharge current of the varistor or GDT used in the application.

Example:

Overvoltage category: II, Rated system voltage: 120/240 V

Impulse voltage – 1500V

Nominal discharge current rating of varistor: 1500V / 2 ohms = 750 A

11.2.10 CLEARANCES of SUPPLEMENTARY INSULATION shall be not less than those specified for BASIC INSULATION in Table 11, case A.

Compliance is checked by measurement.

11.2.11 CLEARANCES of REINFORCED INSULATION shall be not less than those in Table 11, case A but using the next higher step for RATED IMPULSE VOLTAGE as a reference.

NOTE For DOUBLE INSULATION, where there is no intermediate conductive part between the BASIC INSULATION and SUPPLEMENTARY INSULATION, CLEARANCES are measured between LIVE PARTS and the ACCESSIBLE SURFACE or accessible metal parts. The insulation SYSTEM is treated as REINFORCED INSULATION.

Compliance is checked by measurement.

11.2.12 For CONTROLS or portions of CONTROLS supplied from a transformer with DOUBLE INSULATION, CLEARANCES of FUNCTIONAL INSULATION and BASIC INSULATION on the secondary side are based on the secondary voltage of the transformer which is used as the nominal voltage of Table 10.

NOTE 1 The use of a transformer with separate windings alone does not allow a change of OVERVOLTAGE CATEGORY.

In the case of supply voltages derived from transformers without separate windings, the RATED IMPULSE VOLTAGE shall be determined from Table 10 based on the primary voltage for step-down transformers, and based on the maximum measured RMS value of the secondary voltage for step-up transformers.

Part 2s can specify alternative criteria for some situations, for example, high voltage ignition sources.

Annex F, Table F.2 of IEC 60664-1:2007 gives CLEARANCE dimensions for higher RATED IMPULSE VOLTAGE.

NOTE 2 See also references in Clause 12.

Compliance is checked by measurement or test if necessary.

11.2.13 For circuits having ELV levels which are derived from the supply by means of PROTECTIVE IMPEDANCE, CLEARANCES of FUNCTIONAL INSULATION are determined from Table 10 based on the maximum measured value of the WORKING VOLTAGE in the ELV circuit.

11.2.14 The impulse voltage test, when required, is applied in accordance with IEC 60664-1:2007, 6.1.2.2.1.

Part 2s can specify environmental test conditions.

The impulse voltage is applied between LIVE PARTS and metal parts separated by BASIC INSULATION or FUNCTIONAL INSULATION.

NOTE In the case of FUNCTIONAL INSULATION, parts or components of the CONTROL can be disconnected if necessary.

11.2.15 If the secondary of a transformer is earthed, or if there is an earthed screen between the primary and secondary windings, the CLEARANCES of BASIC INSULATION on the secondary side shall not be less than those specified in Table 11 but using the next lower step for RATED IMPULSE VOLTAGE as a reference.

NOTE The use of an isolating transformer without an earthed PROTECTIVE SCREEN or earthed secondary does not allow a reduction in the RATED IMPULSE VOLTAGE.

For circuits supplied with a voltage lower than rated voltage, for example, on the secondary side of a transformer, CLEARANCES of FUNCTIONAL INSULATION are based on the WORKING VOLTAGE, which is used as the nominal voltage for Table 10.

11.3 Creepage distances

11.3.1 Creepage distances shall be based on voltage, material group and the pollution degree.

Allocation of the material group to the proof tracking index (PTI):

– material of material group IIIb with a PTI of 100 and up to but excluding 175;

– material of material group IIIa with a PTI of 175 and up to but excluding 400;

– material of material group II with a PTI of 400 and up to but excluding 600;

– material of material group I with a PTI of 600 and over.

Materials, the PTI values of which have previously been found to comply with these material groups, are acceptable without further testing.

The PTI values refer to values obtained in accordance with IEC 60112:2020, and tested with solution A.

DETACHABLE PARTS are removed. CREEPAGE DISTANCES are measured with movable parts and parts which can be assembled in different orientations placed in the most unfavourable position.

A force is applied to bare conductors and ACCESSIBLE SURFACES in order to attempt to reduce CREEPAGE DISTANCES when making the measurement.

The force is: *2 N for bare conductors;*

30 N for ACCESSIBLE SURFACES.

The force is applied by means of the test finger of Figure 5. Apertures are assumed to be covered by a piece of flat metal.

After application of the force, the CREEPAGE DISTANCES are measured according to Annex B.

11.3.1DV D2 *Modification of Clause 11.3.1 to replace second, third and fourth paragraphs with the following:*

11.3.1DV.1 According to value of comparative tracking index (CTI) for the insulation material used

– material of material group IIIb with a CTI of 100 through 174 (CTI index 4);

– material of material group IIIa with a CTI of 175 through 249 (CTI index 3) or CTI of 250 through 399 (CTI index 2);

– material of material group II with a CTI of 400 through 599 (CTI index 1);

– material of material group I with a CTI of 600 or greater (CTI index 0).

11.3.2 CREEPAGE DISTANCES for BASIC INSULATION shall not be less than those specified in Table 12 for the RATED VOLTAGE, taking into account the material group and the POLLUTION DEGREE.

Compliance is checked by inspection and measurement.

11.3.3 CREEPAGE DISTANCES for FUNCTIONAL INSULATION shall not be less than those specified in Table 13 for WORKING VOLTAGE, taking into account the material group and the POLLUTION DEGREE.

CREEPAGE DISTANCES smaller than those specified in Table 13 are permitted, if:

– compliance with 13.1.3.8 concerning inherent safety is met, and

– for CLASS B and CLASS C CONTROL FUNCTIONS, the FAULT mode as given in Table 14 for printed wiring board is considered.

Compliance is checked by inspection and measurement.

Part 2s can specify alternative criteria for some situations, for example, high voltage ignition sources.

Table 12
Minimum creepage distances for basic insulation

Rated voltage up to and including V	Creepage distances [a] [b] mm											
	Pollution degree											
	Printed wiring material [c]		1	2			3			4		
	Pollution degree			Material group			Material group			Material group		
	1 [d]	2 [e]		I	II	III [f]	I	II	III [f]	I	II	III [f]
50	0,025	0,04	0,2	0,6	0,9	1,2	1,5	1,7	1,9	2,0	2,5	3,2
125	0,16	0,25	0,3	0,8	1,1	1,5	1,9	2,1	2,4	2,5	3,2	4,0
250	0,56	1	0,6	1,3	1,8	2,5	3,2	3,6	4,0	5,0	6,3	8,0
400	1	2	1,0	2,0	2,8	4,0	5,0	5,6	6,3	8,0	10,0	12,5
500	1,3	2,5	1,3	2,5	3,6	5,0	6,3	7,1	8,0	10,0	12,5	16,0
630	1,8	3,2	1,8	3,2	4,5	6,3	8,0	9,0	10,0	12,5	16,0	20,0
800	2,4	4	2,4	4,0	5,6	8,0	10,0	11,0	12,5	16,0	20,0	25,0

[a] Lacquered conductors of windings are considered to be bare conductors but CREEPAGE DISTANCES are not required to be larger than the associated CLEARANCE specified in Table 11.

[b] For glass, ceramics, or other inorganic insulating materials which do not track, CREEPAGE DISTANCES need not be greater than their associated CLEARANCE for the purpose of insulation co-ordination.

[c] When printed circuit boards are coated or protected in accordance with Annex L or Clause M.1 respectively and the coating or protection has a PTI of at least 175, the values specified for pollution degree 1 are permitted.

[d] Material groups I, II, IIIa and IIIb.

[e] Material groups I, II and IIIa.

[f] Material group III includes IIIa and IIIb. Material group IIIb is not permitted for application above 630 V or for application in POLLUTION DEGREE 4.

Compliance is checked by measurement.

Table 13
Minimum creepage distances for functional insulation

Working voltage RMS [a] V	Creepage distances [b c] mm											
	Pollution degree											
	Printed wiring material [d]		1	2			3			4		
	Pollution degree			Material group			Material group			Material group		
	1[e]	2[f]		I	II	III	I	II	III [g]	I	II	III [g]
10	0,025	0,04	0,08	0,40	0,40	0,40	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	21
800	2,4	4	2,4	4	5,6	8	10	11	12,5	16	20	25

[a] For higher WORKING VOLTAGES, the values of IEC 60664-1:2007, Table F.4 apply.

[b] For glass, ceramics and other inorganic materials which do not track, CREEPAGE DISTANCES need not be greater than their associated CLEARANCE.

[c] There are no requirements across MICRO-INTERRUPTION other than between terminals and TERMINATIONS. Between terminals and TERMINATIONS, the requirements are as specified in this table.

[d] When printed circuit boards are coated or protected in accordance with Annex L or Clause M.1 respectively and the coating or protection has a PTI of at least 175, the values specified for POLLUTION DEGREE 1 are permitted.

[e] Material groups I, II, IIIa and IIIb.

[f] Material groups I, II and IIIa.

[g] Material group III includes IIIa and IIIb. Material group IIIb is not permitted for application above 630 V or for application in POLLUTION DEGREE 4.

Compliance is checked by inspection.

11.3.4 CREEPAGE DISTANCES of SUPPLEMENTARY INSULATION shall be not less than those appropriate for BASIC INSULATION taking into account the material group and the POLLUTION DEGREE.

Compliance is checked by inspection and measurement.

11.3.5 CREEPAGE DISTANCES of REINFORCED INSULATION shall be not less than double those appropriate for BASIC INSULATION, taking into account the material group and the POLLUTION DEGREE.

Compliance is checked by inspection and measurement.

11.4 Solid insulation

11.4.1 Solid insulation shall be capable of durably withstanding electrical and mechanical stresses as well as thermal and environmental influences which can occur during the anticipated life of the equipment.

11.4.2 There is no dimensional requirement for the thickness of BASIC INSULATION or FUNCTIONAL INSULATION.

11.4.3 The distance through insulation for SUPPLEMENTARY INSULATION and REINFORCED INSULATION, for WORKING VOLTAGES up to and including 300 V, between metal parts shall not be less than 0,7 mm.

NOTE This does not imply that the distance has to be through insulation only. The insulation can consist of solid material plus one or more air layers.

For CONTROLS having parts with DOUBLE INSULATION where there is no metal between BASIC INSULATION and SUPPLEMENTARY INSULATION, the measurements are made as though there is a metal foil between the two layers of insulation.

11.4.4 The requirement of 11.4.3 does not apply if the insulation is applied in thin sheet form, other than mica or similar scaly material.

– For SUPPLEMENTARY INSULATION, it consists of at least two layers, provided that each of the layers withstands the electric strength test of 15.2 for SUPPLEMENTARY INSULATION.

– For REINFORCED INSULATION, it consists of at least three layers, provided that any two layers together withstand the electric strength test of 15.2 for REINFORCED INSULATION.

Compliance is checked by inspection and by test.

11.4.5 The requirement of 11.4.3 does not apply if the SUPPLEMENTARY INSULATION or the REINFORCED INSULATION is inaccessible and meets one of the following criteria.

– The maximum temperature determined during the tests of Subclause 13.1 does not exceed the permissible value specified in Table 17.

– The insulation, after having been conditioned for 168 h in an oven maintained at a temperature equal to 25 K in excess of the maximum temperature determined during the tests of Clause 16, withstands the electric strength test of 15.2, this test being made on the insulation both at the temperature occurring in the oven and after cooling to approximately room temperature.

For optocouplers, the conditioning procedure is carried out at a temperature of 25 K in excess of the maximum temperature measured on the optocoupler during the tests of Subclause 13.1 and Clause 16, the optocoupler being operated under the most unfavourable conditions which occur during these tests.

Compliance is checked by inspection and by test.

11.4.5DV D2 *Modification of Clause 11.4.5 by replacing the second paragraph with the following:*

Optocouplers shall comply with the requirements for the Standard for Optical Isolators, UL 1577.

12 Components

12.1 Transformers

12.1.1 Transformers other than those used in SMPS, intended to supply power to a SELV-circuit or PELV-circuit shall be of the safety isolating type and shall comply with the relevant requirements of IEC 61558-2-6.

12.1.1DV D2 *Modification of Clause 12.1.1 by adding the following:*

Transformers shall comply with the relevant requirements of the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3.

Thermistors shall either comply with UL 1434 or Annex J of this standard. If evaluated to UL 1434, the deviation and drift shall be expressed as a unit of measurement (K) versus a percentage.

12.1.2 CONTROLS that incorporate a transformer as the source of supply to a SELV-circuit or PELV-circuit are subjected to an output test with the primary energized at the upper limit of the rated voltage as indicated in 19.2.2, 19.2.3 a) and 19.2.3 b).

a) Under any non-capacitive conditions of loading (from no load to the short-circuiting of any or all secondary SELV- or PELV-circuit terminals) and without disturbing internal connections, the secondary output voltage shall not be greater than that defined in 3.1.5.

b) The secondary output power at the terminals to an ISOLATED LIMITED SECONDARY CIRCUIT shall not exceed 100 VA and the secondary output current shall not exceed 8 A after 1 min of OPERATION with overcurrent protection, if provided, bypassed.

12.2 Switch mode power supplies and converters

12.2.1 Requirements

12.2.1.1 If a converter or switch mode power supply is used as the source of supply to a SELV-circuit or PELV-circuit, Clause P.3 applies.

12.2.1.2 Switch mode power supplies and transformers used in switch mode power supplies shall comply with the requirements of IEC 61558-2-16 or the relevant requirements of this document.

12.2.1.3 Switch mode power supplies not covered by 12.8.2, including their peripheral circuitry, used in ELECTRONIC CONTROLS shall comply with the tests of 12.2.2 and all of the applicable requirements of this document.

NOTE Subclause 12.2.2.11 gives the compliance criteria for the tests.

12.2.2 Overload tests for switch mode power supplies

12.2.2.1 *The Switch mode power supply circuit is connected to its rated voltage source of supply and frequency. Each output winding, or section of a tapped winding, is overloaded in turn, one at a time, while the other windings are kept loaded or unloaded, whichever load conditions of* NORMAL USE *is the least favourable.*

12.2.2.2 *The overload is carried out by connecting a variable resistor (or an electronic load) across the winding or the rectified output. The resistor is adjusted as quickly as possible and readjusted, if necessary, after 1 min to maintain the applicable overload. No further readjustments are then permitted.*

12.2.2.3 For this test, any protective devices such as a fuse, manual reset circuit protector, thermal protector, etc. are allowed to remain in the circuit.

12.2.2.4 *If overcurrent protection is provided by a current-breaking device, the overload test current is the maximum current which the overcurrent protection device is just capable of passing for 1 h. If this value cannot be derived from the specification, it is to be established by test.*

12.2.2.5 *If no overcurrent protection is provided, the maximum overload is the maximum power output obtainable from the power supply.*

12.2.2.6 In case of voltage foldback, the overload is slowly increased to the point which causes the output voltage to drop by 5 %. The overload is then established at the point where the output voltage recovers and held for the duration of the test.

12.2.2.7 *The duration of the test is to be for 1 h or until ultimate results are reached.*

12.2.2.8 *The maximum open-circuit voltage of each winding (directly at the winding of the transformer or at the DC link) and the maximum load current are measured and recorded such that the maximum output power is determined.*

12.2.2.9 The maximum open-circuit voltage measurements shall be made during normal OPERATION and under single component FAILURE, see Table 14.

12.2.2.10 *For* SELV *applications, where the maximum open-circuit voltage measured directly at the secondary of the transformer (or at the DC link) exceeds the limits specified in 3.1.5, the measurement of the maximum output voltage of each winding is made after certain* PROTECTIVE IMPEDANCES. *In this case, the limits shall be in accordance with 6.1.10.*

12.2.2.11 *Following each test (while still in a heated condition), the switch mode power supply is to be subjected to the electric strength test of 15.2.*

Compliance shall be in accordance with items a), b), c), d), e) and f) of 13.1.3.8.

12.3 Capacitors

Capacitors connected between two line conductors or between a line conductor and the neutral or between HAZARDOUS LIVE PARTS and protective earth shall be in accordance with IEC 60384-14 and shall be used in accordance with its rated values.

12.4 Fuses

Fuses shall comply with the requirements of IEC 60127 series or IEC 60269 series.

12.4DV D2 *Modification of Clause 12.4 by adding the following:*

Fuses shall comply with the requirements of the relevant standard for low-voltage fuses, UL 248-14. Other fuses are considered to be intentionally weak parts and shall be evaluated in accordance with 13.1.3.5.

12.5 Varistors

12.5.1 Varistors are used as surge protective devices, they shall be selected to withstand the impulses corresponding to the installation class (declared in Table 1, requirement 43) for which it is intended to be used.

12.5.2 Varistors connected to the supply mains shall comply with IEC 61051-1, IEC 61051-2 or IEC 61051-2-2.

12.5.2DV D2 *Modification of Clause 12.5.2 by adding the following:*

Varistors and Gas Discharge Tubes (GDT) shall comply with UL 1449, the Standard for Surge Protective Devices and be suitable for the application with respect to voltage protection rating (VPR), discharge current and other relevant ratings. See 11.2.9DV for additional details.

12.6 Thermistors

12.6.1 If a THERMISTOR is used, J.12.8.2 applies or 12.6.2 shall be met.

12.6.2 Annex J is not applicable for THERMISTORS used in a circuit that meets the following requirements from a) to d) or the requirement stated in e):

a) type 1 CONTROL as declared in Table 1, requirement 33;

b) connected to a SELV/PELV circuit as specified in Clause P.1, or protected against the risk of electric shock through double or REINFORCED INSULATION, or by means of PROTECTIVE IMPEDANCE;

c) low power circuit as specified in 13.1.2, or the CONTROL or final equipment complies with 13.1 when the THERMISTOR is open or short circuited;

d) CONTROL with CLASS A CONTROL FUNCTIONS as declared in Table H.1, requirement H.12;

e) THERMISTORS used in CONTROL functions where further measures to ensure safety are implemented within the CONTROL.

12.7 Relays

Relays with forcibly guided (mechanically linked) contacts shall comply with the requirements of IEC 61810-3.

12.8 Other components

12.8.1 Components other than those detailed in 12.1 to 12.7 are checked when carrying out the tests of this document.

12.8.2 For components which have previously been found to comply with a relevant IEC safety standard, to reduce the testing necessary, assessment is limited to the following:

a) the application of the component within the CONTROL is checked to ensure that it is covered by previous testing to the IEC safety standard;

b) testing according to this document of any conditions not covered by the previous testing to the IEC safety standard.

12.8.2DV D2 *Modification of Clause 12.8.2 by adding 12.8.2DV.1 as follows:*

12.8.2DV.1 A component of a product covered by this standard shall comply with the requirements for that component, and shall be used in accordance with its recognized rating and other limitations of use. A list of standards covering various components are referenced in Clause 2DV. A component need not comply with a specific requirement that:

a) Involves a feature or characteristic not needed in the application of the component in the product covered by this standard; or

b) Is superseded by a requirement in this standard.

13 Fault assessment on electronic circuits

13.1 Fault assessment for inherent safety

13.1.1 General

ELECTRONIC CONTROLS or circuits, as specified in items a) and b) below, shall be assessed in accordance with the requirements of 13.1.3 for the effects of FAILURE or malfunction of circuit components, according to the FAULT conditions specified in Table 14.

a) electronic circuits which do not comply with the requirements for a low power circuit according to 13.1.2.

b) Low-power circuits where protection against electric shock, fire HAZARD, mechanical HAZARD or dangerous malfunction in other parts of the CONTROL relies on the correct functioning of this circuit.

Circuits supplied by rechargeable batteries are subjected to the tests of 13.1.

Non-electronic components such as switches, relays and transformers, which are assessed according to Clause 12 or to the relevant requirements of this document, are not subjected to the tests of 13.1.

During the tests of 13.1.1, for a CONTROL providing ELECTRONIC DISCONNECTION (type 1.Y or 2.Y), any FAILURE of the device described in footnote l to Table 16 is permitted.

13.1.2 Low-power point measurement test

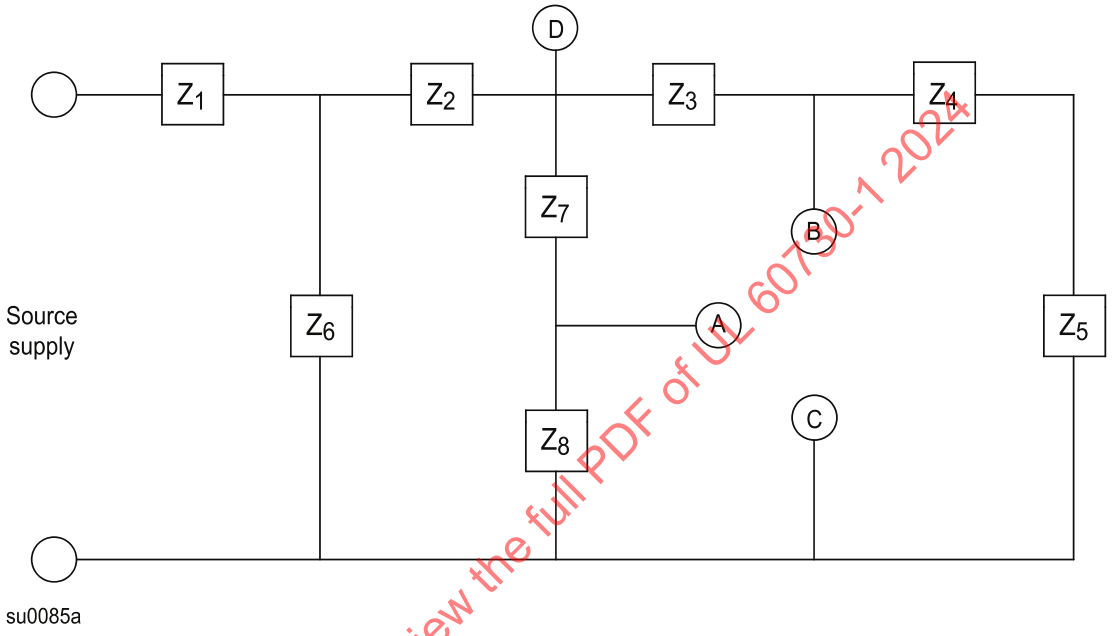
A low-power circuit is determined as follows and further explained in Figure 3. The CONTROL is operated at rated voltage or at the upper limit of the rated voltage range and a variable resistor, adjusted to its maximum resistance, is connected between the point to be investigated and the opposite pole of the supply source.

The resistance is then decreased until the power consumed by the resistor reaches a maximum. Any point nearest to the supply and at which the maximum power delivered to this resistor does not exceed 15 W at

the end of 5 s is called a low-power point. The part of the circuit farther from the supply source than a low-power point is considered to be a low-power circuit.

The measurements are made from only one pole of the supply source, preferably the one that gives the fewest low-power points.

NOTE When determining the low-power points, start with points close to the supply source. The power consumed by the variable resistor is measured by a convenient method, for example, by a wattmeter.



D is a point farthest from the supply source where the maximum power delivered to external load exceeds 15 W.

A and B are points closest to the supply source where the maximum power delivered to external load does not exceed 15 W. These are low-power points.

Figure 3

Example of an electronic circuit with low power points

13.1.3 Component fault assessment

13.1.3.1 Guidelines for the tests of 13.1.3.2

To avoid unnecessary testing, every endeavour should be made to assess all the conditions likely to result in non-compliance with the requirements of 13.1.3.2. Such an assessment shall involve an appraisal of the circuit diagram and simulation of the relevant FAULT conditions so as to test whether these conditions occur. For CONTROLS using software, the FAULT analysis of 13.1.3.2 shall be related to the software FAULT analysis as declared in Table H.1, requirement H.5.

All conditions which result from the introduction of an electronic circuit FAULT as specified in 13.1.3.8 are considered to be one FAULT.

Printed circuit conductors which show signs of deterioration during the tests are considered liable to fail.

13.1.3.2 Test procedure

The control shall be operated under the following conditions.

a) At the most unfavourable voltage for

i) mains powered controls the range 0,9 to 1,1 times the rated supply voltage,

ii) battery powered controls in the range 0 to 100 per cent of the rated open-circuit voltage.

b) Loaded with the type of load, within the declared or measured parameters, producing the most onerous effect.

c) In an ambient temperature of (20 ± 5) °C, unless there are significant reasons (as for example during item b) of 13.1.3.8) for conducting the test at another temperature within the manufacturer's declared range.

d) Connected to a power supply having a fuse rated such that the result of the test is not influenced by the OPERATION of the fuse.

e) With any ACTUATING MEMBER set to the most unfavourable position.

f) The power supply to the control shall have the capability of supplying a short-circuit current of at least 500 A.

g) Components which fail as a result of cumulative stress are replaced if necessary.

h) For IN-LINE CORD CONTROLS, FREE STANDING AND INDEPENDENTLY MOUNTED CONTROLS, the enclosure is wrapped in tissue wrapping paper. For all other controls, the tissue paper is placed over the device under test.

i) The CONTROL is operated to steady state or for 1 h, whichever occurs first.

13.1.3.2DV D2 *Modification of Clause 13.1.3.2 by replacing item (d) with the following:*

d) Connected to an electrical supply having a time-delay fuse rated such that the result of the test is not influenced by the OPERATION of the fuse.

13.1.3.3 Electronic circuit fault conditions

For the purpose of 13.1 and H.13.2, the applicable FAILURE modes are given in Table 14.

Table 14
Electrical/electronic component fault modes

Component type	Short [a]	Open [b]	Remarks
Resistors			
Thin-film [c]		X	Includes SMD type

Table 14 Continued on Next Page

Table 14 Continued

Component type	Short [a]	Open [b]	Remarks
Thick-film [c]		X	Includes SMD type
Wire-wound [c] (single layer) enamelled or suitably coated		X	
Wire-wound (single layer) potentiometer/trimmer		X	
All other types	X [d]	X	Includes MOV, VDR
Capacitors			
X1 and Y types according to IEC 60384-14		X	
Metallized film according to IEC 60384-16 and IEC 60384-17		X	
All other types	X	X	
Inductors			
Wire-wound		X	
All other types	X	X	
Diodes			
All types	X	X	
Semiconductor type devices like transistors			
All types (for example, bipolar; LF; RF; microwave; FET; thyristor; Diac; Triac; Uni junction)	X [d]	X	e
Hybrid circuit	f	f	
Integrated circuits			
All types not covered by H.9.12	X [g]	X	For IC outputs, footnote e applies
Optocouplers			
According to IEC 60747-5-5	X [h]	X	
Relays			
Coils		X	
Contacts	X [l, p]	X	
Reed-relays	X	X	Contacts only
Transformers			
According to IEC 61558-2-6 or IEC 61558-2-16		X	
All other types	X [d]	X	
Crystals	X	X	j
Switches	X	X	k
Connections (jumper wire)		X	l
Cable and wiring		X	
Printed circuit board conductors	X [m]	X [n]	
According to IEC 62326 series			
Sensors			
Polymeric type THERMISTORS	X	X	o
Ceramic type THERMISTORS		X	

[a] The conditions which have led to the design of the CLEARANCES and CREEPAGE DISTANCES according to Clause 11 on the assembly for which exclusion from the FAULT mode “short” is claimed shall be maintained over the lifetime of the CONTROL.

These conditions shall be declared or documented as follows.

Table 14 Continued on Next Page

Table 14 Continued

Component type	Short [a]	Open [b]	Remarks
CONTROL POLLUTION situation (declared in Table 1, requirement 44). POLLUTION situation in the MICRO-ENVIRONMENT of the CREEPAGE DISTANCE or CLEARANCE, if cleaner than that of the control, and how this is designed (documentation) (declared in Table 1, requirement 59). RATED IMPULSE VOLTAGE of the control (declared in Table 1, requirement 55). RATED IMPULSE VOLTAGE for the CREEPAGE DISTANCE or CLEARANCE, if different from that of the CONTROL, and how this is ensured (documentation) (declared in Table 1, requirement 60). The values designed for tolerances of distances for which the exclusion from FAULT mode "short" is claimed. (declaration and documentation) (declared in Table 1, requirement 61).			
[b] Only opening of one pin at any one time.			
[c] These components may be used for protective impedance, if the components comply with 11.3.3 and withstand the impulse voltage test of 11.2.15 for at least overvoltage category III.			
[d] Short-circuit each pin in turn with every other pin; only two pins at a time.			
[e] For discrete or integrated thyristor type devices such as Triacs and SCRs, FAULT conditions shall include short circuit of any terminals with the third terminal open-circuited. The effect of any full wave type of component, such as a Triac going into a half-wave condition, either controlled or uncontrolled (thyristor or diode, respectively) shall be considered. FAILURE of a field effect based electronic power switching device (FET, MOSFET, IGBT) by loss of gate (base) control* resulting in a partial turn-on mode, causing an undefined state shall be considered. Testing and assessment criteria shall correspond to the specific control function and circuitry. Guidance might be given in parts 2. * Loss of gate control might occur due to, for example, an insufficient solder connection of the FET.			
[f] FAILURE modes for individual components of the HYBRID CIRCUIT are applicable as described for the individual components in this table.			
[g] The short circuit of any two adjacent terminals and the short circuiting of – each terminal to the IC-supply, when applicable at the IC; – each terminal to the IC-ground, when applicable at the IC. The number of tests implied for INTEGRATED CIRCUITS may normally make it impracticable to apply all the relevant FAULT conditions or to assess the likely HAZARDS from an appraisal of the circuit diagram of the INTEGRATED CIRCUIT. It is therefore permissible first to analyse in detail all the possible mechanical, thermal and electrical faults which may develop either in the CONTROL itself or its output, due to the malfunction of the electronic devices or other circuit components, separately or in any combination. Except for types evaluated by H.9.12, a FAULT-tree analysis shall be conducted to include the results of multiple steady-state conditions to outputs and programmed bi-directional terminals for the purpose of identifying additional FAULT conditions for consideration. The FAILURE mode "short circuit" is excluded between isolated sections for such ICs that have isolated sections. The isolation between the sections shall comply with the requirements of 15.2 for FUNCTIONAL INSULATION.			
[h] When optocouplers comply with 11.4.5, the shorting between the input and output pins is not considered.			
[i] The short-circuit mode is excluded for relays where the contact is controlling a Class A or B CONTROL function, and the relay contacts do not operate during the test of Clause 16, provided that it is successfully tested to Clause 19 under the following conditions: For CLASS A CONTROL functions, the number of cycles as declared in Table 1, requirement 20 applying the output load as declared in Table 1, requirement 8. For CLASS B control FUNCTIONS, a minimum of 100 000 cycles or as declared in Table 1, requirement 20, whichever is higher, applying the output load as declared in Table 1, requirement 8. For CLASS C control FUNCTIONS, the short-circuit mode is excluded for relays where • the contact function is switching under normal operation without load (no current flowing during make or break), and • the contact function is disconnecting the load under abnormal operation of the CONTROL SYSTEM to reach SAFETY SHUT-DOWN, and • the relay complies with Clause 19 at a minimum of 100 000 cycles or as declared in Table 1, requirement 20 whichever is higher, applying the output load as declared in Table 1, requirement 8.			

Table 14 Continued on Next Page

Table 14 Continued

Component type	Short [a]	Open [b]	Remarks
j For crystal-based clocks, harmonic and sub-harmonic frequency variations affecting the timings should be considered.			
k If switches are applied for the selection of safety times, purge times, programmes and/or other safety-related SETTINGS, these devices should function so that in the event of their opening, the safest possible condition arises (for example, in a burner CONTROL SYSTEM, the shortest safety time or the longest purge time). The short-circuit mode is excluded for switches where the contact is controlling a Class A or B CONTROL function, provided that it is successfully tested to Clause 19 under the following conditions: For CLASS A CONTROL functions, the number of cycles declared by the manufacturer, or certified for the application. For CLASS B control FUNCTIONS, a minimum of 6 000 cycles for MANUAL ACTION, or 100 000 cycles for automatic action, or otherwise specified by the end product standard, or certified for the application. For CLASS C CONTROL FUNCTIONS, short-circuit mode is not excluded.			
l The requirements are the same as footnote n, except they are applied to jumper wires intended for clipping when selecting a SETTING.			
m The short-circuit failure mode is excluded if the requirements of Clause 11 are fulfilled.			
n The open-circuit FAILURE mode, i.e. interruption of a conductor, is excluded if • the thickness of the conductor is equal to, or greater than, a nominal value of 35 µm with a tolerance up to −30 % of the nominal value allowed, and the breadth of the conductor is equal to, or greater than, a nominal value of 0,3 mm with a tolerance up to −30 % of the nominal value allowed, or • the conductor has an additional precaution against interruption, for example, roll-tinned, etc. If a short circuit at the output terminals causes the opening of a printed circuit board conductor, that conductor shall be subject to an open-circuit FAULT analysis. For temperature and current conditions when accepting conductor sizes, see IEC 62326 (all parts).			
o For sensor components intended to measure activating quantities such as temperature, pressure, etc., FAULT modes in addition to open and short shall be considered. These FAULT modes can include step wise shift of resistance, non-responsive component, and component drifting out of accuracy.			
p For relays with forcibly guided contacts according to IEC 61810-3, the FAULT mode "make contacts and break contacts are simultaneously in the closed position" is excluded since this failure in a closed position of the contacts is not possible due to the mechanical linkage of the contacts.			

Table 14DV D2 *Modification of Table 14 to replace the rows for "Sensors" as follows:*

Table 14DV
Electrical/electronic component fault modes

Component type	Short [a]	Open [b]	Remarks
Sensors			
Polymeric type THERMISTORS	X	X	o
Ceramic type THERMISTORS		X	
Other types	X	X	

13.1.3.4 Criteria – termination by electronic circuit

If the test is terminated by the functioning of an electronic circuit in order to comply with 13.1.3.8, the following shall apply:

a) This function of the electronic circuit is disabled without affecting the normal operation of the control and the test is repeated with the same FAULT that caused the electronic circuit to function, or

b) If this function of the electronic circuit cannot be disabled without affecting the normal operation of the control, then the most onerous FAULT condition, as specified in Table 14, should be applied to the electronic circuit that functioned, or

c) If this function of the electronic circuit includes a programmable component and this function cannot be disabled without affecting the normal operation of the control, then the programmable component shall comply with the requirements for a CLASS B CONTROL FUNCTION in Annex H.

13.1.3.5 Criteria – termination by intentionally weak part

If the test is terminated by the functioning of an intentionally weak part other than an overcurrent protective device, the following criteria shall be met, in addition to 13.1.3.8:

a) To ensure consistency and repeatability, the test is to be repeated on two additional samples resulting in the same component terminating the test.

b) To ensure that the disconnection is reliable, an electric strength potential corresponding to FUNCTIONAL INSULATION, as specified in Table 16, shall be applied across the "functioned" component. Each sample shall comply with the criteria of 15.2. Parallel paths that could compromise the electric strength test results shall be disconnected.

To ensure reproducibility of the test results, the following information shall be recorded: specify the component by the type, ratings and other relevant technical information.

13.1.3.6 Criteria – termination by intentionally weak trace

If the test is terminated by the functioning of an INTENTIONALLY WEAK TRACE, an analysis shall be conducted on the open trace and the control shall comply with the criteria of items a), c), and d) of 13.1.3.8. The analysis of the open trace shall consist of at least the following:

a) Upon functioning, an electric strength potential corresponding to FUNCTIONAL INSULATION, as specified in Table 16, shall be applied across the two ends of the opened trace. Each sample shall comply with the criteria of 15.2.

b) To ensure consistency and repeatability, the test is to be repeated on two additional samples with complying results.

To ensure reproducibility of the test results, the following information shall be recorded:

– specify the dimensions of the weak trace (width, length, thickness, shape), and

– material of PCB, and

– other relevant technical information.

NOTE Examples of material are FR4, CEM1, CEM 3, type and thickness of protective coating, etc.

13.1.3.7 Criteria – control for motor loads

If the load includes a motor load, and the failure or malfunction of an electronic circuit component causes a change in the supply waveform to the controlled motor, the control shall be subjected to the following tests.

a) The load shall be adjusted under normal waveform conditions to six times the rated load or the locked rotor rating declared by the manufacturer.

b) Then the FAULT conditions shall be introduced.

c) The test is conducted under the conditions described in items a), c), d) and e) of 13.1.3.2.

The control shall be evaluated according to items a) to e) inclusive of 13.1.3.8, as appropriate to the component being assessed.

13.1.3.8 Compliance criteria

With each FAULT described in Table 14, simulated or applied to one circuit component at a time, the CONTROL shall comply with

– the following items a) to g) inclusive. For components complying with IEC 60065:2014, Clause 14, the CONTROLS need only comply with items a), c), d), f) and g);

– any additional compliance criteria, as specified in the applicable subclauses of part 2; and

– the requirements of specified software class, if declared.

a) The CONTROLS shall not emit flames, hot metal or hot plastics, and no explosion shall result.

There shall be no burning of the tissue paper. Inside the enclosure, some parts can temporarily glow, and there can be a temporary emission of smoke or flame. The tissue paper shall comply with ISO 4046-4:2016, 4.215 as a soft and strong, lightweight wrapping paper of grammage generally between 12 g/m^2 and 30 g/m^2.

b) The temperature for SUPPLEMENTARY INSULATION and REINFORCED INSULATION shall not exceed 1,5 times the relevant values specified in Clause 16, except in the case of thermoplastic material.

There is no specific temperature limit for SUPPLEMENTARY INSULATION and REINFORCED INSULATION of thermoplastic material, the temperature of which shall, however, be recorded for the purpose of Clause 21.

c) Any change in the controlled outputs shall be as declared in Table 1, requirement 52.

d) The CONTROL shall comply with the requirements of Clause 6 and 15.2 for BASIC INSULATION.

e) There shall be no deterioration of the various parts of the CONTROL that would result in non-compliance with the requirements of Clause 11.

f) A fuse in the supply, external to the CONTROL under test and as described in item d) of 13.1.3.2 shall not blow unless an internal protective device also operates that is accessible only after the use of a TOOL.

An internal protective device is deemed not to be required if the sample still complies with the following requirements after replacement of the fuse of the supply:

– items a), b) and d) of 13.1.3.8;

– the requirements of Clause 11 for the CLEARANCES and CREEPAGE DISTANCES from LIVE PARTS to the surfaces of the CONTROL that are accessible when the CONTROL is mounted as for its intended use.

g) The output waveform shall be as declared in Table 1, requirement 51.

13.2 Fault assessment to ensure functional safety

See H.13.2.

14 Moisture and dust resistance

14.1 Protection against ingress of water and dust

14.1.1 CONTROLS shall provide the degree of protection against ingress of water and dust appropriate to their IP classification according IEC 60529 when mounted and used in the declared manner.

14.1.1DV D2 *Modification of Clause 14.1.1 by adding the following:*

Alternatively, CONTROLS classified as having protection against ingress of water and dust shall meet the applicable environmental enclosure requirements of UL 50. Compliance with IEC 529 may be optionally provided, in which case, 14.1.1 to 14.1.6 apply.

14.1.2 *Compliance is checked by first preparing the control as described in 14.1.3 to 14.1.6 inclusive and then by carrying out the appropriate test specified in IEC 60529. Immediately after the appropriate test, the control shall withstand the electric strength test specified in 15.2, and inspection shall show that any water which has entered the control does not impair compliance with this document: in particular, there shall be no trace of water on insulation which could result in reduction of creepage distances and clearances below the values specified in Clause 11.*

14.1.3 *CONTROLS are allowed to stand in normal test room atmosphere for 24 h before being subjected to the appropriate test.*

14.1.4 *CONTROLS provided with a DETACHABLE CORD are fitted with an appropriate equipment inlet and flexible cord; CONTROLS with a NON-DETACHABLE CORD using TYPE X ATTACHMENT are fitted with the appropriate conductors with the thinnest cord according to 9.8 in the range as declared in Table 1, requirement 27; CONTROLS provided with a NON-DETACHABLE CORD using TYPE M ATTACHMENT, TYPE Y ATTACHMENT or TYPE Z ATTACHMENT are tested with the cord declared or delivered with the samples.*

14.1.5 *DETACHABLE PARTS are removed and subjected, if necessary, to the tests with the main part.*

14.1.6 *Sealing rings of glands and other sealing means, if any, are aged in an atmosphere having the composition and pressure of the ambient air, by suspending them freely in a heating cabinet, ventilated by natural circulation. They are kept in the cabinet at a temperature of (70 ± 2) °C, for 10 days (240 h).*

Immediately after ageing, the parts are taken out of the cabinet and left at room temperature, avoiding direct daylight, for at least 16 h, before being reassembled. The glands and other sealing means are then tightened with a torque equal to two-thirds of that given in Table 9 or as specified by the manufacturer in the manufacturer's instructions.

14.1.6DV.1 D2 *Modification of Clause 14.1.6 by adding the following:*

Gaskets and seals that are relied upon to prevent ingress of water and dust shall comply with the requirements of Standard for Gaskets and Seals, UL 157.

14.1.6DV.2 D2 *Modification of Clause 14.1.6 to add the following:*

14.1.6DV.2.1 The gasket and seals material shall have physical properties as specified in Table 14.1.6DV.1 before and after aging under the conditions specified in Table 14.1.6DV.2.

Table 14.1.6DV.1
Physical Properties for Gaskets

	Neoprene or rubber compound		Polyvinyl chloride materials	
	Before test	After test	Before test	After test
Recovery – Maximum set when 1-inch (25.4-mm) gage marks are stretched to 2-1/2 inches (63.5 mm) held for 2 minutes and measured 2 minutes after release	1/4 inch (6.4 mm)	–	Not specified	
Elongation – Minimum increase in distance between 1-inch gage marks at break	250 percent, 1 – 3-1/2 inches (25.4 - 88.9 mm)	65 percent of original	250 percent, 1 – 3-1/2 inches	75 percent of original
Tensile Strength – Minimum force at breaking point	850 psi (5.9 MPa)	75 percent of original	1200 psi (8.3 MPa)	90 percent of original

Table 14.1.6DV.2
Aging Conditions

Measured temperature rise		Material	Test program
°C	(°F)		
35	(63)	Rubber or neoprene	Air oven aging for 70 hours at 100.0 °C ±2.0 °C (212.0 ±3.6 °F)
35	(63)	Thermoplastic	Aged in full-draft, air-circulating oven for 168 hours at 87.0 ±1.0 °C (188.6 ±1.8 °F)
50	(90)	Rubber or neoprene	Air oven aging for 168 hours at 100.0 °C ±2.0 °C (212.0 °F ±3.6 °F)
50	(90)	Thermoplastic	Aged in full-draft, air-circulating oven for 240 hours at 100.0 ±1.0 °C (212.0 ±1.0 °F)
55	(99)	Rubber, neoprene or thermoplastic	Aged in full-draft, air-circulating oven for 168 hours at 113.0 ±1.0 °C (235.4 ±1.8 °F)
65	(117)	Rubber or neoprene	Aged in full-draft, air-circulating oven for 240 hours at 121.0 ±1.0 °C (249.8 ±1.8 °F)
65	(117)	Thermoplastic	Aged in full-draft, air-circulating oven for 168 hours at 121.0 ±1.0 °C (249.8 ±1.8 °F) for 1440 hours at 97.0 ±1.0 °C (206.6 ±1.8 °F)
80	(144)	Rubber, neoprene or thermoplastic	Aged in full-draft, air-circulating oven for 168 hours at 136.0 ±1.0 °C (276.8 ±1.8 °F)

14.1.6DV.2.2 Compliance is checked by inspection. The material shall show no signs of deformation, melt or deterioration to a degree that will affect its sealing properties.

14.1.6DV.2.3 If gaskets are secured by adhesives, samples of the gasket, adhesive and mounting surface shall be exposed for 72 hours to each of the following conditions, for a temperature rise not exceeding 35 °C (63 °F) obtained during the heating test:

a) 100 °C (212 °F);

b) Immersion in distilled water; and

c) Minus 10 °C (14 °F).

14.1.6DV.2.4 Compliance is checked by measuring the force required to peel the gasket from its mounting surface after the above exposure. The force shall not be less than 75 percent of the value determined on the as-received samples.

14.2 Protection against humid conditions

14.2.1 All CONTROLS shall withstand humid conditions which can occur in NORMAL USE.

14.2.2 Compliance is checked by the test sequence described in 14.2.3, after the humidity treatment of 14.2.5 to 14.2.9, inclusive.

14.2.3 *For IN-LINE CORD, FREE-STANDING, INDEPENDENTLY MOUNTED CONTROLS, the test of 15.2 is conducted immediately after the humidity treatment, immediately followed by test of 15.1. For integrated and INCORPORATED CONTROLS, the test of 15.2 is conducted immediately after the humidity treatment. These tests shall be conducted in such a manner that condensation does not occur on any surface of the test samples.*

14.2.4 The CONTROL shall show no damage so as to impair compliance with this document.

14.2.5 *Cable inlet openings, if any, and drain holes are left open. If a drain hole is provided for an IPX7 CONTROL, it is opened.*

14.2.6 *DETACHABLE PARTS are removed and subjected, if necessary, to the humidity treatment with the main part.*

14.2.7 *Before being placed in the humidity cabinet, the sample is brought to a temperature between t and (t + 4) °C, as specified in 14.2.8. The sample is then kept in the humidity cabinet for:*

– 2 days (48 h) for IPX0 CONTROLS;

– 7 days (168 h) for all other CONTROLS.

NOTE In most cases, the sample can be brought to the specified temperature by keeping it at this temperature for at least 4 h before the humidity treatment.

