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Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use —

Part 1: General Requirements

Approved 12 July 2004

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The most recent designation of ANSI/UL 61010-1 and ANSI/ISA-82.02.01 (IEC 61010-1 Mod) as an American National Standard (ANSI) occurred on 12 July 2004.

This ANSI/UL Standard for Safety, which consists of the Second Edition is under continuous maintenance, whereby each revision is ANSI approved upon publication. Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Written comments are to be sent to the UL-Northbrook Standards Department, 333 Pfingsten Road, Northbrook, IL 60062.



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CAN/CSA-C22.2 No. 61010-1
Second Edition
(IEC 61010-1:2001, Mod)



ISA - The Instrumentation, Systems, and Automation Society
ANSI/ISA-82.02.01 (IEC 61010-1 Mod)
Second Edition



Underwriters Laboratories Inc.
ANSI/UL 61010-1
Second Edition

Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use - Part 1: General Requirements

July 12, 2004

This standard is based on IEC 60101-1, Second Edition (2001).



ANSI/UL 61010-1-2004

Approved
by
Standards Council
of Canada



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Preface

This is the common CSA, ISA, and UL standard for *Electrical Equipment for Measurement, Control, and Laboratory Use*. It is the second edition of CAN/CSA-C22.2 No. 61010-1, the second edition of ANSI/ISA-82.02.01 (IEC 61010-1 Mod), and the second edition of UL 61010-1. This edition of CAN/CSA-C22.2 No. 61010-1 supersedes the previous edition published in 1992. This edition of ANSI/ISA-82.02.01 (IEC 61010-1 Mod) supersedes the previous edition of ANSI/ISA-82.02.01 published in 1999. This edition of UL 61010-1 will supersede the first edition of UL 61010A-1 published in 2002, UL 61010B-1 published in 2003, and UL 61010C-1 published in 2002. This standard is based on IEC 61010-1, second edition.

CAN/CSA-C22.2 No. 61010-1, ANSI/ISA-82.02.01 (IEC 61010-1 Mod), and UL 61010-1 contain identical requirements and identical publication dates. The presentation and format of the standards material may differ between the three published standards.

This common standard was prepared by the Canadian Standards Association (CSA), The Instrumentation, Systems, and Automation Society (ISA), and Underwriters Laboratories Inc. (UL).

This standard was reviewed by the CSA Subcommittee on Safety Requirements for Electric Equipment for Measurement Control and Laboratory Use, under the jurisdiction of the CSA Technical Committee on Consumer and Commercial Products and the CSA Strategic Steering Committee on Requirements for Electrical Safety, and has been formally approved by the CSA Technical Committee.

This standard has been approved as a National Standard of Canada by the Standards Council of Canada (SCC).

This standard has been approved by the American National Standards Institute (ANSI) as an American National Standard.

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

Level of Harmonization

This standard adopts the IEC text with national differences.

The requirements are presented in different formats. The ISA version of the standard illustrates the national differences from the IEC text through the use of legislative text (strike-out and underline). The CSA and UL versions of the standard illustrates national differences immediately following the IEC text. National differences between the CSA and UL version and the ISA version shall be word for word except for editorial changes.

Interpretations

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

CSA Effective Date

The effective date for CSA International will be announced through CSA Informs or a CSA Certification notice.

ISA Effective Date

The effective date for ISA is the date of publication.

UL effective date

The effective date for UL is the date of publication. However, the first editions of UL 61010A-1, UL 61010B-1, and UL 61010C-1 will also be effective until January 1, 2014.

A UL effective date is one established by Underwriters Laboratories Inc. and is not part of the ANSI approved standard.

Foreword (ISA)

The suffix "Mod" indicates the document is a modification of the IEC document and includes national differences encompassing both additions and deletions of information.

All text of IEC 61010-1:2001 is included. National Deviations are shown by ~~strikeout~~ through text deleted and underline under text added. Tables, or portions of tables, that are to be deleted are shown as shaded; figures to be deleted are marked with the overlay "X." There are eleven annexes in this standard. Annexes G, H, DVA, DVB, and DVC are informative and are not considered part of this Standard. The remaining Annexes are normative and are considered part of this standard.