14.2.8 *The humidity treatment is carried out in a humidity cabinet containing air with a relative humidity between 91 % and 95 %. The temperature of the air, at all places where samples can be located, is maintained within (t – 1 K) and (t + 1 K), where t is any convenient value between 20 °C and 30 °C.*

14.2.9 *After this treatment, the tests of Clause 15, as applicable, based on the type of control, are made either in the humidity cabinet, or in the room in which the samples were brought to the prescribed temperature after the reassembly of any DETACHABLE PART removed before the humidity treatment.*

14.3 Touch current test for in-line cord controls and free-standing controls

14.3.1 For IN-LINE CORD CONTROLS and FREE-STANDING CONTROLS, one sample is subjected to the test of 14.3.2 to 14.3.6 inclusive prior to the other tests of Clause 14.

CLASS III CONTROLS are not tested under these subclauses.

14.3.2 *The CONTROL is connected to a supply voltage equal to 1,06 times the rated voltage. The test is conducted at the maximum rated current and the maximum declared ambient temperature.*

14.3.3 *The TOUCH CURRENT is measured between any pole of the supply and*

– accessible metal parts;

– metal foil with an area not exceeding 20 cm × 10 cm in contact with accessible surfaces of insulating material, connected together.

Measurements shall be done individually as well as collectively where surfaces are simultaneously accessible from one surface to another.

Where a surface is less than 20 cm × 10 cm, the metal foil is to be the same size as the surface. The metal foil is not to remain in place long enough to affect the temperature of the control.

If the control is provided with protective earthing, the protective earthing connection is to be disconnected at the supply source.

14.3.4 *Measuring circuits for CONTROLS using different supplies are shown in the figures mentioned below:*

– for a single-phase CONTROL having a rated voltage not exceeding 240 V, or three-phase CONTROL used as a single-phase control;

- *if a CLASS II CONTROL, see Figure 19;*
- *if other than a CLASS II CONTROL, see Figure 20;*

– for a single-phase CONTROL having a rated voltage exceeding 240 V, or a three-phase CONTROL not suitable for use as a single-phase CONTROL,

- *if a CLASS II CONTROL, see Figure 21;*
- *if other than a CLASS II CONTROL, see Figure 22;*

– for a single-phase CONTROL connected to a three-wire, center-tapped grounded neutral distribution SYSTEM and having a rating not exceeding 120 V, other than CLASS II CONTROL, see Figure 23;

– for a two-phase CONTROL connected to three-wire, center-tapped grounded neutral distribution SYSTEM and having a rating not exceeding 240 V, other than CLASS II CONTROL, see Figure 24.

CONTROLS having a rated voltage exceeding 240 V shall be connected to two of the phase conductors of a three phase SYSTEM, the remaining phase conductor not being used.

Details of the measuring circuit are shown in Figure K.1 of Annex K.

14.3.5 During measurement, all CONTROL circuits shall be closed. However, CONTROLS tested according to Figure 20, Figure 23 and Figure 24 shall have TOUCH CURRENTS checked with switch S1 in the open and the closed position or with switch in positions 'a' and 'b', according to the applicable test diagram.

It is permissible to short circuit contact points to simulate closed circuits.

14.3.6 The maximum TOUCH CURRENT, after the temperature of the CONTROL has stabilized, shall not exceed the values given in 15.3.5.

15 Electric strength and insulation resistance

15.1 Insulation resistance

15.1.1 The insulation resistance of IN-LINE CORD, FREE STANDING and INDEPENDENTLY MOUNTED CONTROLS shall be adequate.

15.1.2 *Compliance is checked by the test of 15.1.3 to 15.1.5 inclusive. This test is made when specified in Clause 14.*

15.1.3 *When measuring REINFORCED INSULATION or SUPPLEMENTARY INSULATION to other than metal parts, each appropriate surface of the insulation is covered with a metal foil to provide an electrode for the test.*

15.1.4 *The insulation resistance is measured with a DC voltage of approximately 500 V applied, the measurement being made 1 min after application of the voltage.*

15.1.5 *The insulation resistance shall not be less than that shown in Table 15.*

Table 15
Minimum insulation resistance

Insulation to be tested	Insulation resistance MΩ
FUNCTIONAL INSULATION	–
BASIC INSULATION	2
SUPPLEMENTARY INSULATION	5
REINFORCED INSULATION	7

15.2 Electric strength

15.2.1 The electric strength of all CONTROLS shall be adequate.

Compliance of the electric strength of all controls shall be checked by the following test of 15.2.2 to 15.2.4 inclusive, using insulation or disconnection test voltages as shown in Table 16.

Table 16
Insulation or disconnection test voltages

Insulation or disconnection to be tested [b c]	Test voltage for working voltage (U) [a o]		
	SELV/PELV [d]	Working voltage ≤ 50 V [e]	Working voltage [e] 50 V < *U* ≤ 690 V
FUNCTIONAL INSULATION [f]	100	100	2 × *U*
BASIC INSULATION [g h k]	500	1 250	1 200 + *U*
SUPPLEMENTARY INSULATION [g h i j k]	–	1 250	1 200 + (*U*)

Table 16 Continued on Next Page

Table 16 Continued

Insulation or disconnection to be tested [b c]	Test voltage for working voltage (U) [a o]		
	SELV/PELV [d]	Working voltage ≤ 50 V [e]	Working voltage [e] 50 V < *U* ≤ 690 V
REINFORCED INSULATION [g h i j k]	–	2 500	2 400 + (2 × *U*)
FULL DISCONNECTION [m]	N/A	1 250	1 200 + *U*
MICRO-DISCONNECTION [m]	100	100	2 × *U*
ELECTRONIC DISCONNECTION [l]	100	100	2 × *U*
Micro-INTERRUPTION [n]	–	–	–

NOTE 1 A DC potential equivalent to 1,414 times the test voltage specified in Table 16 is applied.

NOTE 2 For CONTROLS intended for incorporating into an appliance or in conjunction with other equipment, the higher electric strength test values of the equipment standard can be considered.

[a] 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 test voltage, the output current is at least 200 mA. The overcurrent relay shall not trip when the output current is less than 100 mA. Care shall be taken that the RMS value of the test voltage is measured within ±3 %.

[b] Special components which might render the test impractical, such as electronic parts, neon lamps, coils or windings shall be disconnected at one pole or bridged as appropriate to the insulation being tested. Capacitors shall be bridged except for the tests for FUNCTIONAL INSULATION when one pole is disconnected. Where such a proceeding is not practical, the tests of Clauses 17 to 19 inclusive are considered to be sufficient.

[c] For CLASS I CONTROLS and CLASS 0I CONTROLS and CONTROLS for CLASS I situations, care shall be taken that adequate CLEARANCE is maintained between metal foil and accessible metal to avoid over stressing of insulation between LIVE PARTS and earthed metal parts.

[d] Applies to circuits connected to SELV SYSTEMS or PELV SYSTEMS. In case of controls connected to PELV SYSTEMS, BASIC INSULATION requirement between the circuit and earth is not applicable.

[e] Applies to CONTROLS galvanically connected to mains.

[f] FUNCTIONAL INSULATION on printed wiring boards submitted in NORMAL USE to a voltage up to 50 V is not subjected to the tests of 15.2.

[g] See 15.3.2.

[h] Any metal in contact with accessible metal is also regarded as accessible.

[i] For the tests of SUPPLEMENTARY INSULATION and REINFORCED INSULATION, the metal foil is applied in such a way that sealing compound, if any, is effectively tested to accessible insulating surfaces.

[j] For ACCESSIBLE PARTS which are protected by means of PROTECTIVE IMPEDANCE, the tests are carried out with the components disconnected, the mid-point of the two impedances being regarded as an intermediate metal part.

[k] For CONTROLS incorporating REINFORCED INSULATION as well as DOUBLE INSULATION, care should be taken that the voltage applied to the REINFORCED INSULATION does not over stress the BASIC INSULATION or the supplementary parts of the DOUBLE INSULATION.

[l] The device which actually performs the disconnection is first removed from the circuit. If necessary, any CONTROL input is connected such that the device is providing the disconnection. The test voltage is then applied to the terminals and terminations of the device which carry the load current.

[m] For the test of FULL DISCONNECTION and MICRO-DISCONNECTION, contacts are opened automatically or manually and tested as soon after opening as possible to ensure that the contact separation and the supporting insulation are satisfactory.

In the case of temperature SENSING CONTROLS, it may be necessary to provide special samples specially calibrated to open between 15 °C and 25 °C to enable this test to be carried out at room temperature immediately after removal from the humidity cabinet.

[n] There are no electric strength requirements for MICRO-INTERRUPTION, since the satisfactory completion of the tests of Clauses 17 to 19 inclusive is considered to be sufficient. Furthermore, for a control which has no MICRO-DISCONNECTION in one position of its ACTUATING MEANS and MICRO-INTERRUPTION in other positions, there are no requirements for electric strength for those positions corresponding to MICRO-INTERRUPTION.

[o] All AC voltages are RMS at 50 Hz to 60 Hz.

15.2.2 When measuring REINFORCED INSULATION or SUPPLEMENTARY INSULATION to other than metal parts, each appropriate surface of the insulation is covered with a metal foil to provide an electrode for the test.

15.2.3 The insulation is subjected to a voltage of substantially sine-wave form, having a frequency of 50 Hz or 60 Hz. Voltage is applied for 1 min across the insulation or disconnection indicated in Table 16 and has the value shown in the Table 16.

15.2.4 Initially, not more than half the prescribed voltage is applied, then it is raised rapidly to the full value. No flashover or breakdown shall occur. Glow discharges without drop in voltage are neglected.

15.3 Additional tests for in-line cord and free-standing controls

15.3.1 For IN-LINE CORD and FREE-STANDING CONTROLS, after the tests of 15.1 or 15.2, as appropriate, the sample that was subjected to the tests of 14.3 shall be subjected to the tests of 15.3.2 to 15.3.5 inclusive.

CLASS III CONTROLS are not tested to 15.3.2 to 15.3.5.

15.3.2 A test voltage, DC for CONTROLS for DC only and AC for all other CONTROLS, is applied between any LIVE PART and

– accessible metal parts;

– metal foil with an area not exceeding 20 cm × 10 cm in contact with ACCESSIBLE SURFACES of insulating material, connected together.

Measurements shall be done individually as well as collectively where surfaces are simultaneously accessible from one surface to another.

Where a surface is less than 20 cm × 10 cm, the metal foil is to be the same size as the surface. The metal foil is not to remain in place long enough to affect the temperature of the CONTROL.

If the CONTROL is provided with protective earthing, the protective earthing connection is to be disconnected at the supply source.

15.3.3 The test voltage is

– 1,06 times rated voltage, or 1,06 times the upper limit of the rated voltage range, for CONTROLS for DC only, for single-phase CONTROLS and for three-phase CONTROLS which are also suitable for single-phase supply, if the rated voltage or the upper limit of the rated voltage range does not exceed 240 V;

– 1,06 times rated voltage, or 1,06 times the upper limit of the rated voltage range, divided by $\sqrt{3}$, for other CONTROLS.

15.3.4 *The TOUCH CURRENT is measured within 5 s after the application of the test voltage.*

15.3.5 The maximum TOUCH CURRENT to accessible metal parts and metal foil shall not exceed the following values:

– for class 0 controls, class 01 controls	0,5 mA,
– for CLASS L CONTROLS	0,75 mA, and
– for CLASS LL CONTROLS	0,25 mA.

15.3.5DV D2 *Modification of Clause 15.3.5 to add the following NOTE:*

NOTE DV1 The values for controls using 250 V or less supply are as follows:

– for CLASS 0 CONTROL, CLASS 01 CONTROL and CLASS I CONTROL	**0,5 mA,**
– for CLASS II CONTROLS	**0,25 mA**

16 Heating

16.1 CONTROLS and their supporting surfaces shall not attain excessive temperatures in NORMAL USE.

Compliance is checked by the test of 16.2 to 16.7 inclusive.

During this test, the temperatures shall not exceed the values specified in Table 17, and the CONTROLS shall not undergo any change so as to impair compliance with this document and in particular with Clauses 6, 15 and 11.

16.2 Terminals and TERMINATIONS which are intended for the connection of EXTERNAL CONDUCTORS, other than those for NON-DETACHABLE CORDS using TYPE M ATTACHMENT, TYPE Y ATTACHMENT or TYPE Z ATTACHMENT, shall be fitted with conductors of the intermediate cross-sectional area appropriate to the type of conductor and rating used in 8.1.5.

a) If TYPE M ATTACHMENT, TYPE Y ATTACHMENT or TYPE Z ATTACHMENT are used then the cord declared or supplied shall be used for the test.

b) If a terminal is suitable for both flexible cords and for fixed conductors, then the appropriate flexible cord is used.

c) Terminals not intended for the connection of EXTERNAL CONDUCTORS shall be fitted with conductors of the minimum cross-sectional area, as specified in 8.2.1, or with a special conductor if declared in 5.2.

16.3 For this test, CONTROLS shall be mounted as indicated in a) to c).

a) IN-LINE CORD CONTROLS and FREE-STANDING CONTROLS are stood or rested on a dull black painted plywood surface.

b) INDEPENDENTLY MOUNTED CONTROLS are mounted as in normal use.

c) INCORPORATED CONTROLS are mounted according to the manufacturer's instructions

16.4 Controls shall be connected to a supply having the most unfavourable voltage between 0,90 VR and 1,10 VR. Circuits which are not voltage sensitive are connected to a lower voltage (but not less than 10 % of VR and loaded such that the most unfavourable current between 0,90 and 1,10 times the rated current flows in the circuit). For battery powered controls, the test is carried out with a fully charged battery.

a) Circuits and contacts not intended for external loads shall be specified by the manufacturer.

b) ACTUATING MEMBERS are placed in the most unfavourable position.

c) Contacts required to be closed initially for the purpose of this test are closed at the rated current and the rated voltage of the circuit.

1) For temperature SENSING CONTROLS, the temperature SENSING ELEMENT is raised or lowered to a temperature which differs from the measured operating temperature under the conditions of this clause (5 ± 1) K such that the contacts are then in the closed position.

2) For all other SENSING CONTROLS, the SENSING ELEMENT shall be maintained such that the contacts are in the closed position, but are as near the point of opening as is practical.

3) It may be necessary to raise or lower, as appropriate, the value of the ACTIVATING QUANTITY beyond the OPERATING VALUE so as to cause OPERATION and then to return the value of ACTIVATING QUANTITY TO THE REQUIRED LEVEL.

4) For other AUTOMATIC CONTROLS, the most arduous OPERATING SEQUENCE or segment of the OPERATING SEQUENCE shall be selected.

d) If the CONTROL starts to operate during this test, the CONTROL is reset so that the contacts will remain closed.

If resetting to reclose the contacts is not practical, then the test is discontinued. A new OPERATING VALUE is determined and the test repeated using this new OPERATING VALUE.

16.5 CONTROLS are tested in an appropriate heating and/or refrigerating apparatus such that the conditions in a) and b) are obtained.

Except for CONTROLS submitted in or with appliances, the test shall be conducted in an environment protected from drafts. Natural convection is permitted.

a) The temperature of the SWITCH HEAD is maintained between T_{max} and either (T_{max} + 5) °C or 1,05 times T_{max}, whichever is greater. The temperature of any mounting surface is maintained between $T_{s\ max}$ and either ($T_{s\ max}$ + 5) °C or 1,05 times $T_{s\ max}$, whichever is the greater if $T_{s\ max}$ is higher than T_{max} by more than 20 K .

b) IN-LINE CORD CONTROLS, INDEPENDENTLY MOUNTED CONTROLS and those parts of INTEGRATED and INCORPORATED CONTROLS which are accessible when the CONTROL is mounted as in NORMAL USE shall be in a room temperature in the range of 15 °C to 30 °C, the resulting measured temperature being corrected to a 25 °C reference value. Accessible surfaces shall be tested at a higher temperature as declared in Table 1, requirement 15.

16.6 The temperatures specified for the SWITCH HEAD, the mounting surfaces and SENSING ELEMENT shall be attained in approximately 1 h.

a) The electrical and thermal conditions are maintained for 4 h, or for 1 h after steady state, whichever occurs first.

b) For CONTROLS designed for short-time or intermittent OPERATION, the resting time(s) declared in Table 1, requirement 29, shall be included in the 4 h.

16.7 The temperature of the medium in which the SWITCH HEAD is located, and the value of the ACTIVATING QUANTITY to which the SENSING ELEMENT is exposed, shall be measured as near as possible to the centre of the space occupied by the samples and at a distance of approximately 50 mm from the CONTROL.

a) The temperature of the parts and surfaces indicated in Table 17 shall be determined by means of fine wire thermocouples or other equivalent means, so chosen and positioned that they have the minimum effect on the temperature of the part under test.

b) Thermocouples used for determining the temperature of supporting surfaces are attached to the back of small blackened discs of copper or brass, 15 mm in diameter and 1 mm thick, which are flush with the surface. So far as is possible, the CONTROL is positioned such that parts likely to attain the highest temperatures touch the discs.

c) In determining the temperature of ACTUATING MEMBERS and other handles, knobs, grips and the like, consideration is given to other parts which are gripped in NORMAL USE, and if of non-metallic material to parts in contact with hot metal.

d) The temperature of electrical insulation, other than that of windings, is determined on the surface of the insulation at places where FAILURE could cause:

– a short circuit;

– a fire HAZARD;

– an adverse effect on the protection against electric shock;

– contact between LIVE PARTS and accessible metal parts;

– bridging of insulation;

– reduction of CREEPAGE DISTANCES or CLEARANCES below the values specified in Clause 11.

Table 17
Maximum heating temperatures

Parts	Maximum temperature permitted °C
Pins of appliance inlets and plug-in devices [a]:	
– for very hot conditions	155
– for hot conditions	120
– for cold conditions	70
Windings [b c d e] and core laminations in contact therewith, if winding insulation is:	
– of class A material	100 [90]
– of class E material	115 [105]
– of class B material	120 [110]
– of class F material	140
– of class H material	165
Terminals and TERMINATIONS for EXTERNAL CONDUCTORS [a f g]	85
Other terminals and TERMINATIONS [a h]	85
Rubber or polyvinyl chloride insulation of conductors: [a]	
– if flexing occurs or is likely to occur	60
– if no flexing occurs or is likely to occur	75

Table 17 Continued on Next Page

Table 17 Continued

Parts	Maximum temperature permitted °C
– with temperature marking or temperature rating	value marked
Cord sheath used as SUPPLEMENTARY INSULATION [i]	60
Rubber other than synthetic when used for gaskets or other parts, the deterioration of which could impair compliance with this document:	
– when used as SUPPLEMENTARY INSULATION or as REINFORCED INSULATION	65
– in other cases	75
Materials used as insulation other than for wires [i j k]:	
– impregnated or varnished textile, paper or press board	95
– laminates bonded with:	
• melamine formaldehyde, phenol-formaldehyde or phenol-furfural resins	110 [200]
• urea-formaldehyde resins	90 [175]
– mouldings of [j]	
• phenol-formaldehyde, with cellulose fillers	110 [200]
• phenol-formaldehyde, with mineral fillers	125 [225]
• melamine-formaldehyde	100 [175]
• urea-formaldehyde	90 [175]
• polyester with glass fibre reinforcement	135
• pure mica and tightly sintered ceramic material when such products are used as SUPPLEMENTARY INSULATION or REINFORCED INSULATION	425
• other thermosetting materials and all thermo-plastic material [l]	–
All ACCESSIBLE SURFACES except those of ACTUATING MEMBERS, handles, knobs, grips and the like	85
ACCESSIBLE SURFACES of handles, knobs, grips and the like used for carrying and transporting the CONTROL:	
– of metal	55
– of porcelain or vitreous material	65
– of moulded material, rubber or wood	75
ACCESSIBLE SURFACE of ACTUATING MEMBERS, or of other handles, grips or the like which are held for short periods only:	
– of metal	60
– of porcelain or vitreous material	70
– of moulded material, rubber or wood	85
Other parts made out of wood	90
Supported painted plywood surface	85
Current-carrying parts made of copper or brass [a m n]	230
Current-carrying parts made of steel [a]	400
Other current-carrying parts [a m]	–

[a] For these parts, the tests of 16.7 are repeated after Clause 19.

[b] The classification is in accordance with IEC 60085.

Examples of class A material are: impregnated cotton, silk, artificial silk and paper; enamels based on oleo- or polyamide resins.

Table 17 Continued on Next Page

Table 17 Continued

Parts	Maximum temperature permitted °C

Examples of class B material are: glass fibre, melamine and phenol formaldehyde resins.

Examples of class E material are:

– mouldings with cellulose fillers, cotton fabric laminates and paper laminates, bonded with melamine-formaldehyde, phenol-furfural resins;

– cross-linked polyester resins, cellulose triacetate films, polyethylene terephthalate films;

– varnished polyethylene terephthalate textile bonded with oil modified alkyd resin varnish;

– enamels based on polyvinylformal, polyurethane or epoxy resins.

More extensive accelerated temperature tests and, in addition, compatibility testing is required for insulation SYSTEMS of class B and higher temperature classes.

For totally enclosed motors using class A, E and B material, the temperatures may be increased by 5 K. A totally enclosed motor is a motor so constructed that the circulation of the air between the inside and the outside of the case is prevented but not necessarily sufficiently enclosed to be called airtight.

[c] To allow for the fact that the temperature of windings of universal motors, relays, solenoids, etc., is usually below the average at the points accessible to thermo-couples, the figures without square brackets apply when the resistance method is used and those with square brackets apply when thermocouples are used. For the windings of vibrator coils and AC motors, the figures without square brackets apply in both cases.

[d] The value of the temperature rise of a copper winding is calculated from the formula:

$$\Delta t = \frac{R_2 - R_1}{R_1}(234{,}5 + t_1) - (t_2 - t_1)$$

where

Δt is the temperature rise [K];

R_1 is the resistance at the beginning of the test [Ω];

R_2 is the resistance at the end of the test [Ω];

t_1 is the working ambient temperature at the beginning of the test, to be set at T_{max} [°C];

t_2 is the working ambient temperature at the end of the test [°C];

At the beginning of the test, the windings are to be at T_{max}.

It is recommended that the resistance of windings at the end of the test be determined by taking resistance measurements as soon as possible after switching off, and then at short intervals so that a curve of resistance against time can be plotted for ascertaining the resistance at the instant of switching off.

The maximum temperature attained for the purposes of Clause 16 is derived by adding the temperature rise to T_{max}.

[e] For small windings with a cross section, the minor dimension of which is no greater than 5 mm, the maximum temperature permitted when measured by the resistance method is:

Class	°C
A	105
E	120
B	130
F	155
H	180

[f] For CONTROLS submitted in or on equipment, only the temperatures of terminals for fixed conductors are verified, as such equipment is not usually delivered with EXTERNAL CONDUCTORS. For equipment with other than terminals for fixed conductors, the temperature of the insulation of the EXTERNAL CONDUCTOR is determined instead of the temperature of the terminals.

Table 17 Continued on Next Page

Table 17 Continued

Parts	Maximum temperature permitted °C
g For incorporated and INTEGRATED CONTROLS, no temperature limit is applicable, but attention is drawn to the fact that most equipment standards limit the temperature of terminals of fixed appliances to 85 °C, which is the maximum allowable temperature for ordinary PVC cable insulation. The maximum temperature recorded should not exceed the value declared in Table 1, requirement 14. When a CONTROL is incorporated/integrated into an appliance, the terminals for EXTERNAL CONDUCTORS will, as part of the appliance, be subject to the specified tests of the appliance standard and assessed for compliance with the temperature limits of that standard.	
h The temperature measured shall not exceed 85 °C unless a higher value has been declared by the manufacturer.	
l The temperature values given, which are related to heat resistant properties of the material, may be exceeded where particular materials have been investigated and recognized as having special heat resistant properties.	
j The values in square brackets apply to those parts of a material used for ACTUATING MEMBERS, handles, knobs, grips and the like and which are in contact with hot metal, but are not accessible.	
k Where a metal part is in contact with a part made of insulating material, it is assumed that the temperature of the insulating material at the point of contact is the same as the temperature of the metal part.	
l The maximum permissible temperatures shall not exceed those which can be shown to be acceptable in service for these materials. The temperatures shall be recorded for the purposes of Clause 21.	
m The maximum permissible temperature shall not exceed those which have been shown to be acceptable in service for these materials.	
n Higher temperatures are acceptable for specific copper alloys if substantiated by test data from the alloy manufacturer to a recognized metallurgical standard. See also footnote m.	

Table 17DV D2 *Modification of Table 17 to replace with the following:*

Table 17DV
Maximum Heating Temperatures

Parts	Maximum temperature permitted °C
Pins of appliance inlets and plug-in devices [a]:	
– for very hot conditions	**155**
– for hot conditions	**120**
– for cold conditions	**65**
Windings [b c d e] and core laminations in contact therewith, if winding insulation is:	
– of class A material	**100 [90]**
– of class E material	**115 [105]**
– of class B material	**120 [110]**
– of class F material	**140**
– of class H material	**165**
Terminals and TERMINATIONS for EXTERNAL CONDUCTORS [a f g DV3)]	**85**
Other terminals and TERMINATIONS [a h]	**85**
Rubber or polyvinyl chloride insulation of conductors [a]:	
– if flexing occurs or is likely to occur	**60**
– if no flexing occurs or is unlikely to occur	**75**

Table 17DV Continued on Next Page

Table 17DV Continued

Parts	Maximum temperature permitted °C
– with temperature marking or temperature rating	value marked
Cord sheath used as SUPPLEMENTARY INSULATION [i]	60
Rubber other than synthetic when used for gaskets or other parts, the deterioration of which could impair compliance with this standard: [DV1)]	
– when used as SUPPLEMENTARY INSULATION or as REINFORCED INSULATION	65
– in other cases	75
Materials used as insulation other than for wires [i j k]:	
– impregnated or varnished textile, paper or press board	95
– laminates bonded with:	
melamine formaldehyde, phenol-formaldehyde or phenol-furfural resins	110 [200]
urea-formaldehyde resins	90 [175]
– mouldings of [j]	
phenol-formaldehyde, with cellulose fillers	110 [200]
phenol-formaldehyde, with mineral fillers	125 [225]
melamine-formaldehyde	100 [175]
urea-formaldehyde	90 [175]
polyester with glass fibre reinforcement	135
pure mica and tightly sintered ceramic material when such products are used as SUPPLEMENTARY INSULATION or REINFORCED INSULATION	425
other thermosetting materials and all thermo-plastic material [l]	–
All ACCESSIBLE SURFACES except those of ACTUATING MEMBERS, handles, knobs, grips and the like	85
ACCESSIBLE SURFACES of handles, knobs, grips and the like used for carrying and transporting the control: DV2)	
– of metal	55
– of porcelain or vitreous material	65
– of moulded material, rubber or wood	75
ACCESSIBLE SURFACE of ACTUATING MEMBERS, or of other handles, grips or the like which are held for short periods only:	
– of metal	60
– of porcelain or vitreous material	70
– of moulded material, rubber or wood [DV2)]	85
Wood in general	90
Supporting painted plywood surface	85
Current-carrying parts made of copper or brass [a m n]	230
Current-carrying parts made of steel [a]	400
Other current-carrying parts [a m]	–
Points on or within a terminal box or compartment on which conductors to be connected to the control may rest [DV3)]	60
Solid contacts, busses, and connecting bars [DV4)]	90
Fuses [DV7)]	90

Table 17DV Continued on Next Page

Table 17DV Continued

Parts	Maximum temperature permitted °C
Power switching semi-conductors DV8)	–
Sealing compounds DV5)	–
Capacitors DV6)	–

[a] For these parts, the tests of 16.7 are repeated after Clause 19.

[b] The classification is in accordance with IEC 60085.

Examples of class A material are: impregnated cotton, silk, artificial silk and paper; enamels based on oleo-or polyamide resins.

Examples of class B material are: glass fibre, melamine and phenol formaldehyde resins.

Examples of class E material are:

– moldings with cellulose fillers, cotton fabric laminates and paper laminates, bonded with melamine-formaldehyde, phenol-furfural resins;

– cross-linked polyester resins, cellulose triacetate films, polyethylene terephthalate films;

– varnished polyethylene terephthalate textile bonded with oil modified alkyd resin varnish;

– enamels based on polyvinylformal, polyurethane or epoxy resins.

More extensive accelerated temperature tests and, in addition, compatibility testing is required for insulation systems of class B and higher temperature classes.

For totally enclosed motors using class A, E and B material, the temperatures may be increased by 5 K.

A totally enclosed motor is a motor so constructed that the circulation of the air between the inside and the outside of the case is prevented but not necessarily sufficiently enclosed to be called airtight.

[c] To allow for the fact that the temperature of windings of universal motors, relays, solenoids, etc., is usually below the average at the points accessible to thermocouples, the figures without square brackets apply when the resistance method is used and those with square brackets apply when thermocouples are used. For the windings of vibrator coils and a.c. motors, the figures without square brackets apply in both cases.

[d] The value of the temperature rise of a copper winding is calculated from the formula:

$$\Delta t = \left(\frac{R_2 - R_1}{R_1}\right)(234{,}5 + t_1) - (t_2 - t_1)$$

where:

Δt is the temperature rise;

R_1 is the resistance at the beginning of the test;

R_2 is the resistance at the end of the test;

t_1 is the working ambient temperature at the beginning of the test, to be set at T_{max};

t_2 is the working ambient temperature at the end of the test;

At the beginning of the test, the windings are to be at T_{max}.

It is recommended that the resistance of windings at the end of the test be determined by taking resistance measurements as soon as possible after switching off, and then at short intervals so that a curve of resistance against time can be plotted for ascertaining the resistance at the instant of switching off.

The maximum temperature attained for the purposes of this clause is derived by adding the temperature rise to T_{max}.

[e] For small windings with a cross section, the minor dimension of which is no greater than 5 mm, the maximum temperature permitted when measured by the resistance method is:

Class	°C
A	105

Table 17DV Continued on Next Page

Table 17DV Continued

Parts		Maximum temperature permitted °C
E		120
B		130
F		155
H		180

[f] For controls submitted in or on equipment, only the temperatures of terminals for fixed conductors are verified, as such equipment are not usually delivered with external conductors. For equipment with other than terminals for fixed conductors, the temperature of the insulation of the external conductor is determined instead of the temperature of the terminals.

The maximum temperature permitted is 75 °C. Higher temperatures are permitted if the control is marked with the required T rating for the external conductors.

[g] For incorporated and integrated controls, no temperature limit is applicable, but attention is drawn to the fact that most equipment standards limit the temperature of terminals of fixed appliances to 85 °C, which is the maximum allowable temperature for ordinary PVC cable insulation. The maximum temperature recorded should not exceed the value declared in Table 1, requirement 21.

When a CONTROL is incorporated/integrated into an appliance, the terminals for external conductors will, as part of the appliance, be subject to the specified tests of the appliance standard and assessed for compliance with the temperature limits of that standard.

[h] The temperature measured shall not exceed 85 °C unless a higher value has been declared by the manufacturer.

[i] The temperature values given, which are related to heat resistant properties of the material, may be exceeded where particular materials have been investigated and recognized as having special heat resistant properties.

[j] The values in square brackets apply to those parts of a material used for actuating members, handles, knobs, grips and the like and which are in contact with hot metal, but are not accessible.

[k] Where a metal part is in contact with a part made of insulating material it is assumed that the temperature of the insulating material at the point of contact is the same as the temperature of the metal part.

[l] The maximum permissible temperatures shall not exceed those which can be shown to be acceptable in service for these materials. The temperatures shall be recorded for the purposes of Clause 21.

[m] The maximum permissible temperature shall not exceed those which have been shown to be acceptable in service for these materials.

[n] Higher temperatures are acceptable for specific copper alloys if substantiated by test data from the alloy manufacturer to a recognized metallurgical standard. See also footnote m.

[DV1)] See 14.1.6.

[DV2)] Void.

[DV3)] The temperature observed on the terminals and at points within a terminal box of a control for use with other than a residential appliance that is rated for continuous use above 25 °C (77 °F) may exceed the values specified but may not attain a temperature higher than 90 °C (194 °F). See R31DV.1.3.1 and R31DV.1.3.2.

[DV4)] If contacts of any metal and their supporting blades, busses, and connecting bars attain a temperature greater than 90 °C (194 °F) where a high ambient temperature or other external temperature prevails, or where affected by a bi-metal heater or other heat source in the assembly, the control shall perform acceptably when subjected to overload and endurance tests conducted at the high temperatures involved.

[DV5)] The maximum acceptable temperature, corrected to a 25 °C (77 °F) assumed ambient temperature, of a sealing compound is 15 °C (27 °F) less than the melting-point temperature of the compound.

[DV6)] For a capacitor, the maximum allowable temperature is the marked temperature limit of the capacitor.

[DV7)] A fuse that has been investigated and found acceptable for use at a higher temperature may be used at that temperature.

[DV8)] For power switching semi-conductors, the maximum temperature rise on the case is the maximum case temperature for the applied power dissipation recommended by the semi-conductor manufacturer minus an assumed ambient of 40 °C (104 °F).

17 Manufacturing deviation and drift

Manufacturing deviation and drift are required for TYPE 2 ACTION which are part of functional safety as indicated in Figure 2. See Clause H.17.

17DV D2 *Modification of Clause 17 to add the following NOTE:*

NOTE DV1 MANUFACTURING DEVIATION AND DRIFT are expressed as separate tolerances to the declared OPERATING VALUE. For some CONTROLS with TYPE 2 ACTION, allowable values of MANUFACTURING DEVIATION AND DRIFT are specified. The consistency is then determined, using prescribed apparatus, by measurement of the OPERATING VALUE of the sample and comparison to the declared OPERATING VALUE.

18 Environmental stress

18.1 Transportation and storage

Controls which are sensitive to the environmental stresses of temperature shall withstand the level of the appropriate stress likely to occur in transportation and storage.

Compliance is checked by the appropriate tests of 18.2, carried out with the CONTROL being left in the same condition declared as a transportation condition. If no transportation condition is declared, the CONTROL is tested with an ACTUATING MEMBER or ACTUATING MEANS in the most unfavourable position.

18.2 Environmental stress of temperature

18.2.1 *The effect of temperature is tested as follows:*

– The entire CONTROL shall be maintained at a temperature of (–10 ± 2) °C for a period of 24 h.

– The entire CONTROL shall then be maintained at a temperature of (60 ± 5) °C for a period of 4 h.

18.2.2 *The CONTROL is not energized during either test.*

18.2.3 *After each test, a CONTROL with an ACTUATING MEMBER or ACTUATING MEANS shall be capable of being actuated to provide correctly the class of circuit disconnection declared, in so far as this can be determined without dismantling the CONTROL. This test is carried out at normal room temperature.*

The CONTROL is held at room temperature for 8 h prior to ACTUATION.

18.2.4 *In addition, for CONTROLS with TYPE 2 ACTIONS, the appropriate test of Clause 17 shall be repeated after each of the above tests. The value measured in these tests shall not differ from the value recorded in Clause H.17 for the same sample, by an amount greater than the DRIFT declared in Table 1, requirement 36.*

19 Endurance

19.1 General requirements

19.1.1 Objectives of the test

The endurance test is intended

a) to evaluate the robustness of switching contacts and associated parts that are either integrated in the control or separately controlled,

b) to ensure inherent and functional safety as applicable, as well as normal operation of the control,

c) for electromechanical controls with TYPE 1 and TYPE 2 ACTION,

d) for ELECTRONIC CONTROLS that have moving parts.

19.1.2 All controls

CONTROLS, including those submitted in or with an equipment, shall withstand the mechanical, electrical and thermal stresses that occur in NORMAL USE.

19.1.3 Electronic controls

19.1.3.1 An endurance test is not carried out on ELECTRONIC CONTROLS with TYPE 1 ACTION when the associated components with manual actions, relays, etc. do comply with the appropriate IEC standard or when they do comply with the appropriate IEC standard, ratings and conditions for the specific application of the control.

19.1.3.2 An endurance test is also carried out on ELECTRONIC CONTROLS with TYPE 1 ACTION when the functions of integral switching elements or MANUAL ACTIONS can not be realized by independence of the CONTROL and are dependent on the electronics or design of the control. ELECTRONIC CONTROLS with TYPE 2 ACTION are not subjected to an endurance test but to a thermal cycling test under the conditions described in H.19.1.3.3. This test can be combined with the testing of any associated components such as those with MANUAL ACTIONS, relays, etc., if this is possible.

NOTE Electronic keypads are not subject to an endurance test unless they are used to manually operate a safety function. Examples include induction hob control units.

19.1.3.3 Thermal cycling test, see H.19.1.3.3

19.1.4 Controls with type 2 actions

Controls with TYPE 2 ACTIONS shall operate such that any operating value, operating time or operating sequence does not change by an amount greater than the declared drift, see Clause H.17.

19.1.5 Compliance criteria

Compliance with 19.1.2 and 19.1.3 is checked by the tests of 19.1.6 or as indicated in 19.15.

Compliance with 9.1.3 is checked by the tests of 19.1.6.

19.1.6 Test sequence and conditions

19.1.6.1 Unless specified otherwise in the part 2 or the end equipment standard, the sequence of tests is

– an ageing test specified in 19.6 (this test applies only to those actions classified as type 1.M or 2.M);

– an overvoltage test of AUTOMATIC ACTION at accelerated rate specified in 19.7.;

– a test of AUTOMATIC ACTION at accelerated rate specified in 19.8;

– a test of AUTOMATIC ACTION at slow rate specified in 19.9 (this test applies only to SLOW-MAKE SLOW-BREAK AUTOMATIC ACTIONS);

– an overvoltage test of MANUAL ACTION at accelerated speed specified in 19.10;

– a test of MANUAL ACTION at slow speed specified in 19.11;

– a test of MANUAL ACTION at high speed specified in 19.12 (this test applies only to actions with more than one pole, and where polarity reversal occurs during the OPERATION);

– a test of MANUAL ACTION at accelerated speed specified in 19.13.

19.1.6DV D2 *Modification of Clause 19.1.6 to revise as follows:*

In the second and fifth dashed items, replace "overvoltage" by "overload".

19.1.6.2 The electrical, thermal and mechanical conditions of test shall in general be those specified in 19.2, 19.3 and 19.4. The general test requirements are given in 19.6 to 19.14 inclusive. The particular test requirements are given in the appropriate part 2.

19.1.6.3 Tests for a MANUAL ACTION forming part of an AUTOMATIC ACTION are normally specified in the subclause appropriate to the AUTOMATIC ACTION. If, however, tests are not specified, then 19.10 to 19.13 inclusive apply to such MANUAL ACTIONS.

19.1.6.4 After all the tests specified, the samples shall meet the requirements of 19.14, unless otherwise specified in the appropriate part 2.

19.1.6.5 *Independently mounted devices performing remote RESET functions shall be tested for a minimum 1 000 reset actions. For integrated and incorporated devices, unless otherwise specified, the minimum reset cycles shall be declared by the manufacturer. After the test, the RESET device shall be capable to reset the SYSTEM as intended. Unintended RESETS shall not occur.*

19.2 Electrical conditions for the tests

19.2.1 Each circuit of the CONTROL shall be loaded according to the ratings declared by the manufacturer. Circuits and contacts which are not intended for external loads are operated with the designed load. Some changeover circuits may require testing separately for each part if such a manner has been declared by the manufacturer, particularly if the rating of one part of the changeover circuit depends upon the current carried by the other part.

19.2.2 In all countries which use an overvoltage test, the electrical loads to be used are those specified in Table 18 at rated voltage V_R, and with this voltage then being increased to 1,15 V_R for the overvoltage test of 19.7 and 19.10.

19.2.3 In all countries which use an overload test, the conditions specified in Table 19 and Table 20 apply. The overload tests are performed on a single pole or throw at a time, with all other poles or throws at normal load.

a) The overload test, test voltages (VT) are

– 120 V for CONTROLS rated at any voltage between 110 V to 120 V;

– 208 V for controls rated at any voltage between 200 V to 208 V;

– 240 V for CONTROLS rated at any voltage between 220 V to 240 V;

– 277 V for CONTROLS rated at any voltage between 254 V to 277 V;

– 480 V for CONTROLS rated at any voltage between 440 V to 480 V;

– 600 V for CONTROLS rated at any voltage between 550 V to 600 V.

b) If the rating of the CONTROL does not fall within any of the indicated voltage ranges, it is to be tested at its rated voltage.

19.2.4 When there is an earthed neutral SYSTEM, the enclosure shall be connected through a 3 A cartridge fuse to the PROTECTIVE CONDUCTOR of the circuit, and for other than an earthed neutral SYSTEM, the enclosure shall be connected through such a fuse to the live pole least likely to break down to earth.

19.2.5 For type 1.G or 2.G actions, or other off-load actions, auxiliary switches are used to simulate the intended OPERATION during the test.

Table 18
Electrical conditions for the overvoltage and endurance tests

(This table applies to all tests in accordance with 19.2.2 and countries that uses an overvoltage test.)

Type of circuit as given in Table 1, Requirement 8	Operation	AC circuit			DC circuit		
		V	A	Power factor (±0,05) [a]	V	A	Time constant (±1 ms)
Substantially resistive [d]	Making and breaking	V_R	I_R	0,95	V_R	I_R	Non-inductive
Resistive or inductive [e]	Making [b]	V_R	6,0 I_X or I_R if arithmetically the greater	0,6 0,95	V_R	2,5 I_X or I_R if arithmetically the greater	7,5
	Breaking	V_R	I_X or I_R if arithmetically the greater	0,95		I_X or I_R if arithmetically the greater	Non-inductive
Declared specific load	Making and breaking	V_R	As determined by load		V_R	As determined by load	
20 mA load	Making and breaking	V_R	20 mA	0,95	V_R	20 mA	Non-inductive
Declared motor load	Making and breaking	V_R	As declared		V_R	As declared	
PILOT DUTY load	Making [b]	V_R	10 VA/ V_R	0,35		c	
	Breaking	V_R	VA/ V_R	0,95			

Circuits intended for inductive loads only can either be tested as resistive or inductive load by declaring that the resistive load is equal to the inductive load, or may be tested as a declared specific load.

The following abbreviations are used:

V_R is the rated voltage, I_R is the rated current for resistive load, I_X is the rated current for induction load.

For test purposes, a PILOT DUTY load consists of an electromagnet representative of the magnet coil which is to be controlled. The normal current is that determined from the voltage and volt-ampere ratings of the electromagnet. The test current is the normal current and, for an alternating current, the power factor is to be 0,35 or less and the inrush current is to be 10 times the normal current. The test contactor is to be free to operate i.e., not blocked in either the open or the closed position.

An alternating-current PILOT DUTY rating may be determined for a control which has been tested for controlling an alternating-current motor on the following basis:

– during the overload test, the CONTROL was caused to make and break, for 50 cycles at a rate of 6 cycles per minute, a current having a value equivalent to six times the full-load motor current at a power factor of 0,5 or less, and

– the PILOT DUTY INRUSH CURRENT rating (10 times the normal current rating) is to be not more than 67 % of the current value for the overload test described above.

Table 18 Continued on Next Page

Table 18 Continued

Type of circuit as given in Table 1, Requirement 8	Operation	AC circuit			DC circuit		
		V	A	Power factor (±0,05) [a]	V	A	Time constant (±1 ms)
A switch that is not intended primarily to make and break motor current under locked-rotor conditions, but which has a manual adjusting or regulating means that may cause it to be so used, shall comply with the requirements of 19.7 for a locked-rotor test. For a switch intended for DC OPERATION, the number of OPERATIONS shall be five (5), conducted at intervals of 30 s and the device shall also comply with the requirements of a).							
[a] Resistors and inductors are not connected in parallel except that if any air-core inductor is used, a resistor taking approximately 1 % of the current through the inductor is connected in parallel with it. Iron-core inductors may be used provided that the current has a substantially sine waveform. For three-phase tests, three-core inductors are used. [b] The specified making conditions are maintained for a period between 50 ms and 100 ms, and are then reduced by an auxiliary switch to the specified breaking conditions. If during any test to this clause, contact break occurs within 2 s of contact make, the conditions specified for making are also used for breaking. [c] These values are not applicable. [d] Such circuits can be used for an inductive load, provided that the power factor is not less than 0,8, and the inductive load does not exceed 60 % of the current rating for the resistive load. Such circuits can also be used for other reactive loads provided that the reactive current does not exceed 5 % of the rated resistive current, and that the load is not greater than 10 VA. [e] Circuit suitable for either a resistive load or for an inductive load with a power factor not less than 0,6 or a combination of both. Example A circuit in a fan-heater which incorporates both a heating element and a motor.							

Table 19
Electrical conditions for the overload tests of 19.7 and 19.10

(this table applies in all countries which use an overload test in accordance with 19.1.6.1)

Type of circuit as given in Table 1, requirement 8	Operation	AC circuit			DC circuit		
		V	A	Power factor	V	A	
Substantially resistive	Making and breaking	V_T	$1{,}5I_R$	1,0	V_T	$1{,}5I_R$	
Inductive (non-motor)	Making and breaking	V_T	$1{,}5I_X$	0,75 to 0,8	V_T	$1{,}5I_X$	
Declared motor load	Making and breaking	V_T	$6I_m$ or as declared	0,4 to 0,5 or as declared	V_T	$10I_m$ or as declared	
Declared specific load	Making and breaking	V_T	$1{,}5I_X$	0,75 to 0,8	V_T	$1{,}5I_X$	
20 mA load	Making and breaking	V_T	$1{,}5I_X$	0,95	V_T	20 mA	Non-inductive
PILOT DUTY load	Making	1,1 V_T	10 VA/ V_T	0,35 maximum or as declared	As declared		
	Breaking	1,1 V_T	VA/ V_T or as declared				

The following abbreviations are used:

V_R is the rated voltage, V_T is the test voltage (see 19.2.3 a)). A circuit in which the closed-circuit voltage is 100 % to 110 % of V_T is acceptable for the tests.