The standards referenced within this document may contain provisions which, through reference in this text, constitute requirements of this document. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this document are encouraged to investigate the possibility of applying the most recent editions of the standards indicated within this document. Members of IEC and ISO maintain registers of currently valid International Standards. ANSI maintains registers of currently valid U.S. National Standards.

This document has been prepared as part of the service of ISA - The Instrumentation, Systems, and Automation Society - toward a goal of uniformity in the field of instrumentation. To be of real value, this document should not be static but should be subject to periodic review. Toward this end, the Society welcomes all comments and criticisms and asks that they be addressed to the Secretary, Standards and Practices Board; ISA; 67 Alexander Drive; P. O. Box 12277; Research Triangle Park, NC 27709; Telephone (919) 549-8411; Fax (919) 549-8288; E-mail: standards@isa.org.

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This document was approved for publication by the ISA Standards and Practices Board on 16 February 2004,

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Manufacturers should note that, in the event of the failure of CSA International to resolve an issue arising from the interpretation of requirements, there is an appeal procedure: the complainant should submit the matter, in writing, to the Secretary of the Canadian Standards Association.

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Foreword (UL)

A. This Standard contains basic requirements for products covered by Underwriters Laboratories Inc. (UL) under its Follow-Up Service for this category within the limitations given below and in the Scope section of this Standard. These requirements are based upon sound engineering principles, research, records of tests and field experience, and an appreciation of the problems of manufacture, installation, and use derived from consultation with and information obtained from manufacturers, users, inspection authorities, and others having specialized experience. They are subject to revision as further experience and investigation may show is necessary or desirable.

B. The observance of the requirements of this Standard by a manufacturer is one of the conditions of the continued coverage of the manufacturer's product.

C. A product which complies with the text of this Standard will not necessarily be judged to comply with the Standard if, when examined and tested, it is found to have other features which impair the level of safety contemplated by these requirements.

D. A product employing materials or having forms of construction which conflict with specific requirements of the Standard cannot be judged to comply with the Standard. A product employing materials or having forms of construction not addressed by this Standard may be examined and tested according to the intent of the requirements and, if found to meet the intent of this Standard, may be judged to comply with the Standard.

E. UL, in performing its functions in accordance with its objectives, does not assume or undertake to discharge any responsibility of the manufacturer or any other party. The opinions and findings of UL represent its professional judgment given with due consideration to the necessary limitations of practical operation and state of the art at the time the Standard is processed. UL shall not be responsible to anyone for the use of or reliance upon this Standard by anyone. UL shall not incur any obligation or liability for damages, including consequential damages, arising out of or in connection with the use, interpretation of, or reliance upon this Standard.

F. Many tests required by the Standards of UL are inherently hazardous and adequate safeguards for personnel and property shall be employed in conducting such tests.

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NATIONAL DIFFERENCES

In the CSA and UL publications of this standard, National Differences from the text of International Electrotechnical Commission (IEC) Publication 61010-1, Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use, Part 1: General Requirements copyright 2001 are indicated by notations (differences) and are presented in bold text. The national difference type is included in the body.

In the ISA publication of this standard, National Differences are presented using legislative text (strike-out and underline). The national difference type is identified in an informative annex.

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.

Note: The CSA and UL printed standards include the national difference types within the body of the text. The ISA printed standard includes the national difference types in an annex at the back of the standard.

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 based on **safety practices**. These are differences for IEC requirements that may be acceptable, but adopting the IEC requirements would require considerable retesting or redesign on the manufacturer's part.

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**.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**SAFETY REQUIREMENTS FOR ELECTRICAL EQUIPMENT FOR
MEASUREMENT, CONTROL, AND LABORATORY USE –****Part 1: General requirements****FOREWORD**

- 1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the 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, the IEC publishes International Standards. 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. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of the IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested National Committees.
- 3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical specifications, technical reports or guides and they are accepted by the National Committees in that sense.
- 4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.
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- 6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 61010-1 has been prepared by IEC technical committee 66: Safety of measuring, control and laboratory equipment.

It has the status of a group safety publication, as specified in IEC Guide 104.

This second edition cancels and replaces the first edition published in 1990, amendment 1 (1992) and amendment 2 (1995). It constitutes a technical revision.

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

FDIS	Report on voting
66/233/FDIS	66/244/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 3.

Annexes A to H form an integral part of this standard.

In this standard, the following print types are used:

- requirements and definitions: in roman type;
- NOTES: in smaller roman type;
- *conformity: in italic type*;
- terms used throughout this standard which have been defined in clause 3: SMALL ROMAN CAPITALS.

The committee has decided that the contents of this publication will remain unchanged until 2002. At this date, the publication will be

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

INTRODUCTION

This part 1 specifies the safety requirements that are generally applicable to all equipment within its scope. For certain types of equipment, these requirements will be supplemented or modified by the special requirements of one, or more than one, particular part 2 of the standard which must be read in conjunction with the part 1 requirements.

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SAFETY REQUIREMENTS FOR ELECTRICAL EQUIPMENT FOR MEASUREMENT, CONTROL, AND LABORATORY USE –

Part 1: General requirements

1 Scope and object

1.1 Scope

1.1.1 Equipment included in scope

This part of IEC 61010 specifies general safety requirements for electrical equipment intended for professional, industrial process, and educational use, any of which may incorporate computing devices, as defined in a) to d) below, when used under the environmental conditions of 1.4.

a) Electrical test and measurement equipment

This is equipment which by electrical means tests, measures, indicates or records one or more electrical or non-electrical quantities, also non-measuring equipment such as signal generators, measurement standards, power supplies, transducers, transmitters, etc.

NOTE All indicating and recording electrical measuring instruments (except those excluded in 1.1.2) fall within the scope of IEC 61010 unless they are panel meters designed only for building-in to other equipment. Built-in panel meters are considered to be components and only need to meet the relevant requirements of IEC 61010, or other standards, as part of the equipment into which they are built.

This Part 1 applies to test equipment integrated into manufacturing facilities intended for testing electronic devices, including silicon wafers and other semiconductor devices.

Note: This equipment is likely to be installed adjacent to and interconnected with industrial machinery in this application.

b) Electrical control equipment

This is equipment which controls one or more output quantities to specific values, with each value determined by manual setting, by local or remote programming, or by one or more input variables.

c) Electrical laboratory equipment

This is equipment which measures, indicates, monitors or analyses substances, or is used to prepare materials, and includes in vitro diagnostic (IVD) equipment

This equipment may also be used in areas other than laboratories, for example self-test IVD equipment may be used in the home.

d) Accessories intended for use with the above (for example, sample handling equipment)

1.1.2 Equipment excluded from scope

This standard does not apply to equipment within the scope of

- a) IEC 60065 (Safety requirements for audio, video and similar electronic apparatus);
- b) IEC 60204 (Controls for electrical machines);
- c) IEC 60335 (Safety of household and similar electrical appliances);
- d) IEC 60364 (Electrical installations of buildings);
- e) IEC 60439-1 (Low-voltage switchgear and controlgear assemblies);

- f) IEC 60521 (Class 0.5; 1 and 2 alternating current watt-hour meters);
- g) IEC 60601 (Medical electrical equipment);
- h) IEC 60950 (Safety of information technology equipment including electrical business equipment, except as specified in 1.1.3); and
- i) IEC 61558 (Power transformers, power supply units and similar).

1.1.3 Computing equipment

This standard applies only to computers, processors, etc. which form part of equipment within the scope of this standard or are designed for use exclusively with the equipment.

NOTE Computing devices and similar equipment within the scope of IEC 60950 and conforming to its requirements are considered to be suitable for use with equipment within the scope of this standard. However, some of the requirements of IEC 60950 for resistance to moisture and liquids are less stringent than those in this standard. If HAZARDS from moisture or liquids could affect equipment that conforms to IEC 60950 and is used with equipment which conforms to this standard, the instructions for use should specify any additional precautions required.