I_m is the rated current or motor load, I_R is the rated current for resistive load, I_X is the rated current for induction load.

For test purposes, a PILOT DUTY load consists of an electromagnet representative of the magnet coil which is to be controlled. The normal current is that determined from the voltage and volt-ampere ratings of the electromagnet. The test current is the normal current and, for an alternating current, the power factor is to be 0,35 or less and the INRUSH CURRENT is to be 10 times the normal current. The test contactor is to be free to operate i.e., not blocked in either the open or the closed position.

An alternating-current PILOT DUTY rating may be determined for a CONTROL which has been tested for controlling an alternating-current motor on the following basis:

– during the overload test, the CONTROL was caused to make and break, for 50 cycles at a rate of 6 cycles per minute, a current having a value equivalent to six times the full-load motor current at a power factor of 0,5 or less, and

– the PILOT DUTY INRUSH CURRENT RATING (10 times the normal current rating) is to be not more than 67 % of the current value for the overload test described above.

For CONTROLS that may make a motor circuit under locked rotor conditions but that are never required to break the circuit under such conditions, the following applies:

a) 100 % V_T for AC and 0,5 V_T for DC for 1,5 rated current,

b) 100 % V_T for locked-rotor current (make only).

A switch that is not intended primarily to make and break motor current under locked-rotor conditions, but which has a manual adjusting or regulating means that may cause it to be so used, shall comply with the requirements of 19.7 for a locked-rotor test.

For a switch intended for DC OPERATION, the number of OPERATIONS shall be five (5), conducted at intervals of 30 s and the device shall also comply with the requirements of a) above.

Table 19DV D2 ***Modification of Table 19 to add the following:***

Table 19DV

Type of circuit as given in Table 1, requirement 8	Operation	AC circuit			DC circuit	
		V	A	Power factor	V	A
Incandescent (Tungsten) loads	Making and breaking	V_T	1,5 I_R	0,75 – 0,8	V_T	1,5 I_R
Electrical Discharge lamp loads (Magnetic Ballast)	Making and breaking	V_T	3,0 I_X	0,4 – 0,5	–	–
A switch that is not intended primarily to make and break motor current under locked-rotor conditions, but which has a manual adjusting or regulating means that may cause it to be so used, shall comply with the requirements of 19.7 for a locked rotor test. For a switch intended for d.c. OPERATION, the number of operations shall be five (5), conducted at intervals of 30 s and the device shall also comply with the requirements of (a) above.						

Table 20
Electrical conditions for the endurance tests of 19.8, 19.9, 19.11, 19.12 and 19.13

(this table applies in all countries which use an overload test in accordance with 19.1.6.1)

Type of circuit as given in Table 1, requirement 8	Operation	AC circuit			DC circuit		
		V	A	Power factor	V	A	
Substantially resistive	Making and breaking	V_T	I_R	1	V_T	I_R	
Inductive (non-motor)	Making and breaking	V_T	I_X	0,75 to 0,8	V_T	I_X	
Declared motor load	Making and breaking	V_T	I_m or as determined by load	0,75 to 0,8 or as declared	V_T	I_m	
Declared specific load	Making and breaking	V_T	As determined by load[a]		V_T	As determined by load[a]	
20 mA load	Making and breaking	V_T	20 mA	0.95	V_T	20 mA	Non-inductive
PILOT DUTY load	Making	V_T	10 VA/ V_T	0,35 maximum	As declared		
	Breaking	V_T	VA/ V_T or as declared	or as declared			

The following abbreviations are used:

V_R is the rated voltage, V_T is the test voltage (see 19.2.3 a)).

I_m is the rated current for motor load, I_R is the rated current for resistive load, I_X is the rated current for induction load.

For test purposes, a PILOT DUTY load consists of an electromagnet representative of the magnet coil which is to be controlled. The normal current is that determined from the voltage and volt-ampere ratings of the electromagnet. The test current is the normal current and for an alternating current the power factor is to be 0,35 or less and the inrush current is to be 10 times the normal current. The test contactor is to be free to operate i.e., not blocked in either the open or the closed position.

For CONTROLS that may make a motor circuit under locked rotor conditions but that are never required to break the circuit under such conditions, the following applies 100 % V_T for AC and 0,5 V_T for DC.

[a] A control may be operated faster than 1 cycle per minute if synthetic loads are used or if a sufficient number of banks of lamps controlled by a commutator are employed so that each bank will cool for at least 59 seconds between successive applications.

Table 20DV D2 ***Modification of Table 20 to add the following:***

Table 20DV

Type of circuit as given in Table 1, requirement 8	Operation	AC circuit			DC circuit	
		V	A	Power factor	V	A
Incandescent (Tungsten) loads[b]	Making and breaking	V_T	I_R	1	V_T	I_R
Electrical Discharge lamp loads (Magnetic Ballast)	Making and breaking	V_T	2,0 I_X	0,4 – 0,5	–	–
Electrical Discharge lamp loads (Electronic Ballasts, CFLs, LED drivers, etc)	Making and breaking	V_T	c	c	–	–

The following abbreviations are used:

a) For test purposes, a PILOT DUTY load consists of an electromagnet representative of the magnet coil which is to be controlled. The normal current is that determined from the voltage and volt-ampere ratings of the electromagnet. The test current is the normal current and for an alternating current the power factor is to be 0,35 or less and the inrush current is to be 10 times the normal current. The test contactor is to be free to operate i.e., not blocked in either the open or the closed position.

An alternating-current PILOT DUTY rating may be determined for a control which has been tested for controlling an alternating-current motor on the following basis:

– during the overload test the control was caused to make and break, for 50 cycles at a rate of 6 cycles per minute, a current having a value equivalent to six times the full-load motor current at a power factor of 0,5 or less, and

– the pilot duty inrush current rating (10 times the normal current rating) is to be not more than 67 % of the current value for the overload test described above.

b) For tungsten loads, the cycle times shall be 1 s “on”, 59 s “off” if tungsten lamps are used as the loads. A control may be operated faster than 1 cycle per minute if synthetic loads are used or if a sufficient number of banks of lamps controlled by a commutator are employed so that each bank will cool for at least 59 seconds between successive applications.

If tungsten-filament lamps are used as the load, the load is to be made up of the smallest possible number of 500-watt lamps, or of larger lamps if agreeable to those concerned; except that one or two lamps smaller than the 500-watt size may be used if necessary to make up the required load.

A synthetic load may be used in place of tungsten-filament lamps if it is equivalent to a tungsten-filament lamp load on the test circuit in question, and the inrush current is at least ten times the normal current. A synthetic load used in place of tungsten-filament lamps may consist of noninductive resistors if they are connected and controlled so that a portion of the resistance is shunted during the closing of the switch under test. A synthetic load may also consist of a noninductive resistor or resistors that are connected in parallel with a capacitor.

c) Devices rated 120 and 277 VAC, intended to control electronic ballast, CFL, LED drivers and similar loads up to 16 amps of steady state current shall be endurance tested using the load in accordance with Clause 19.18DV.

19.3 Thermal conditions for the tests

19.3.1 For parts of the CONTROL other than any temperature SENSING ELEMENT, the following shall apply:

– those parts which are accessible when the CONTROL is mounted in a declared manner shall be exposed to normal room temperature (see 4.3);

– the mounting surface of the control shall be maintained between $T_{s\,max}$, and either ($T_{s\,max}$ + 5) °C, or 1,05 times $T_{s\,max}$, whichever is greater;

– the remainder of the SWITCH HEAD shall be maintained between T_{max} and either (T_{max} + 5) °C or 1,05 times T_{max}, whichever is greater. If T_{min} is less than 0 °C, additional tests shall be carried out with the SWITCH HEAD maintained between T_{min} and (T_{min} – 5) °C.

19.3.2 During the tests of 19.8 and 19.13, the temperatures of 19.3.1 are applied for the last 50 % of each test. For the first 50 % of each test, the SWITCH HEAD is maintained at normal room temperature.

Additional samples will be required if tests have to be performed at both temperatures (T_{max} and T_{min}).

19.3.2DV D2 *Modification of Clause 19.3.2 by adding the following:*

100 % of the tests in 19.3.1 and 19.3.2 will be run at room ambient temperature or T_{max}, whichever is greater and at $T_{s\,max}$ for controls.

19.4 Manual and mechanical conditions for the tests

19.4.1 For all MANUAL ACTIONS, each cycle of ACTUATION shall consist of a movement of the ACTUATING MEMBER such that the CONTROL is successively moved into all positions appropriate to that action and then returned to its starting point; except that if a CONTROL has more than one intended OFF POSITION, then each MANUAL ACTION shall be a movement from one OFF POSITION to the next OFF POSITION.

19.4.2 The speed of movement of the ACTUATING MEMBER shall be

– for slow speed:

(9 ± 1)° per s for rotary actions;

(5 ± 0,5) mm/s for linear actions;

– for high speed:

the ACTUATING MEMBER shall be actuated by hand as fast as possible. If an ACTUATING MEMBER is not supplied with a CONTROL then a suitable ACTUATING MEMBER shall be fitted by the test house for the purpose of this test;

– for accelerated speed:

(45 ± 5)° per s for rotary actions;

(25 ± 2,5) mm/s for linear actions.

19.4.3 During the slow speed test of 19.4.2:

the test apparatus shall drive the ACTUATING MEMBER positively, without significant backlash between the apparatus and the ACTUATING MEMBER.

19.4.4 During the accelerated speed test of 19.4.2

– the test apparatus allows the ACTUATING MEMBER to operate freely, so that it does not interfere with the normal action of the mechanism;

– for CONTROLS where the movement of the ACTUATING MEMBER is limited:

- *there shall be a dwell period of not less than 2 s at each reversal of direction;*

- *a torque (for rotary CONTROLS), or a force (for non-rotary CONTROLS) shall be applied at the extreme of each movement to verify the strength of the limiting end stops. The torque shall be either five times the normal actuating torque, or 1,0 Nm, whichever is the smaller, but with a minimum of 0,2 Nm. The force shall be either five times the normal actuating force, or 45 N, whichever is the smaller, but with a minimum of 9 N. If the normal actuating torque exceeds 1,0 Nm, or the normal actuating force exceeds 45 N, then the torque or force applied shall be the same as the normal actuating torque or force;*

– for CONTROLS designed for a rotary ACTUATION where the movement is not limited in either direction, three quarters of the number of cycles of ACTUATION in each test shall be made in a clockwise direction, and one quarter in an anti-clockwise direction.

– for CONTROLS which are designed for ACTUATION in one direction only, the test shall be in the designed direction, provided that it is not possible to rotate the ACTUATING MEMBER in the reverse direction using the torques specified above.

19.4.5 Additional lubrication shall not be applied during these tests.

19.5 Dielectric strength requirements

After all the tests of this clause, the requirements of 15.2 shall apply, with the exception that the samples are not subjected to the humidity treatment before the application of the test voltage. The test voltages shall be 75 % of the corresponding test voltages shown in 15.2.

19.5DV D2 *Modification of Clause 19.5 to replace the last sentence as follows:*

The test voltage shall be that given in 15.2.

19.6 Ageing test

19.6.1 During this test, the SENSING ELEMENT shall be maintained at that value of the ACTIVATING QUANTITY determined and used in Clause 16. Other parts shall be maintained as specified in 19.3. CONTROLS are electrically loaded as specified in 19.2 for the appropriate breaking condition. The duration of the test is (100 + 0,02 *y*) h where "*y*" is the value declared in requirement 21 of Table 1. The test applies to CONTROLS with actions classified as type 1.M or 2.M.

19.6.2 If during this test, the action being tested operates, the value of the ACTIVATING QUANTITY is increased or decreased to cause reverse OPERATION and then returned to a value differing by a quantity "*x*" from the original to enable the test to be resumed. This procedure can be repeated as many times as is necessary to complete the test, or until, when repeating the appropriate procedure of Clause H.17, the DRIFT limits declared in 5.2 are exceeded. The value of "*x*" is given in the appropriate part 2.

19.7 Overvoltage test or overload test in all countries using an overload test of automatic action at accelerated rate

19.7.1 The electrical conditions shall be those specified for overvoltage or overload conditions in 19.2.

19.7.2 The thermal conditions shall be those specified in 19.3.

19.7.3 The method and rate of OPERATION is:

– for TYPE 1 ACTIONS, the rate of OPERATION and the method of OPERATION shall be agreed between the test house and the manufacturer;

– for TYPE 2 ACTIONS, the method of OPERATION shall be that intended by design. For type 2 sensing actions, the rate of OPERATION can be increased, either to the maximum cycling rate declared in Table 1, requirement 31 or so that the rates of change of ACTIVATING QUANTITY do not exceed α_2 and β_2 declared in the same subclause.

NOTE 1 Examples of such methods are the replacement of the capillary of a hydraulic SYSTEM with an air pressure device or the fitting of a PRIME MOVER of a different speed.

– CONTROLS with TYPE 2 ACTION are tested at the most unfavourable OPERATING VALUE declared in Table 1, requirement 42.

NOTE 2 For temperature and pressure operated CONTROLS, this is normally the maximum value.

19.7.4 For type 2 sensing actions, overshoot at each OPERATION shall be between the values declared in 5.2.

19.7.5 It is permissible in the case of sensing actions to increase the rates of change of ACTIVATING QUANTITY, or for other TYPE 1 ACTIONS, to override the PRIME MOVER between OPERATIONS, provided that this does not significantly affect the results.

19.7.6 The number of automatic cycles for the test is either one tenth of the number declared in Table 1, requirement 20, or 200 cycles, whichever is the smaller.

19.7.6DV D2 *Modification of Clause 19.7.6 to replace with the following:*

The number of automatic cycles for the test is 50.

19.7.7 During the test, ACTUATING MEMBERS are placed in their most unfavourable position.

19.8 Test of automatic action at accelerated rate

19.8.1 The electrical conditions shall be those specified in 19.2.

19.8.2 The thermal conditions shall be those specified in 19.3.

19.8.3 The method and rate of OPERATION shall be as used during the test of 19.7.3.

19.8.4 The number of automatic cycles (except as shown below for SLOW-MAKE SLOW-BREAK AUTOMATIC ACTIONS) shall be as declared in Table 1, requirement 20, less the number of cycles actually made during the test of 19.7. During the test, ACTUATING MEMBERS shall be placed in their most unfavourable position.

During the test, the FAILURE of any component part of a TYPE 1 ACTION which is not significant according to the requirements of the test, and which is considered to have failed as a result of the acceleration of the test, shall not be a cause of rejection, provided that it can be repaired or replaced, or that the test can be continued in an agreed alternative manner, such that the total number of automatic cycles declared in Table 1, requirement 20 can be completed.

For SLOW-MAKE SLOW-BREAK AUTOMATIC ACTIONS, only 75 % of the number of automatic cycles referred to in 19.8.4 shall be carried out during this test. The remaining 25 % are carried out as specified in 19.9.

19.8.4DV D2 ***Modification of Clause 19.8.4 to replace the last paragraph with the following:***

For SLOW-MAKE SLOW-BREAK AUTOMATIC ACTIONS, the number of cycles is specified in Table 1, requirement 20 for TYPE 2 ACTION and some TYPE 1 ACTION CONTROLS.

19.9 Test of automatic action at slow rate

19.9.1 SLOW-MAKE SLOW-BREAK AUTOMATIC ACTIONS shall be tested for the 25 % remainder of the number of automatic cycles specified in 19.8.

19.9.2 The electrical and thermal conditions shall be as specified in 19.2 and 19.3.

19.9.3 The method of OPERATION is either by imposing a change of value of ACTIVATING QUANTITY on the SENSING ELEMENT, or by the PRIME MOVER. For SENSING CONTROLS, the rates of change of ACTIVATING QUANTITY shall be α_1 and β_1 as declared in 5.2. It is permissible, in the case of a SENSING CONTROL to increase the rates of change of ACTIVATING QUANTITY, or for other AUTOMATIC CONTROLS to override the PRIME MOVER, between OPERATIONS, provided that this does not significantly affect the results. For SENSING CONTROLS, overshoot at each OPERATION shall be between the values declared in 5.2. During this test for a TYPE 2 ACTION, continuous monitoring is essential to provide a record of OPERATING VALUE, overshoots or OPERATING SEQUENCES.

Such monitoring is also recommended for other CONTROLS to determine consistency of testing.

19.9.4 If only the make or the break is a slow AUTOMATIC ACTION, then it may, by agreement between the test house and the manufacturer, be possible to accelerate the rest of the action, to which the details of 19.8 apply.

19.10 Overvoltage test or overload test in all countries that use the overload test of manual action at accelerated speed

19.10.1 The electrical conditions shall be those specified for overvoltage or overload in 19.2.

19.10.2 The thermal conditions shall be those specified in 19.3.

19.10.3 The method of OPERATION shall be that specified in 19.4 for accelerated speed. The number of cycles of ACTUATION shall be either one tenth of the number declared in 5.2 or 100, whichever is smaller. During the test, SENSING ELEMENTS are maintained at suitable values of ACTIVATING QUANTITY, and PRIME MOVERS are so positioned as to ensure that ACTUATION causes the appropriate OPERATION.

19.10.3DV D2 ***Modification of Clause 19.10.3 second sentence as follows:***

The number of cycles is 50.

19.11 Test of manual action at slow speed

19.11.1 The electrical conditions shall be those specified in 19.2.

19.11.2 The thermal conditions shall be those specified in 19.3.

19.11.3 The method of OPERATION shall be that specified in 19.4 for slow speed.

19.11.4 The number of cycles of ACTUATIONS shall be either one tenth of the number declared in 5.2 or 100, whichever is smaller. During the test, SENSING ELEMENTS are maintained at suitable values of ACTIVATING QUANTITY, and PRIME MOVERS are so positioned, to ensure that ACTUATION causes the appropriate OPERATION.

19.11.4DV D2 ***Modification of Clause 19.11.4 by adding the following:***

The number of cycles is 50.

19.12 Test of manual action at high speed which has multiple poles, and where polarity reversal occurs during the action

19.12.1 The electrical conditions are those specified in 19.2.

19.12.2 The thermal conditions are those specified in 19.3.

19.12.3 The method of OPERATION is that specified in 19.4 for high speed.

19.12.4 The number of cycles of ACTUATION is 100. During the tests, SENSING ELEMENTS are maintained at suitable values of ACTIVATING QUANTITY, and PRIME MOVERS are so positioned as to ensure that ACTUATION causes the appropriate OPERATION.

19.12.4DV D2 ***Modification of Clause 19.12.4 by replacing the first sentence with the following:***

The number of cycles of actuation is 50.

19.13 Test of manual action at accelerated speed

19.13.1 The electrical conditions are those specified in 19.2.

19.13.2 The thermal conditions are those specified in 19.3.

19.13.3 The method of OPERATION is that specified in 19.4 for accelerated speed.

19.13.4 The number of cycles of ACTUATION is that number declared in 5.2 less the number actually made during the tests of 19.10, 19.11 and 19.12. During the test, SENSING ELEMENTS are maintained at a suitable value of ACTIVATING QUANTITY, and PRIME MOVERS are so positioned as to ensure that ACTUATION causes the appropriate OPERATION.

19.13.5 During the test, the FAILURE of any component part of a TYPE 1 ACTION which is not significant according to the requirements of the test shall not be a cause of rejection providing that it can be repaired

or replaced, or that the test can be continued in an agreed alternative manner such that the total required number of cycles of ACTUATION can be completed.

19.14 Evaluation of compliance

19.14.1 After all the appropriate tests of 19.6 to 19.13 inclusive, modified as specified in the appropriate part 2, the CONTROL shall be deemed to comply if:

– all actions function automatically and manually in the intended and declared manner within the meaning of this document;

– the requirements of Clause 16 with regard to those items designated by footnote a of Table 17, that is, terminals, current-carrying parts and supporting surfaces, are still met;

– the requirements of Clause 6, 11 and 19.5 are still met. For the tests of 19.5 and Clause 11, CONTROLS for which special samples were submitted for Clause 15, are tested at an appropriate condition to ensure that the contacts are open;

– for TYPE 2 ACTIONS, the appropriate test of Clause H.17 is repeated and the OPERATING VALUE, OPERATING TIME or OPERATING SEQUENCE shall still be within the value of DRIFT, or within the values of combined DRIFT and MANUFACTURING DEVIATION, whichever was declared;

– the circuit disconnection declared for each MANUAL ACTION can still be obtained;

– there is no evidence (at least the fuse from 19.2.4 shall not have ruptured) that any transient FAULT between LIVE PARTS and earthed metal, accessible metal parts or ACTUATING MEMBERS has occurred.

19.14.2 For ELECTRONIC CONTROLS, after all the appropriate tests of 19.6 to 19.13 inclusive and 19.1.4, modified as specified in the appropriate part 2, the CONTROL shall be deemed to comply if:

– the criteria of 19.14.1 are satisfied,

– for CONTROLS providing ELECTRONIC DISCONNECTION (type 1.Y or 2.Y), the requirements of 9.4.16 are still met.

19.14.2DV D2 *Modification of Clause 19.14.2 to add the following dashed item:*

– Electronic controls with Class B or C control functions shall comply with the requirements of H.25.14.4.

19.15 Test for particular purpose controls

The tests for particular purpose controls are specified in the appropriate part 2s.

19.16 See J.19.16.

19.17 See J.19.17.

19.18DV D2 ***Add the following section titled, "Electronic Ballasts, CFLs and LED driver rated controls"***

19.18DV.1 A control rated for use with electronic ballasts, self ballasted LED and Compact Fluorescent Lamps, LED drivers, LED luminaires, and similar loads with capacitive load characteristics, having a rated current (steady state current) and voltage in accordance with Table 19.18DV.1 or Table 19.18DV.2 shall be tested as described in 19.18DV.2 – 19.18DV.4 and marked in accordance with R31DV.1.1.23.

19.18DV.2 The test circuit, as shown in Figure 19.18DV.1, shall provide the inrush characteristics meeting or exceeding those characteristics defined in Table 19.18DV.2 in parallel with an AC resistive load based on the steady state current rating of the switch or lighting control being tested.

19.18DV.3 The series coil values must be adjusted based on the input line characteristics to achieve the peak currents listed in Table 19.18DV.1. The series coil shall be sized such that it does not saturate during testing and shall be able to handle the resulting power dissipation with less than 10 °C temperature rise. Peak current and pulse width are illustrated in Figure 19.18DV.2.

19.18DV.4 The circuit shall provide a method to discharge the capacitor bank in between test cycles without influencing the performance of the device under test. This is accomplished by S2 and R2 in Figure 19.18DV.1. S2 shall be switched alternately with S1 and R2 shall be sized to allow for complete discharge of C during the period that S1 is open. The values of the bulk energy capacitors used in the simulated circuit are noted in Table 19.18DV.3 and corresponds to the system voltage.

Table 19.18DV.1
Peak Current Requirements with Pulse Width Less Than or Equal To 2 ms for Endurance Test

Steady state current (A)	Peak current (A), 120 V AC	Pulse width 120 V AC (mS). See Note 2	I^2t (A^2 sec) 120 V AC. See Note 1	Peak current (A), 277 V AC	Pulse width 277 V AC (mS). See Note 2	I^2t (A^2 sec) 277 V AC. See Note 1
0.5	75	0.34	11	77	0.07	11
1	107	0.48	24	131	0.71	27
2	144	0.70	41	205	0.85	76
3	166	0.89	51	258	0.98	111
5	192	1.20	74	320	1.20	205
8	221	1.25	98	370	1.25	274
10	230	1.50	106	430	1.50	370
12	235	1.80	110	440	1.80	387
15	239	2.00	114	458	2.00	420
16	242	2.10	117	480	2.10	461

NOTES:

1 – The values used to calculate I^2t are the peak current shown and pulse duration of 2 mS (t).

2 – Pulse widths shown will provide adequate performance with electronic ballasts having pulse widths up to 2 ms, in accordance with the Standard for Lamp Ballasts – High Frequency Fluorescent Lamp Ballasts, ANSI_ANSLG C82.11, or the Standard for Lamp Ballasts Low-Frequency Square Wave Electronic Ballasts – for Metal Halide Lamps, ANSI_ANSLG C82.14.

Table 19.18DV.2
Peak Current Requirements with Pulse Width Less Than or Equal To 2.35 ms for Endurance Test

Steady state current (A)	Peak current (A), 347 Vac	Pulse width 347 Vac (ms). See Note 2	I^2t (A^2 sec) 347 Vac. See Note 1
0.5	198	0.34	92
1	270	0.47	173
2	354	0.70	294
3	396	0.86	369
5	450	1.15	476
8	492	1.5	569
10	508	1.67	606
12	529	1.86	658
15	550	2.05	711
16	552	2.10	716

NOTES:

1 – The values used to calculate I^2t are the peak current shown and pulse duration of 2.35 ms (t).

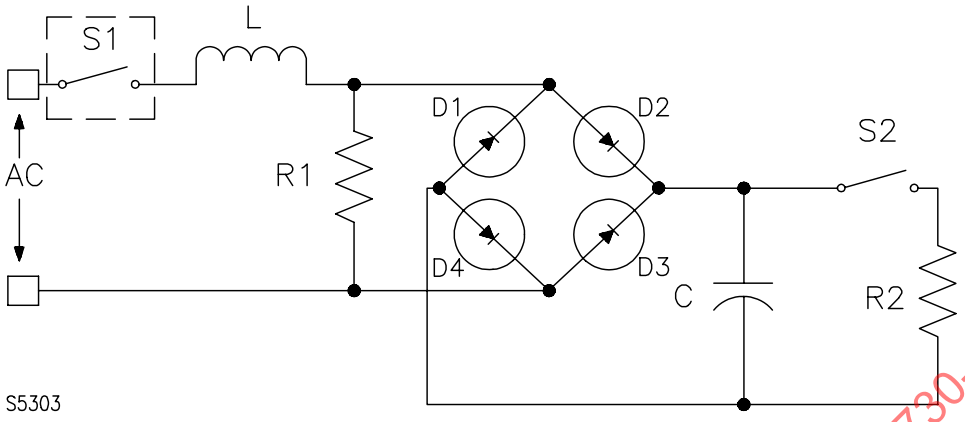
2 – Pulse widths shown will provide adequate performance with electronic ballasts having pulse widths up to 2.35 ms, in accordance with the Standard for Lamp Ballasts – High Frequency Fluorescent Lamp Ballasts, ANSI_ANSLG C82.11, or the Standard for Lamp Ballasts Low-Frequency Square Wave Electronic Ballasts – for Metal Halide Lamps, ANSI_ANSLG C82.14.

Table 19.18DV.3
Bulk Energy Capacitances

System voltage (V)	Bulk energy capacitance per ampere of steady state current (μF)
120	175
277, 347	125

Figure 19.18DV.1

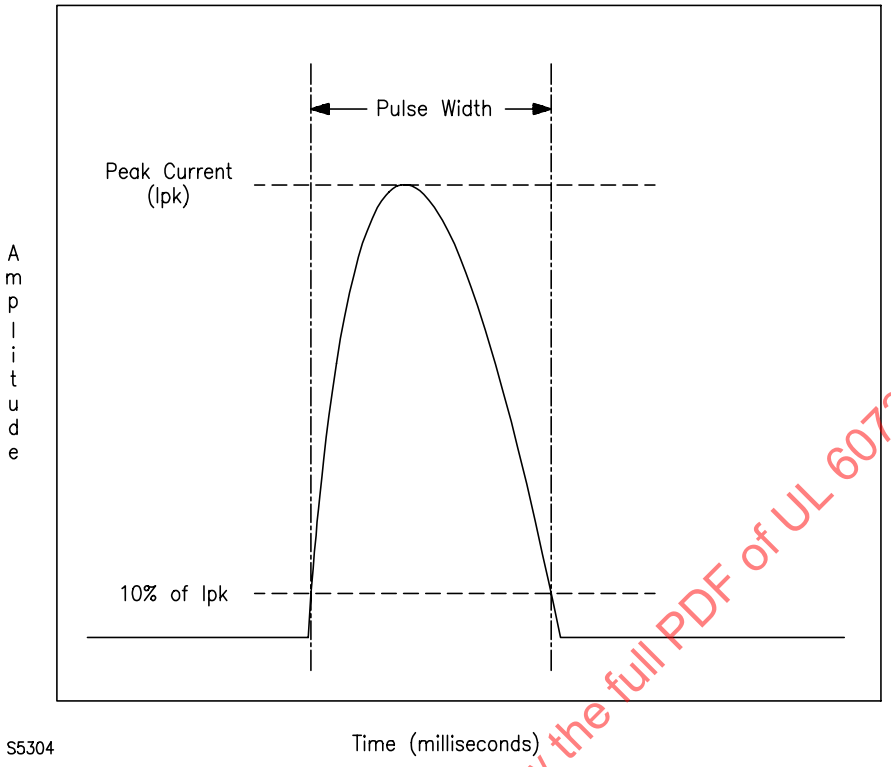
Typical Test Circuit Diagram



Reference	Description
AC	Test voltage is either 120 VAC, 277 VAC or 347 VAC
S1	Device Under Test
L	Series Inductor, its value of inductance (L) and resistance (R) are selected. When combined with the AC line source impedance it provides the specified Reference Waveforms
R1	AC synthetic load resistor, value to provide desired continuous current. (e.g., 5A, 8A, ... 6A)
D1 – D4	Bridge rectifier
C	Capacitor load bank, design value to provide 125 µF for each continuous amp of load current at a test voltage of 277 or 347 VAC, and 175 µF for each continuous amp of load current at a test voltage of 120 VAC.
S2	Capacitor discharge switch
R2	Bleeder resistor, value to provide appropriate capacitor load bank discharge rate

Figure 19.18DV.2

Waveform Per Synthetic Measurement of Pulse Width and Peak Current



20 Mechanical strength

20.1 General requirements

20.1.1 CONTROLS shall be so constructed as to withstand the mechanical stress that occurs in NORMAL USE.

20.1.2 ACTUATING MEMBERS of CLASS I CONTROLS and CLASS II CONTROL, and ACTUATING MEMBERS of CONTROLS for class I and class II equipment, shall either have adequate mechanical strength or be such that adequate protection against electric shock is maintained if the ACTUATING MEMBER is broken.

20.1.3 INTEGRATED CONTROLS and INCORPORATED CONTROLS are not tested as in 20.2 as their impact resistance will be tested by the equipment standard.

20.1.4 *Compliance is checked by the tests of the appropriate Subclauses 20.2 to 20.6 inclusive, carried out sequentially on one sample.*

20.1.5 After the appropriate tests, the CONTROL shall show no damage that would impair compliance with this document and in particular with Clauses 6, 15, and 11. Insulating linings, barriers and the like shall not have worked loose.

It shall still be possible to remove and to replace detachable and other external parts such as COVERS without such parts or their insulating linings breaking.

It shall still be possible to actuate a CONTROL to any position which is intended to provide FULL DISCONNECTION and MICRO-DISCONNECTION.

In case of doubt, SUPPLEMENTARY INSULATION or REINFORCED INSULATION is subject to an electric strength test as specified in Clause 15.

Damage to the finish, small dents which do not reduce CREEPAGE DISTANCES or CLEARANCES below the values specified in Clause 11, and small chips which do not adversely affect the protection against electric shock or moisture are neglected. Cracks not visible to the naked eye, and surface cracks in fibre reinforced mouldings and the like are ignored. If a decorative COVER is backed by an inner COVER, fracture of the decorative COVER is neglected, if the inner COVER withstands the test after removal of the decorative COVER.

20.1.5DV D2 *Modification of Clause 20.1.5 to add 20.1.5DV.1 – 20.1.5DV.4 and Table 20.1.5DV.1 as follows:*

20.1.5DV.1 If threads for the connection of metal conduit are tapped all the way through a hole in an enclosure wall or if an equivalent construction is employed, there shall not be any sharp edges, not less than three nor more than five full threads in the metal and the construction of the device shall be such that a suitable conduit bushing can be properly attached.

20.1.5DV.2 If threads for the connection of metal conduit are not tapped all the way through a hole in an enclosure wall, conduit hub or the like, there shall not be less than 3,5 full threads in the metal with a conduit stop, and a smooth well-rounded inlet hole having an internal diameter approximately the same as that of the corresponding size of rigid metal conduit, which shall afford protection to the conductors equivalent to that provided by a standard conduit bushing.

20.1.5DV.3 An enclosure threaded for support by rigid metal conduit shall provide at least five full threads for engaging the conduit.

Compliance with the above three paragraphs is checked by inspection.

20.1.5DV.4 A conduit hub or nipple attached to the enclosure by swaging, staking or similar means shall withstand without pulling apart the following tests:

– a direct pull of 890 N for 5 min. For this test, the device is to be supported by a rigid conduit in the intended manner and is to support a suspended weight of 90,8 kg;

– the device is to be rigidly supported by means other than the conduit fittings. A bending force of 67,8 Nm is to be applied for 5 min to the conduit at right angles to its axis and the lever arm is measured from the wall of the enclosure in which the hub is located to the point of application of the bending force;

– a torque of 67,8 Nm is to be applied to the conduit for 5 min in a direction tending to tighten the connection and the lever arm is to be measured from the centre of the conduit.

Some distortion of the enclosure under test may result. Such distortion does not constitute a FAILURE.

A fitting for flexible metal conduit shall secure the conduit so that the connection withstands without pulling apart a steady pull, as specified in Table 20.1.5DV.1 for 5 minutes

Table 20.1.5DV.1
Pull Forces

Trade size of fitting	Metric designator	Force	
		N	(lbf)
1/2	16	333	(75)
3/4	21	444	(100)
1	27	556	(125)
1-1/4 to 4	35 to 103	667	(150)

20.2 Impact resistance

20.2.1 IN-LINE CORD, FREE-STANDING and INDEPENDENTLY MOUNTED CONTROLS, except as provided in 20.3, are checked by applying blows to the sample by means of the apparatus in IEC 60068-2-75.

20.2.1DV D2 *Modification of Clause 20.2.1 by adding the following:*

The impact resistance of controls constructed of polymeric materials shall be in accordance with UL 50E. The impact resistance of controls constructed of metallic materials is determined as indicated in 20.4.

20.2.2 All surfaces which are accessible when the CONTROL is mounted as in NORMAL USE are tested with the apparatus.

20.2.3 *The CONTROL is held in contact with a vertical sheet of plywood 8 mm thick and 175 mm square without any metallic back plate, the plywood being mounted on a rigid frame which is fixed to a solid wall of brick, concrete or the like.*

20.2.4 Blows are applied to all ACCESSIBLE SURFACES, including ACTUATING MEMBERS, at any angle, the test apparatus being calibrated to deliver an energy of (0,5 ± 0,04) Nm.

Foot actuated CONTROLS shall be subject to the same test, but using a test apparatus calibrated to deliver an energy of (1,0 ± 0,05) Nm.

20.2.5 *For all such surfaces, three blows are applied to every point that is likely to be weak.*

20.2.5.1 *Care shall be taken that the results from one series of three blows does not influence subsequent series.*

20.2.5.2 *If there is a doubt whether a defect has been caused by the application of preceding blows, this defect is neglected and the group of three blows which led to the defect is applied to the same place of a new sample, which shall then withstand the test.*

20.2.6 *Signal lamps and their COVERS are only tested if they protrude from the enclosure by more than 10 mm or if their area exceeds 4 cm^2, unless they form part of an ACTUATING MEMBER, in which case they shall be tested in the same manner as an ACTUATING MEMBER.*

20.2.7DV D2 *Modification of Clause 20.2 to add the following new clause:*

20.2.7DV.1 Alternate compliance – Impact resistance

The minimum thicknesses of sheet metal or case metal shown in Table 20.1.5DV.1 and Table 20.1.5DV.2 are considered to meet the requirements of 20.2 and the tests specified are not required.

Table 20.2.7DV.1
Minimum Thickness of Sheet Metal for Enclosures Made of Carbon Steel or Stainless Steel

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness in inches (mm)			
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length[c]		Uncoated		Metal coated	
in inches	(cm)	in inches	(cm)	in inches	(cm)	in inches	(cm)				
4,0	(10,2)	Not limited		6,25	(15,9)	Not limited		0,020[d]	(0,51)	0,023[d]	(0,58)
4,75	(12,1)	5,75	(14,6)	6,75	(17,1)	8,25	(21,0)				
6,0	(15,2)	Not limited		9,5	(24,1)	Not limited		0,026[d]	(0,66)	0,029[d]	(0,74)
7,0	(17,8)	8,75	(22,2)	10,0	(25,4)	12,5	(31,8)				
8,0	(20,3)	Not limited		12,0	(30,5)	Not limited		0,032	(0,81)	0,034	(0,86)
9,0	(22,9)	11,5	(29,2)	13,0	(33,0)	16,0	(40,6)				
12,5	(31,8)	Not limited		19,5	(49,5)	Not limited		0,042	(1,07)	0,045	(1,14)
14,0	(35,6)	18,0	(45,7)	21,0	(53,3)	25,0	(63,5)				
18,0	(45,7)	Not limited		27,0	(68,6)	Not limited		0,053	(1,35)	0,056	(1,42)
20,0	(50,8)	25,0	(63,5)	29,0	(73,7)	36,0	(91,4)				
22,0	(55,9)	Not limited		33,0	(83,8)	Not limited		0,060	(1,52)	0,063	(1,60)
25,0	(63,5)	31,0	(78,7)	35,0	(88,9)	43,0	(109,2)				
25,0	(63,5)	Not limited		39,0	(99,1)	Not limited		0,067	(1,70)	0,070	(1,78)
29,0	(73,7)	36,0	(91,4)	41,0	(104,1)	51,0	(129,5)				
33,0	(83,8)	Not limited		51,0	(129,5)	Not limited		0,080	(2,03)	0,084	(2,13)
38,0	(96,5)	47,0	(119,4)	54,0	(137,2)	66,0	(167,6)				
42,0	(106,7)	Not limited		64,0	(162,6)	Not limited		0,093	(2,36)	0,097	(2,46)
47,0	(119,4)	59,0	(149,9)	68,0	(172,7)	84,0	(213,4)				
52,0	(132,1)	Not limited		80,0	(203,2)	Not limited		0,108	(2,74)	0,111	(2,82)
60,0	(152,4)	74,0	(188,0)	84,0	(213,4)	103,0	(261,6)				
63,0	(160,0)	Not limited		97,0	(246,4)	Not limited		0,123	(3,12)	0,126	(3,20)
73,0	(185,4)	90,0	(228,6)	103,0	(261,6)	127,0	(322,6)				

[a] With reference to Table 20.1.5DV.1 and Table 20.1.5DV.2, a supporting frame is a structure of angle or channel or a folded rigid section of sheet metal that is rigidly attached to and has essentially the same outside dimensions as the enclosure surface, and that has sufficient torsional rigidity to resist the bending moments that may be applied via the enclosure surface when it is deflected. Construction that is considered to have equivalent reinforcing may be accomplished by designs that will produce a structure that is as rigid as one built with a frame of angles or channels. Construction considered to be without supporting frame includes:

a) single sheet with single formed flanges or formed edges,
b) a single sheet that is corrugated or ribbed,
c) an enclosure surface loosely attached to a frame, for example, with spring clips.

[b] The width is the smaller dimension of a rectangular piece of sheet metal that is part of an enclosure. Adjacent surfaces of an enclosure may have supports in common and be made of a single sheet.

[c] "Not limited" applies only if the edge of the surface is flanged at least 0,5 in (12,7 mm) or fastened to adjacent surfaces not normally removed in use.

[d] Sheet metal for an enclosure intended for outdoor use shall be not less than 0,034 in (0,86 mm) thick if zinc coated and not less than 0,032 in (0,81 mm) thick if uncoated.

Table 20.1.5DV.2
Minimum Thickness of Sheet Metal for Enclosures of Aluminium, Copper or Brass

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]					
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length[c]		Maximum thickness	
in inches	(cm)	in inches	(cm)	in inches	(cm)	in inches	(cm)	in inches	(mm)
3,0	(7,6)	Not limited		7,0	(17,8)	Not limited		0,023d	(0,58)
3,5	(8,9)	4,0	(10,2)	8,5	(21,6)	9,5	(24,1)		
4,0	(10,2)	Not limited		10,0	(25,4)	Not limited		0,029	(0,74)
5,0	(12,7)	6,0	(15,2)	10,5	(26,7)	13,5	(34,3)		
6,0	(15,2)	Not limited		14,0	(35,6)	Not limited		0,036	(0,91)
6,5	(16,5)	8,0	(20,3)	15,0	(38,1)	18,0	(45,7)		
8,0	(20,3)	Not limited		19,0	(48,3)	Not limited		0,045	(1,14)
9,5	(24,1)	11,5	(29,2)	21,0	(53,3)	25,0	(63,5)		
12,0	(30,5)	Not limited		28,0	(71,1)	Not limited		0,058	(1,47)
14,0	(35,6)	16,0	(40,6)	30,0	(76,2)	37,0	(94,0)		
18,0	(45,7)	Not limited		42,0	(106,7)	Not limited		0,075	(1,91)
20,0	(50,8)	25,0	(63,4)	45,0	(114,3)	55,0	(139,7)		
25,0	(63,5)	Not limited		60,0	(152,4)	Not limited		0,095	(2,41)
29,0	(73,7)	36,0	(91,4)	64,0	(162,6)	70,0	(198,1)		
37,0	(94,0)	Not limited		87,0	(221,0)	Not limited		0,122	(3,10)
42,0	(106,7)	53,0	(134,6)	93,0	(236,2)	114,0	(289,6)		
52,0	(132,1)	Not limited		123,0	(312,4)	Not limited		0,153	(3,89)
60,0	(152,4)	74,0	(188,0)	130,0	(330,2)	160,0	(406,4)		

[a] With reference to Table 20.1.5DV.1 and Table 20.1.5DV.2, a supporting frame is a structure of angle or channel or a folded rigid section of sheet metal that is rigidly attached to and has essentially the same outside dimensions as the enclosure surface, and that has sufficient torsional rigidity to resist the bending moments that may be applied via the enclosure surface when it is deflected. Construction that is considered to have equivalent reinforcing may be accomplished by designs that will produce a structure that is as rigid as one built with a frame of angles or channels. Construction considered to be without supporting frame includes:

a) single sheet with single formed flanges or formed edges,
b) a single sheet that is corrugated or ribbed,
c) an enclosure surface loosely attached to a frame, for example, with spring clips.

[b] The width is the smaller dimension of a rectangular piece of sheet metal that is part of an enclosure. Adjacent surfaces of an enclosure may have supports in common and be made of a single sheet.

[c] "Not limited" applies only if the edge of the surface is flanged at least 0,5 in (12,7 mm) or fastened to adjacent surfaces not normally removed in use.

[d] Sheet copper, brass, or aluminium for an enclosure intended for outdoor use (raintight or rainproof) shall be not less than 0,029 in (0,74 mm) thick.

20.2.7DV.2 At points at which a wiring system is to be connected, uncoated steel shall not be less than 0,032 in (0,81 mm) thick, zinc-coated steel shall not be less than 0,034 in (0,86 mm).

20.2.7DV.3 At points at which a wiring system is to be connected, nonferrous metal shall not be less than 0,045 inch (1,14 mm) thick.

20.2.7DV.4 Cast metal shall be not less than 3 mm thick but not more than 6 mm thick at threaded holes for conduit; except that, other than at plain or threaded holes for conduit, die-cast metal may be not less than 1,6 mm thick for an area not greater than 150 cm^2, and having no dimension greater than 150 mm, and may be not less than 2,4 mm thick for larger areas.

20.2.7DV.5 A cast metal enclosure shall be not less than 0,035 inch (0,89 mm) thick if the enclosure will not be used as a splice box and if the voltage rating of the complete device is such that the voltage between any two conductors is 250 V or less and is limited to d.c. or single-phase a.c.

20.2.7DV.6 A cast metal enclosure shall be not less than 0,028 inch (0,71 mm) thick if the enclosure houses only low-voltage circuits.

20.2.7DV.7 A sheet-steel transformer enclosure shall have a thickness of not less than 0,026 inch (0,66 mm) if uncoated and less than 0,029 inch (0,74 mm) if galvanized.

20.2.7DV.8 Sheet steel having a thickness of not less than 0,020 inch (0,51 mm) if uncoated and not less than 0,023 inch (0,58 mm) if galvanized may be used for a drawn end bell having maximum dimensions of 2-1/4 inches (57,2 mm) on the flat portion and 1-1/2 inches (38,1 mm) at the base of the drawn portion.

20.3 Free-standing controls

20.3.1 FREE-STANDING CONTROLS shall be additionally checked by the test of 20.3.2 and 20.3.3 using the apparatus shown in Figure 7.

20.3.2 *Two metres of flexible cord of the lightest type used in 8.1.5 shall be connected to the input terminals and secured as intended. CONTROLS intended for use with a flexible cord connected to the output terminals shall have 2 m of the lightest intended type similarly connected and arranged as shown in Figure 7.*

The sample shall be stood or rested on the glass surface as shown and the cord shall be subjected to a steady pull gradually increasing up to, but not exceeding that shown in Table 22. If the sample moves, it is pulled off the glass surface as slowly as possible and allowed to fall onto the concrete backed hard wood base.

The height of the surface above the base is 0,5 m. The size of the hard wood and concrete base shall be sufficient for the CONTROL to remain on the base after falling.

The test is repeated three times.

20.3.3 After the test, the sample shall be evaluated as in 20.1.5.

20.4 In-line cord controls

20.4.1 IN-LINE CORD CONTROLS other than FREE-STANDING CONTROLS shall be additionally tested in a tumbling barrel as shown in Figure 8. The width of the barrel shall not be less than 200 mm, and shall be as wide as is necessary to ensure the uninterrupted fall of the CONTROL when fitted with the cords as required in 20.4.2.

20.4.2 *CONTROLS with NON-DETACHABLE CORDS using TYPE X ATTACHMENT shall be fitted with the flexible cord or cords having the smallest cross-sectional area specified in 8.1.5 and a free length of approximately 50 mm. Terminal screws are tightened with two-thirds of the torque specified in 10.1. CONTROLS with NON-DETACHABLE CORDS using TYPE M ATTACHMENT, TYPE Y ATTACHMENT or TYPE Z ATTACHMENT shall be tested with cord or cords declared or supplied, the cord or cords being cut so that a free length of about 50 mm projects from the CONTROL.*

20.4.3 *The sample falls from a height of 50 cm onto a steel plate, 3 mm thick, the number of falls being:*

– 1 000 if the mass of the sample without cord does not exceed 100 g;

– 500 if the mass of the sample without cord exceeds 100 g, but does not exceed 200 g.

20.4.4 IN-LINE CORD CONTROLS with a mass exceeding 200 g are not tested in the tumbling barrel, but shall be subjected to the test of 20.3.

20.4.5 *The barrel is turned at a rate of five revolutions per min, 10 falls per min thus taking place.*

20.4.6 *After this test, the CONTROL shall be evaluated as in 20.1.5. Special attention is paid to the connection of flexible cord or cords.*

20.5 Pull-cord actuated controls

20.5.1 PULL-CORD ACTUATED CONTROLS shall be additionally tested as in 20.5.2 and 20.5.3.

20.5.2 *The CONTROL shall be mounted as declared by the manufacturer, and the PULL-CORD shall be subjected to a force, applied without jerks, first for 1 min in the normal direction, and then for 1 min in the most unfavourable direction, but not exceeding 45° from the normal direction.*

20.5.3 *The values of the force are shown in Table 21.*

Table 21
Pull-cord force test values

Rated current A	Force N	
	Normal direction	Most unfavourable direction
Up to and including 4	50	25
Over 4	100	50

20.5.4 *After this test, the CONTROL shall be evaluated as in 20.1.5.*

20.6 Foot actuated controls

20.6.1 CONTROLS actuated by foot shall be additionally tested as indicated in 20.6.2 to 20.6.4:

20.6.2 *The CONTROL is subjected to a force applied by means of a circular steel pressure plate with a diameter of 50 mm. The force is increased continuously from an initial value of about 250 N, up to 750 N, within 1 min, after which it is maintained at this value for 1 min.*

20.6.3 *The CONTROL is placed on a flat horizontal steel support with the appropriate flexible cord fitted. The force is applied three times with the sample placed in different positions, the most unfavourable positions being chosen.*

20.6.4 *After the test, the CONTROL shall be evaluated as in 20.1.5.*

20.7 Actuating member and actuating means

20.7.1 CONTROLS supplied with, or intended to be fitted with ACTUATING MEMBERS shall be tested as follows.

– First an axial pull shall be applied for 1 min to try to pull off the ACTUATING MEMBER.

– If the shape is such that it is not possible to apply an axial pull in NORMAL USE, this first test does not apply.

– If the shape of the ACTUATING MEMBER is such that an axial pull is unlikely to be applied in NORMAL USE, the force is 15 N.

– If the shape is such that an axial pull is likely to be applied, the force is 30 N.

– Secondly, an axial push of 30 N for 1 min is then applied to all ACTUATING MEMBERS.

20.7.2 If a CONTROL is intended to have an ACTUATING MEMBER but is submitted for approval without, or is intended to have an easily removable ACTUATING MEMBER then a pull and push of 30 N are applied to the ACTUATING MEANS.

NOTE Sealing compound and the like, other than self-hardening resins, is not deemed to be adequate to prevent loosening.

20.7.3 During and after each of these tests, the CONTROL shall show no damage, nor shall an ACTUATING MEMBER have moved so as to impair compliance with this document.

20.7.4DV D2 *Modification of Clause 20.7 to add 20.7.4DV.1 – 20.7.4DV.7 as follows:*

20.7.4DV.1 For a CONTROL that is operated by a push, pull, slide, toggle, or lever adjustment, a force is to be applied to the free end of the adjustment in line with the intended movement in each direction of OPERATION for one minute. The force is to be 89 N (20 pounds) for a commercial control and 45 N (10 pounds) for a household product CONTROL . A separate sample is to be used for each test.

20.7.4DV.2 A CONTROL adjustment operated as described in 20.7.4DV.1 and intended for use with an extended operator, handle, or lever is to be tested with in in-line force applied to the free end of an extension representing the intended end-use application.

20.7.4DV.3 For a CONTROL that is operated by a rotary adjustment intended for use with a knob having a grip diameter or grip length of 25,4 mm (1 inch) or less, a torque is to be applied to the shaft in each direction of intended OPERATION. The torque is to be 1,0 N·m (9 pound-inches) for a commercial control and 0,8 N·m (7 pound-inches) for a household product CONTROL. A separate sample is to be used for each test.

20.7.4DV.4 A CONTROL that is operated by a rotary adjustment intended for use with a knob having a grip diameter or grip length of more than 25,4 mm (1 inch) is to be subjected to a torque that is proportionally greater than that specified in 20.7.4DV.2, based on the larger grip diameter or grip length of the knob used; the value for the torque to be used is to be determined by the formula:

$$T = \frac{D_1}{D} K$$

in which:

T is the test torque in N·m (pound inches)

D_1 is the grip diameter or grip length, as applicable in m (inches)

D is the 0,025 m (1 inch)

K is the 1,0 N·m (9 pound-inches) for a commercial CONTROL, or 0,8 N·m (7 pound-inches) for a household CONTROL.

20.7.4DV.5 If a lever arm is intended to be attached to a rotary-control shaft, the assembly is to be tested as described in 20.7.4DV.2 with the force applied to the free end of the lever.

20.7.4DV.6 If an adjustment means is not provided with a control, the manufacturer is to assign a maximum dimension for the knob, lever, toggle, or the like, to be used with the CONTROL, and this dimension is to be used for determining the torque value.

20.7.4DV.7 Compliance is checked as in 20.1.5. In addition, for TYPE 2 CONTROLS the test of Clause 19 is conducted before and after this test and the measured OPERATING VALUE shall be within the declared DRIFT.

20.8 Flexing – test

20.8.1 The flexing test is applied to in-line cord controls and free-standing controls. The CONTROL is mounted in the flexing apparatus shown in Figure 10. The axis of oscillation is so chosen that the weight attached to the cord and the cord itself make the minimum lateral movement during the test.

Samples with flat cords are mounted so that the major axis of the cross-section is parallel to the axis of oscillation. Each flexible cord passing through the inlet opening is loaded with a weight of 1 kg. A current equal to the current passing through that particular core when the CONTROL is operated at rated voltage is passed through each core, the voltage between cores being maximum rated voltage. The oscillating member is moved backwards and forwards through an angle of 90° (45° on either side of the vertical). The number of flexings (that is one movement through 90°) being 5 000, and the rate of the flexing being 60 flexings per minute.

20.8.2 After the test, the sample shall show no damage within the meaning of this document. During the test, no interruption of the current and no short circuit between the individual conductors shall occur, neither shall broken strands pierce the insulation to the outer surface of the accessory. A short circuit between individual conductors is considered to occur if the current reaches twice the value of the test current.

20.8.3 Not more than 10 % of the total number of conductors of the flexible cord shall have been broken.

20.9 Cord anchorages – test

20.9.1 The CONTROL is fitted with a flexible cord and the conductors are introduced into the terminals, the terminal screws, if any, being tightened just sufficiently to prevent the conductors from easily changing their position. The cord anchorage is used in the intended manner, the screws being tightened with a torque equal to two-thirds of the torque specified in 10.1.

20.9.2 After this preparation, it shall not be possible to push the cord into the CONTROL to such an extent that the cord or internal parts of the CONTROL could be damaged, or that internal parts are interfered with in a way which might impair compliance with this document.

20.9.3 The cord is then subjected to pulls of the value and number shown in Table 22. The pulls are applied in the most unfavourable direction, without jerks, each time for 1 s.

20.9.3DV D2 *Modification of Clause 20.9.3 to replace with the following:*

For mains connected devices, including I/O ports, a strain-relief device shall withstand without damage to the cord or conductors and without displacement a direct pull of 35 pounds (156 N) applied to the cord for 1 minute. Supply connections within the equipment are to be disconnected from terminals or splices during the test.

For SELV or PELV powered devices, including I/O ports employing a flexible output cord, or a multi-conductor cord where the interconnection of outputs:

a) Exceeds a voltage of 30 Vrms or 42,4 V pk or 60 Vdc;

b) Exceeds 15 W of available power (see 13.1.2);

c) Does not exceed a voltage of 30 Vrms or 42,4 V pk or 60 Vdc but exceeds 15 W of power,

a 89 N (20 pounds-force) is to be applied to the cord and supported by the unit so that the strain relief means is stressed from the most severe angle that the construction of the unit permits.

For units employing output wiring consisting of separate leads, a 44 N (10 pounds-force) is to be applied to each lead.

20.9.4 Immediately afterwards, the cord is subjected for 1 min to a torque of the value shown in Table 22.

20.9.4DV D2 *Modification of Clause 20.9.4 to add the following:*

The torque test is not applicable.

Table 22
Pull and torque values

Control	Pull [a] N	Torque [a] Nm	Number of pulls [a]
FREE-STANDING CONTROLS and INDEPENDENTLY MOUNTED CONTROLS:			
Up to and including 1 kg	30	0,1	25
Over 1 kg up to and including 4 kg	60	0,25	25
Over 4 kg	100	0,35	25
IN-LINE CORD CONTROLS (other than FREE-STANDING CONTROLS)	90	0,25	100

[a] Some equipment standards may require a different value.

20.9.5 For TYPE X ATTACHMENT, the tests are made first with the lightest permissible type of flexible cord of the smallest cross-sectional area used in 8.1.5, and then with the next heavier type of flexible cord of the

largest cross-sectional area used. For TYPE M ATTACHMENT, TYPE Y ATTACHMENT or TYPE Z ATTACHMENT, only declared or fitted cord is used.

20.9.6 During the tests, the cord shall not be damaged. After the tests, the cord shall not have been displaced longitudinally by more than 2 mm, the conductors shall not have been moved over a distance of more than 1 mm in the terminals, and there shall be no appreciable strain at the connection. CREEPAGE DISTANCES and CLEARANCES shall not have been reduced below the value specified in Clause 11.

20.9.7 For the measurement of the longitudinal displacement, a mark is made on the cord while it is subjected to the pull, at a distance of approximately 20 mm from the cord anchorage, before starting the tests. After the tests, the displacement of the mark on the cord in relation to the cord anchorage is measured while the cord is subjected to the pull.

21 Resistance to heat, fire and tracking

21.1 General requirements

All non-metallic parts of a CONTROL shall be resistant to heat, fire and tracking.

Compliance is checked by the tests of 21.2, except that INDEPENDENTLY MOUNTED CONTROLS and FREE-STANDING CONTROLS are checked by the tests of 21.3.

21.1DV D2 *Modification of Clause 21.1 by replacing the last sentence with the following and adding 21.1DV.1 and 21.1DV.2:*

Compliance is checked in accordance with the requirements of the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

21.1DV.1 A non-metallic enclosure of a Class III INDEPENDENTLY MOUNTED or IN-LINE CORD CONTROL with an available energy greater than 15W and less than or equal to 100W (Class 2) shall have a minimum flammability rating of V-2.

21.1DV.2 A non-metallic enclosure of a CLASS III INTEGRATED or INCORPORATED CONTROL with an available energy greater than 15W and less than or equal to 100W (Class 2) shall have a minimum flammability rating of V-2, V-1 or V-0 or tested in accordance with Sections 15 or 16 of UL 746C provided that the construction of the end-use product safeguards the other relevant properties as noted in UL 746C.

21.2 Integrated, incorporated and in-line cord controls

21.2.1 The test sequences shall be conducted as appropriate to the position or function of the non-metallic part and the declared ball pressure and glow-wire test temperatures.

21.2.2 *No requirements for heat and resistance to fire exist for small parts as specified in IEC 60695-2-11:2021, 4.4.*

21.2.3 *No requirements for heat and resistance to fire exist for insignificant mass of combustible material as specified in IEC 60695-2-11:2021, 4.1; default mass value of insignificant mass is 2 g.*

21.2.4 CONTROLS declared in Table 1, requirement 74 shall be tested in accordance with IEC 60335-1:2020, Clause 30.

NOTE CONTROLS can be used in widely different end applications. Selection of test levels from the requirements below can be influenced by consideration of the end-application standard's requirements.

21.2.5 For parts which are accessible when the CONTROL is mounted in its manner of intended use and the deterioration of which can result in the CONTROL becoming unsafe, the following tests are required. See Annex G:

– *ball pressure test 1 of G.3.2;*

– *the glow-wire test of Clause G.1 carried out at 550 °C.*

21.2.6 For parts which retain in position current-carrying parts other than electrical connections, the following tests are required. See Annex G:

– *ball pressure test 2 of G.3.3;*

– *the glow-wire test of Clause G.1 carried out at 550 °C.*

The tests are not applicable to parts retaining in position current-carrying parts in low-power circuits as described in 13.1.2.

21.2.7 For parts which maintain or retain in position electrical connections, the following tests are required. See Annex G:

– *ball pressure test 2 of G.3.3,*

followed by the glow-wire test at the temperature appropriate for the application and as declared for the CONTROL:

Glow-wire test at 650 °C

– *the glow-wire test of Clause G.1 carried out at 650 °C.*

Glow-wire test at 750 °C

– *the glow-wire test of Clause G.1 carried out at 750 °C.*

Glow-wire test at 850 °C

– *the glow-wire test of Clause G.1 carried out at 850 °C.*

The tests are not applicable to parts retaining in position current-carrying parts in low-power circuits as described in 13.1.2.

21.2.8 For all other parts, (except decorative trim, knobs, etc.), the following test is required. See Annex G:

– *the glow-wire test of Clause G.1 carried out at 550 °C.*

Unless otherwise indicated in a part 2, diaphragms, gaskets and sealing rings of glands are not subjected to the tests of 21.2.8.

21.2.9 Resistance to tracking for all non-metallic parts for which a CREEPAGE DISTANCE is specified in 11.3 shall be as declared in Table 1, requirement 23.

NOTE 1 Required values of resistance to tracking are given either in the part 2s of IEC 60730 or in the relevant equipment standard.

NOTE 2 Within a CONTROL, different parts can have different PTI values appropriate to the MICRO-ENVIRONMENT of the part.

Compliance is checked by the tests of Clause G.2 carried out at the value declared in Table 1, requirement 23:

– 100 V;

– 175 V;

– 250 V;

– 400 V;

– 600 V.

NOTE 3 For the purposes of 21.2.9, the proximity of arcing contacts is not considered to increase the deposition of external conductive material as the endurance tests of Clause 1919, followed by the electric strength tests of Clause 15, are deemed sufficient to determine the effect of POLLUTION arising from within the CONTROL.

21.3 Independently mounted, free-standing controls

21.3.1 The test sequence of 21.2.5 through 21.2.9 applies, preceded by the preconditioning of 21.3.2.

21.3.2 *Preconditioning shall be carried out in a heating cabinet as follows:*

– without T rating: 1 × 24 h at (80 ± 2) °C, the circuit of the switching part and the driving mechanism not being connected, with detachable COVERS removed;

– with T rating for temperatures not exceeding 85 °C: 1 × 24 h at (80 ± 2) °C, the switching part of the CONTROL and the driving mechanism not being connected and without COVERS and subsequently 6 × 24 h at T_{max} ± 2 K with COVERS, with the circuit of the switching part and driving mechanism being connected;

– with T rating for temperatures exceeding 85 °C: 6 × 24 h at T_{max} ± 2 K with COVERS, with the circuit of the switching part and driving mechanism being connected.

21.3.4DV DR *Modification of Clause 21.3 to add the following:*

21.3.4DV Controls installed in air handling spaces

21.3.4DV.1 Electrical CONTROLS employing polymeric parts that are intended to be installed in air handling spaces or in other environmental air space (plenums) shall be investigated for the application and their fire-resistance and low-smoke-producing characteristics in accordance with the Standard for Fire test for Heat and Visible Smoke Release for Discrete Products and Their Accessories Installed in Air-Handling Spaces, UL 2043.

22 Resistance to corrosion

22.1 Resistance to rusting

22.1.1 Ferrous parts, including COVERS and enclosures, the corrosion of which might impair compliance with this document, shall be protected against corrosion.

22.1.2 This requirement does not apply to temperature SENSING ELEMENTS or to other component parts whose performance would be adversely affected by protective treatment.

22.1.3 *Compliance is checked by 22.1.4 to 22.1.6:*

22.1.4 *The parts are subjected to a test of 14 days duration at 93 % to 97 % relative humidity at (40 ± 2) °C.*

22.1.5 *After the parts have been dried for 10 min in a heating cabinet at a temperature of (100 ± 5) °C, their surfaces shall show no corrosion which might impair compliance with Clauses 6, 15, and 11.*

22.1.6 *Traces of rust on sharp edges and a yellowish film removable by rubbing are ignored.*

NOTE 1 Parts protected by enamelling, galvanizing, sherardizing, plating or other recognized equivalent protection are deemed to meet this requirement.

NOTE 2 For small helical springs and the like, and for parts exposed to abrasion, when a layer of grease is used to provide protection against rusting, such parts are subjected to the test only if the effectiveness of the grease film is unknown. The test is then made without removal of the grease.

23 Electromagnetic compatibility (EMC) requirements – Emission

23.1 General requirement

Electrical controls shall be so constructed that they do not emit excessive electric or electromagnetic disturbances in their environment as tested in 23.2 and 23.3.

INTEGRATED and INCORPORATED CONTROLS are not subjected to the tests of 23.2 and 23.3, as the results of these tests are influenced by the incorporation of the CONTROL into the equipment and the use of measures to control emissions used therein. They can, however, be carried out under declared conditions if so requested by the manufacturer or defined in dedicated standards given in Table 23 or Table 24.

An EMC test plan and report (see 25.2) shall be established prior to testing. It shall contain, as a minimum, the elements given in configuration of EUT during testing 23.2 to 23.3. It may be determined from consideration of the electrical characteristics and usage of a particular apparatus that some tests are inappropriate and therefore unnecessary. In such cases, the decision not to test shall be recorded in the EMC test plan and EMC test report.

23.1DV D2 *Modification of Clause 23.1 to add the following:*

Free-standing, independently-mounted and in-line cord electronic controls shall comply with FCC, Part 15, sub part B for unintentional radiators, or sub part C for intentional radiators (e.g., controls with incorporated/integrated wireless transmitter devices), if mandated by local authorities having jurisdiction.

23.2 High frequency emission

23.2.1 Requirements

Electrical controls using wired network ports, software, oscillating circuits, or switching power supplies shall comply with the following:

– for RESIDENTIAL ELECTROMAGNETIC ENVIRONMENT or INDUSTRIAL ELECTROMAGNETIC ENVIRONMENTS, as indicated in Table 23,

NOTE 1 See also Table 1, requirement 75

– for INDUSTRIAL ELECTROMAGNETIC ENVIRONMENT, as indicated in Table 24,

NOTE 2 See also Table 1, requirement 75

– for discontinuous disturbances as indicated in CISPR 14-1:2020, Subclause 4.4 if the test as detailed in 23.2.2 and 23.2.3 results in a maximum duration of radio frequency emission of 20 ms and where such controls have a click rate greater than 5 unless that examination and/or tests show that the minimum time between contact operations during normal operation cannot be less than 10 min.

– for ISM (Industrial, Scientific and Medical) equipment and free-standing, independently mounted and in-line cord controls for use with ISM equipments shall comply with the requirements of CISPR 11.

NOTE 3 See also Table 1, requirement 65.

NOTE 4 Wired network port is defined in CISPR 32:2015, 3.1.32.

NOTE 5 The relevant part 2 will indicate whether the requirements of this clause apply to integrated and incorporated ELECTRICAL CONTROLS.

23.2.2 Test conditions

One previously untested sample is subjected to the test.

The electrical and thermal conditions are as specified in 19.2 and 19.3, except as follows:

– for SENSING CONTROLS, the rate of change of activating quantities is α_1 and β_1;

– for non-SENSING CONTROLS, the CONTROLS are caused to operate at the lowest contact operating speed possible during normal operation;

– for CONTROLS declared for use with inductive loads, the power factor is 0,6, unless declared otherwise in Table 1, requirement 8. For CONTROLS declared with purely resistive loads, the power factor is 1,0.

23.2.3 Test procedure

The CONTROL is operated continuously but for a minimum of five CYCLES OF CONTACT OPERATION during measuring cycle if relevant.

The duration of radio interference is measured by an oscilloscope connected to the CONTROL so as to measure the voltage drop across the contacts. The measuring instrumentation shall be in accordance with CISPR 14-1:2020, 5.1.7.

NOTE For the purpose of this test, radio interference is any observed fluctuation of voltage across the contacts which is superimposed on the supply waveform as a result of contact OPERATION.

Table 23
Emission limit for residential electromagnetic environment

Port	Frequency range 230 MHz to 1 GHz	Limits	Limits for reference/example	Procedure	Applicability note	Remarks
Enclosure	30 MHz to 230 MHz	CISPR 32 [a], Table A.4.2	40 dB(μV/m) quasi peak at 3 m 47 dB(μV/m) quasi peak at 3 m	CISPR 32 [a], Table A.1	See Note 1 Note 2	Allowed measurement distances: 3 m or 10 m
	30 MHz to 230 MHz 230 MHz to 1 GHz	CISPR 32 [a], Table A.4.1	30 dB(μV/m) quasi peak at 10 m 37 dB(μV/m) quasi peak at 10 m	CISPR 32 [a], Table A.1		
	1 GHz to 6 GHz	CISPR 32 [a], Table A.5	74 (μV/m) peak at 3 m 54 dB(μV/m) average at 3 m	CISPR 32 [a], Table A.1		
AC main	0,15 MHz to 0,5 MHz Limits decrease linearly with log. frequency	CISPR 32 [a], Table A.10	66 dB(μV) to 56 dB(μV) quasi peak 56 dB(μV) to 46 dB(μV) average	CISPR 32 [a], Table A.8, Clause A8.1		
	0,5 MHz to 5 MHz		56 dB(μV) quasi peak 46 dB(μV) average			
	5 MHz to 30 MHz		60 dB(μV) quasi peak 50 dB(μV) average			
	0,15 MHz to 30 MHz	CISPR 14-1:2020, Clause 4.4.2	Discontinuous disturbances	CISPR 14-1: 2020, Subclause 4.4		The statistical evaluation in the basic standard does not apply
DC power port	0,15 MHz to 0,5 MHz	IEC 61000-6-3 Table 5, Clause 5.1	79 dB(μV) quasi peak 66 dB(μV) average	IEC 61000-6-3: 2020, Annex B	See Note 3 Note 4	Measurement network V-AN
	0,5 MHz to 30 MHz		73 dB(μV) quasi peak 60 dB(μV) average			
	0,15 MHz to 0,5 MHz	IEC 61000-6-3 Table 5, Clause 5.2	84 dB(μV) to 74 dB(μV) quasi peak 74 dB(μV) to 64 dB(μV) average	IEC 61000-6-3: 2020, Annex B	See Note 3 Note 4	Measurement network Δ-AN

Table 23 Continued on Next Page

Table 23 Continued

Port	Frequency range 230 MHz to 1 GHz	Limits	Limits for reference/example	Procedure	Applicability note	Remarks
	0,5 MHz to 30 MHz		74 dB(µV) quasi peak 64 dB(µV) average			
HBES/BACS network port	0,15 MHz to 0,5 MHz	CISPR 32 [a], Table A.12 Clause A12.1	84 dB(µV) to 74 dB(µV) quasi peak 74 dB(µV) to 64 dB(µV) average	CISPR 32 [a], Table A.8, Clause A8.2	See Note 5	Coupling device AAN
	Limits decrease linearly with log frequency	CISPR 32 [a], Table A.12 Clause A12.3	40 dB(µA) to 30 dB(µA) quasi peak 30 dB(µA) to 20 dB(µA) average	CISPR 32 [a], Table A.8, Clause A8.3	See Note 5	Coupling device Current probe
	0,5 MHz to 30 MHz	CISPR 32 [a], Table A.12 Clause A12.1	74 dB(µV) quasi peak 64 dB(µV) average	CISPR 32 [a], Table A.8, Clause A8.2	See Note 5	Coupling device AAN
		CISPR 32 [a], Table A.12 Clause A12.3	30 dB(µA) quasi peak 20 dB(µA) average	CISPR 32 [a], Table A.8, Clause A8.3	See Note 5	Coupling device Current probe

NOTE 1 Applicable only to controls containing processing devices, for example, microprocessors operating at frequencies greater than 9 kHz.

NOTE 2 Apply either 3 m or 10 m measuring distance.

NOTE 3 According IEC 61000-6-3, apply either Table 5, Subclause 5.1 (V-AM/V-AMN) or Subclause 5.2 (Δ-AN) across the required frequency range.

NOTE 4 For the applicability of the test in relation to the DC power source connection, see information in IEC 61000-6-3:2020 Annex B, Table B.1.

NOTE 5 According to CISPR 32, apply either coupling device A12.1 (AAN) or A12.3 (current probe).

[a] CISPR 32:2015 and CISPR 32:2015/AMD1:2019.

Table 24
Emission limit for industrial electromagnetic environment

Port	Frequency range	Limits	Limits for reference/example	Procedure	Applicability note	Remarks
Enclosure	30 MHz to 230 MHz 230 MHz to 1 GHz	CISPR 32 [a], Table A.2.2	50 dB(µV/m) quasi peak at 3 m 57 dB(µV/m) quasi peak at 3 m	CISPR 32 [a], Table A.1	See Note 1 Note 2	Allowed measurement distances: 3 m or 10 m
	30 MHz to 230 MHz 230 MHz to 1 GHz	CISPR 32 [a], Table A.2.1	40 dB(µV/m) quasi peak at 10 m	CISPR 32 [a], Table A.1		

Table 24 Continued on Next Page

Table 24 Continued

Port	Frequency range	Limits	Limits for reference/example	Procedure	Applicability note	Remarks
			47 dB(μV/m) quasi peak at 10 m			
	1 GHz to 6 GHz	CISPR 32 [a], Table A.3	80 (μV/m) peak at 3 m 60 dB(μV/m) average at 3 m	CISPR 32 [a], Table A.1		
AC main	0,15 MHz to 0,5 MHz	CISPR 32 [a] Table A.9	79 dB(μV) quasi peak 66 dB(μV) average	CISPR 32 [a], Table A.8, Clause A8.1		
	0,5 MHz to 30 MHz		73 dB(μV) quasi peak 60 dB(μV) average			
	0,15 MHz to 30 MHz	CISPR 14-1: 2020, Clause 4.4.2	Discontinuous disturbances	CISPR 14-1:2020, Subclause 4.4		The statistical evaluation in the basic standard does not apply
DC power port	0,15 MHz to 0,5 MHz	IEC 61000-6-4 Table A.1, Clause A.1.1 (informative)	89 dB(μV) quasi peak 76 dB(μV) average	IEC 61000-6-4: 2018, Annex A	See Note 3 Note 4	Measurement network AMN
	0,5 MHz to 30 MHz		83 dB(μV) quasi peak 70 dB(μV) average			
HBES/ BACS network port	0,15 MHz to 0,5 MHz	CISPR 32 [a], Table A.11 Clause A11.1	97 dB(μV) to 87 dB(μV) quasi peak 84 dB(μV) to 74 dB(μV) average	CISPR 32 [a], Table A.8, Clause A8.2	See Note 5	Coupling device AAN
	Limits decrease linearly with log frequency	CISPR 32 [a] Table A.11 Clause A11.3	53 dB(μA) to 43 dB(μA) quasi peak 40 dB(μA) to	CISPR 32 [a], Table A.8, Clause A8.3	See Note 5	Coupling device Current probe
	0,5 MHz to 30 MHz	CISPR 32 [a], Table A.11 Clause A11.1	87 dB(μV) quasi peak 74 dB(μV) average	CISPR 32 [a], Table A.8, Clause A8.2	See Note 5	Coupling device AAN
		CISPR 32 [a], Table A.11 Clause A11.3	43 dB(μA) quasi peak 30 dB(μA) average	CISPR 32 [a], Table A.8, Clause A8.3	See Note 5	Coupling device Current probe

NOTE 1 Applicable only to controls containing processing devices, for example, microprocessors operating at frequencies greater than 9 kHz.

NOTE 2 Apply either 3 m or 10 m measuring distance.

NOTE 3 According IEC 61000-6-4:2018, if declared in Table 1, requirement 75 of this document.
Remark: IEC 61000-6-4:2018, Annex A is informative.

NOTE 4 For the applicable test in relation to the DC power source connection, see information in IEC 61000-6-4:2018 Annex A, Table A.2.

NOTE 5 According to CISPR 32, apply either coupling device A11.1 (AAN) or A11.3 (current probe).

[a] CISPR 32:2015 and CISPR 32:2015/AMD1:2019.

23.3 Low frequency emission

23.3.1 Requirements

CONTROLS in which an ELECTRONIC DEVICE controls directly an external load connected to the mains power supply (the CONTROL port) shall comply with the requirements of IEC 61000-3-2 and IEC 61000-3-3 for external load current ≤ 16 A per phase, and IEC 61000-3-11 and IEC 61000-3-12 for external load current > 16 A and ≤ 75 A per phase.

23.3.2 Test procedure

For these tests, a load and measures to control emissions, if any, shall be used as declared by the manufacturer in Table 1 requirement 54. This requirement does not apply to CONTROLS declared and designed for PILOT DUTY load only.

24 Normal operation

24.1 Output waveform of electronic controls

The output waveform of ELECTRONIC CONTROLS shall be as declared.

The output waveform of the CONTROL shall be examined under all normal operating conditions and shall be either sinusoidal or as declared in Table 1, requirement 48.

NOTE Attention is drawn to IEC 61000-3-2 and IEC 61000-3-3, which impose restriction on mains disturbances.

24.2 Operation within the voltage range

A CONTROL incorporating an electro-magnet shall operate as intended at any voltage within the range of 85 % of the minimum rated voltage and 110 % of the maximum rated voltage, inclusive.

Compliance is checked by subjecting the CONTROL to the following tests at the maximum and minimum operating conditions declared, except that only a CONTROL having T_{min} less than 0 °C is tested at T_{min}:

The CONTROL is subjected to 1,1 $V_{R\,max}$ until equilibrium temperature is reached and then tested immediately for OPERATION at 1,1 $V_{R\,max}$ and at rated voltage.

The CONTROL is also subjected to 0,85 $V_{R\,min}$ until equilibrium temperature is reached and then tested immediately for OPERATION at 0,85 $V_{R\,min}$.

Battery powered controls shall be tested at a maximum voltage and at a minimum voltage as declared by the manufacturer in Table 1, requirement 85.

25 Electromagnetic compatibility (EMC) requirements – Immunity

25.1 General

ELECTRONIC CONTROLS shall be evaluated in accordance with the Table 25:

Table 25
The applicable EMC test in relation to the class of control function and type of Action

Construction of control/ application	Class of control function			
	Class A		Class B	Class C
	Type 1 action	Type 2 action		
INTEGRATED CONTROLS	25.7 to 25.10 (if declared)[a] 25.5 to 25.10 (if requested)[b]	25.7 to 25.10 25.5 to 25.10 (if requested)[b]	25.5, 25.6 and Clause H.25	Clause H.25
INCORPORATED CONTROLS	25.7 to 25.10 (if declared)[a] 25.5 to 25.10 (if requested)[b]	25.7 to 25.10 25.5 to 25.10 (if requested)[b]	Clause H.25	Clause H.25
IN-LINE CORD CONTROLS, FREE-STANDING CONTROLS AND INDEPENDENTLY MOUNTED CONTROLS for HBES/BACS application and equipment that uses integrated/ incorporated controls for HBES/BACS application	25.5, 25.6 and 25.7 to 25.10 (if declared)[a]	25.5 to 25.10	25.7 to 25.10 and Clause H.25	25.7 to 25.10 and Clause H.25

[a] If declared in Table 1, requirement 86.

[b] If requested by the manufacturer of the control in Table 1, requirement 84.

25.1DV DR *Modification of Clause 25.1 to add the following NOTE:*

NOTE DV1 The requirements of Clause 25 apply to controls declared in Table 1, requirement 86 and intended to satisfy the EMC directive in Europe.

25.2 EMC test plan and report

25.2.1 General

An EMC test plan shall be established prior to testing. It shall contain, as a minimum, the elements given in configuration of EUT during testing for emission in 23.1 and for immunity in 25.5 to 25.10. It may be determined from consideration of the electrical characteristics and usage of a particular apparatus that some tests are inappropriate and therefore unnecessary. In such cases, the decision not to test shall be recorded in the EMC test plan and EMC test report.

25.2.2 Configuration of EUT during testing

25.2.2.1 General

Controls and control equipment often consists of SYSTEMS with no fixed configuration. The kind, number and installation of different subassemblies within the control equipment may vary from SYSTEM to SYSTEM. Thus it is reasonable, and also recommended, not to test every possible arrangement.

To simulate EMC conditions (related both to emission and immunity), the control equipment assembly shall represent a typical installation as specified by the manufacturer. Such tests shall be carried out as type tests under normal conditions as specified by the manufacturer.

25.2.2.2 Composition of EUT

All devices, racks, modules, boards, etc. significant to EMC and belonging to the EUT shall be documented in the EMC test plan and EMC test report. If relevant, the software version shall be documented in the EMC test plan and EMC test report.

25.2.2.3 Assembly of EUT

If an EUT has a variety of internal and external configurations, the type tests shall be made with one or more typical configurations that represent normal use. The rationale for this selection shall be documented in the EMC test plan and EMC test report.

25.2.2.4 I/O ports

Where there are multiple I/O ports which are all of the same type, connecting a cable to just one of those ports is sufficient, provided that it can be shown that the additional cables would not affect the results significantly.

25.2.2.5 Auxiliary equipment

When a variety of devices is provided for use with the EUT, at least one of each type of device shall be selected to simulate actual operating conditions. Auxiliary devices can be simulated.

25.2.2.6 Cabling and earthing (grounding)

The cables and earth (ground) shall be connected to the EUT in accordance with the manufacturer's specifications. There shall be no additional earth connections.

25.2.3 Operation conditions of EUT during testing

25.2.3.1 Operation modes

A selection of representative operation modes shall be made, taking into account that not all functions, but only the most typical functions of the electronic control can be tested. The estimated worst-case operating modes for normal application shall be selected.

NOTE The standby condition of the control is considered to be an operating mode.

25.2.3.2 Environmental conditions

The tests shall be carried out within the manufacturer’s specified environmental operating range (for example, ambient temperature, humidity, atmospheric pressure), and within the rated ranges of supply voltage and frequency.

25.2.3.3 EUT software during test

The software used for simulating the different modes of operation shall be documented. This software shall represent the estimated worst-case operating mode for normal application.

25.2.3.4 Specification of performance criteria

For immunity tests, performance criteria for each operating mode and test shall be specified; where possible, as quantitative values.

25.2.3.5 Test description

Each test to be applied shall be specified in the EMC test plan. The description of the tests, the test methods, the characteristics of the test, and the test set-ups are given in the basic standards, which are referred for emission in Table 23 or Table 24 and for immunity in Table 26 or Table 27. Additional information needed for the practical implementation of the tests is given in this document. The contents of standards need not be reproduced in the test plan. In some cases, the EMC test plan shall specify the application in detail.

25.3 Immunity requirements

25.3.1 Conditions during the test

The configuration and modes of operation during the tests shall be precisely noted in the test report.

Tests shall be applied to the relevant ports in accordance with Table 26 or Table 27 as applicable.

The tests shall be conducted in accordance with the basic standards. The tests shall be carried out one at a time. If additional methods are required, the method and rationale shall be documented in the test report.

25.3.2 Immunity test requirements

The immunity testing requirements for RESIDENTIAL ELECTROMAGNETIC ENVIRONMENTS are given in Table 26 as declared in Table 1, requirement 77.

The immunity testing requirements for INDUSTRIAL ELECTROMAGNETIC ENVIRONMENT are given in Table 27 as declared in Table 1, requirement 78.

Table 26
Immunity test requirements for residential electromagnetic environments

Port	Phenomenon	Basic standard	Test value	Performance criteria	
				m	n
ENCLOSURE	Electrostatic discharge ESD	IEC 61000-4-2	±8 kV air / ±4 kV contact	B	
	EM field	IEC 61000-4-3 [g, h, i]	3 V/m (80 MHz to 1 GHz)	A	
			3 V/m (1,4 GHz to 6 GHz)	A	
			10 V/m (80 MHz to 1GHz)		B
	Power-frequency magnetic field [e]	IEC 61000-4-8	3 A/m (50 Hz, 60 Hz)	A	
AC POWER SUPPLY (including protective earth)	Voltage dip [k]	IEC 61000-4-11	0 % during 0,5 cycle	B	A
			0 % during 1 cycle	B	A
			70 % during 25/30 cycles [l]	C	
			40 % during 10/12 cycles [l]		B
	Voltage interruptions [k]	IEC 61000-4-11	0 % during 250/300 cycles [l]	C	
	Burst	IEC 61000-4-4	±1 kV (5/50 ns, 5 kHz) [o]	B	A
			±2 kV (5/50 ns, 5 kHz) [o]		B

Table 26 Continued on Next Page

Table 26 Continued

Port	Phenomenon	Basic standard	Test value	Performance criteria	
				m	n
	Surge [p]	IEC 61000-4-5	±1 kV a, n / ±2 kV [b, o]	B	
	Conducted RF	IEC 61000-4-6	3 V (150 kHz to 80 MHz) [q]	A	
			10 V (150 kHz to 80 MHz) [q]		B
DC POWER PORT [f] (including protective earth)	Burst [j, r]	IEC 61000-4-4	±0,5 kV (5/50 ns, 5 kHz) [o]	B	A
			±1 kV (5/50 ns, 5 kHz) [o]		B
	Surge [c, j, r]	IEC 61000-4-5	±0,5 kV a, n /±1 kV [b, o]	B	
			±2 kV [b, o]		B
	Conducted RF [d]	IEC 61000-4-6	3 V (150 kHz to 80 MHz) [q]	A	
			10 V (150 kHz to 80 MHz) [q]		B
I/O SIGNAL/CONTROL PORTS (including lines connected to functional earth port)	Burst [d]	IEC 61000-4-4	±0,5 kV (5/50 ns, 5 kHz) [o]	B	A
			±1 kV (5/50 ns, 5 kHz) [o]		B
	Surge [c]	IEC 61000-4-5	±1kV [b, o]	B	
			±0,5 kV [a, o] / ±2 kV [b, o]		B
	Conducted RF [d]	IEC 61000-4-6	3 V (150 kHz to 80 MHz) [q]	A	
			10 V (150 kHz to 80 MHz) [q]		B
HBES/BACS NETWORK LINES	Burst [d]	IEC 61000-4-4	±0,5 kV (5/50 ns, 5 kHz) [o]		A
			±1 kV (5/50 ns, 5 kHz) [o]		B
	Surge [c]	IEC 61000-4-5	±0,5 kV [a, o] / ±2 kV [b, o]		B
	Conducted RF [d]	IEC 61000-4-6	3 V (150 kHz to 80 MHz) [q]		A
			10 V (150 kHz to 80 MHz) [q]		B

[a] Line to line.

[b] Line to earth (ground).

[c] Only in the case of long-distance lines, see 3.24.9 (declared in Table 1, requirement 79).

[d] Only in the case of lines >3 m (declared in Table 1, requirement 80).

[e] Applicable only to apparatus containing devices susceptible to magnetic fields (declared in Table 1, requirement 83).

[f] DC ports and connections between parts of equipment/SYSTEM which are not connected to a DC distribution network are treated as I/O signal/control ports.

[g] IEC 61000-4-20 may be used for small EUTs as defined in IEC 61000-4-20.

[h] A fully anechoic room (FAR) as described in IEC 61000-4-22 may also be used as a test site for radio-frequency immunity test.

[i] A reverberation chamber (RVC) as described in IEC 61000-4-21 may also be used (details see IEC 61000-6-1 and IEC 61000-4-21).

[j] Not applicable to input ports intended for connection to a battery or a rechargeable battery which shall be removed or disconnected from the apparatus for recharging.

[k] Applicable only to input ports.

[l] For example, “25/30 cycles" means "25 cycles for 50 Hz test" or "30 cycles for 60 Hz test” (declared in Table 1, requirement 81).

[m] Default performance criteria for all controls.

[n] Additional requirement to Footnote [m] for controls intended to be used in accordance with IEC 63044-5-2 HBES/BACS networks (declared in Table 1, requirement 82).

[o] Open-circuit test voltage.

[p] Apparatus with an AC power input port intended for use with a mains transformer shall be tested on the mains input of the transformer specified by the manufacturer or, where none is so specified, using a typical transformer of min. 300 VA.

Table 26 Continued on Next Page

Table 26 Continued

Port	Phenomenon	Basic standard	Test value	Performance criteria	
				m	n

[q] The test level specified is the RMS value of the un-modulated carrier.

[r] Equipment with a DC power input port intended for use with an AC-DC power adaptor shall be tested on the AC power input of the AC-DC power adaptor specified by the manufacturer or, where no adaptor is specified, the test shall be done on the DC power port using the test levels of this table.

Table 27
Immunity test requirements for industrial electromagnetic environment

Port	Phenomenon	Basic standard	Test value	Performance criteria
ENCLOSURE	Electrostatic discharge (ESD)	IEC 61000-4-2	±8 kV air / ±4 kV contact	B
	EM field	IEC 61000-4-3 [g, h, i]	10 V/m (80 MHz to 1 GHz)	A
			3 V/m (1,4 GHz to 6 GHz)	A
	Rated power frequency magnetic field [e]	IEC 61000-4-8	30 A/m	A
AC POWER SUPPLY	Voltage dip [k]	IEC 61000-4-11	0 % during 0,5 cycle	B
			0 % during 1 cycle	B
			70 % during 25/30 cycles [l]	C
	Short interruptions [k]	IEC 61000-4-11	0 % during 250/300 cycles [l]	C
	Burst	IEC 61000-4-4	±2 kV (5/50 ns, 5 kHz) [n]	B
	Surge [o]	IEC 61000-4-5	±1 kV a, n / ±2 kV [b, n]	B
	Conducted RF	IEC 61000-4-6	10 V (150 kHz to 80 MHz) [o]	A
DC POWER PORT [f] (including protective earth)	Burst [j, q]	IEC 61000-4-4	±1 kV (5/50 ns, 5 kHz) [n]	B
	Surge [c, j, q]	IEC 61000-4-5	±1 kV [a, n] / ±2 kV [b, n]	B
	Conducted RF [d]	IEC 61000-4-6	10 V (150 kHz to 80 MHz) [p]	A
I/O SIGNAL/CONTROL PORTS (including lines connected to functional earth port)	Burst [d]	IEC 61000-4-4	±1 kV (5/50 ns, 5 kHz) [n]	B
	Surge [c]	IEC 61000-4-5	±1 kV [b, n]	B
	Conducted RF [d]	IEC 61000-4-6	10 V (150 kHz to 80 MHz) [p]	A
HBES/BACS NETWORK LINES [m]	Burst [d]	IEC 61000-4-4	±0,5 kV (5/50 ns, 5 kHz) [n]	A
	Surge [c]	IEC 61000-4-5	±1kV [a, n] / ±2kV [b, n]	B
	Conducted RF [d]	IEC 61000-4-6	10 V (150 kHz to 80 MHz) [p]	A

[a] Line to line.

[b] Line to earth (ground).

[c] Only in the case of long-distance lines, see 3.24.9 (declared in Table 1, requirement 79).

[d] Only in the case of lines >3 m (declared in Table 1, requirement 80).

[e] Applicable only to apparatus containing devices susceptible to magnetic fields (declared in Table 1, requirement 83).

[f] DC ports and connections between parts of equipment/SYSTEM which are not connected to a DC distribution network are treated as I/O signal/control ports.

Table 27 Continued on Next Page

Table 27 Continued

Port	Phenomenon	Basic standard	Test value	Performance criteria
[g] IEC 61000-4-20 may be used for small EUTs as defined in IEC 61000-4-20. [h] A fully anechoic room (FAR) as described in IEC 61000-4-22 may also be used as a test site for radio-frequency immunity test. [i] A reverberation chamber (RVC) as described in IEC 61000-4-21 may also be used (details see IEC 61000-6-1 and IEC 61000-4-21). [j] Not applicable to input ports intended for connection to a battery or a rechargeable battery which shall be removed or disconnected from the apparatus for recharging. [k] Applicable only to input ports. [l] For example “25/30 cycles" means "25 cycles for 50 Hz test" or "30 cycles for 60 Hz test” (declared in Table 1, requirement 81). [m] Additional requirement for controls intended to be used in accordance with IEC 63044-5-3 HBES/BACS networks (declared in Table 1, requirement 82). [n] Open-circuit test voltage. [o] Apparatus with an AC power input port intended for use with a mains transformer shall be tested on the mains input of the transformer specified by the manufacturer or, where none is so specified, using a typical transformer of min. 300 VA. [p] The test level specified is the RMS value of the un-modulated carrier. [q] Equipment with a DC power input port intended for use with an AC-DC power adaptor shall be tested on the AC power input of the AC-DC power adaptor specified by the manufacturer or, where no adaptor is specified the test shall be done on the DC power port using the test levels of this table.				

25.4 Performance criteria

The performance criteria are given in Table 28 and are based on the operating conditions and the functional specification of the control during and after the test.

After the test, the control shall meet the requirements of Clause 6, 15.2 and Clause 11.

Table 28
Performance criteria

Operating conditions	Performance criteria		
	A	B	C
Digital Inputs/Outputs	No deviation on input readings.	No deviation on input readings.	Any error, such as a change of state, destruction of data, and loss of a connection is permitted, provided the initial state is restored automatically after the test – Automatic recovery after the test [b]
	No deviation on output settings.	No deviation on output settings.	
	(no change of state)	(no change of state)	
Analogue Inputs/Outputs	Deviation as declared in the final product specification is permitted [a]	Deviation is permitted during test	
Display, Monitor	Operation shall be possible at reasonable comfort	Deviation is permitted (e.g. display FAULT, such as flickering)	
Local operator override/ switching	No deviation	Deviation is permitted for analogue values No change of state for digital values	
HBES/BACS network port Communication ports	No deviation detectable by the user. The reduced data transfer rate shall be reasonable for the control operation	Degradation of performance is allowed, but not loss of communication for longer than 1 min.	

[a] The permissible deviation is with respect to the value without electromagnetic interference. This means that any basic deviation is ignored.

[b] This performance criteria is based on the fact that the control operation in the end user application will be unsupervised.

25.5 Surge immunity test

The control is mounted as specified in 4.3.2.1, supplied at rated voltage and operated at representative operating conditions. It is tested in accordance with IEC 61000-4-5.

The test values for the declared EMC level are specified in Table 26 or Table 27.

Repetition rate:	maximum 1/min
Polarity:	positive (+) and negative (−)
Number of pulses:	five pulses for each polarity are applied
Phase angle:	0°, 90°, 180° and 270° versus the phase angle of the ac line voltage to the equipment under test.

NOTE Most protectors in common use have low average power capabilities, even though their peak power or peak energy handling can deal with high currents. Therefore, the maximum repetition rate (the time between two surges and the recovery time) depends on the built-in protection devices of the EUT.

25.6 Electrical fast transient immunity test

The control is mounted as specified in 4.3.2.1, supplied at rated voltage and operated at representative operating conditions. It is tested in accordance with IEC 61000-4-4.

The test values for the declared EMC level are specified in Table 26 or Table 27.

Polarity:	positive (+) and negative (−)
Duration:	one minute for each polarity

25.7 Radio-frequency electromagnetic field immunity

25.7.1 Immunity to conducted disturbances

The control is mounted as specified in 4.3.2.1, supplied at rated voltage and operated at representative operating conditions. It is tested in accordance with IEC 61000-4-6. The complete frequency range being swept at least once.

The test levels/test voltage values for the declared EMC level are specified in Table 26 or Table 27.

25.7.2 Immunity to radiated electromagnetic fields

The control is mounted as specified in 4.3.2.1, supplied at rated voltage and operated at representative operating conditions. It is tested in accordance with IEC 61000-4-3. The complete frequency range being swept at least once.

The test values for the declared EMC level are specified in Table 26 or Table 27.

25.8 Electrostatic discharge

The control is mounted as specified in 4.3.2.1, supplied at rated voltage and operated at representative operating conditions. It is tested in accordance with IEC 61000-4-2.

The test values for the declared EMC level are specified in Table 26 or Table 27, where 5 discharges in each polarity (+/–) shall be applied:

- Contact discharges: shall be applied to those points and surfaces of the EUT which are accessible to persons during normal use and to the HCP and VCP in accordance with the basic standard.

- Air discharges: shall be applied to those points and surfaces of the EUT which are accessible to persons during normal use.

25.9 Immunity to power-frequency magnetic fields

This test is only applicable to controls containing devices susceptible to magnetic fields. (e.g. hall-effect devices) and if declared by the manufacturer (declared in Table 1, requirement 83).

The control is mounted as specified in 4.3.2.1, supplied at rated voltage and operated at representative operating conditions. It is tested in accordance with IEC 61000-4-8.

The test values for the declared EMC level are specified in Table 26 or Table 27.

25.10 Test of the influence of voltage dips and voltage interruption in the power supply network

During the test, the control shall be initially operated at its rated voltage. The control is operated at representative operating conditions.

It is tested in accordance with IEC 61000-4-11. The test is only applicable to AC power input ports.

The test values for the declared EMC level are specified in Table 26 or Table 27.

26 Abnormal operation tests

26.1 Abnormal temperature test

26.1.1 Burnout test

26.1.1.1 Controls incorporating electro-magnets shall withstand the effects of blocking of the control mechanism.

Compliance is checked by the tests of 26.1.1.2 and 26.1.1.3.

NOTE For relays and contactors, compliance with this requirement is established by successful completion of the tests of Clause 19.

26.1.1.2 The control mechanism is blocked in the position assumed when the control is de-energized. The control is then energized at rated frequency and rated voltage as indicated in 19.2.2, 19.2.3 a) and 19.2.3 b).

The duration of the test is either 7 h; or until an internal protective device, if any, operates; or until burnout, whichever occurs first.

26.1.1.3 After this test, the control shall be deemed to comply if:

– there has been no emission of flame or molten metal, and there is no evidence of damage to the CONTROL which would impair compliance with this document;

– the requirements of 15.2 are still met.

NOTE The CONTROL need not be operative following the test.

26.1.2 Blocked mechanical output test

26.1.2.1 CONTROLS with motors, such as electric actuators, shall withstand the effects of blocked output without exceeding the temperatures indicated in Table 29. Temperatures are measured by the method specified in 16.7 a). This test is not conducted on CONTROLS with motors, such as electric actuators, where, when tested under blocked output conditions for 7 h, any protective device, if provided, does not cycle under stalled conditions, and which do not exceed temperature limits in Table 17.

26.1.2.2 CONTROLS with motors, such as electric actuators, are tested for 24 h with the output blocked at rated voltage and in a room temperature in the range of 15 °C to 30 °C, the resulting measured temperature being corrected to a 25 °C reference value.

For CONTROLS with motors declared for three-phase OPERATION, the test is to be carried out with any one phase disconnected.

Table 29
Maximum winding temperature
(for test of mechanical blocked output conditions)

Condition	Temperature of insulation by class °C							
	A	E	B	F	H	200	220	250
If impedance protected:	150	165	175	190	210	230	250	280
If protected by protective devices:								
During first hour	200	215	225	240	260	280	300	330
– maximum value								
After first hour								
– maximum value	175	190	200	215	235	255	275	305
– arithmetic average	150	165	175	190	210	230	250	280

26.1.2.3 The average temperature shall be within the limits during both the second and the twenty-fourth hours of the test.

NOTE The average temperature of a winding is the arithmetic average of the maximum and minimum values of the winding temperature during the 1 h period.

26.1.2.4 During the test, power shall be continually supplied to the motor.

26.1.2.5 Immediately upon completion of the test, the motor shall be capable of withstanding the electric strength test specified in Clause 15, without first applying the humidity treatment of 14.2.

26.2 Overload tests

26.2.1 Overload tests carried out on in-line cord controls as indicated in 9.10.2 and provided with a plug and socket outlet

The tests according to 26.2.3 shall be carried out.

The temperature shall not exceed those indicated in Table 17.

26.2.2 For controls not covered by 26.2.1

The tests according to 26.2.3 shall be carried out at ambient temperature (20 ± 5) °C. If declared in Table 1, requirement 70, the test will not be done for INCORPORATED CONTROLS and INTEGRATED CONTROLS.

26.2.2DV D2 *Modification of Clause 26.2.2 to add the following:*

For controls intended for fixed wiring or independently mounted controls where the load is either integrated in the control or fixed, the tests of 26.2 are not applicable.

26.2.3 Tests

The tests of 26.2.3 are not applicable to controls where the load is integrated within the control or when the connected load is declared in Table 1, requirement 8 and controlled; Example: fixed equipment.

The tests are conducted as follows.

– CONTROLS as specified without protective devices and without incorporated fuses are loaded for 1 h with the conventional tripping current for the fuse which in the installation will protect the CONTROL.

– CONTROLS protected by protective devices (including fuses) are loaded in such a way that the current through the CONTROL is 0,95 times the current with which the protective device releases after 1 h. The temperature rise is measured after a steady state has been reached or after 4 h, whichever is the shorter time.

– CONTROLS protected by incorporated fuses complying with IEC 60127 series or IEC 60269 series shall have those fuses replaced by links of negligible impedance and shall be loaded in such a manner that the current through the links shall be 2,1 times the rated current of the fuse. The temperature rise is measured after the CONTROL has been loaded for 30 min. The value 2,1 times can be de-rated by 0,5 %/K, if the overload test is carried out at a higher temperature compared to normal room temperature.

– CONTROLS protected both by incorporated fuses and by protective devices are loaded either as described above with incorporated fuses or with another protective device, choosing the test requiring the lower load.

– CONTROLS protected by protective devices which will short-circuit only in case of overload shall be tested both as CONTROLS with protective devices and as CONTROLS without protective devices.

The compliance with items a) to g) of 13.1.3.8, where applicable, is verified.

26.3 Battery short-circuit test

26.3.1 For CONTROLS having batteries that can be removed without the aid of a TOOL and having terminals that can be short-circuited by a thin straight bar, the terminals of the battery are short-circuited with the battery being fully charged.

The duration of the test is either 1 h or until ultimate condition exists, whichever occurs first.

26.3.2 After this test, the CONTROL shall be deemed to comply if:

– there has been no emission of flame or molten metal, and there is no evidence of damage to the CONTROL which would impair compliance with this document;

– the requirements of 15.2 are still met.

NOTE The CONTROL need not be operative following the test.

Dimension in millimetres

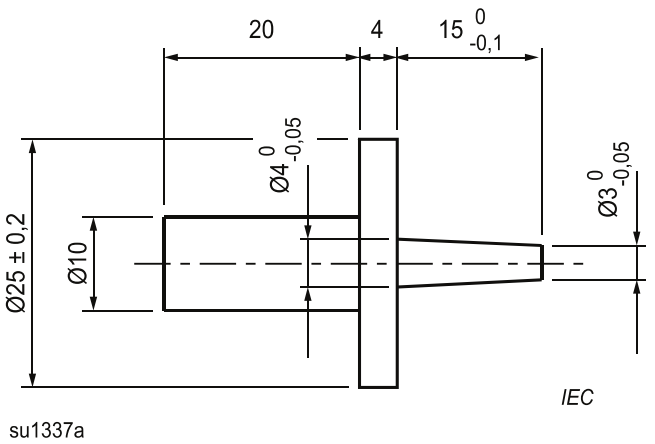
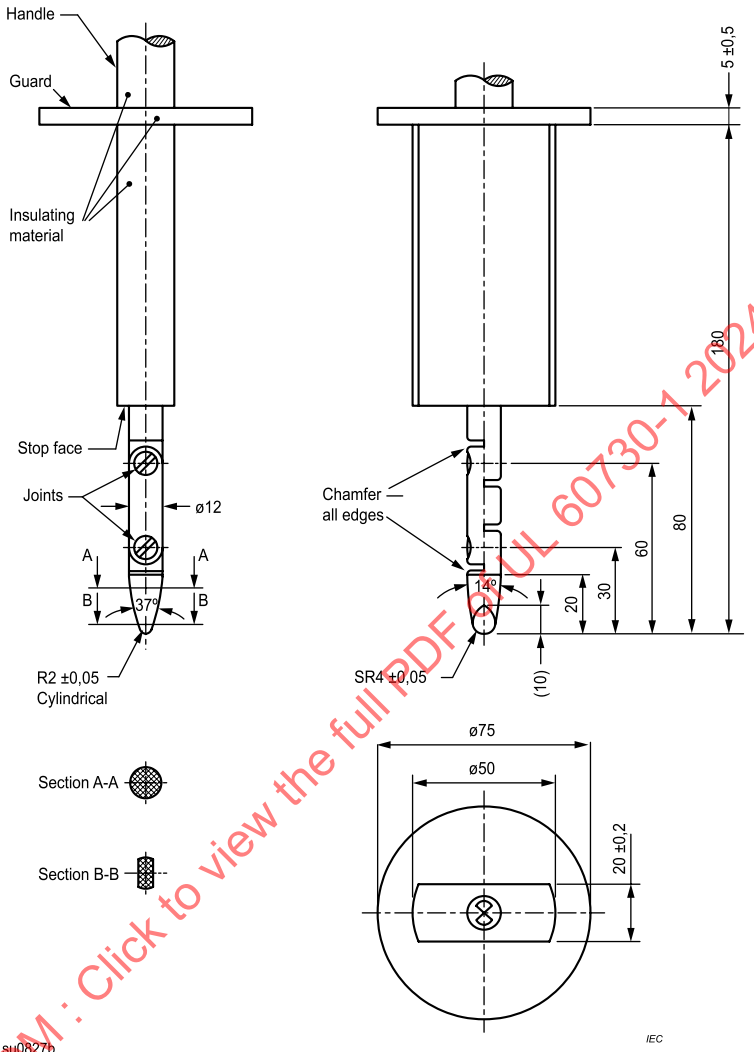


Figure 4

Test pin probe 13 of IEC 61032:1997

Linear dimensions in millimetres



Tolerances on dimensions without specific tolerance:

on angles $^{0°}_{-10}$

on linear dimensions:

up to 25 mm: $^{0}_{-0,05}$

over 25 mm: ±2

Material of finger: for example, heat-treated steel.

Both joints of this finger may be bent through an angle of 90° but in one and the same direction only.

Using the pin and groove solution is only one of the possible approaches in order to limit the bending angle to 90°. For this reason, dimensions and tolerances of these details are not given in the drawing. The actual design shall ensure a 90° bending angle with a 0° to 10° tolerance.

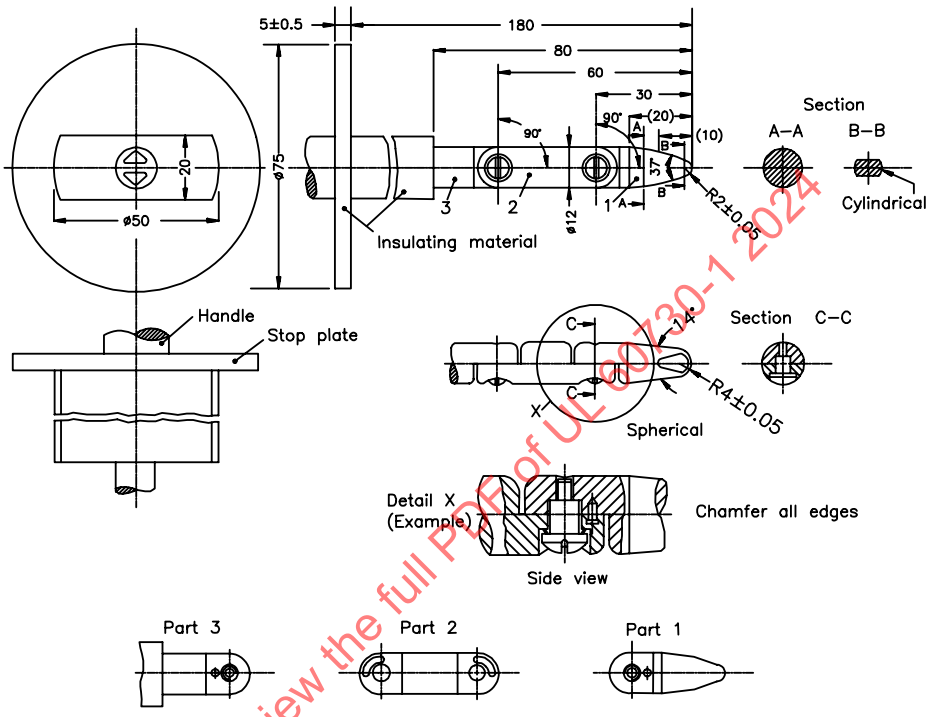
Figure 5

Test finger probe B of IEC 61032:1997

Figure 5DV D2 ***Modification of Figure 5 to replace with the following:***

Figure 5DV

Standard Test Finger



Dimensions in millimetres

Tolerances on dimensions without specific tolerance:

- on angles: $^{0}_{-10'}$
- on linear dimensions:

up to 25 mm: $^{0}_{-0,05}$ mm

over 25 mm: ±0,2 mm

Material of finger: heat–treated steel, etc.

Both joints of this finger may be bent through an angle of $(90\ ^{+10}_{0})°$ but in one and the same direction only.

Using the pin and groove solution is only one of the possible approaches in order to limit the bending angle to 90°. For this reason dimensions and tolerances of these details are not given in the drawing. The actual design must ensure a $(90\ ^{+10}_{0})°$ bending angle.

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Dimensions in millimetres

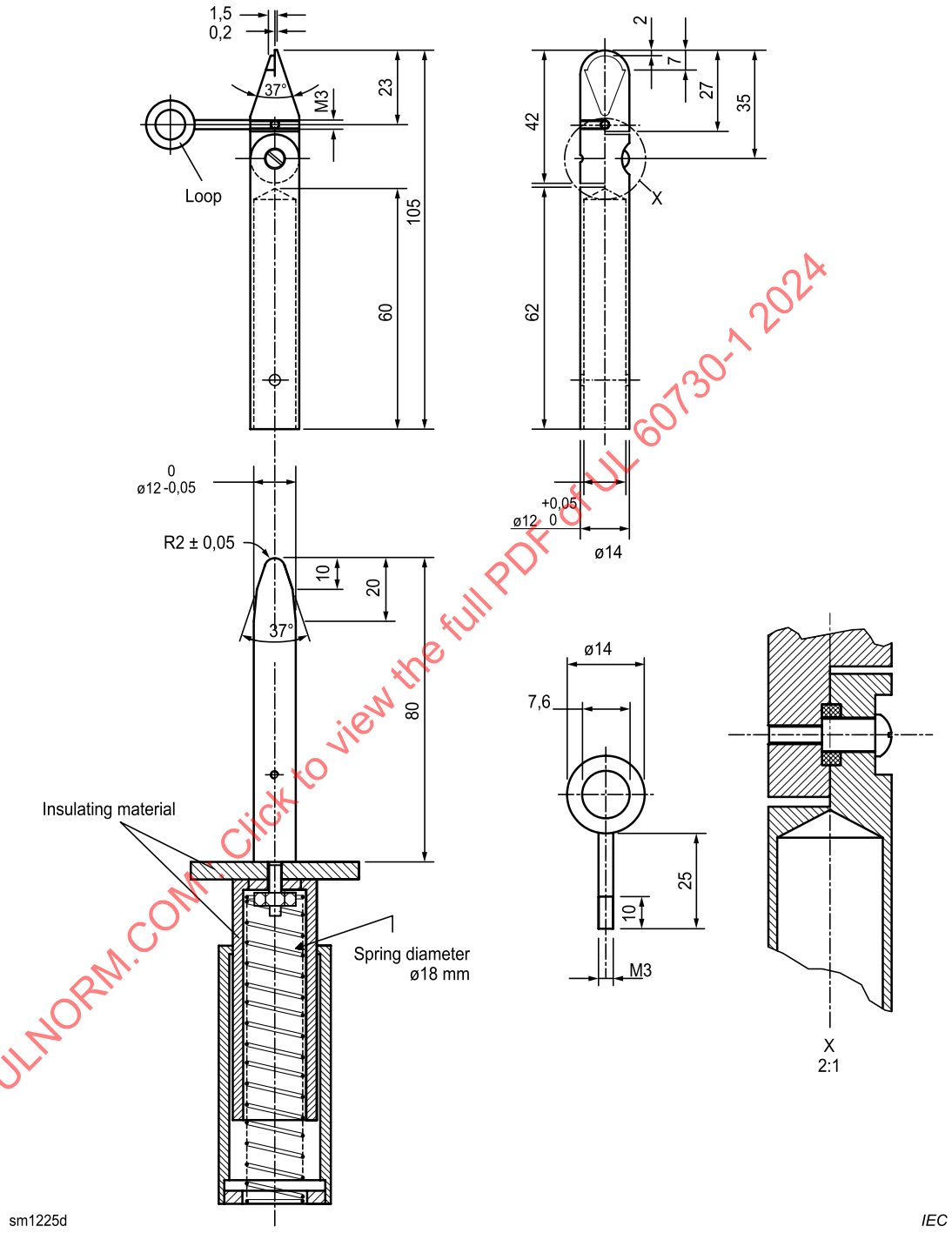


Figure 6

Test fingernail

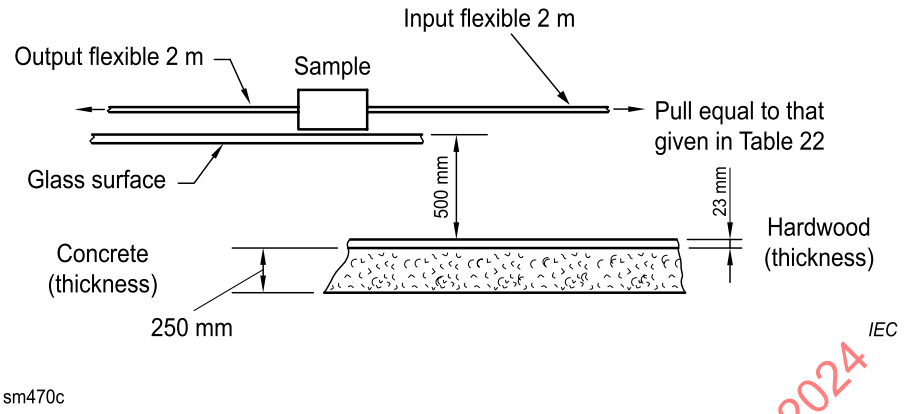


Figure 7

Impact test for free-standing controls

Dimensions in millimetres

Dimensions in millimetres

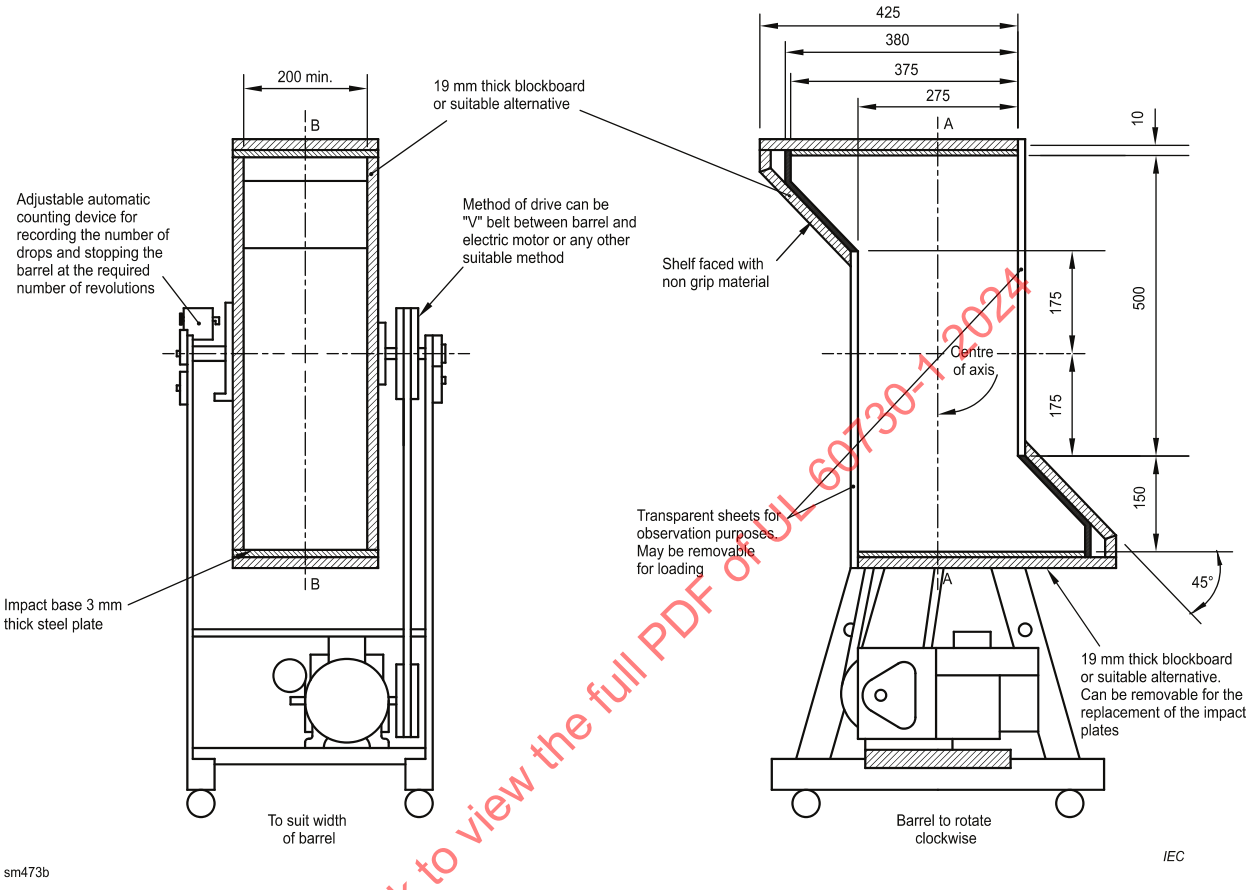


Figure 8

Tumbling barrel

Dimensions in millimetres

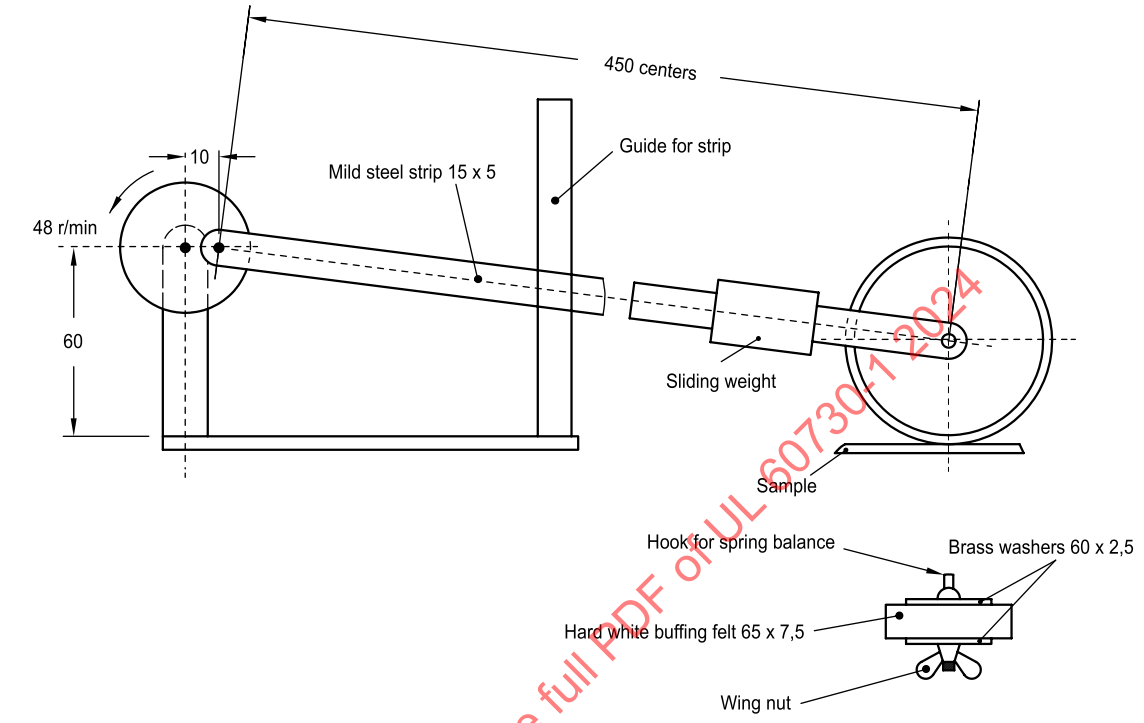


Figure 9

Apparatus for testing durability of markings on rating labels

Dimensions in millimetres

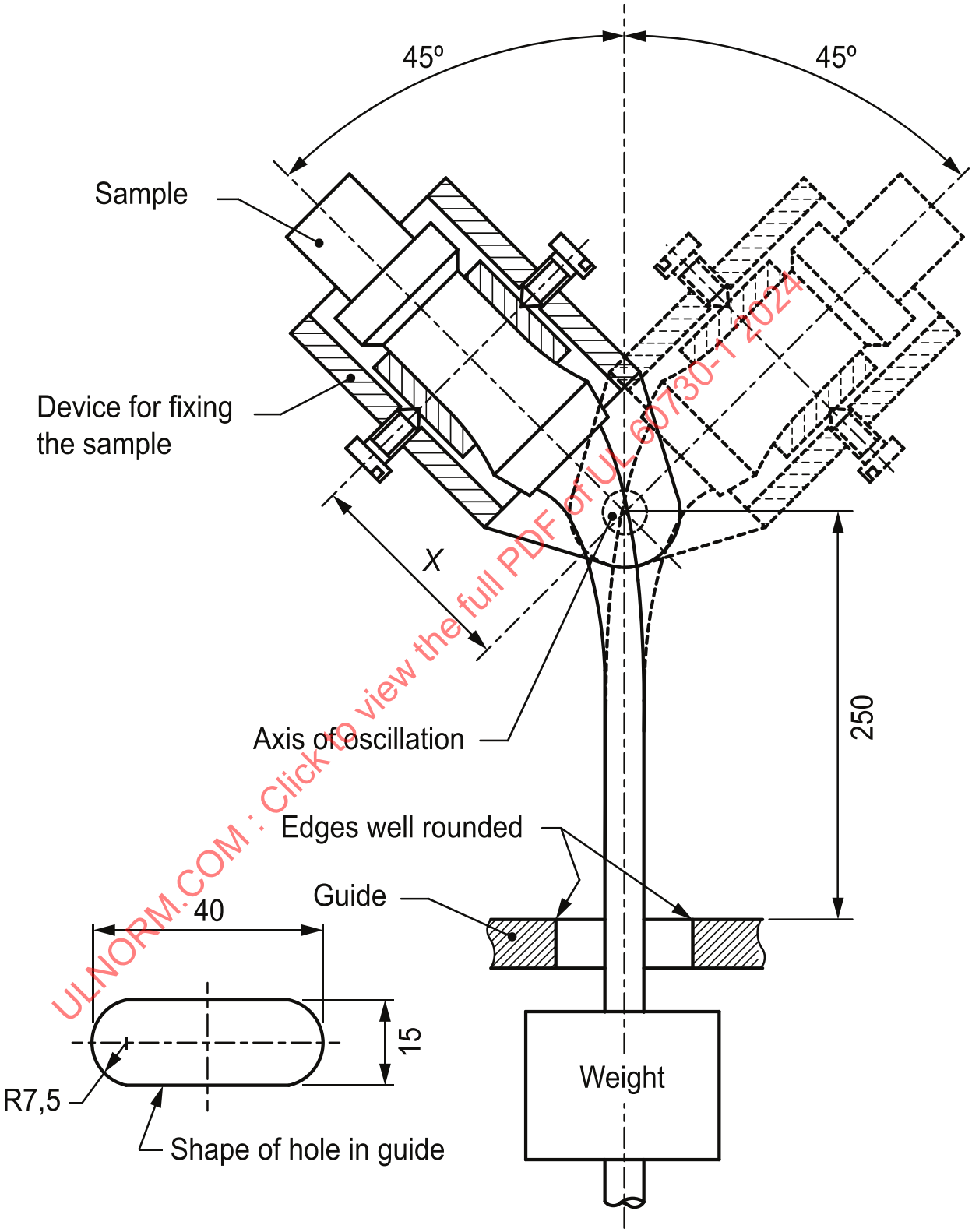
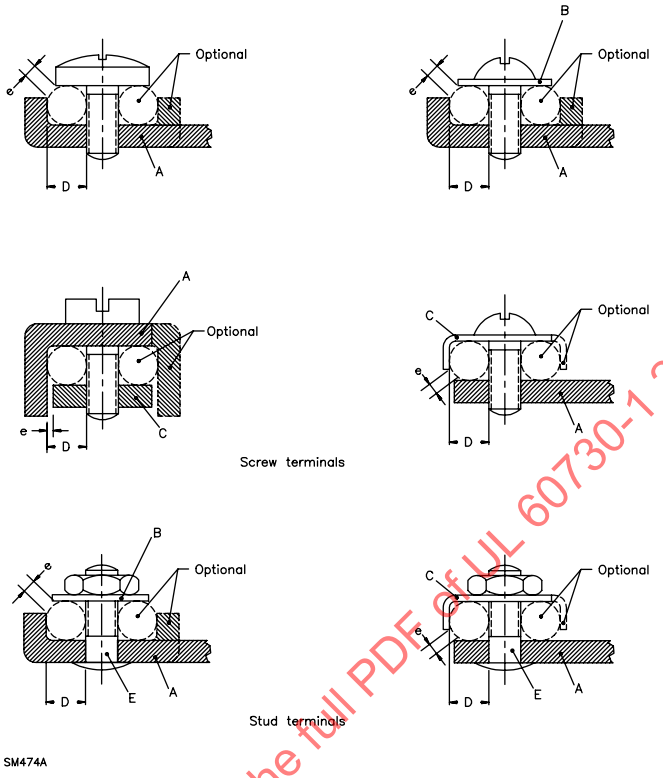


Figure 10

Apparatus for flexing test

Screws not requiring washer, clamping plate or anti-spread device

Screws requiring washer, clamping plate or anti-spread device



A fixed part

B washer or clamping plate

C anti-spread device

D conductor space

E stud

Current carried by terminal[a]		Minimum diameter conductor space	Maximum gap between conductor restraining parts	Minimum torque Nm			
				Slotted screws		Other screws	
For flexible conductor	For fixed conductor			One screw	Two screws	One screw	Two screws
A	*A*	*D*	*e*	*g*	*g*		
0 to 6	0 to 6	1,4	1,0	0,4	–	0,4	–
6 to 10	0 to 6	1,7	1,0	0,5	–	0,5	–
10 to 16	6 to 10	2,0	1,5	0,8	–	0,8	–
16 to 25	10 to 16	2,7	1,5	1,2	0,5	1,2	0,5
25 to 32	16 to 25	3,6	1,5	2,0	1,2	2,0	1,2
–	25 to 32	4,3	2,0	2,0	1,2	2,0	1,2
32 to 40	32 to 40	5,5	2,0	2,0	1,2	2,0	1,2
40 to 63	40 to 63	7,0	2,0	2,0	2,0	3,0	2,0

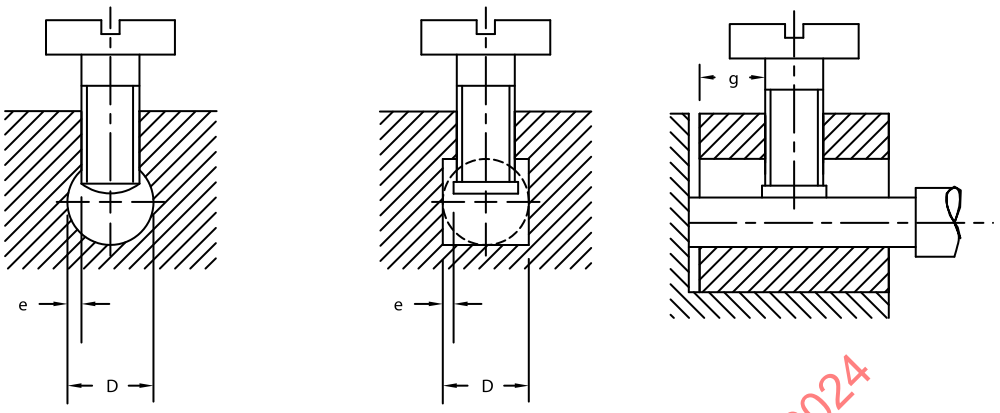
The part which retains the conductor in position may be of insulating material, provided that the pressure necessary to clamp the conductor is not transmitted through the insulating material.

The sketches are not intended to govern design except as regards the dimensions shown.

[a] Requirements for applications greater than 63 A are under consideration.

Figure 11

Screw terminals and stud terminals



Terminal without pressure plate

Terminal with pressure plate

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IEC

Dimensions in millimetres

Current carried by terminal [a]		Minimum diameter conductor space	Maximum gap between conductor restraining parts	Minimum distance between clamping screw and end of conductor when fully inserted		Minimum torque Nm					
						Screws without heads		Slotted screws		Other screws	
For flexible conductor	For fixed conductor			One screw	Two screws	One screw	Two screws	One screw	Two screws	One screw	Two screws
A	A	*D*	*e*	*g*	*g*						
0 to 10	0 to 6	2,5	0,5	1,5	1,5	0,2	0,2	0,4	0,4	0,4	0,4
10 to 16	6 to 10	3,0	0,5	1,5	1,5	0,25	0,2	0,5	0,4	0,5	0,4
16 to 25	10 to 16	3,6	0,5	1,8	1,5	0,4	0,2	0,8	0,4	0,8	0,4
25 to 32	16 to 25	4,0	0,6	1,8	1,5	0,4	0,25	0,8	0,5	0,8	0,5
–	25 to 32	4,5	1,0	2,0	1,5	0,7	0,25	1,2	0,5	1,2	0,5
32 to 40	32 to 40	5,5	1,3	2,5	2,0	0,8	0,7	2,0	1,2	2,0	1,2
40 to 63	40 to 63	7,0	1,5	3,0	2,0	1,2	0,7	2,5	1,2	3,0	1,2

The part of the terminal containing the threaded hole and the part of the terminal against which the conductor is clamped by the screw may be two separate parts; as in the case of terminals provided with a stirrup.

The shape of the conductor space may differ from those shown in the figures, provided a circle with a diameter equal to the minimum value specified for D can be inscribed.

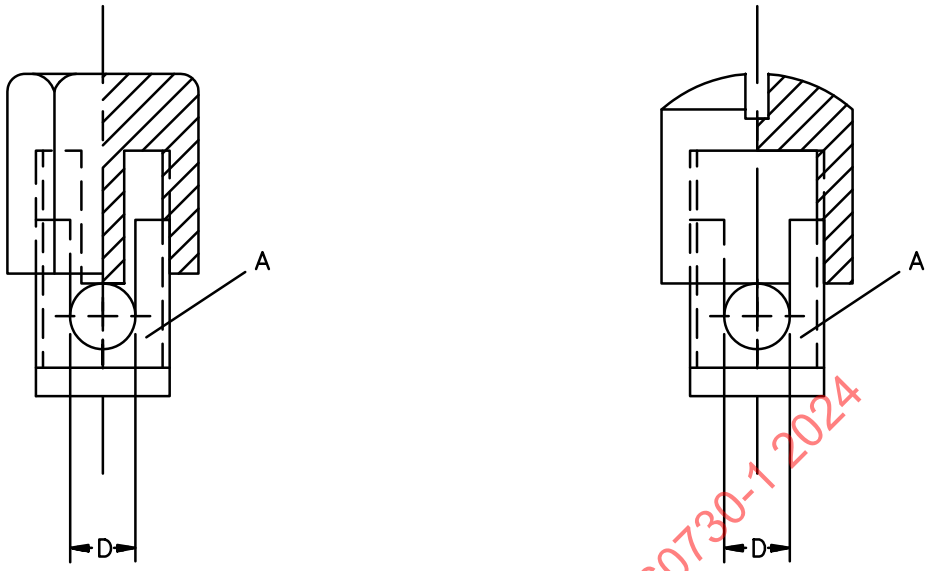
The minimum distance between the clamping screw and the end of the conductor when fully inserted applies only to the terminals in which the conductor cannot pass right through.

The sketches are not intended to govern design except as regards the dimensions shown.

[a] Requirements for applications greater than 63 A are under consideration.

Figure 12

Pillar terminals



SM463

A fixed part

D conductor space

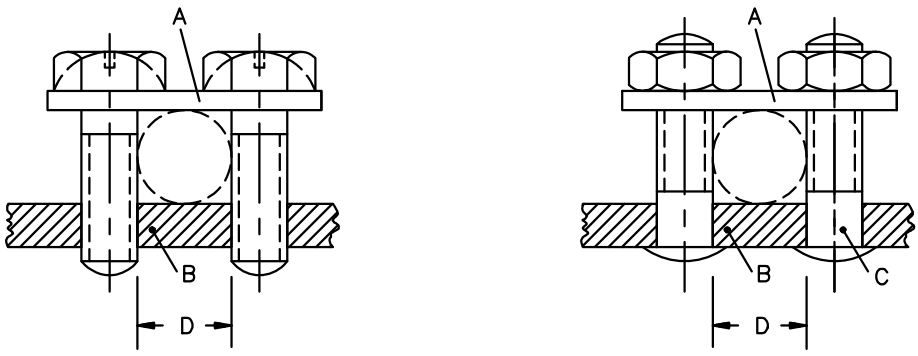
The bottom of the conductor space shall be slightly rounded, in order to obtain a reliable connection.

Terminal size	Minimum diameter of conductor space [a] mm	Minimum distance between fixed part and end of conductor when fully inserted mm
0	1,4	1,5
1	1,7	1,5
2	2,0	1,5
3	2,7	1,8
4	3,6	1,8
5	4,3	2,0
6	5,0	2,5
7	7,0	3,0
8	8,5	4,0

a The value of the torque to be applied is that specified in Table 9.

Figure 13

Mantle terminals



SM464

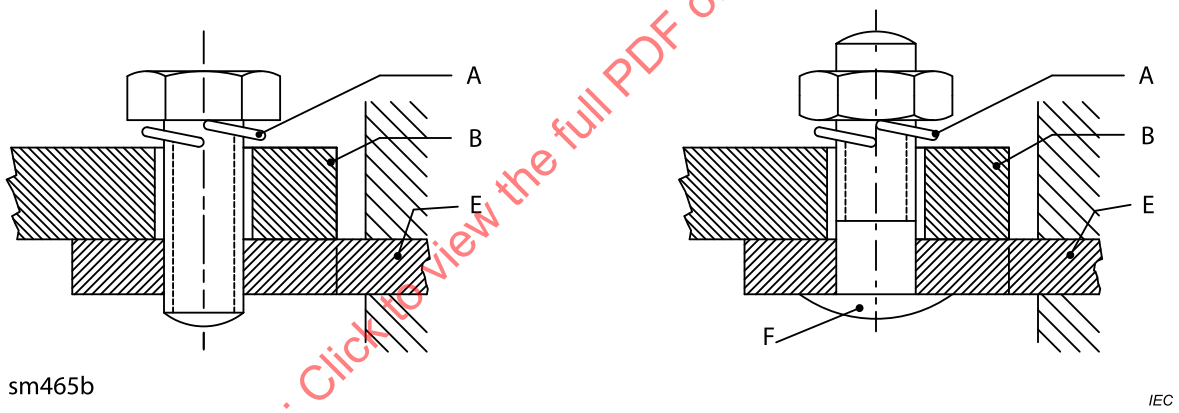
A saddle

B fixed part

C stud

D conductor space

a) Saddle terminals



sm465b

IEC

A locking means

B cable lug or bar

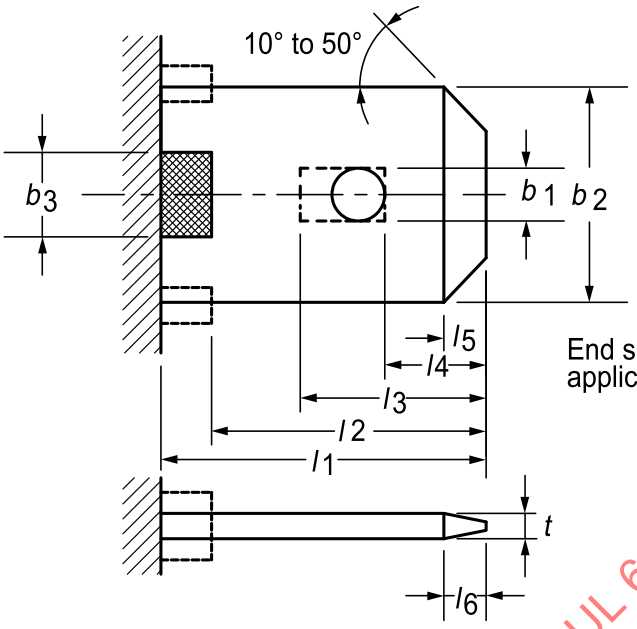
E fixed part

F stud

b) Lug terminals

Figure 14

Saddle and lug terminals



su1662a

Dimensions in millimetres

Dimension for Figure 14 and Figure 15 [a]	Connector size			
	2,8	**4,8**	**6,3**	**9,5**
l_1 (min.) [b]	7,7	6,9	8,6	14,0
l_2 (min.) [b]	7,0	6,2	7,9	12,0
l_3 (max.) [c]	3,0	5,2	6,7	8,2
l_4	1,0 ± 0,2	2,5 ± 0,25	3,2 ± 0,3	4,2 ± 0,3
l_5 (max.)	0,7	1,2	1,3	1,7
l_6 (max.)	0,7	1,2	1,3	1,7
b_1 (hole) [a]	$1,2^{+0,1}_{0}$	$1,4^{+0,2}_{0}$	$1,6^{+2,0}_{0}$ [d]	$2,1^{+2,0}_{0}$ [d]
b_1 (slot) [a]	$1,2^{+0,1}_{0}$	$1,4^{+0,2}_{0}$	$1,6^{+0,1}_{0}$	$2,1^{+2,0}_{0}$
b_2	2,8 ± 0,1	4,75 ± 0,2	$6,3^{+0,15}_{-1,0}$	$9,5^{+0,15}_{-1,0}$
b_3 (min.) [e]	2,0	2,0	2,5	2,5
t [f]	0,5 ± 0,025	0,8 ± 0,03	0,8 ± 0,03	1,2 ± 0,03
p (max.) [g]	0,8	1,2	1,2	1,7
k	–	$0,7^{0}_{-0,1}$	$1,0^{0}_{-0,1}$	$1,5^{0}_{-0,1}$
x	–	1,0 ± 0,2	1,0 ± 0,2	1,4 ± 0,2

NOTE The sketches are not intended to govern design except as regards the dimensions shown.

[a] TABS may have an optional detent for latching. Round dimple detents, rectangular dimple detents and hold detents shall be located in the area bounded by dimensions b_1, l_3 and l_4 along the centre line of the TAB.

TABS may be manufactured from more than one layer of materials, provided that the resulting TAB complies with this document.

Details for TABS having corrugations or depressions are under consideration.

[b] In order to provide sufficient CLEARANCE for RECEPTACLES intended to be provided with a sleeve, it may be necessary to increase this dimension by 0,5 mm to ensure that the means of location operates correctly.

Dimensions in millimetres

Dimension for Figure 14and Figure 15 [a]	Connector size			
	2,8	4,8	6,3	9,5

[c] The length of the slot (l_3-l_4) shall be at least equal to its width (b_1).

[d] These tolerances are chosen so as to allow the tabs to be used as a part of a terminal with screw clamping.

[e] Over the double-hatched area, the thickness shall not exceed the upper limit of the material thickness specified.

[f] With the exception of the dimple or hole and the area indicated by dimension "b", the thickness "t" shall be maintained over the whole connecting area. Compliance shall be determined by measurement over any section (3,2 ± 0,2) mm^2, in a circular area. In addition, the overall flatness shall have a tolerance of 0,03 mm.

[g] This dimension applies only to the raised side of the tab; on the reverse side, the flatness tolerance extends across the full width of the tab.

Figure 15

Tabs

For dimensions, see Figure 14

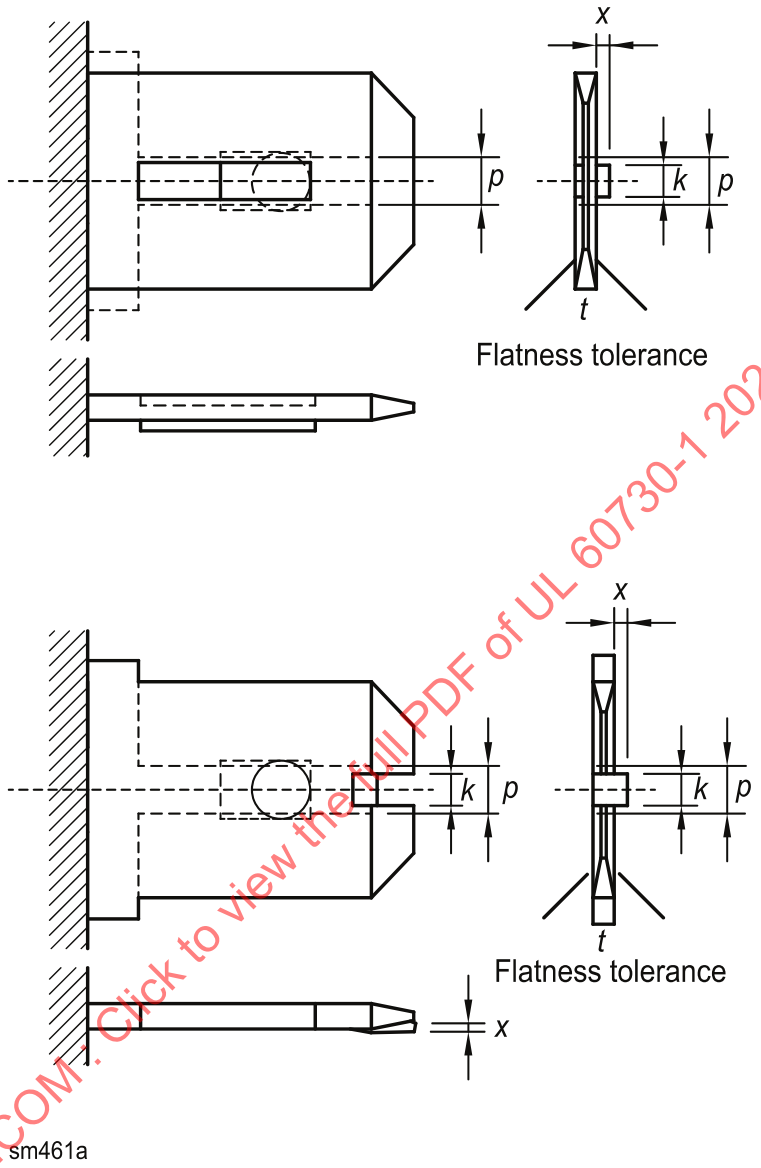
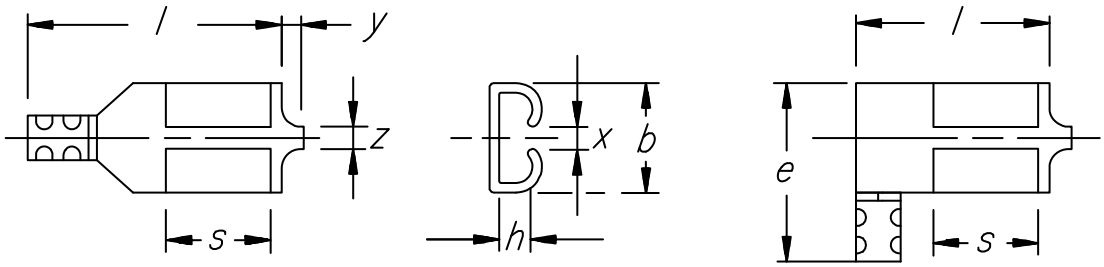


Figure 16

Tabs for non-reversible connectors



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Dimension	Connector size			
	2,8	**4,8**	**6,3**	**9,5**
b (max.)	4	6	8	12,5
e (max.)	12	12	15	20
h (max.)[a]	1	2	2,5	3,2
l (max.)	18	18	22	27
s (min.)	4,5	5	6	10
x (min.)[b]	-	0,9	1,2	1,7
y (max.)	0,5	0,5	0,5	1,0
z (max.)	1,5	1,5	2,0	2,0

The dimensions shown apply to the crimped condition.

Dimensions for RECEPTACLES provided with a sleeve and for RECEPTACLES with a pre-insulated barrel are under consideration.

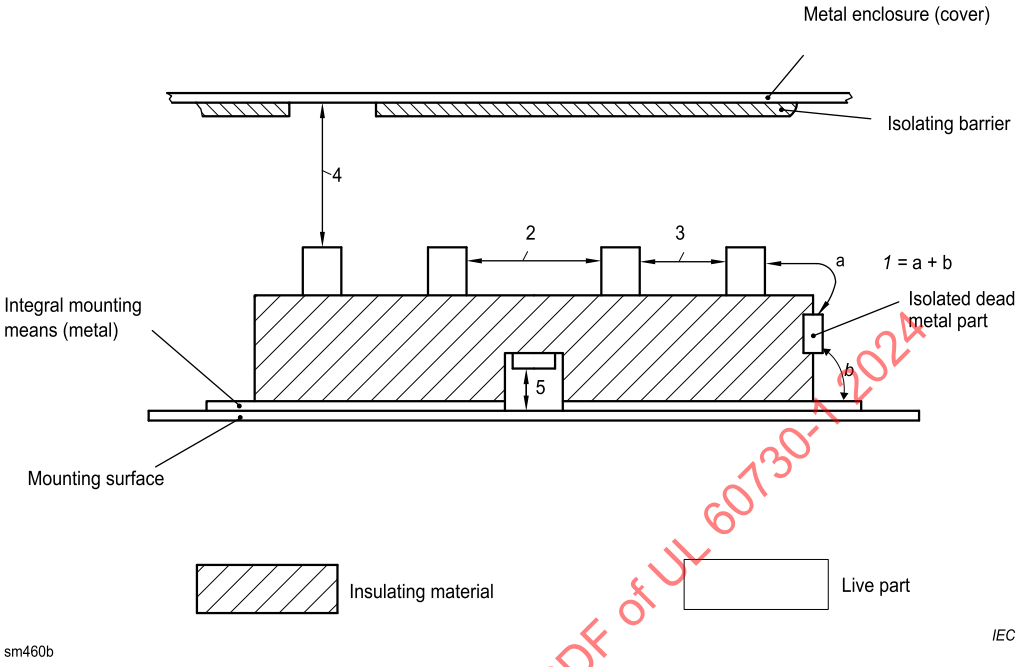
The sketches are not intended to govern design except as regards the dimensions shown.

[a] Maximum offset dimension from the centre line of the TAB blade.

[b] Applies only to RECEPTACLES for non-reversible connectors.

Figure 17

Receptacles



Key

1 between LIVE PARTS and other metal parts (including physically exposed electrical isolated metal parts)

2 between LIVE PARTS required to be insulated from each other (FUNCTIONAL INSULATION), except between contacts

3 between LIVE PARTS separated by the action of the control where their interconnection allows a flow of current through a load, and which current is thus limited by the load:

– FULL DISCONNECTION

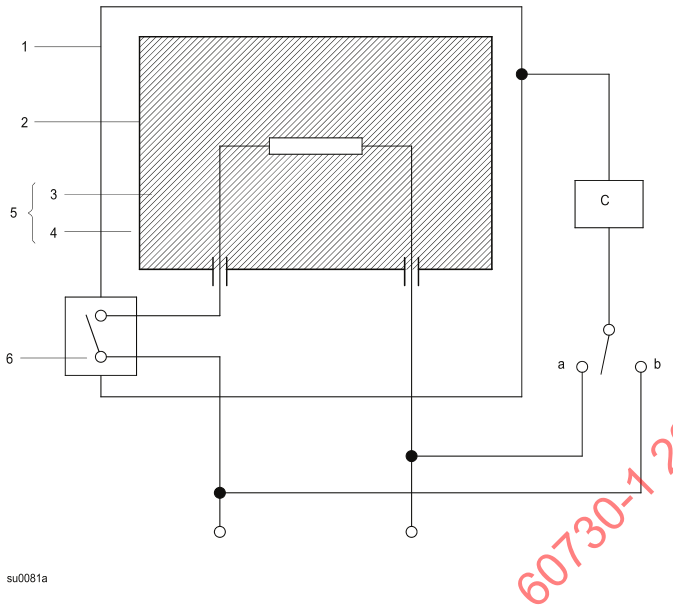
– this distance does not apply between terminals intended for connection to fixed wiring

4 between LIVE PARTS and metal enclosure of enclosed controls (these distances do not apply to the housing, frame or integral mounting means of a control intended for installation within an enclosure of the equipment controlled)

5 between LIVE PARTS in recesses of independently mounted controls and the surface to which the control is mounted. This distance may be reduced with the addition of an appropriate seal or barrier.

Figure 18

Measurement of creepage distance and clearance



Key

C circuit of Figure K.1

1 ACCESSIBLE PART

2 inaccessible metal part

3 BASIC INSULATION

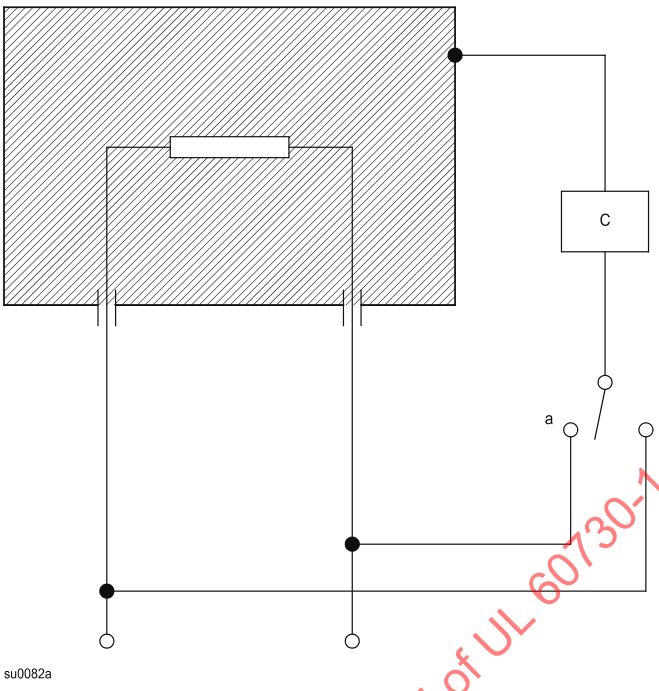
4 SUPPLEMENTARY INSULATION

5 DOUBLE INSULATION

6 REINFORCED INSULATION

Figure 19

Diagram for touch current measurement at operating temperature for single-phase connection of class II controls

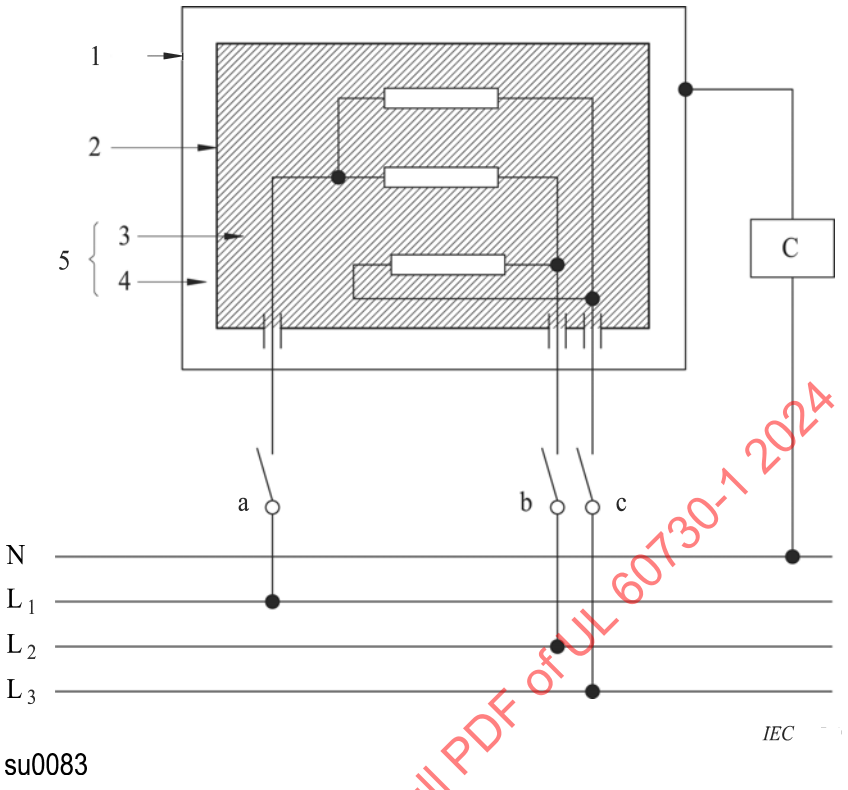


Key

C circuit of Figure K.1

Figure 20

Diagram for touch current measurement at operating temperature for single-phase connection of controls other than class II



Key

C circuit of Figure K.1

1 ACCESSIBLE PART

2 inaccessible metal part

3 BASIC INSULATION

4 SUPPLEMENTARY INSULATION

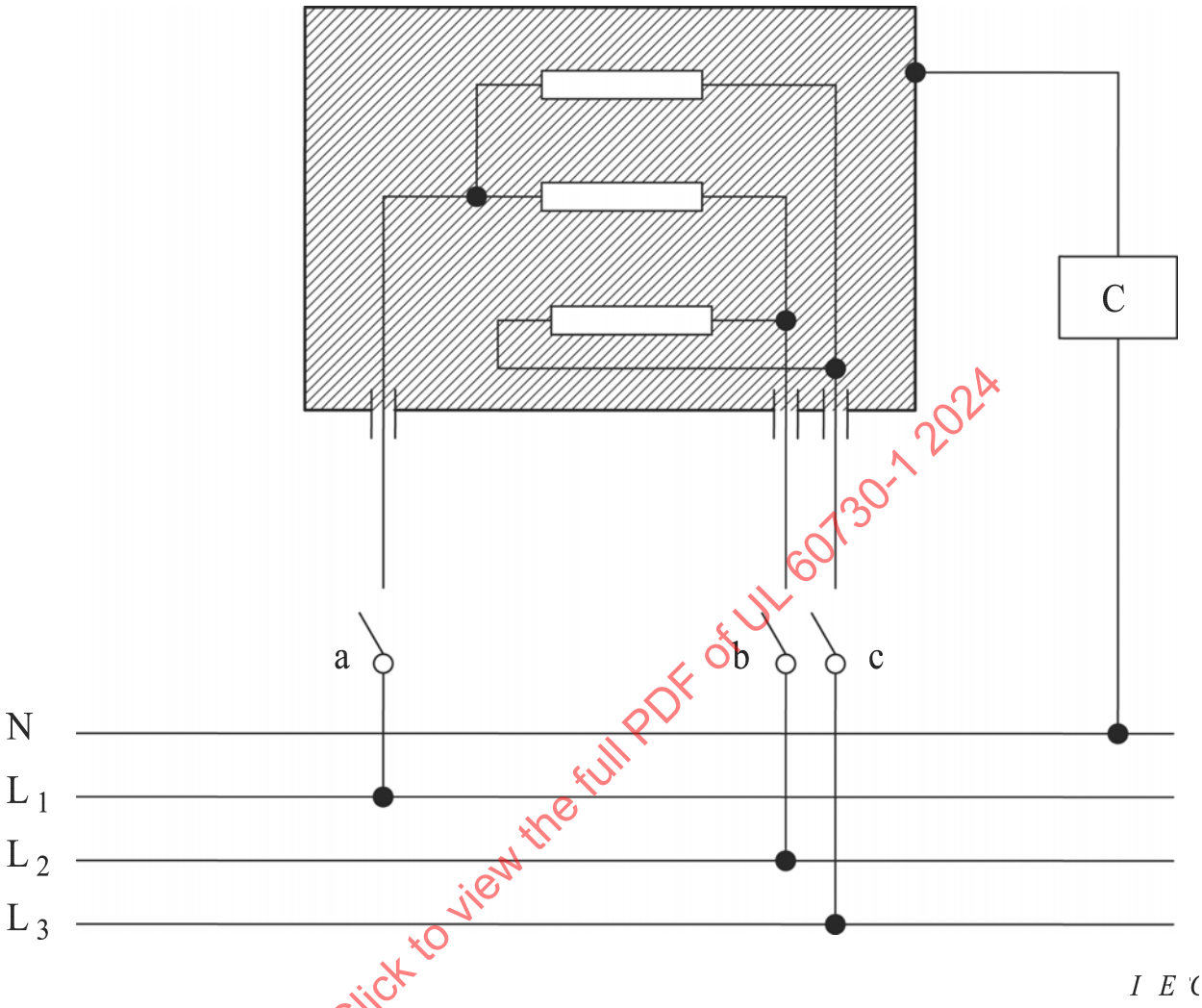
5 DOUBLE INSULATION

Connections and supplies

L_1, L_2, L_3, N supply voltage with neutral

Figure 21

Diagram for touch current measurement at operating temperature for three-phase connection of class II controls



Key

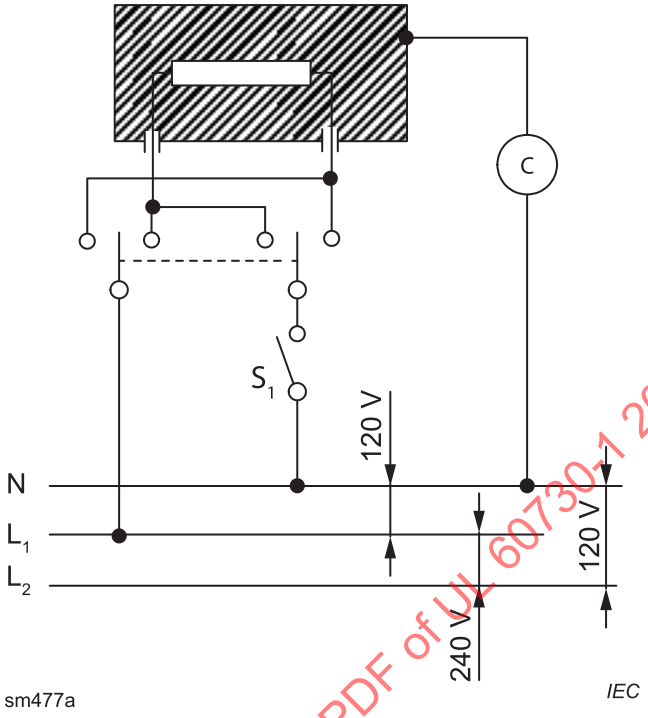
C circuit of Figure K.1

Connections and supplies

L_1, L_2, L_3, N supply voltage with neutral

Figure 22

Diagram for touch current measurement at operating temperature for three-phase connection of controls other than class II



Key

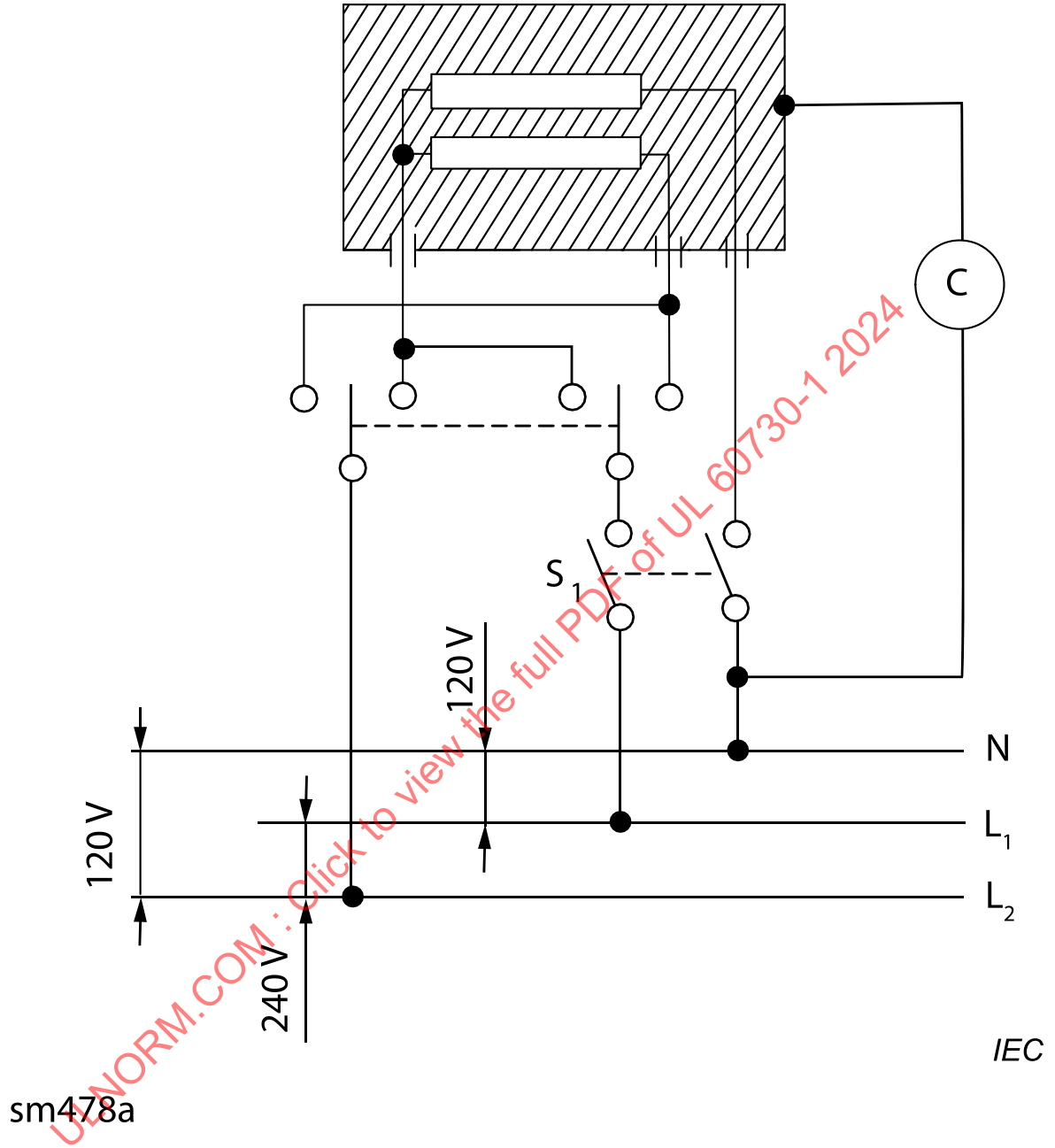
C circuit of Figure K.1

Connections and supplies

L_1, L_2, N supply voltage with neutral

Figure 23

Diagram for touch current measurement at operating temperature for single-phase connection of controls to three-wire, ground neutral supply other than class II



Key

C circuit of Figure K.1

Connections and supplies

L_1, L_2, N supply voltage with neutral

Figure 24

Diagram for touch current measurement at operating temperature for two-phase connection of controls to three-wire, ground neutral supply other than class II

Annex A
(normative)

Indelibility of markings

A.1 Requirements for indelibility

A.1.1 Markings on controls shall be adequately indelible for safety and are therefore classified according to the applicable requirements of A.1.2 to A.1.5.

A.1.2 Markings which are not mandatory within the requirements of this document.

A.1.3 Markings which are mandatory within the requirements of this document but which are not accessible to the final user when the control is mounted or installed in the equipment.

These markings have to be sufficiently resistant to removal to withstand the manual handling in the CONTROL MANUFACTURER'S factory after final inspection, being packed and transported to the EQUIPMENT MANUFACTURER'S factory, and handled during installation. Additionally, the marking shall remain legible in the presence of any vapour or other contaminant likely to be present.

A.1.4 Markings which are mandatory within the requirements of this document and which are accessible to the final user of the equipment after the control is mounted or installed as for normal use.

These markings, in addition to being resistant to the handling, etc., described in A.1.3, have also to withstand the rubbing and handling expected during the use of the equipment. Markings on knobs, handles, etc., shall survive the continual handling and rubbing as a result of manual ACTUATION. Other markings should be resistant to cleaning, polishing and the like.

A.1.5 Compliance with the requirements for indelibility of markings classified according to A.1.3 and A.1.4 is checked by the tests of Clause A.2 or Clause A.3 using the apparatus shown in Figure 9.

The principal part consists of a disc of hard white buffing felt, 65 mm in diameter and 7,5 mm thick. This is locked against rotation and is arranged to move across the surface to be tested with a stroke of 20 mm and to exert a measurable force on this surface. The standard test shall be 12 strokes (i.e., rotations of the eccentric) and shall take approximately 15 s.

During the tests, the appropriate part of the buffing disc is covered with one layer of white absorbent lint with the nap surface external.

The solvents used are

– neutral liquid detergent blended from alkyl benzene sulphonate and non-ionic detergents or 2 % of a solvent in deionized (distilled) water where the solvent consists of

  • 70 % (with volume) Natriumdodecylbenzylsulfonat, (Isomere), formula: C18H29NaO3S, CAS-No. 25155-30-0, and

  • 30 % (with volume) Glycerin (other names: Glycerol, 1,2,3-Propantriol, Propantriol,E 422), formula: C3H8O3, CAS-No. 56-81-5;

– n-hexane (aliphatic solvent hexane with a content of aromatics of maximum 0,1 volume %, initial boiling point of approximately 69 °C and specific gravity of approximately 0,66 g/cm^3, CAS-No. 110-54-3), and

– deionized (distilled) water.

A.2 Test procedure for markings classified to A.1.3

A.2.1 *The markings under consideration shall withstand drops of detergent standing on the marked surface for a period of 4 h. At the end of this period, the detergent "scab(s)" shall be removed by a very fine spray of warm water (40 ± 5) °C or by lightly wiping with a damp cloth.*

A.2.2 *The sample shall then be allowed to dry completely in an ambient room temperature of (25 ± 5) °C.*

A.2.3 *The sample shall then be rubbed in the apparatus of Figure 9, using dry lint and a weight of 250 g measured as indicated.*

A.2.4 *The sample shall then be rubbed using water-soaked lint and a weight of 250 g.*

A.2.5 *If the shape or position of marking is such that it cannot be bleached or rubbed with this apparatus (for example, by recessing the marked surface), then the tests of A.2.3 and A.2.4 are not applied.*

A.2.6 *At the conclusion of these tests, the marking shall still be legible.*

A.3 Test procedure for markings classified to A.1.4

A.3.1 *The marking under consideration shall be rubbed in the apparatus of Figure 9 using a dry lint and a weight of 750 g.*

A.3.2 *The marking shall then be rubbed in the apparatus using a water-soaked lint and a weight of 750 g.*

A.3.3 *The marking under consideration shall then withstand drops of detergent standing on the marked surface for a period of 4 h. At the end of this period, the detergent "scab(s)" shall be removed by a very fine spray of warm water (40 ± 5) °C or by lightly wiping with a damp cloth.*

A.3.4 *After being allowed to dry, it shall be rubbed in the apparatus using a detergent soaked lint and a weight of 750 g.*

A.3.5 *After surplus detergent has been shaken off, it shall be rubbed in the apparatus, using a petroleum spirit soaked lint and a weight of 750 g.*

A.3.6 *For the tests of A.3.1 to A.3.5, the thickness of the buffing disc can be progressively reduced such that the marking is reached and rubbed. However, the minimum thickness of the buffing disc shall be not less than 2,5 mm. If the thickness of the buffing disc is reduced, the weight of 750 g shall be reduced in linear proportion.*

A.3.7 *At the conclusion of these tests, the marking shall still be legible.*

Annex B
(normative)

Measurement of creepage distances and clearances in air

When determining and measuring CREEPAGE DISTANCES and CLEARANCES, the following assumptions are made, where D is equal to the CLEARANCE in air prescribed for the distance under consideration (see Figure B.1 to Figure B.11 for examples of methods of measurement of CREEPAGE DISTANCE and CLEARANCES):

– a groove may have parallel, converging or diverging side walls;

– if a groove has diverging side walls, it is regarded as an air gap if its minimum width exceeds D/12, its depth exceeds D/2 and its width at the bottom of the groove is at least equal to D/3 (see Figure B.8) but in no case smaller than the minimum value X as permitted in the tabulation below;

– any corner having an angle less than 80° is assumed to be bridged by an insulating link having a width equal to D/3 or 1 mm, whichever is less, which is placed in the most unfavourable position (see Figure B.3);

– if the distance across the top of a groove is a least equal to D/3, or 1 mm, whichever is less, the CREEPAGE DISTANCES path follows the contour of the groove unless otherwise specified immediately above (see Figure B.2);

– for CREEPAGE DISTANCES and CLEARANCES in air between parts moving relatively one to another, these parts are considered to be in their most unfavourable position to each other;

– CREEPAGE DISTANCES determined according to these rules are not less than the corresponding (measured) clearances in air;

– any air gap having a width less than D/3 or 1 mm, whichever is less, is ignored in calculating the total CLEARANCE in air;

– for inserted or set-up barriers, the CREEPAGE DISTANCES are measured through the joint unless the parts are so cemented or heat-sealed together that ingress of humidity or dirt into the joint is not liable to occur.

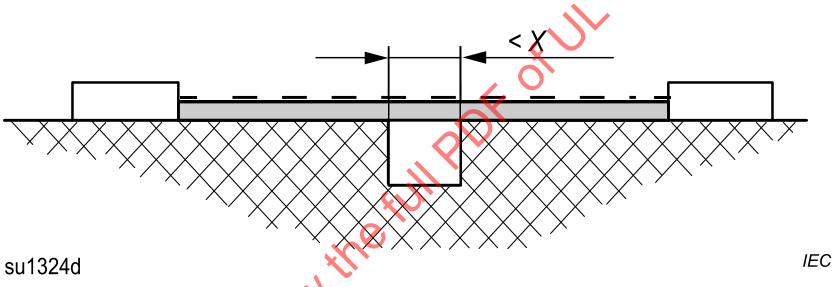
In the examples shown in Figure B.1 to Figure B.11, the following identification is used:

See Table B.1 for the value of X.

Table B.1
Value of *X*

Pollution degree	Width X of grooves: minimum values mm
1	0,25
2	1,0
3	1,5
4	2,5

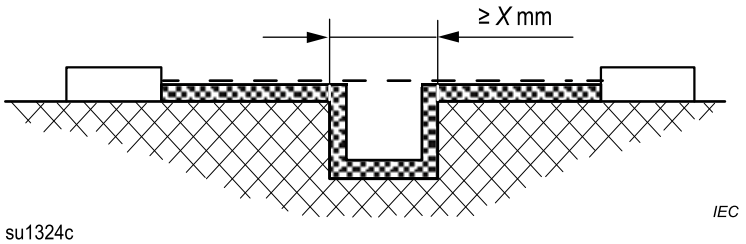
If the associated CLEARANCE is less than 3 mm, the minimum groove width may be reduced to one-third of this CLEARANCE.



The path under consideration includes a groove of any depth, having a width less than *X*.

Rule: The CLEARANCE path is the "line of sight" path.

Figure B.1
Narrow groove

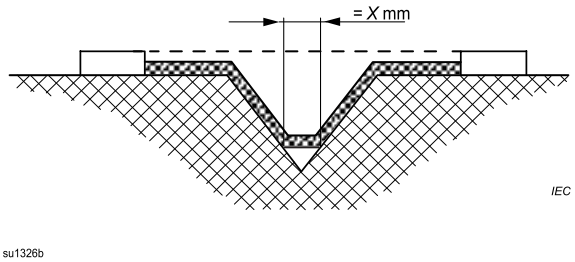


The path under consideration includes a groove of any depth, having a width equal to or more than *X*.

Rule: The CLEARANCE path is the "line of sight" path.

The CREEPAGE DISTANCE path follows the contour of the groove.

Figure B.2
Wide groove



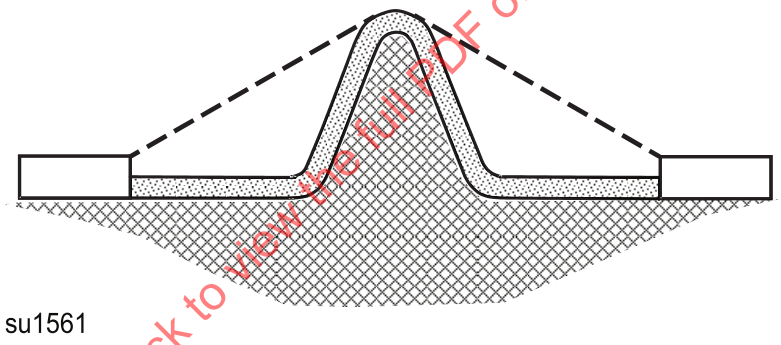
The path under consideration includes a V-shaped groove having a width greater or equal to *X*.

Rule: The CLEARANCE path is the "line of sight" path.

The CREEPAGE DISTANCE path follows the contour of the groove except that it bridges the groove where its width is equal to *X*.

Figure B.3

V-shaped groove



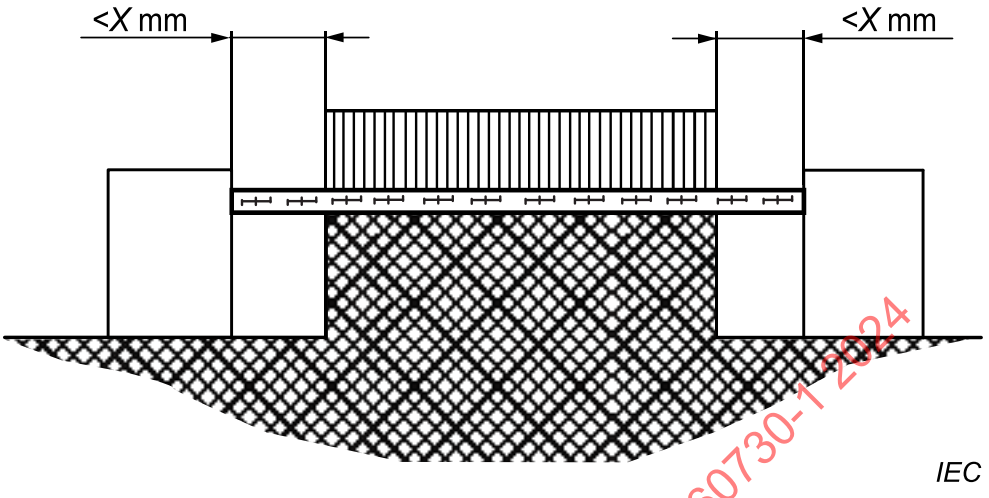
The path under consideration includes a rib.

Rule: The CLEARANCE path is the shortest air path over the top of the rib.

The CREEPAGE DISTANCE path follows the contour of the rib.

Figure B.4

Rib



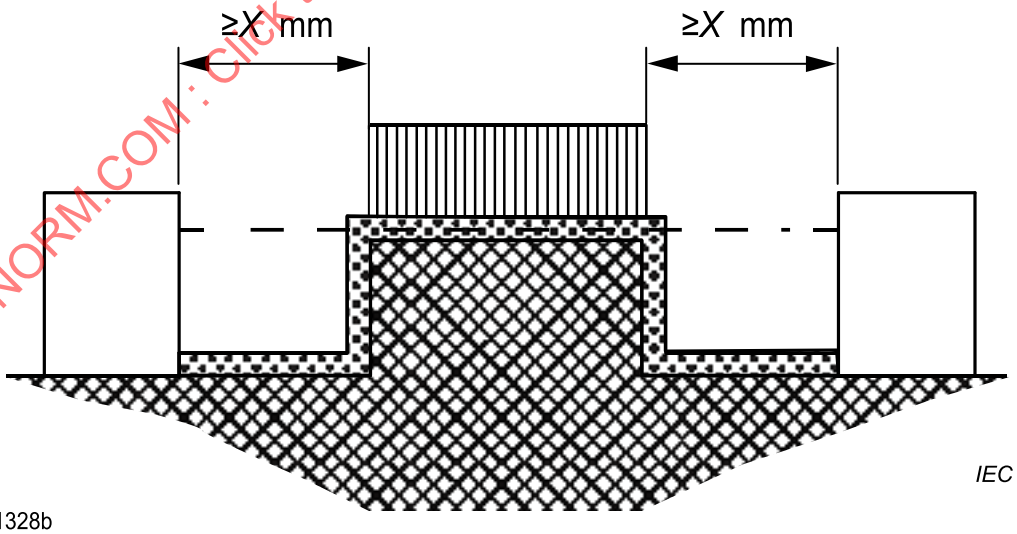
su1329b

The path under consideration includes an uncemented joint and grooves having a width less than *X* on either side.

Rule: The CREEPAGE DISTANCE path and the clearance path is the "line of sight" path as shown.

Figure B.5

Uncemented joint with narrow groove



su1328b

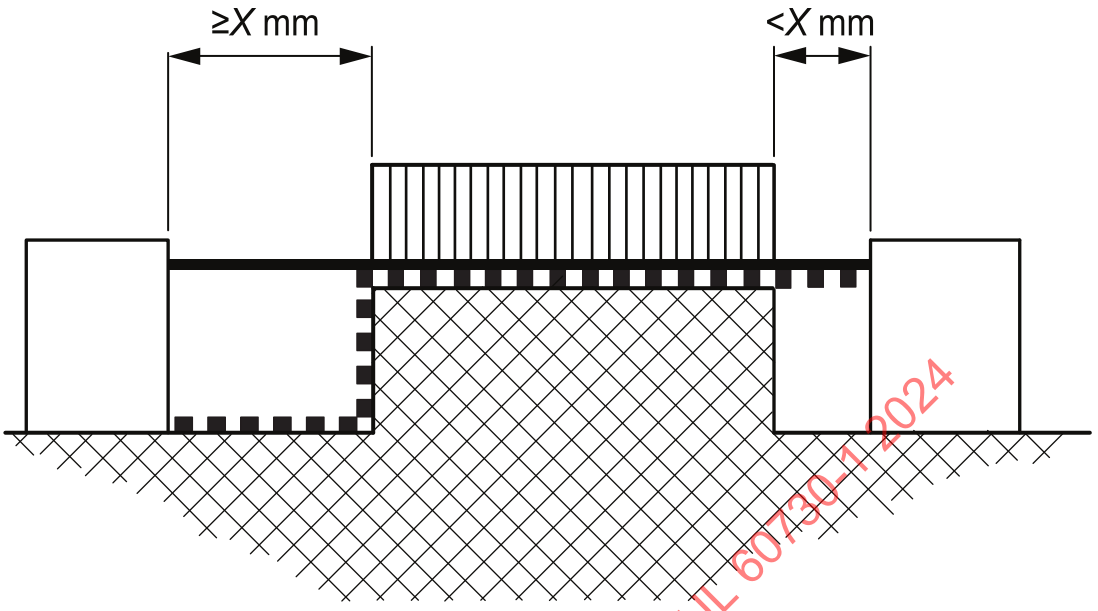
The path under consideration includes an uncemented joint and grooves having a width equal to or more than *X*.

Rule: The CLEARANCE path is the "line of sight" path as shown.

The CREEPAGE DISTANCE path follows the contour of the grooves.

Figure B.6

Uncemented joint with wide groove



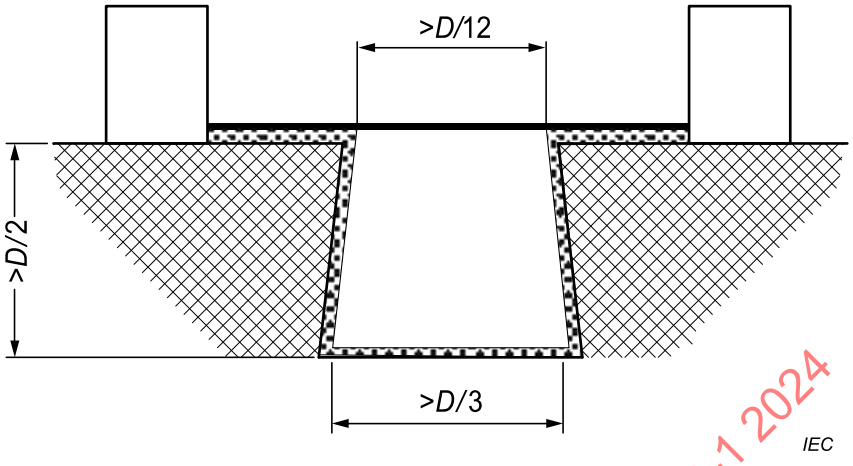
su1330

The path under consideration includes an uncemented joint, a groove on one side having a width less than *X*, and a groove on the other having a width equal to or more than *X*.

Rule: The CLEARANCE path and the CREEPAGE DISTANCE path are as shown.

Figure B.7

Uncemented joint with narrow and wide grooves



su1663a

The path under consideration includes a groove having diverging side walls, a depth equal to or greater than *D/2* and a width exceeding *D/12* at the narrowest part and equal to or greater than *D/3* at the bottom.

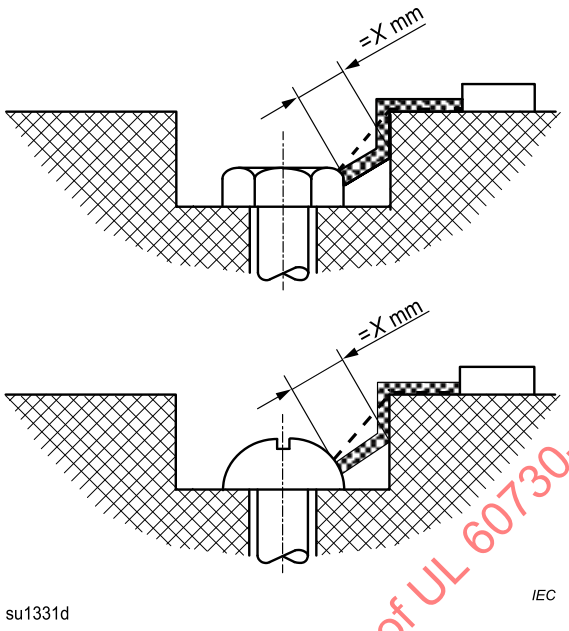
Rule: The CLEARANCE path is equal to the "line of sight" path.

The CREEPAGE DISTANCE path follows the contour of the groove.

The rule for Figure B.3 applies as well to the internal corners if they are less than 80°.

Figure B.8

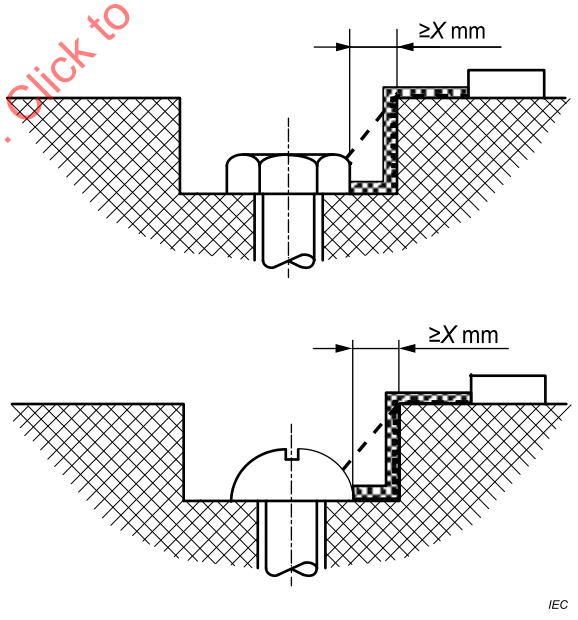
Diverging side walls



Gap between head of screw and wall of recess too narrow to be taken into account for the creepage distance path.

Figure B.9

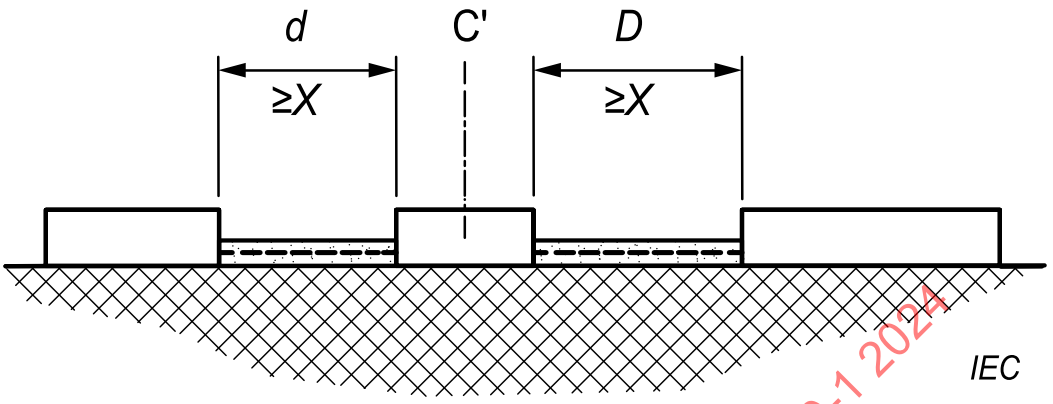
Narrow recess



Gap between head of screw and wall of recess wide enough to be taken into account for the creepage distance path.

Figure B.10

Wide recess



su1569c

CLEARANCE is the distance *d* + *D*

CREEPAGE DISTANCE is also *d* + *D*

Figure B.11

Conductive floating part

Annex C
(informative)

Nominal voltages of supply systems for different modes of overvoltage control

Nominal voltages of supply SYSTEMS for different modes of overvoltage control are as indicated in Table C.1 and Table C.2.

Insulation coordination with regard to transient overvoltage is based on controlled overvoltage conditions. There are two kinds of control:

– inherent control: the condition within an electrical SYSTEM wherein the characteristics of the SYSTEM can be expected to limit the prospective transient overvoltages to a defined level;

– protective control: the condition within an electrical SYSTEM wherein specific overvoltage attenuating means can be expected to limit the prospective transient overvoltages to a defined level.

NOTE The above paragraph is taken from IEC 60664-1:2007, 4.2.3.

Table C.1
Inherent control or equivalent protective control

Voltage line-to-neutral from nominal voltages AC or DC [a] V	Nominal voltages presently used in the world				Rated impulse voltage for equipment [a] V			
	Three-phase four-wire systems with earthed neutral V	Three-phase three-wire systems unearthed V	Single-phase two-wire systems AC or DC V	Single-phase three-wire systems AC or DC V	Overvoltage category I	II	III	IV
50			12,5; 24; 25; 30; 42; 48	30 / 60	330	500	800	1 500
100	66 / 115	66	60		500	800	1 500	2 500
150	120 / 208 [b] 127 / 220	115; 120; 127	110; 120	110 / 220 120 / 240 [c]	800	1 500	2 500	4 000
300	220 / 380 230 / 400 240 / 415 260 / 440 277 / 480	220; 230; 240; 260; 277; 347; 380; 400; 415; 440; 480	220	220 / 440	1 500	2 500	4 000	6 000
600	347 / 600 380 / 660 400 / 690 417 / 720 480 / 830	500; 577; 600	480	480 / 960	2 500	4 000	6 000	8 000
1 000		660; 690; 720; 830; 1 000	1 000		4 000	6 000	8 000	12 000

[a] These columns are taken from IEC 60664-1:2007, Annex F, Table F.1 in which the RATED IMPULSE VOLTAGE values are specified.

[b] Practice in the USA and Canada.

[c] For 120/240 V in Japan, the preferred series of RATED IMPULSE VOLTAGES of 1 500 V, 2 500 V, 4 000 V and 6 000 V are used corresponding to OVERVOLTAGE CATEGORIES I, II, III and IV.

Table C.2
Cases where protective control is necessary and control is provided by surge arresters having a ratio of clamping voltage to rated voltage not smaller than that specified by IEC 60099-1

Voltage line-to-neutral from nominal voltages AC or DC a	Nominal voltages presently used in the world				Rated impulse voltage for equipment [a] V			
	Three-phase four-wire systems with earthed neutral	Three-phase three-wire systems unearthed	Single-phase two-wire systems AC or DC	Single-phase three-wire systems AC or DC	Overvoltage category			
V	V	V	V	V	I	II	III	IV
50			12,5; 24; 25; 30; 42; 48	30/60	330	500	800	1 500
100	66 / 115	66	60		500	800	1 500	2 500
150	120 / 208 [b] 127 / 220	115; 120; 127	110; 120	110/220 120/240	800	1 500	2 500	4 000
300	220 / 380 230 / 400 240 / 415 260 / 440 277 / 480	220; 230; 240; 260; 277	220	220/440	1 500	2 500	4 000	6 000
600	347 / 600 380 / 660 400 / 690 417 / 720 480 / 830	347; 380; 400; 415; 440; 480; 500; 577; 600	480	480/960	2 500	4 000	6 000	8 000
1 000		660; 690; 720; 830; 1 000	1 000		4 000	6 000	8 000	12 000

[a] These columns are taken from IEC 60664-1:2007, Annex F, Table F.1 in which the RATED IMPULSE VOLTAGE values are specified.

[b] Practice in the USA and Canada.

Annex D
(normative)

Overvoltage categories

OVERVOLTAGE CATEGORY is a numeral characterizing a TRANSIENT OVERVOLTAGE condition.

The following information on OVERVOLTAGE CATEGORIES based on IEC 60664-1. IEC TR 60664-2 series may specify a different OVERVOLTAGE CATEGORY for particular applications.

Equipment of OVERVOLTAGE CATEGORY IV is for use at the origin of the installation.

NOTE 1 Examples of such equipment are electricity meters and primary overcurrent protection equipment.

Equipment of OVERVOLTAGE CATEGORY III is equipment in fixed installations and for cases where the reliability and the availability of the equipment is subject to special requirements.

NOTE 2 This category normally applies to CONTROLS intended for connection to FIXED WIRING or for incorporation into equipment intended for permanent connection to FIXED WIRING. When the control or equipment application is provided with a means of suppressing the transient voltage, for the purposes of insulation coordination, the expected impulse voltage is based on the clamping voltage of the voltage surge suppressor.

Equipment of OVERVOLTAGE CATEGORY II is energy consuming equipment to be supplied from the fixed installation.

NOTE 3 This category normally applies to CONTROLS not provided with terminals for FIXED WIRING, or connected after a socket-outlet, or for incorporation into equipment connected after a socket-outlet. CONTROLS intended for permanent connection to FIXED WIRING are considered overvoltage category III; however, where methods of suppressing the transient voltage, such as voltage limiting means at the line terminal or CLEARANCES between conductive parts are incorporated in the CONTROL or equipment, for the purposes of insulation coordination, the expected impulse voltage is based on the clamping voltage of the voltage surge suppressor. Where the contacts of a CONTROL are designed to allow flashover of the transient voltage and are adequate to withstand the let-through current, this can provide adequate suppression; for example, CONTROLS for household appliances satisfying the above descriptions.

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

Equipment of OVERVOLTAGE CATEGORY I is equipment for connection to circuits in which measures are taken to limit TRANSIENT OVERVOLTAGES to an appropriately low level.

NOTE 4 This category normally applies to CONTROLS connected after category II equipment and which, for example, includes electronic logic SYSTEMS, ISOLATED LIMITED SECONDARY CIRCUITS, SELV-circuits or PELV-circuits, and circuits on the secondary side of a transformer.

Annex E
(informative)

Typical usage of controls and related overvoltage categories

Table E.1
Typical usage

Control situation	Overvoltage category			
	I	II	III	IV
Special				
ISOLATED LIMITED SECONDARY CIRCUIT	X			
Transient limited supply	X	X	X	X
Energy consuming utilization equipment				
Integrated and INCORPORATED CONTROLS in household appliances		X		
INDEPENDENTLY MOUNTED CONTROLS for fixed-wiring to energy consuming loads		X	X	
Other household and similar applications:				
CONTROLS which are not integrated, incorporated, or for fixed-wiring to energy consuming loads			X	
CONTROLS mounted at the origin of installation (i.e. service entrance equipment, electricity meters and primary overcurrent equipment)				X
CONTROLS covered by special part 2 considerations	X	X	X	X

Annex F
(normative)

Pollution degrees

F.1 Pollution

The MICRO-ENVIRONMENT determines the effects of POLLUTION on the insulation. The MACRO-ENVIRONMENT, however, shall be taken into account when considering the MICRO-ENVIRONMENT.

Means may be provided to reduce POLLUTION at the insulation under consideration by the effective use of coatings, enclosures, encapsulation or hermetic sealing. Such means to reduce POLLUTION is not effective when the equipment is subject to condensation or if, in normal operation, it generates pollutants itself.

Small CLEARANCES can be bridged completely by solid particles, dust and water and therefore minimum CLEARANCES are specified where POLLUTION can be present in the MICRO-ENVIRONMENT.

NOTE 1 POLLUTION will become conductive in the presence of humidity. POLLUTION caused by contaminated water, soot, metal or carbon dust is inherently conductive.

NOTE 2 Conductive POLLUTION by ionized gases and metallic depositions occurs only in specific instances, for example in arc chambers of switchgear or controlgear, and is not covered by this document.

F.2 Degrees of pollution in the micro-environment

For the purpose of evaluating CREEPAGE DISTANCES and CLEARANCES, the following four degrees of POLLUTION in the MICRO-ENVIRONMENT are established:

– POLLUTION DEGREE 1

No POLLUTION or only dry, non-conductive pollution occurs. The POLLUTION has no influence.

NOTE 1 Special considerations (for example, coating evaluated to Annex L or Annex M, sealed enclosure) are necessary to establish POLLUTION DEGREE 1.

– POLLUTION DEGREE 2

Only non-conductive POLLUTION occurs except that occasionally a temporary conductivity caused by condensation is to be expected.

NOTE 2 POLLUTION DEGREE 2 is representative of normal household air circulation.

NOTE 3 POLLUTION from the operation of contacts is classified as POLLUTION DEGREE 2 unless the area is affected by other POLLUTION, in which case the POLLUTION DEGREE corresponding to the other POLLUTION applies.

– POLLUTION DEGREE 3

Conductive POLLUTION occurs or dry non-conductive POLLUTION occurs which becomes conductive due to condensation which is to be expected.

– POLLUTION DEGREE 4

The POLLUTION generates persistent conductivity caused by conductive dust or by rain or snow.

Annex G
(normative)

Resistance to heat, fire and tracking tests

G.1 Glow-wire test

The glow-wire test is carried out in accordance with IEC 60695-2-10 and IEC 60695-2-11.

The glow-wire test shall be carried out on the complete CONTROL. If this is not possible, on parts removed from the CONTROL. If this is not possible, on test plaques of similar thickness but not thicker than the part.

G.2 Proof tracking test

The proof tracking test is made in accordance with IEC 60112:2020.

For the purpose of this document, the following applies:

– In IEC 60112:2020, Clause 5, Test specimen, Note 3 also applies to the proof tracking tests of Clause 10 of IEC 60112:2020.

– In IEC 60112:2020, Clause 7, Test apparatus, Note 1 in 7.1 does not apply. The test solution A described in IEC 60112:2020, 7.3 is used.

– In IEC 60112:2020, 8.2, Preparation, the voltage referred to in the last sentence is set in 21.2.9 of this document. The proof tracking test of IEC 60112:2020, Clause 10 is carried out, five times.

G.3 Ball pressure test

G.3.1 Ball pressure tests

The ball pressure test is carried out in accordance with IEC 60695-10-2.

G.3.2 Ball pressure test 1

For the purpose of this document, the temperature in the heating oven is the highest of:

– 20 °C ± 2 K in excess of the maximum temperature measured during the tests of Clause 16,

– 75 °C ± 2 °C, – as declared.

NOTE 1 For CONTROLS intended for incorporation into appliances within the scope of IEC 60335-1:2020, the temperature might differ as per 30.1 of that standard.

The support and the ball shall be at the prescribed test temperature before the test is started.

NOTE 2 The test is not made on parts of ceramic material and glass.

G.3.3 Ball pressure test 2

The ball pressure test is carried out as described in G.3.2 except that the temperature in the heating oven shall be T_b ± 2 °C where T_b is equal to the higher of:

– 100 °C when T_{max} is 30 °C and up to, but excluding, 55 °C;

– 125 °C when T_{max} is 55 °C and up to, but excluding, 85 °C;

– T_{max} + 40 °C if T_{max} is 85 °C or above;

– 20 K in excess of the maximum temperature recorded during the heating test of Clause 16;

– the temperature achieved during the test of 13.1.3.8, if this is higher than the temperature given in the preceding four dashed paragraphs.

NOTE For controls intended for incorporation into appliances within the scope of IEC 60335-1:2020, the temperature might differ as per 30.1 of that standard.

Annex H
(normative)

Requirements related to functional safety

Annex H supplements or modifies the corresponding clauses of this document, However, this is not applicable for Clause H.5 and H.25.4 to H.25.10.

H.3 Terms and definitions

Add the following definitions:

H.3.16 Definitions relating to the structure of controls using software

H.3.16.1
DUAL CHANNEL
structure which contains two mutually independent functional means to execute specified OPERATIONS

Note 1 to entry: Special provision may be made for control of COMMON MODE FAULT/errors. It is not required that the two channels each be algorithmic or logical in nature.

H.3.16.2
DUAL CHANNEL (DIVERSE) WITH COMPARISON
DUAL CHANNEL structure containing two different and mutually independent functional means, each capable of providing a declared response, in which comparison of output signals is performed for FAULT/error recognition

H.3.16.3
DUAL CHANNEL (HOMOGENEOUS) WITH COMPARISON
DUAL CHANNEL structure containing two identical and mutually independent functional means, each capable of providing a declared response, in which comparison of internal signals or output signals is performed for FAULT/error recognition

H.3.16.4
SINGLE CHANNEL
structure in which a single functional means is used to execute specified OPERATIONS

H.3.16.5
SINGLE CHANNEL WITH FUNCTIONAL TEST
SINGLE CHANNEL structure in which test data is introduced to the functional unit prior to its OPERATION

H.3.16.6
SINGLE CHANNEL WITH PERIODIC SELF-TEST
SINGLE CHANNEL structure in which components of the CONTROL are periodically tested during OPERATION

H.3.16.7
SINGLE CHANNEL WITH PERIODIC SELF-TEST AND MONITORING
SINGLE CHANNEL STRUCTURE WITH PERIODIC SELF-TEST in which independent means, each capable of providing a declared response, monitor such aspects as safety-related timing, sequences and software operations

H.3.17 Definitions relating to error avoidance in controls using software

H.3.17.1
DYNAMIC ANALYSIS
method of analysis in which inputs to a CONTROL are simulated and logic signals at the circuit nodes are examined for correct value and timing

H.3.17.2
FAILURE RATE CALCULATION
calculation of the theoretical number of FAILURES of a given kind per unit

Note 1 to entry: For example, FAILURES per hour or FAILURES per cycle of operation.

H.3.17.3
HARDWARE ANALYSIS
evaluation process in which the circuitry and components of a CONTROL are examined for correct function within their specified tolerances and ratings

H.3.17.4
HARDWARE SIMULATION
method of analysis in which circuit function and component tolerances are examined by use of a computer model

H.3.17.5
INSPECTION
evaluation process in which the hardware or the software specification, design or code is examined in detail by a person or group other than the designer or programmer in order to identify possible errors

Note 1 to entry: In contrast to the WALK-THROUGH, the designer or programmer is passive during this evaluation.

H.3.17.6
OPERATIONAL TEST
evaluation process in which a CONTROL is operated under the extremes of its intended operating conditions (for example, cycle rate, temperature, voltage) to detect errors in design or construction

H.3.17.7 Static analysis

H.3.17.7.1
STATIC ANALYSIS – HARDWARE
evaluation process in which a hardware model is systematically assessed

Note 1 to entry: The evaluation may typically be computer-aided and may include examination of parts lists and circuit layouts, an interface analysis and functional checks.

H.3.17.7.2
STATIC ANALYSIS – SOFTWARE
evaluation process in which a software programme is systematically assessed without necessarily executing the programme

Note 1 to entry: The evaluation may typically be computer-aided and usually includes analysis of such features as programme logic, data paths, interfaces and variables.

H.3.17.8
SYSTEMATIC TEST
method of analysis in which a SYSTEM or a software programme is assessed for correct execution by the introduction of selected test data

Note 1 to entry: For example, see BLACK BOX TEST and WHITE BOX TEST.

H.3.17.8.1
BLACK BOX TEST
SYSTEMATIC TEST in which test data derived from the functional specification is introduced to a functional unit to assess its correct OPERATION

H.3.17.8.2
WHITE BOX TEST
SYSTEMATIC TEST in which test data based on the software specification is introduced to a programme to assess the correct OPERATION of subparts of the programme

Note 1 to entry: For example, data may be selected to execute as many instructions as possible, as many branches as possible, as many subroutines as possible, etc.

H.3.17.9
WALK-THROUGH
evaluation process in which a designer or programmer leads members of an evaluation team through the hardware design, software design and/or software code the designer or programmer has developed in order to identify possible errors

Note 1 to entry: In contrast to the INSPECTION, the designer or programmer is active during this review.

H.3.17.10
SOFTWARE FAULT/ERROR DETECTION TIME
the period of time between the occurrence of a FAULT/error and the INITIATION by the software of a declared CONTROL response

H.3.18 Definitions relating to fault/error control techniques for controls using software

H.3.18.1 Bus redundancy

H.3.18.1.1
FULL BUS REDUNDANCY
FAULT/error CONTROL technique in which full redundant data and/or address are provided by means of redundant bus structure

H.3.18.1.2
MULTI-BIT BUS PARITY
FAULT/error CONTROL technique in which the bus is extended by two or more bits and these additional bits are used for error detection

H.3.18.2
CODE SAFETY
FAULT/error CONTROL techniques in which protection against coincidental and/or systematic errors in input and output information is provided by the use of DATA REDUNDANCY and/or TRANSFER REDUNDANCY (see also H.3.18.2.1 and H.3.18.2.2)

H.3.18.2.1
DATA REDUNDANCY
form of CODE SAFETY in which the storage of redundant data occurs

H.3.18.2.2
TRANSFER REDUNDANCY
form of CODE SAFETY in which data is transferred at least twice in succession and then compared

Note 1 to entry: This technique will recognize intermittent errors.

H.3.18.3
COMPARATOR
device used for FAULT/error CONTROL in DUAL CHANNEL structures

Note 1 to entry: The device compares data from the two channels and initiates a declared response if a difference is detected.

H.3.18.4
DC FAULT MODE
STUCK-AT FAULT MODE incorporating short circuits between signal lines

Note 1 to entry: Because of the number of possible shorts in the device under test, usually only shorts between related signal lines will be considered. A logical signal level is defined, which dominates in cases where the lines try to drive to the opposite level.

H.3.18.5
EQUIVALENCE CLASS TEST
SYSTEMATIC TEST intended to determine whether the instruction decoding and execution are performed correctly

Note 1 to entry: The test data is derived from the CPU instruction specification.

Note 2 to entry: Similar instructions are grouped and the input data set is subdivided into specific data intervals (equivalence classes). Each instruction within a group processes at least one set of test data, so that the entire group processes the entire test data set. The test data can be formed from the following:

– data from valid range;

– data from invalid range;

– data from the bounds;

– extreme values and their combinations.

The tests within a group are run with different addressing modes, so that the entire group executes all addressing modes.

H.3.18.6
ERROR RECOGNIZING MEANS
independent means provided for the purpose of recognizing errors internal to the SYSTEM

Note 1 to entry: Examples are monitoring devices, COMPARATORS, and code generators.

H.3.18.7
HAMMING DISTANCE
statistical measure, representing the capability of a code to detect and correct errors

Note 1 to entry: The HAMMING DISTANCE of two code words is equal to the number of positions different in the two code words.

Note 2 to entry: See H. Holscher and J. Rader; "Microcomputers in safety techniques." Verlag TUV Bayern. TUV Rheinland. (ISBN 3-88585-315-9).

H.3.18.8
INPUT COMPARISON
FAULT/error CONTROL technique by which inputs that are designed to be within specified tolerances are compared

H.3.18.9
INTERNAL ERROR DETECTION
FAULT/error CONTROL technique in which special circuitry is incorporated to detect or correct errors

H.3.18.10 Programme sequence

H.3.18.10.1
FREQUENCY MONITORING
FAULT/error CONTROL technique in which the clock frequency is compared with an independent fixed frequency

Note 1 to entry: An example is comparison with the line supply frequency.

H.3.18.10.2
LOGICAL MONITORING OF THE PROGRAMME SEQUENCE
FAULT/error CONTROL technique in which the logical execution of the programme sequence is monitored

Note 1 to entry: Examples are the use of counting routines or selected data in the programme itself or by independent monitoring devices.

H.3.18.10.3
TIME-SLOT AND LOGICAL MONITORING
this is a combination of H.3.18.10.2 and H.3.18.10.4

H.3.18.10.4
TIME-SLOT MONITORING OF THE PROGRAMME SEQUENCE
FAULT/error CONTROL technique in which timing devices with an independent time base are periodically triggered in order to monitor the programme function and sequence

Note 1 to entry: An example is a watchdog TIMER.

H.3.18.11
MULTIPLE PARALLEL OUTPUTS
FAULT/error CONTROL technique in which independent outputs are provided for operational error detection or for INDEPENDENT COMPARATORS

H.3.18.12
OUTPUT VERIFICATION
FAULT/error CONTROL technique in which outputs are compared to independent inputs

Note 1 to entry: This technique may relate an error to the output which is defective.

H.3.18.13
PLAUSIBILITY CHECK
FAULT/error CONTROL technique in which programme execution, inputs or outputs are checked for inadmissible programme sequence, timing or data

Note 1 to entry: Examples are the introduction of an additional interrupt after completion of a certain number of cycles or checks for division by zero.

H.3.18.14
PROTOCOL TEST
FAULT/error CONTROL technique in which data is transferred to and from computer components to detect errors in the internal communications protocol

H.3.18.15
RECIPROCAL COMPARISON
FAULT/error CONTROL technique used in DUAL CHANNEL (homogeneous) structures in which a comparison is performed on data reciprocally exchanged between the two processing units

Note 1 to entry: Reciprocal refers to an exchange of similar data.

H.3.18.17
REDUNDANT MONITORING
availability of two or more independent means such as watchdog devices and COMPARATORS to perform the same task

H.3.18.18
SCHEDULED TRANSMISSION
communication procedure in which information from a particular transmitter is allowed to be sent only at a predefined point in time and sequence, otherwise the receiver will treat it as a communication error

H.3.18.19
SOFTWARE DIVERSITY
FAULT/error CONTROL technique in which all or parts of the software are incorporated twice in the form of alternate software code

Note 1 to entry: For example, the alternate forms of software code may be produced by different programmers, different languages or different compiling schemes and may reside in different hardware channels or in different areas of memory within a SINGLE CHANNEL.

H.3.18.20
STUCK-AT FAULT MODE
FAULT mode representing an open-circuit or a non-varying signal level

Note 1 to entry: These are usually referred to as "stuck-open", "stuck at 1" or "stuck at 0".

H.3.18.21
TESTED MONITORING
the provision of independent means such as watchdog devices and COMPARATORS which are tested at start-up or periodically during OPERATION

H.3.18.22
TESTING PATTERN
FAULT/error CONTROL technique used for periodic testing of input units, output units and interfaces of the CONTROL

Note 1 to entry: A test pattern is introduced to the unit and the results compared to expected values. Mutually independent means for introducing the test pattern and evaluating the results are used. The test pattern is constructed so as not to influence the correct OPERATION of the CONTROL.

H.3.19 Definitions relating to memory tests for controls using software

H.3.19.1
ABRAHAM TEST
specific form of a VARIABLE MEMORY pattern test in which all stuck-at and coupling FAULTS between memory cells are identified

Note 1 to entry: The number of OPERATIONS required to perform the entire memory test is about 30 *n*, where *n* is the number of cells in the memory. The test can be made transparent for use during the operating cycle, by partitioning the memory and testing each partition in different time segments.

Note 2 to entry: See Abraham, J.A.; Thatte, S.M.; "Fault coverage of test programs for a microprocessor", Proceedings of the IEEE Test Conference 1979, pp 18-22.

H.3.19.2
GALPAT MEMORY TEST
FAULT/error CONTROL technique in which a single cell in a field of uniformly written memory cells is inversely written, after which the remaining memory under test is inspected

Note 1 to entry: After each read OPERATION to one of the remaining cells in the field, the inversely written cell is also inspected and read. This process is repeated for all memory cells under test. A second test is then performed as above on the same memory range without inverse writing to the test cell.

Note 2 to entry: The test can be made transparent for use during the operating cycle, by partitioning the memory and testing each partition in different time segments (see TRANSPARENT GALPAT TEST).

H.3.19.2.1
TRANSPARENT GALPAT TEST
GALPAT MEMORY TEST in which first a signature word is formed representing the content of the memory range to be tested and this word is saved

Note 1 to entry: The cell to be tested is inversely written and the test is performed as above. However, the remaining cells are not inspected individually, but by formation of and comparison to a second signature word. A second test is then performed as above by inversely writing the previously inverted value to the test cell.

Note 2 to entry: This technique recognizes all static bit errors as well as errors in interfaces between memory cells.

H.3.19.3 Checksum

H.3.19.3.1
MODIFIED CHECKSUM
FAULT/error CONTROL technique in which a single word representing the contents of all words in memory is generated and saved

Note 1 to entry: During self-test, a checksum is formed from the same algorithm and compared with the saved checksum.

Note 2 to entry: This technique recognizes all the odd errors and some of the even errors.

H.3.19.3.2
MULTIPLE CHECKSUM
FAULT/error CONTROL technique in which a separate words representing the contents of the memory areas to be tested are generated and saved

Note 1 to entry: During self-test, a checksum is formed from the same algorithm and compared with the saved checksum for that area.

Note 2 to entry: This technique recognizes all the odd errors and some of the even errors.

H.3.19.4 Cyclic redundancy check (CRC)

H.3.19.4.1
CRC – SINGLE WORD
FAULT/error CONTROL technique in which a single word is generated to represent the contents of memory

Note 1 to entry: During self-test, the same algorithm is used to generate another signature word which is compared with the saved word.

Note 2 to entry: This technique recognizes all one-bit, and a high percentage of multi-bit, errors.

H.3.19.4.2
CRC – DOUBLE WORD
FAULT/error CONTROL technique in which at least two words are generated to represent the contents of memory

Note 1 to entry: During self-test, the same algorithm is used to generate the same number of signature words which are compared with the saved words.

Note 2 to entry: This technique can recognize one-bit and multi-bit errors with a greater accuracy than in CRC – SINGLE WORD.

H.3.19.5
REDUNDANT MEMORY WITH COMPARISON
structure in which the safety-related contents of memory are stored twice in different format in separate areas so that they can be compared for error control

H.3.19.6
STATIC MEMORY TEST
FAULT/error control technique which is intended to detect only static errors

H.3.19.6.1
CHECKERBOARD MEMORY TEST
STATIC MEMORY TEST in which a checkerboard pattern of zeros and ones is written to the memory area under test and the cells are inspected in pairs

Note 1 to entry: The address of the first cell in each pair is variable and the address of the second cell is derived from a bit inversion of the first address. In the first INSPECTION, the variable address is first incremented to the end of the address space of the memory and then decremented to its original value. The test is repeated with the checkerboard pattern inversed.

H.3.19.6.2
MARCHING MEMORY TEST
STATIC MEMORY TEST in which data is written to the memory area under test as in normal operation

Note 1 to entry: Every cell is then inspected in ascending order and a bit inversion performed on the contents. The inspection and bit inversion are then repeated in descending order. Then this process is repeated after first performing a bit inversion on all the memory cells under test.

H.3.19.7
WALKPAT MEMORY TEST
FAULT/error control technique in which a standard data pattern is written to the memory area under test as in normal operation

Note 1 to entry: A bit inversion is performed on the first cell and the remaining memory area is inspected. Then the first cell is again inverted and the memory inspected. This process is repeated for all memory cells under test. A second test is conducted by performing a bit inversion of all cells in memory under test and proceeding as above.

Note 2 to entry: This technique recognizes all static bit errors as well as errors in interfaces between memory cells.

H.3.19.8 Word protection

H.3.19.8.1
WORD PROTECTION WITH MULTI-BIT REDUNDANCY
a FAULT/error control technique in which redundant bits are generated and saved for each word in the memory area under test

Note 1 to entry: As each word is read, a parity check is conducted.

Note 2 to entry: An example is a Hamming code which recognizes all one and two bit errors as well as some three bit and multi-bit errors.

H.3.19.8.2
WORD PROTECTION WITH SINGLE BIT REDUNDANCY
a FAULT/error control technique in which a single bit is added to each word in the memory area under test and saved, creating either even parity or odd parity

Note 1 to entry: As each word is read, a parity check is conducted.

Note 2 to entry: This technique recognizes all odd bit errors.

H.3.20 Definitions of software terminology – General

H.3.20.1
COMMON MODE ERROR
error(s) in a DUAL CHANNEL or other redundant structure such that each channel or structure is affected simultaneously and in the same manner

H.3.20.2
COMMON CAUSE ERROR
errors of different items, resulting from a single event, where these errors are not consequences of each other

Note 1 to entry: COMMON CAUSE ERRORS should not be confused with COMMON MODE ERRORS.

H.3.20.3
FAILURE MODES AND EFFECTS ANALYSIS
FMEA
analytical technique in which the FAILURE modes of each hardware component are identified and examined for their effects on the safety-related functions of the CONTROL

H.3.20.4
INDEPENDENT
not being adversely influenced by the control data flow and not being impaired by FAILURE of other CONTROL functions, or by common mode effects

H.3.20.5
INVARIABLE MEMORY
memory ranges in a processor SYSTEM containing data which is not intended to vary during programme execution

Note 1 to entry: INVARIABLE MEMORY may include RAM construction where the data is not intended to vary during programme execution.

H.3.20.6
VARIABLE MEMORY
memory ranges in a processor SYSTEM containing data which is intended to vary during programme execution

H.3.21 Definitions relating to classes of control functions

For the evaluation of protective measures for FAULT tolerance and avoidance of HAZARDS, it is necessary to classify CONTROL functions with regard to their FAULT behaviour.

At the classification of CONTROL functions, their integration into the complete safety concept of the appliance shall be taken into account.

NOTE A CONTROL function consists of the entire loop beginning with the sensing means through the processing circuitry (hardware and software if used) and including the actuator drive.

For the purpose of evaluating the design of a CONTROL function, present requirements recognise three distinct classes, given in the following definitions.

H.3.21.1
CLASS A CONTROL FUNCTION
CONTROL functions which are not intended to be relied upon for the safety of the application

Note 1 to entry: Examples are: room THERMOSTATS, temperature CONTROL.

H.3.21.2
CLASS B CONTROL FUNCTION
CONTROL functions which are intended to prevent an unsafe state of the appliance

Note 1 to entry: FAILURE of the CONTROL function will not lead directly to a hazardous situation.

Note 2 to entry: Examples are: thermal limiter, pressure limiter.

H.3.21.3
CLASS C CONTROL FUNCTION
CONTROL functions which are intended to prevent special HAZARDS such as explosion or whose FAILURE could directly cause a HAZARD in the appliance

Note 1 to entry: Examples are: burner CONTROL SYSTEMS, THERMAL CUT-OUTS for closed water SYSTEMS (without vent protection).

H.3.22 Definitions relating to functional safety

H.3.22.1
FUNCTIONAL SAFETY
correct operation of the declared safety related output function(s), failure or malfunction of which, can cause a hazard

Note 1 to entry: The hazard could result from a loss of protective function (output function) leading to a risk of explosion, excessive temperature, electric shock, fire and/or personal injury, etc.

H.3.22.2
FAULT TOLERATING TIME
time between the occurrence of a FAULT and the shut-down of the controlled equipment, which is tolerated by the application without creating a hazardous situation

Note 1 to entry: Actions other than shut-down of the controlled equipment are possible if they can be shown to prevent hazardous situations.

H.3.22.3
FAULT REACTION TIME
time between the occurrence of a FAULT and the point where the CONTROL has reached a DEFINED STATE

H.3.22.4
DEFINED STATE
state of a CONTROL with the following characterisation:

a) the CONTROL passively assumes a state in which the output terminals ensure a safe situation under all circumstances. When the cause of the transition to DEFINED STATE is lifted, the application should start-up in accordance with the appropriate requirements; or

b) the CONTROL actively executes a protective action, within the time as specified in the relevant part 2, causing a shut-down, or preventing an unsafe condition; or

c) the CONTROL remains in OPERATION, continuing to satisfy all safety related functional requirements

H.3.22.5
COMPLEX ELECTRONICS
denote assemblies which use electronic components with the following characteristics:

a) the component provides more than one functional output;

b) it is impractical or impossible to represent the FAILURE mode of such a component by stuckat and cross-links at the pins or by other FAILURE modes which are described in Table 14.

H.3.22.6
RESET
action which provides reset from safe-state to allow the SYSTEM to attempt a restart

H.3.22.7
DEGRADATION (OF PERFORMANCE)
undesired departure in the operational performance of any device, equipment or SYSTEM from its intended performance

Note 1 to entry: The term "degradation" can apply to temporary or permanent FAILURE.

[SOURCE: IEC 60050-161:1990, 161-01-19]

H.3.22.8
HARM
physical injury or damage to health of people, or damage to property or the environment

[SOURCE: ISO/IEC Guide 51:2014, 3.1]

H.3.22.9
HAZARD
potential source of HARM

[SOURCE: ISO/IEC Guide 51:2014, 3.2]

H.3.22.10
RISK
combination of the probability of occurrence of HARM and the severity of that HARM

[SOURCE: ISO/IEC Guide 51:2014, 3.9]

H.3.23 Definitions related to access to data exchange

H.3.23.1
SEQUENCE NUMBER
additional data field containing a number that changes in a predefined way from message to message

H.3.23.2
TIME STAMP
information concerning time of TRANSMISSION attached to a message by the sender

H.3.23.3
SOURCE AND DESTINATION IDENTIFIER
identifier which is assigned to each entity

Note 1 to entry: This identifier can be a name, number or arbitrary bit pattern. This identifier will be used for the safety-related communication. Usually the identifier is added to the USER data.

H.3.23.4
FEED-BACK MESSAGE
response from a receiver to the sender, via a return channel

H.3.23.5
IDENTIFICATION PROCEDURE
procedure that forms a part of the safety-related application process

Note 1 to entry: Two types of IDENTIFICATION PROCEDURE can be distinguished:

– bi-directional identification – Where a return communication channel is available, exchange of entity identifiers between senders and receivers of information can provide additional assurance that the communication is actually between the intended parties,

– dynamic IDENTIFICATION PROCEDURES – Dynamic exchange of information between senders and receivers, including transformation and feedback of received information to the sender. Can provide assurance that the communicating parties not only claim to possess the correct identity, but also behave in the manner expected. This type of dynamic IDENTIFICATION PROCEDURE can be used to preface the transmission of information between communicating safety-related processes and/or it can be used during the information transmission itself.

H.3.23.6
SAFETY CODE
redundant data included in a safety-related message to permit data corruptions to be detected by the safety-related transmission function

H.3.23.7
CRYPTOGRAPHIC TECHNIQUES
output data are calculated by an algorithm using input data and a key as a parameter

Note 1 to entry: By knowing the output data, it is impossible within a reasonable time to calculate the input data without knowledge of the key. It is also impossible within a reasonable time to derive the key from the output data, even if the input data are known.

H.3.23.8
TIME-OUT
delay between two messages exceeding a predefined allowed maximum time

Note 1 to entry: If this is the case, an error can be assumed.

H.3.23.9
PUBLIC NETWORK
data and signals not confined to the physical space within the household, or locations specified as being covered within the scope of this document

Note 1 to entry: Examples of PUBLIC NETWORKS include but are not limited to:

– Internet;

– Wi-Fi Devices;

– Bluetooth > 10 m Devices.

H.5 Information

Table H.1
Additional items to Table 1

	Information	Clause or subclause	Method
H.1	For integrated and incorporated ELECTRONIC CONTROLS, if any protection against mains borne perturbations, magnetic and electromagnetic disturbances is claimed, which of the tests of Clause H.25 shall be performed and the effect on controlled output(s) and function after a FAILURE to operate as a result of each test	Table H.12, H.25.2 H.25.14	X
H.2	For other than integrated and incorporated ELECTRONIC CONTROLS, the effect on controlled output(s) and function after a FAILURE to operate as a result of the tests of Clause H.25	H.25.1 H.25.14	X
H.3	Software sequence documentation [a b c d]	H.9.12.2.9	X
H.4	Programme documentation [a d e]	H.9.12.2.9 H.9.12.2.11	X
H.5	Software FAULT analysis [a c d]	H.9.12, 13.1.3	X
H.6	Software class(es) and structure [f] This information is not required for class A CONTROLS	H.9.12.2 H.9.12.3 H.13.2.2.1 H.13.2.3.1	D
H.7	Analytical measures and FAULT/error control techniques employed [a g]	H.9.12.1.2 H.9.12.2.2 H.9.12.2.4	X
H.8	SOFTWARE FAULT/ERROR DETECTION TIME(S) for CONTROLS with software classes B or C [a h]	H.3.17.10 H.9.12.2.6	X
H.9	CONTROL response(s) in case of detected FAULT/error [a]	H.9.12.2.7	X
H.10	CONTROLS subjected to a second FAULT analysis and declared condition as a result of the second FAULT	H.13.2.3	X
H.11	FAULT reaction time	H.3.22.2 H.13.2.2.2 H.13.2.2.3 H.13.2.3.2 H.13.2.3.3 H.13.2.4.2 H.13.2.4.3	X
H.12	Class or classes of CONTROL function(s)	H.13.2.2 H.13.2.3	X

[a] For CONTROLS declared as entirely class A, the requirements H.3, H.4, H.5, H.7, H.8 and H.9 of Table H.1 are exempted. For CONTROLS with software classes B or C, information shall be provided only for the safety-related segments of the software. Information on the non-safety related segments shall be sufficient to establish that they do not influence the safety-related segments.

[b] The software sequence shall be documented and, together with the OPERATING SEQUENCE of table requirement 46, shall include a description of the CONTROL SYSTEM philosophy, the CONTROL flow, data flow and the timings.

[c] Safety-related data and safety-related segments of the software sequence, the malfunction of which could result in non-compliance with the requirements of Clause 13, 19, 24 and H.25 shall be identified. This identification shall include the OPERATING SEQUENCE and may, for example, take the form of a FAULT tree analysis which shall include those FAULT/errors of Table H.2 which could result in non-compliance. The software FAULT analysis shall be related to the hardware fault analysis in H.13.2.

[d] Examples of other information which may be suitable for inclusion in the documentation required by footnotes a, b, c, e, f and g are:

Original software SYSTEM specification, for example:

Table H.1 Continued on Next Page

Table H.1 Continued

	Information	Clause or subclause	Method
	− functional specification, including procedure for restart on loss of supply,		
	− module design, including description of equipment interfaces, and description of user interfaces,		
	− detailed design, including description of use of memory,		
	− code listing, including programming language identification, comments and listing of subroutines,		
	− test specification,		
	− manuals for installation, use and/or maintenance.		
	[e] Programming documentation shall be supplied in a programming design language declared by the manufacturer.		
	[f] Within a CONTROL, different software classes may apply to different CONTROL functions. Examples of CONTROL functions that may include software classes A to C are as follows:		
	Class A – Examples are room thermostats, humidity controls, lighting controls, timers and time switches.		
	Class B – An example is a thermal cut-out.		
	Class C – Examples are automatic burner CONTROLS and thermal cut-outs for closed water heater SYSTEMS (unvented).		
	[g] Measures to be declared are those chosen by the manufacturer from the requirements of H.9.12.1.2 toH.9.12.2.4 inclusive.		
	[h] This can be expressed as a time following the execution of a specific software segment.		

H.9 Constructional requirements

H.9.12 Controls using software

CONTROLS using software shall be so constructed that the software does not impair compliance with the requirements of this document.

Compliance is checked by the tests for ELECTRONIC CONTROLS in this document, by INSPECTION according to the requirements of H.9.12 and by examination of the documentation required in Table H.1, requirements H.3 to H.9 inclusive.

Subclauses H.9.12.1 to H.9.12.4 inclusive are only applicable to CONTROL functions using software class B or class C.

Subclause H.9.12.4 contains additional requirements for REMOTELY ACTUATED CONTROL FUNCTIONS.

H.9.12.1 Requirements for the architecture

H.9.12.1.1 CONTROL functions with software class B or C shall use measures to CONTROL and avoid software-related FAULTS/errors in safety-related data and safety-related segments of the software, as detailed in H.9.12.1.2 to H.9.12.3 inclusive.

H.9.12.1.2 Structure for control functions with software class B or C

H.9.12.1.2.1 CONTROL functions with software class C shall have one of the following structures:

– SINGLE CHANNEL WITH PERIODIC SELF-TEST AND MONITORING (H.3.16.7);

– DUAL CHANNEL (HOMOGENOUS) WITH COMPARISON (H.3.16.3);

– DUAL CHANNEL (DIVERSE) WITH COMPARISON (H.3.16.2).

NOTE Comparison between DUAL CHANNEL structures can be performed:

– by the use of a COMPARATOR (H.3.18.3), or

– by RECIPROCAL COMPARISON (H.3.18.15).

H.9.12.1.2.2 CONTROL functions with software class B shall have one of the following structures:

– SINGLE CHANNEL WITH FUNCTIONAL TEST (H.3.16.5);

– SINGLE CHANNEL WITH PERIODIC SELF-TEST (H.3.16.6);

– DUAL CHANNEL without comparison (H.3.16.1).

A software class C structure is also acceptable for a software class B structure.

H.9.12.1.3 Other structures are permitted if they can be shown to provide an equivalent level of safety to those in H.9.12.1.2.

H.9.12.2 Measures to control faults/errors

H.9.12.2.1 When redundant memory with comparison is provided on two areas of the same component, the data in one area shall be stored in a different format from that in the other area (see H.3.18.19 SOFTWARE DIVERSITY).

H.9.12.2.2 CONTROLS with software class C using dual channel structures with comparison shall have additional FAULT/error detection means (such as PERIODIC FUNCTIONAL TESTS, PERIODIC SELF-TESTS, or independent monitoring) for any FAULT/errors not detected by the comparison.

H.9.12.2.3 For CONTROLS with software class B or C, means shall be provided for the recognition and control of errors in transmissions to external safety-related data paths within a closed network (non-public network). Such means shall take into account errors in data, addressing, transmission timing and sequence of protocol (see Table H.2, external communication).

H.9.12.2.4 For CONTROL with software class B or C, the manufacturer shall provide, within the control, measures to address the FAULT/errors in safety-related segments and data indicated in Table H.2 and declared in Table H.1, requirement H.5.

Table H.2
Acceptable measures to address fault/errors a

Component b	Fault/error	Software class		Example of acceptable measures c d e	Definitions
		B	C		
1. CPU					
1.1 Registers	Stuck-at	rq		Functional test, or	H.3.16.5
				periodic self-test using either:	H.3.16.6
				– STATIC MEMORY TEST, or	H.3.19.6
				– WORD PROTECTION WITH SINGLE BIT REDUNDANCY	H.3.19.8.2
	DC FAULT		rq	Comparison of redundant CPUs by either:	
				– RECIPROCAL COMPARISON	H.3.18.15
				– INDEPENDENT hardware COMPARATOR, or	H.3.18.3

Table H.2 Continued on Next Page

Table H.2 Continued

Component [b]	Fault/error	Software class		Example of acceptable measures [c d e]	Definitions
		B	C		
				INTERNAL ERROR DETECTION, or	H.3.18.9
				REDUNDANT MEMORY WITH COMPARISON, or	H.3.19.5
				periodic self-tests using either	
				– WALKPAT MEMORY TEST	H.3.19.7
				– ABRAHAM TEST	H.3.19.1
				– TRANSPARENT GALPAT TEST; or	H.3.19.2.1
				WORD PROTECTION WITH MULTI-BIT REDUNDANCY, or	H.3.19.8.1
				STATIC MEMORY TEST and WORD PROTECTION	H.3.19.6
				WITH SINGLE BIT REDUNDANCY	H.3.19.8.2
1.2 Instruction decoding and execution	Wrong decoding and execution		rq	Comparison of redundant CPUs by either:	
				– RECIPROCAL COMPARISON	H.3.18.15
				– INDEPENDENT hardware COMPARATOR, or	H.3.18.3
				INTERNAL ERROR DETECTION, or	H.3.18.9
				periodic self-test using EQUIVALENCE CLASS TEST	H.3.18.5
1.3 Programme counter	Stuck at	rq		Functional test, or	H.3.16.5
				periodic self-test, or	H.3.16.6
				INDEPENDENT TIME-SLOT MONITORING OF THE PROGRAM SEQUENCE, or	H.3.18.10.4
				LOGICAL MONITORING OF THE PROGRAMME SEQUENCE	H.3.18.10.2
				PERIODIC SELF-TEST AND MONITORING using either:	H.3.16.7
	DC FAULT		rq	– INDEPENDENT TIME-SLOT AND LOGICAL MONITORING	H.3.18.10.3
				– INTERNAL ERROR DETECTION, or	H.3.18.9
				comparison of redundant functional channels by either:	
				– RECIPROCAL COMPARISON	H.3.18.15
				– INDEPENDENT hardware COMPARATOR	H.3.18.3
1.4 Addressing	DC FAULT		rq	Comparison of redundant CPUs by either:	
				– RECIPROCAL COMPARISON	H.3.18.15
				– INDEPENDENT hardware COMPARATOR; or	H.3.18.3
				INTERNAL ERROR DETECTION; or	H.3.18.9
				periodic self-test using a TESTING PATTERN of	H.3.16.7
				the address lines; or	H.3.18.22
				FULL BUS REDUNDANCY, or	H.3.18.1.1

Table H.2 Continued on Next Page

Table H.2 Continued

Component [b]	Fault/error	Software class		Example of acceptable measures [c d e]	Definitions
		B	C		
				MULTI-BIT BUS PARITY	H.3.18.1.2
1.5 Data paths instruction decoding	DC FAULT		rq	Comparison of redundant CPUs by either:	
	and			RECIPROCAL COMPARISON, or	H.3.18.15
	execution			INDEPENDENT hardware COMPARATOR, or	H.3.18.3
				INTERNAL ERROR DETECTION, or	H.3.18.9
				periodic self-test using a TESTING PATTERN, or	H.3.16.7
				DATA REDUNDANCY, or	H.3.18.2.1
				MULTI-BIT BUS PARITY	H.3.18.2.2
2. Interrupt handling and execution	No interrupt or too frequent interrupt	rq		Functional test; or	H.3.16.5
				time-slot monitoring	H.3.18.10.4
	No interrupt or too frequent interrupt related to different sources		rq	Comparison of redundant functional channels by either	
				RECIPROCAL COMPARISON,	H.3.18.15
				INDEPENDENT hardware COMPARATOR, or	H.3.18.3
				INDEPENDENT TIME-SLOT AND LOGICAL MONITORING	H.3.18.10.3
3. Clock		rq		FREQUENCY MONITORING, or	H.3.18.10.1
				time slot monitoring	H.3.18.10.4
	Wrong frequency (for quartz synchronized clock: harmonics/subharmonics only)		rq	FREQUENCY MONITORING, or	H.3.18.10.1
				time-slot monitoring, or	H.3.18.10.4
				comparison of redundant functional channels	
				by either:	
				– RECIPROCAL COMPARISON	H.3.18.15
				– INDEPENDENT hardware COMPARATOR	H.3.18.3
4. Memory					
4.1 INVARIABLE MEMORY	All single bit FAULTS	rq		Periodic MODIFIED CHECKSUM; or	H.3.19.3.1
				MULTIPLE CHECKSUM, or	H.3.19.3.2
				WORD PROTECTION WITH SINGLE BIT REDUNDANCY	H.3.19.8.2
	99,6 % coverage of all information errors		rq	Comparison of redundant CPUs by either:	
				– RECIPROCAL COMPARISON	H.3.18.15

Table H.2 Continued on Next Page

Table H.2 Continued

Component [b]	Fault/error	Software class		Example of acceptable measures [c d e]	Definitions
		B	C		
				– INDEPENDENT hardware COMPARATOR, or	H.3.18.3
				REDUNDANT MEMORY WITH COMPARISON, or	H.3.19.5
				periodic cyclic redundancy check, either	
				– single word	H.3.19.4.1
				– double word, or	H.3.19.4.2
				WORD PROTECTION WITH MULTI-BIT REDUNDANCY	H.3.19.8.1
4.2 Variable memory	DC FAULT	rq		Periodic STATIC MEMORY TEST, or	H.3.19.6
				WORD PROTECTION WITH SINGLE BIT REDUNDANCY	H.3.19.8.2
	DC FAULT and dynamic cross links		rq	Comparison of redundant CPUs by either:	
				– RECIPROCAL COMPARISON	H.3.18.15
				– INDEPENDENT hardware COMPARATOR, or	H.3.18.3
				REDUNDANT MEMORY WITH COMPARISON, or	H.3.19.5
				periodic self-tests using either:	
				– WALKPAT MEMORY TEST	H.3.19.7
				– ABRAHAM TEST	H.3.19.1
				– TRANSPARENT GALPAT TEST, or	H.3.19.2.1
				WORD PROTECTION WITH MULTI-BIT REDUNDANCY	H.3.19.8.1
4.3 Addressing (relevant to variable memory and invariable memory)	Stuck-at	rq		WORD PROTECTION WITH SINGLE BIT REDUNDANCY	H.3.19.8.2
				including the address, or	
	DC FAULT		rq	comparison of redundant CPUs by either:	
				– RECIPROCAL COMPARISON, or	H.3.18.15
				– INDEPENDENT hardware COMPARATOR, or	H.3.18.3
				FULL BUS REDUNDANCY	H.3.18.1.1
				TESTING PATTERN, or	
				periodic cyclic redundancy check, either:	H.3.18.22
				– single word	H.3.19.4.1
				– double word, or	H.3.19.4.2
				WORD PROTECTION WITH MULTI-BIT REDUNDANCY including the address	H.3.19.8.1
5. Internal data path					
5.1 Data	Stuck-at	rq		WORD PROTECTION WITH SINGLE BIT REDUNDANCY	H.3.19.8.2
	DC FAULT		rq	Comparison of redundant CPUs by either:	
				– RECIPROCAL COMPARISON	H.3.18.15

Table H.2 Continued on Next Page

Table H.2 Continued

Component [b]	Fault/error	Software class		Example of acceptable measures [c d e]	Definitions
		B	C		
				– INDEPENDENT hardware COMPARATOR, or	H.3.18.3
				WORD PROTECTION WITH MULTI-BIT REDUNDANCY	H.3.19.8.1
				including the address, or DATA REDUNDANCY, or	H.3.18.2.1
				TESTING PATTERN, or	H.3.18.22
				PROTOCOL TEST	H.3.18.14
5.2 Addressing	Wrong address	rq		WORD PROTECTION WITH SINGLE BIT REDUNDANCY including the address	H.3.19.8.2
	Wrong address and multiple addressing		rq	Comparison of redundant CPUs by:	
				– RECIPROCAL COMPARISON	H.3.18.15
				– INDEPENDENT hardware COMPARATOR, or	H.3.18.3
				WORD PROTECTION WITH MULTI-BIT REDUNDANCY, including the address, or FULL BUS REDUNDANCY; or TESTING PATTERN including the address	H.3.19.8.1 H.3.18.1.1 H.3.18.22
6. External communication 6.1 Data					
	HAMMING DISTANCE 3	rq		WORD PROTECTION WITH MULTI-BIT REDUNDANCY, or CRC – SINGLE WORD, or	H.3.19.8.1 H.3.19.4.1
				TRANSFER REDUNDANCY, or	H.3.18.2.2
				PROTOCOL TEST	H.3.18.14
	HAMMING DISTANCE 4		rq	DATA REDUNDANCY or comparison of redundant functional channels by either:	H.3.18.2.1
				– RECIPROCAL COMPARISON	H.3.18.15
				– INDEPENDENT hardware COMPARATOR	H.3.18.3
6.2 Addressing	Wrong address	rq		WORD PROTECTION WITH MULTI-BIT REDUNDANCY,	H.3.19.8.1
				including the address, or CRC – SINGLE WORD	H.3.19.4.1
				including the addresses, or	
				TRANSFER REDUNDANCY or	H.3.18.2.2
				PROTOCOL TEST	H.3.18.14
	Wrong and multiple addressing		rq	CRC – DOUBLE WORD, including the address, or	H.3.19.4.2
				FULL BUS REDUNDANCY of data and address, or	H.3.18.1.1
				comparison of redundant communication channels by either:	
				– RECIPROCAL COMPARISON	H.3.18.15
				– INDEPENDENT hardware COMPARATOR	H.3.18.3
6.3 Timing	Wrong point in time	rq		Time-slot monitoring, or SCHEDULED TRANSMISSION	H.3.18.10.4 H.3.18.18

Table H.2 Continued on Next Page

Table H.2 Continued

Component [b]	Fault/error	Software class		Example of acceptable measures [c d e]	Definitions
		B	C		
			rq	TIME-SLOT AND LOGICAL MONITORING, or	H.3.18.10.3
				comparison of redundant communication channels by either:	
				– RECIPROCAL COMPARISON	H.3.18.15
				– INDEPENDENT hardware COMPARATOR	H.3.18.3
	Wrong sequence	rq		Logical monitoring, or	H.3.18.10.2
				time-slot monitoring, or	H.3.18.10.4
				SCHEDULED TRANSMISSION	H.3.18.18
			rq	(same options as for wrong point in time)	
7. Input/output periphery	FAULT conditions specified in Clause 13	rq		PLAUSIBILITY CHECK	H.3.18.13
			rq	Comparison of redundant CPUs by either:	
				– RECIPROCAL COMPARISON	H.3.18.15
				– INDEPENDENT hardware COMPARATOR, or	H.3.18.3
7.1 Digital I/O					
				INPUT COMPARISON, or	H.3.18.8
				MULTIPLE PARALLEL OUTPUTS; or	H.3.18.11
				OUTPUT VERIFICATION, or	H.3.18.12
				TESTING PATTERN, or	H.3.18.22
				CODE SAFETY	H.3.18.2
7.2 Analog I/O					
7.2.1 A/D- and D/A-convertor	FAULT conditions specified in Clause 13	rq		PLAUSIBILITY CHECK	H.3.18.13
			rq	Comparison of redundant CPUs by either:	
				– RECIPROCAL COMPARISON	H.3.18.15
				– INDEPENDENT hardware COMPARATOR, or	H.3.18.3
				INPUT COMPARISON, or	H.3.18.8
				MULTIPLE PARALLEL OUTPUTS, or	H.3.18.11
				OUTPUT VERIFICATION, or	H.3.18.12
				TESTING PATTERN	H.3.18.22
7.2.2 Analog multiplexer	Wrong addressing	rq		PLAUSIBILITY CHECK	H.3.18.13
			rq	Comparison of redundant CPUs by either:	
				– RECIPROCAL COMPARISON	H.3.18.15
				– INDEPENDENT hardware COMPARATOR, or	H.3.18.3
				INPUT COMPARISON or	H.3.18.8
				TESTING PATTERN	H.3.18.22
8. Monitoring devices and comparators	Any output outside the		rq	TESTED MONITORING, or	H.3.18.21

Table H.2 Continued on Next Page

Table H.2 Continued

Component [b]	Fault/error	Software class		Example of acceptable measures [c d e]	Definitions
		B	C		
	static and dynamic functional specification			REDUNDANT MONITORING and comparison, or ERROR RECOGNIZING MEANS	H.3.18.17 H.3.18.6
9. Custom chips [f] for example, ASIC, GAL, Gate array	Any output outside the static and dynamic functional specification	rq	rq	Periodic self-test Periodic self-test and monitoring, or DUAL CHANNEL (DIVERSE) WITH COMPARISON, or ERROR RECOGNIZING MEANS	H.3.16.6 H.3.16.7 H.3.16.2 H.3.18.6
CPU: Central programmation unit rq: Coverage of the FAULT is required for the indicated software class.					
[a] Table H.2 is applied according to the requirements of H.9.12 to H.9.12.2.11 inclusive. [b] For FAULT/error assessment, some components are divided into their subfunctions. [c] For each subfunction in the table, the software class C measure will cover the software class B FAULT/error. [d] It is recognized that some of the acceptable measures provide a higher level of assurance than is required by this document. [e] Where more than one measure is given for a subfunction, these are alternatives. [f] To be divided as necessary by the manufacturer into subfunctions.					

H.9.12.2.5 Measures others than those specified in H.9.12.2.4 are permitted if they can be shown to satisfy the requirements listed in Table H.2.

H.9.12.2.6 Software FAULT/error detection shall occur not later than the time declared in Table H.1, requirement H.8. The acceptability of the declared time(s) is evaluated during the FAULT analysis of the control.

Part 2 standards may limit this declaration.

H.9.12.2.7 For controls with functions, classified as Class B or C, detection of a FAULT/error shall result in the response declared in Table H.1, requirement H.9. For controls with functions declared as class C, independent means capable of performing this response shall be provided.

H.9.12.2.8 The loss of dual channel capability is deemed to be an error in a control function using a dual channel structure with software class C.

H.9.12.2.9 The software shall be referenced to relevant parts of the operating sequence and the associated hardware functions.

H.9.12.2.10 The software shall be protected from user alteration of safety-related segments and data.

H.9.12.2.11 The software and safety-related hardware under its control shall be initialized to, and terminate at, as stated in Table H.1, requirement H.4.

H.9.12.3 Measures to avoid errors

H.9.12.3.1 General

For CONTROLS with software class B or C the measures shown in Figure H.1 to avoid systematic FAULTS shall be applied.

Measures used for software class C are inherently acceptable for software class B.

The content of this is extracted from IEC 61508-3 and adapted to the needs of this document.

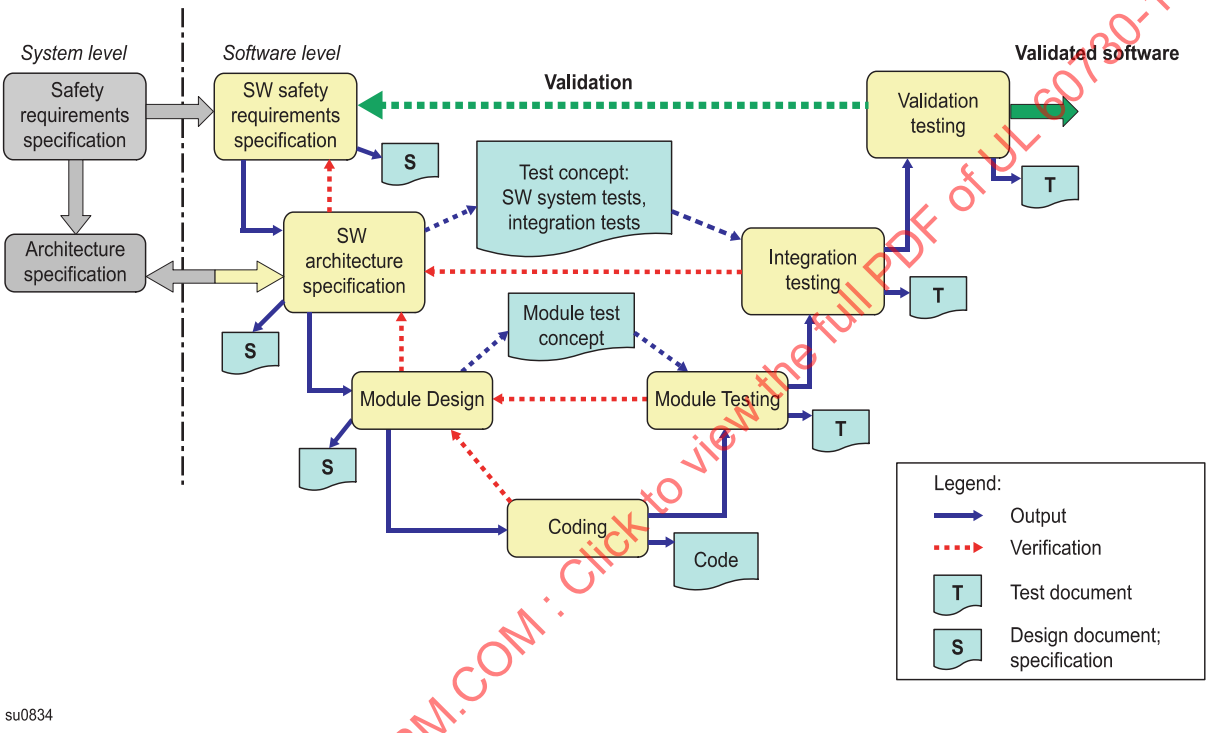


Figure H.1

V-Model for the software life cycle

Other software lifecycle models are permitted if they incorporate disciplined and structured processes including design and test phases.

H.9.12.3.2 Specification

H.9.12.3.2.1 Software safety requirements

H.9.12.3.2.1.1 The specification of the software safety requirements shall include

– a description of each safety related function to be implemented, including its response time(s):

- functions related to the application, including their related software classes;
- functions related to the detection, annunciation and management of software or hardware FAULTS;

– a description of interfaces between software and hardware;

– a description of interfaces between any safety and non-safety related functions.

Examples of techniques/measures can be found in Table H.3.

Table H.3
Examples of techniques/measures for semi-formal methods

Technique/Measure	References (informative)
Standards identification	
Semi-formal methods – Logical/functional block diagrams – Sequence diagrams – Finite state machines/state transition diagrams – Decision/truth tables	 IEC 61508-7:2010, B.2.3.2 IEC 61508-7:2010, C.6.1

H.9.12.3.2.2 Software architecture

H.9.12.3.2.2.1 The description of software architecture shall include the following aspects:

– techniques and measures to control software FAULTS/errors (refer to H.9.12.2);

– interactions between hardware and software;

– partitioning into modules and their allocation to the specified safety functions;

– hierarchy and call structure of the modules (CONTROL flow);

– interrupt handling;

– data flow and restrictions on data access;

– architecture and storage of data;

– time based dependencies of sequences and data.

Examples of techniques/measures can be found in Table H.4.

Table H.4
Examples of techniques/measures for software architecture specification

Technique/Measure	References (informative)
FAULT detection and diagnosis	IEC 61508-7:2010, C.3.1
Semi-formal methods: − Logic/function block diagrams − Sequence diagrams − Finite state machines/state transition diagrams − Data flow diagrams	 IEC 61508-7:2010, B.2.3.2 IEC 61508-7:2010, C.2.2

H.9.12.3.2.2.2 The architecture specification shall be verified against the specification of the software safety requirements by static analysis.

NOTE Acceptable methods for STATIC ANALYSIS are

– CONTROL flow analysis;

– data flow analysis;

– WALK-THROUGHS/design reviews.

H.9.12.3.2.3 Module design and coding

NOTE 1 The use of computer aided design tools is accepted.

NOTE 2 For defensive programming (for example, range checks, check for division by 0, PLAUSIBILITY CHECKS), see IEC 61508-7:2010, C.2.5.

H.9.12.3.2.3.1 Based on the architecture design, software shall be suitably refined into modules. Software module design and coding shall be implemented in a way that is traceable to the software architecture and requirements.

The module design shall specify

– function(s),

– interfaces to other modules,

– data.

Examples of techniques/measures can be found in Table H.5.

Table H.5
Examples of techniques/measures for module design specification

Technique/Measure	References (informative)
Limited size of software modules	IEC 61508-7:2010, C.2.9
Information hiding/encapsulation	IEC 61508-7:2010, C.2.8
One entry/one exit point in subroutines and functions	IEC 61508-7:2010, C.2.9
Fully defined interface	IEC 61508-7:2010, C.2.9
Semi-formal methods:	
– Logic/function block diagrams	
– Sequence diagrams	
– Finite state machines/state transition diagrams	IEC 61508-7:2010, B.2.3.2
– Data flow diagrams	IEC 61508-7:2010, C.2.2

H.9.12.3.2.3.2 Software code shall be structured.

NOTE Structural complexity can be minimized by applying the following principles:

– keep the number of possible paths through a software module small, and the relation between the input and output parameters as simple as possible;

– avoid complicated branching and, in particular, avoid unconditional jumps (GOTO) in higher level languages;

– where possible, relate loop constraints and branching to input parameters;

– avoid using complex calculations as the basis of branching and loop decisions.

Examples of techniques/measures can be found in Table H.6.

Table H.6
Examples of techniques/measures for design and coding standards

Technique/Measure	References (informative)
Use of coding standard (see H.9.12.3.2.4)	IEC 61508-7:2010, C.2.6.2
No use of dynamic objects and variables (see Note)	IEC 61508-7:2010, C.2.6.3
Limited use of interrupts	IEC 61508-7:2010, C.2.6.5
Limited use of pointers	IEC 61508-7:2010, C.2.6.6
Limited use of recursion	IEC 61508-7:2010, C.2.6.7
No unconditional jumps in programs in higher level languages	IEC 61508-7:2010, C.2.6.2
Dynamic objects and/or variables are allowed if a compiler is used which ensures that sufficient memory for all dynamic objects and/or variables will be allocated before runtime, or which inserts runtime checks for the correct online allocation of memory.	

H.9.12.3.2.3.3 Coded software shall be verified against the module specification, and the module specification shall be verified against the architecture specification by static analysis.

NOTE Examples of methods for STATIC ANALYSIS are

– CONTROL flow analysis;

– data flow analysis;

– WALK-THROUGHS/design reviews.

H.9.12.3.2.4 Design and coding standards

Program design and coding standards shall be consequently used during software design and maintenance.

Coding standards shall specify programming practice, proscribe unsafe language features, and specify procedures for source code documentation as well as for data naming conventions.

H.9.12.3.3 Testing

H.9.12.3.3.1 Module design (software system design, software module design and coding)

H.9.12.3.3.1.1 A test concept with suitable test cases shall be defined based on the module design specification.

H.9.12.3.3.1.2 Each software module shall be tested as specified within the test concept.

H.9.12.3.3.1.3 Test cases, test data and test results shall be documented.

H.9.12.3.3.1.3 Code verification of a software module by static means includes such techniques as software INSPECTIONS, WALK-THROUGHS, STATIC ANALYSIS and formal proof.

Code verification of a software module by dynamic means includes functional testing, white-box testing and statistical testing.

It is the combination of both types of evidence that provides assurance that each software module satisfies its associated specification.

Examples of techniques/measures can be found in Table H.7:

Table H.7
Examples of techniques/measures for software module testing

Technique/Measure	References (informative)
Dynamic analysis and testing:	IEC 61508-7:2010, B.6.5
– Test case execution from boundary value analysis	IEC 61508-7:2010, C.5.4
– Structure-based testing	IEC 61508-7:2010, C.5.8
Data recording and analysis	IEC 61508-7:2010, C.5.2
Functional and black-box testing:	IEC 61508-7:2010, B.5.1, B.5.2
– Boundary value analysis	IEC 61508-7:2010, C.5.4
– Process simulation	IEC 61508-7:2010, C.5.18
Performance testing:	IEC 61508-7:2010, C.5.20
– Avalanche/stress testing	IEC 61508-7:2010, C.5.21
– Response timings and memory constraints	IEC 61508-7:2010, C.5.22
Interface testing	IEC 61508-7:2010, C.5.3

NOTE Software module testing is a verification activity.

H.9.12.3.3.2 Software integration testing

H.9.12.3.3.2.1 A test concept with suitable test cases shall be defined based on the architecture design specification.

H.9.12.3.3.2.2 The software shall be tested as specified within the test concept.

H.9.12.3.3.2.3 Test cases, test data and test results shall be documented.

Examples of techniques/measures can be found Table H.8.

Table H.8
Examples of techniques/measures for software integration testing

Technique/Measure	References (informative)
Functional and black-box testing:	IEC 61508-7:2010, B.5.1, B.5.2
– Boundary value analysis	IEC 61508-7:2010, C.5.4
– Process simulation	IEC 61508-7, C.5.18
Performance testing:	IEC 61508-7:2010, C.5.20
– Avalanche/stress testing	IEC 61508-7:2010, C.5.21
– Response timings and memory constraints	IEC 61508-7:2010, C.5.22

NOTE Software integration testing is a verification activity.

H.9.12.3.3.3 Software validation

H.9.12.3.3.3.1 A validation concept with suitable test cases shall be defined based on the software safety requirements specification.

H.9.12.3.3.3.2 The software shall be validated with reference to the requirements of the software safety requirements specification as specified within the validation concept.

The software shall be exercised by simulation or stimulation of

– input signals present during normal OPERATION,

– anticipated occurrences,

– undesired conditions requiring SYSTEM action.

H.9.12.3.3.3.3 Test cases, test data and test results shall be documented.

Examples of techniques/measures can be found in Table H.9.

Table H.9
Examples of techniques/measures for software safety validation

Technique/Measure	References (informative)
Functional and black-box testing:	IEC 61508-7:2010, B.5.1, B.5.2
– Boundary value analysis	IEC 61508-7:2010, C.5.4
– Process simulation	IEC 61508-7:2010, C.5.18
Simulation, modeling:	
– Finite state machines	IEC 61508-7:2010, B.2.3.2
– Performance modeling	IEC 61508-7:2010, C.5.20

NOTE Testing is the main validation method for software; modelling can be used to supplement the validation activities.

H.9.12.3.4 Other Items

H.9.12.3.4.1 Tools, programming languages

Equipment used for software design, verification and maintenance, such as design tools, programming languages, translators and test tools, shall be qualified appropriately, and shall be shown to be suitable for purpose in manifold applications.

They are assumed to be suitable if they comply with "increased confidence from use" according to IEC 61508-7:2010, C.4.4.

H.9.12.3.4.2 Management of software versions

A software version management system at the module level shall be put in place. All versions shall be uniquely identified for traceability.

H.9.12.3.4.3 Software modification

H.9.12.3.4.3.1 Software modifications shall be based on a modification request which details the following:

– the HAZARDS affected,

– the proposed change,

– the reasons for change.

H.9.12.3.4.3.2 An analysis shall be carried out to determine the impact of the proposed modification on functional safety.

H.9.12.3.4.3.3 A detailed specification for the modification shall be generated including the necessary activities for verification and validation, such as a definition of suitable test cases.

H.9.12.3.4.3.4 The modification shall be carried out as planned.

H.9.12.3.4.3.5 The assessment of the modification shall be carried out based on the specified verification and validation activities. This can include:

– a reverification of changed software modules;

– a reverification of affected software modules;

– a revalidation of the complete SYSTEM.

H.9.12.3.4.3.6 All details of modification activities shall be documented.

H.9.12.3.5 For CLASS C CONTROL FUNCTIONS, the manufacturer shall have used one of the combinations (a–p) of analytical measures given in the columns of Table H.10 during hardware development.

Table H.10
Combinations of analytical measures during hardware development

Hardware development stage		a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p
H.3.17.5	INSPECTION	x		x		x		x		x		x		x		x	
H.3.17.9	WALK-THROUGH				x		x		x		x		x		x		x
H.3.17.7.1	STATIC ANALYSIS	x	x							x	x						
H.3.17.1	DYNAMIC ANALYSIS			x	x							x	x				
H.3.17.3	HARDWARE ANALYSIS					x	x							x	x		
H.3.17.4	HARDWARE SIMULATION							x	x							x	x
H.3.17.2	FAILURE RATE CALCULATION	x	x	x	x	x	x	x	x								
H.3.20.3	FMEA									x	x	x	x	x	x	x	x
H.3.17.6	OPERATIONAL TEST	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

H.9.12.4 Remotely actuated control functions

H.9.12.4.2.3 Communication of safety related data

H.9.12.4.2.3.1 Transmission

Safety relevant data shall be transmitted authentically concerning:

– data corruption;

– address corruption;

– wrong timing or sequence.

Data variation or corrupted data shall not lead to an unsafe state. Before the use of transmitted data, it shall be ensured that the above items are addressed using the measures as given in Annex H of the same or higher software class used by that function.

Compliance is checked by assessment according to Table H.11 that provides threats to be considered and examples of defences against unauthorised access and transmission failure modes.

NOTE Special attention is drawn to Table H.2, item "6. External communication", with regard to the following items:

- data deletion from the original message;
- data insertion into the original message;
- corruption of the data in the original message;
- change in sequence of data in the original message;
- make a non-authentic message look like an authentic message;
- incomplete address;
- corruption of the address of the original message;
- wrong address;
- more addresses;

- receive message more than once;
- delay in transmitting or receiving the message;
- wrong sequence of sending/receiving.
- permanent "auto-sending" or repetition,
- interruption of data transfer.

H.9.12.4.2.3.2 Access to data exchange

For CLASS B CONTROL FUNCTION or CLASS C CONTROL FUNCTION related operating data, configuration parameters and/or software modules are allowed to be transmitted via communication, if adequate hardware/software measures are taken to prevent unauthorized access to the CONTROL function. Examples are given in Table H.11.

For access to data exchange of CLASS B CONTROL FUNCTION or CLASS C CONTROL FUNCTION related operating data through PUBLIC NETWORKS, appropriate CRYPTOGRAPHIC TECHNIQUES shall be implemented. See H.9.12.4.6.

NOTE Aspects concerning security are found under the work of ISO/IEC JTC 1/SC 27 (TC 205).

Table H.11
Examples of defences against unauthorised access and transmission failure modes

		Defences							
To cover	**Threats**	**Sequence number [b]**	**Time stamp [c]**	**Time-out [d]**	**Feedback message [e]**	**Sourced destination identifier [f]**	**Identification procedure**	**Safety code [g]**	**Cyrpto-graphic techniques**
Transmission failure modes [h]	Repetition of a message	x	x						
	Deletion of message	x							
	Insertion of message	x			x	x	x		
	Re-sequence of data in message	x	x						
	Corrupted, deleted or inserted data in message							x [a]	x
	Delay in sending/receiving the message		x	x					
Unauthorized access	Masquerade [i]				x		x		x

Examples of defences against unauthorized access can also be found in the applications covered by IEC 62280.

[a] See Table H.2, items 6.1 and 6.2.

[b] additional data field containing a number that changes in a predefined way from message to message.

[c] information concerning time of transmission attached to a message by the sender.

[d] delay between two messages exceeding a predefined allowed maximum time.

NOTE 1 If this is the case, an error can be assumed.

[e] response from a receiver to a sender, via a return channel.

[f] identifier which is assigned to each entity.

NOTE 2 This identifier can be a name, number or arbitrary bit pattern. This identifier will be used for the safety-related communication. Usually, the identifier is added to the user data.

[g] redundant data included in a safety-related message to permit data corruptions to be detected by the safety-related transmission function.

[h] These failure modes are of random and systematic nature.

[i] Masquerade: Making an inauthentic message look like an authentic message by an unauthorized user.

H.9.12.4.2.3.3 Revision of class B and class C software

Requirements of H.9.12.3 shall apply to class B and class C software revisions. In addition, hardware configuration management shall be required, and measures shall be taken to ensure the CONTROL maintains its protective functions in accordance with this document.

NOTE Hardware configuration management is meant to be in addition to software verification in order to maintain the integrity of the CONTROL. SYSTEM level implications are taken into consideration.

H.9.12.4.5 Software download and installation

H.9.12.4.5.1 Software updates for class B and class C software provided by the manufacturer and transmitted to the control via remote communication shall be checked, at the control, prior to its use:

– against corruption through communication ensuring HAMMING DISTANCE 3 for software class B, or HAMMING DISTANCE 4 for software class C. (Refer to Table H.2 for external communication.);

– if the software version is compatible with the hardware version of the control according to the version management documentation.

Additionally, the software which performs the above mentioned checks shall contain measures to control the FAULT/error conditions specified in H.9.12.2.

H.9.12.4.5.2 In case of software download via remote communication, the CRYPTOGRAPHIC TECHNIQUES in H.9.12.4.6 shall be provided. In addition to the requirements in H.9.12.4.6, identification procedures shall also be provided for the software packages.

The CRYPTOGRAPHIC TECHNIQUES employed shall be part of the CONTROL, and not rely upon part of the router or similar data TRANSMISSION device itself, and shall be performed prior to TRANSMISSION.

H.9.12.4.5.3 For each update of software, the CONTROL shall have provisions for authorization by the user and a version ID number which shall be accessible.

H.9.12.4.5.4 The installation of class B software or class C software is permitted when during and after the software installation process, the CONTROL remains in compliance with the requirements of this document.

Compliance is checked by software inspection.

H.9.12.4.6 Cryptographic techniques

In cases where CLASS B CONTROL FUNCTION or CLASS C CONTROL FUNCTION related operating data, configuration parameters and/or software modules are transmitted over a PUBLIC NETWORK, and/or where software updates are provided by the manufacturer via remote communication, CRYPTOGRAPHIC TECHNIQUES shall be employed.

Compliance is checked by software inspection and review of technical documentation which provides adherence to the commonly accepted data integrity protection methods.

NOTE Examples of commonly accepted CRYPTOGRAPHIC TECHNIQUES are defined and described in ISO/IEC 9796, ISO/IEC 9797, ISO/IEC 9798, ISO/IEC 10118, ISO/IEC 11770, ISO/IEC 14888, ISO/IEC 15946, ISO/IEC 18033, ISO/IEC 29192, as well as ISO/IEC 19772.

H.13 Fault assessment on electronic circuits

H.13.2 Fault assessment to ensure functional safety

H.13.2.1 Design and construction requirements

H.13.2.1.1 Fault avoidance and fault tolerance

CONTROLS incorporating CONTROL functions of class B or class C shall be designed according to H.13.2 taking into account the FAILURE modes of Table 14 and H.9.12 for software, if applicable.

FAILURES of COMPLEX ELECTRONICS can be caused by either systematic errors (built into the design, see H.9.12.3) or by random FAULTS (component FAULTS, see H.9.12.2). Therefore, the SYSTEM shall be designed in such a way that systematic errors are avoided and random FAULTS shall be dealt with by a proper SYSTEM configuration.

The design of the software and hardware shall be based on the functional analysis of the application-resulting in a structured design explicitly incorporating the CONTROL flow, data flow and time related functions required by the application. In the case of custom-chips, special attention is required with regard to measures taken to minimize systematic errors.

This shall result in a SYSTEM configuration which is either inherently failsafe or in which components with direct safety-critical functions (e. g. gas valve drivers, microprocessors with their associated circuits, etc.) are guarded by safeguards in accordance with H.9.12 software class B or class C. These safeguards shall be built into hardware (e. g. watch-dog, supply voltage supervision) and can be supplemented by software (e. g. ROM-test, RAM-test, etc.). It is important that these safeguards can cause a completely INDEPENDENT SAFETY SHUT-DOWN.

If time slot monitoring is used, it shall be sensitive to both an upper and a lower limit of the time interval. FAULTS resulting in shift of the upper and/or lower limit shall be taken into account.

In case of a CONTROL function that is classified as class C, if a single FAULT in a primary safeguard can render the safeguard inoperative, a secondary safeguard shall be provided. The reaction time of the secondary safeguard shall be in accordance with H.13.2.3.

NOTE 1 Reaction times of these safeguards can be equal or smaller than the relevant FAULT TOLERATING TIME.

NOTE 2 The secondary guarding can be realized by:

a) a physically separate circuit monitoring the primary safeguard; or

b) mutual action between the circuit being safeguarded and the primary safeguard (e. g. a watch-dog guarded by the microprocessor); or

c) action between primary safeguards (e. g. a ROM-test guarding a RAM-test).

Components shall be dimensioned on the basis of the worst-case conditions which can arise in the CONTROL, as stated by the manufacturer.

NOTE 3 A component failure could cause a degradation of safety critical insulation.

H.13.2.1.2 Documentation

The documentation shall be based on H.9.12.3.

H.13.2.2 Class B control function

H.13.2.2.1 Design and construction requirements

A CLASS B CONTROL FUNCTION shall be designed such that under single FAULT conditions it remains in or proceeds to the DEFINED STATE. A second INDEPENDENT FAULT is not considered.

NOTE FAILURE of CLASS B CONTROL FUNCTION in the presence of another FAULT in the appliance, or FAILURE of CLASS C CONTROL FUNCTION alone, could result in a dangerous malfunction, electric shock, fire, mechanical or other HAZARDS.

Software shall comply with software class B.

The class of CONTROL function shall be declared in Table H.1, requirement H.12.

The assessment shall be performed according to H.13.2.2.2 and H.13.2.2.3 and under the test conditions and criteria of H.13.2.5.

H.13.2.2.2 First fault

Any first FAULT (see Table 14) in any one component or any one FAULT together with any other FAULT arising from that first FAULT shall result in either

a) the CONTROL becoming inoperative with all safety related output terminals de-energized or assuming a status in which they ensure a safe situation;

b) the CONTROL reacting within the FAULT REACTION TIME (declared in Table H.1, requirement H.11) by proceeding to a DEFINED STATE, provided that subsequent RESET from the DEFINED STATE under the same FAULT condition results in the SYSTEM returning to the same DEFINED STATE;

c) the CONTROL continuing to operate, the FAULT being identified during the next start-up sequence, the result being a) or b);

d) the CONTROL remaining operational in accordance with the safety related functional requirements of the relevant part 2.

The relevant part 2 shall specify the FAULT REACTION TIME as well as the applicability of c).

For DEFINED STATE with a mechanical actuator, a test up to but not including the switching contacts is sufficient. If the test of the DEFINED STATE fails, the SYSTEM shall proceed to SAFETY SHUT-DOWN. Frequency of test is given in the relevant part 2. Internal FAULTS on components of the checking circuit are not considered.

H.13.2.2.3 Fault introduced during defined state

Whenever the CONTROL is in a DEFINED STATE without an internal FAULT, the following requirements apply.

Any first FAULT (together with any other FAULT arising from that FAULT) in any one component (see Table 14), induced while the CONTROL is staying in a DEFINED STATE, shall result in either

a) the CONTROL remaining in a DEFINED STATE, safety related output terminals remaining deenergized; or

b) the CONTROL becoming inoperative with all safety related output terminals remaining de-energized; or

c) the CONTROL comes again in OPERATION resulting in a) or b) as mentioned in this clause under the condition that the safety related output terminals are energized not longer than the FAULT REACTION TIME (declared in Table H.1, requirement H.11). If the cause of the DEFINED STATE condition no longer remains

and the CONTROL comes again in OPERATION, it shall operate in accordance with the safety related functional requirements of the relevant part 2.

H.13.2.3 Class C control function

H.13.2.3.1 Design and construction requirements

A CLASS C CONTROL FUNCTION shall be designed such that under first and second FAULT conditions, it remains in or proceeds to the DEFINED STATE. A third INDEPENDENT FAULT is not considered.

NOTE FAILURE of CLASS B CONTROL FUNCTION in the presence of another FAULT in the appliance, or FAILURE of CLASS C CONTROL FUNCTION alone, could result in a dangerous malfunction, electric shock, fire, mechanical or other HAZARDS.

Software shall comply with software class C.

The class of CONTROL function shall be identified in Table H.1, requirement H.12.

The assessment shall be performed according to H.13.2.3.2, H.13.2.3.3 and H.13.2.4 and under the test conditions and criteria of H.13.2.5.

H.13.2.3.2 First fault

Any first FAULT (see Table 14) in any one component or any one FAULT together with any other FAULT arising from that first FAULT shall result in either

a) the CONTROL becoming inoperative with all safety related output terminals de-energized or assuming a status in which they ensure a safe situation;

b) the CONTROL reacting within the FAULT REACTION TIME (see Table H.1, requirement H.11) by proceeding to a DEFINED STATE, provided that subsequent reset from the DEFINED STATE condition under the same FAULT condition results in the SYSTEM returning to the DEFINED STATE;

c) the CONTROL continuing to operate, the FAULT being identified during the next start-up sequence, the result being a) or b);

d) the CONTROL remaining operational in accordance with the safety related functional requirements of the relevant part 2.

The relevant part 2 shall specify the FAULT REACTION TIME as well as the applicability of c).

H.13.2.3.3 Second fault

If the assessment of the first FAULT results in the control remaining operational in accordance with the safety related functional requirements of the relevant part 2 (see H.13.2.3.2 d)), any further INDEPENDENT FAULT considered together with the first FAULT shall result in either H.13.2.3.2 a), b), c) or d).

During assessment, the second FAULT shall only be considered to occur:

a) either when a start-up sequence has been performed between the first and the SECOND fault, or

b) 24 h after the first FAULT.

The relevant part 2 shall specify the applicability of a) or b) and the FAULT REACTION TIME (see Table H.1, requirement H.11).

It may also specify a different time span in which the second FAULT does not occur, if different from 24 h.

H.13.2.4 Faults during defined state

H.13.2.4.1 General

Whenever the CONTROL is in a DEFINED STATE without an internal FAULT, an assessment according to H.13.2.4.2 and H.13.2.4.3 shall be performed.

Whenever the CONTROL is inoperative with all safety related output terminals de-energized or in a status in which they ensure a safe situation, in a DEFINED STATE with an internal FAULT, an additional single FAULT assessment according to H.13.2.4.3 shall be performed.

NOTE Safety related output terminal as used in H.13.2.4.2 and H.13.2.4.3 are terminals which are safety related even in the SAFETY SHUT-DOWN or in a DEFINED STATE, for example, gas valve terminal, but not a terminal for an actuator driving the controlling element which does not degrade the safety in the DEFINED STATE.

H.13.2.4.2 First fault introduced during defined state

Any first FAULT (together with any other FAULT arising from that FAULT) in any one component (see Table 14), induced while the CONTROL is staying in the SAFETY SHUT-DOWN position, shall result in either:

a) the CONTROL remaining in a DEFINED STATE, safety related output terminals remaining de-energized or in a status in which they ensure a safe situation;

b) the CONTROL becoming inoperative with all safety related output terminals remaining de-energized or assuming a status in which they ensure a safe situation;

c) the CONTROL comes again in OPERATION resulting in a) or b) as mentioned in H.13.2.4.2 under the condition that the safety related output terminals are energized not longer than the FAULT REACTION TIME (see Table H.1, requirement H.11). If the cause of the original SAFETY SHUTDOWN condition no longer remains and the CONTROL comes again in OPERATION, it shall operate in accordance with the safety related functional requirements of the relevant part 2 and the second FAULT assessment shall be carried out in accordance with H.13.2.3.3.

H.13.2.4.3 Second fault introduced during defined state

Any second FAULT (together with any other FAULT arising from that FAULT) in any one component (see Table 14), induced while the CONTROL is staying in the DEFINED STATE, shall result in either H.13.2.4.2 a), b) or c).

During assessment, the second FAULT shall not be considered to occur within 24 h after the first FAULT.

The relevant part 2 shall specify the FAULT REACTION TIME.

It may also specify a different time span in which the second FAULT does not occur, if different from 24 h.

H.13.2.5 Circuit and construction evaluation

H.13.2.5.1 Test conditions

The effect of internal FAULTS shall be assessed by simulation and/or by an examination of the circuit design.

The FAULT shall be considered to have occurred at any stage in the CONTROL programme sequence.

The CONTROL shall be operated or considered to operate under the following conditions:

a) at the most unfavourable voltage in the range 85 % to 110 % of the rated supply voltage;

b) loaded with the most unfavourable load declared by the manufacturer;

c) in an ambient temperature of (20 ± 5) °C, unless there are significant reasons for conducting the test at another temperature within the manufacturer's declared range;

d) with any ACTUATING MEMBER placed in the most unfavourable position;

e) with tissue paper placed on the supporting surface(s) of the CONTROL;

f) with sparks of about 3 mm in length and having an energy of not less than 0,5 J applied to those components which are likely to liberate flammable gases during the test.

H.13.2.5.2 Test criteria

During the appraisal, it shall be verified that under the conditions described above, the following criteria are satisfied.

a) The CONTROL shall not emit flames, hot metal or hot plastics, the tissue paper shall not ignite, no explosion shall result from the liberation of flammable gases and any flame produced shall not continue to burn for more than 10 s after switching off the spark generator. When a CONTROL is incorporated with any appliance, any enclosure afforded by the appliance is taken into consideration.

b) If the CONTROL continues to function, it shall comply with Clauses 6 and 15. If it ceases to function, it shall still continue to comply with Clause 6.

c) There shall be no loss of protective function.

After the tests, there shall be no deterioration of the various parts of the CONTROL that would result in failure to comply with Clause 11.

H.13.2.5.3 Assessment

A thorough appraisal of the circuit shall be carried out to determine its performance under the specified FAULT conditions. This appraisal shall take the form of a theoretical analysis and a component FAILURE simulation test. FAULT simulations can also be carried out to simulate FAULTS within complex devices, for example, EPROM emulation tests.

Only the safety related software (software class B and C) as identified according to H.13.2.1.2 shall be subjected to further assessment. For the identification of the class, a FAULT tree analysis may be used.

H.17 Manufacturing deviation and drift

H.17.1 Those parts of controls providing a TYPE 2 ACTION shall have adequate consistency of manufacture with regard to their declared operating value, operating time, or operating sequence.

H.17.2 *Compliance is checked by the appropriate tests of this clause.*

H.17.3 For those controls which are completely or partially destroyed during their intended normal operation (e.g. single operating device), the tests of the appropriate subclauses of Clause 19 are deemed to be sufficient.

H.17.4 For those controls which are dependent on the method of mounting on, or incorporation in an equipment for their operation, the manufacturing deviation and the drift shall be declared separately and be comparative values. The declared manufacturing deviation should be expressed as a bandwidth or spread (for example, 10 K) and the drift by an alteration of value (for example, ±10 K or +5 K, −10 K).