1.1.4 Compliance with National Codes

This standard applies to equipment to be employed in accordance with ANSI/NFPA 70, National Electrical Code® (NEC) or designed to be installed in accordance with the Canadian Electrical Code (CEC), Part I, CSA C22.1; CSA C22.2 No. 0 or designed to comply with both.

1.2 Object

1.2.1 Aspects included in scope

The purpose of the requirements of this part 1 is to ensure that the design and methods of construction used provide adequate protection for the OPERATOR and the surrounding area against

- a) electric shock or burn (see clause 6);
- b) mechanical HAZARDS (see clauses 7 and 8);
- c) excessive temperature (see clauses 9 and 10);
- d) spread of fire from the equipment (see clause 9);
- e) effects of fluids and fluid pressure (see clause 11);
- f) effects of radiation, including lasers sources, and sonic and ultrasonic pressure (see clause 12); and
- g) liberated gases, explosion and implosion (see clause 13).

NOTE Attention is drawn to the existence of additional requirements which may be specified by national authorities responsible for the health and safety of labour forces.

1.2.2 Aspects excluded from scope

This standard does not cover

- a) reliable function, performance or other properties of the equipment not related to safety;
- b) effectiveness of transport packaging;
- c) EMC requirements, which are covered by IEC 61326;
- d) protective measures for explosive atmospheres (see IEC 60079);

- e) servicing (repair); and
- f) protection of servicing (repair) personnel.

NOTE Servicing personnel are expected to be reasonably careful in dealing with obvious HAZARDS, but the design should protect against mishap by the use of warning labels, shields for hazardous voltage TERMINALS, segregation of low-voltage circuits from hazardous voltages, etc. More important, servicing personnel should be trained to recognize unexpected HAZARDS and to react accordingly.

1.3 Verification

This standard also specifies methods of verifying, through inspection and type testing, that the equipment meets the requirements of this standard.

NOTE Requirements for ROUTINE TESTS are given in Annex F.

1.4 Environmental conditions

1.4.1 Normal environmental conditions

This standard applies to equipment designed to be safe at least under the following conditions:

- a) Indoor use
 - b) Altitude up to 2 000 m
 - c) Temperature 5 °C to 40 °C
 - d) Maximum relative humidity 80 % for temperatures up to 31 °C decreasing linearly to 50 % relative humidity at 40 °C
 - e) MAINS supply voltage fluctuations up to ± 10 % of the nominal voltage
 - f) Transient overvoltages typically present on the MAINS supply
- NOTE The normal level of transient overvoltages is impulse withstand (overvoltage) category II of IEC 60364-4-443.
- g) Applicable RATED POLLUTION degree

1.4.2 Extended environmental conditions

This standard applies to equipment designed to be safe not only in the environmental conditions specified in 1.4.1, but also in any of the following conditions for which the equipment is RATED by the manufacturer:

- a) Outdoor use
- b) Altitude above 2 000 m
- c) Ambient temperatures below 5 °C or above 40 °C
- d) Relative humidity above the levels specified in 1.4.1
- e) MAINS supply voltage fluctuations exceeding ± 10 % of the nominal voltage

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 61010. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of IEC 61010 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

IEC 60027, *Letter symbols to be used in electrical technology*

IEC 60060, *High-voltage test techniques*

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

IEC 60085, *Thermal evaluation and classification of electrical insulation*

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

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

IEC 60309, *Plugs, socket-outlets and couplers for industrial purposes*

IEC 60335, *Safety of household and similar electrical appliances*

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

IEC 60651, *Sound level meters*

IEC 60664-3, *Insulation coordination for equipment within low-voltage systems – Part 3: Use of coatings to achieve insulation coordination of printed board assemblies*

IEC 60707, *Flammability of solid non-metallic materials when exposed to flame sources – List of test methods*

IEC 60799, *Electrical accessories – Cord sets and interconnection cord sets*

IEC 60804, *Integrating-averaging sound level meters*

IEC 60825-1, *Safety of laser products – Part 1: Equipment classification, requirements and user's guide*

IEC 60947-1, *Low-voltage switchgear and controlgear – Part 1: General rules*

IEC 60947-3, *Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units*

ISO 306:1994, *Plastics – Thermoplastic materials – Determination of Vicat softening temperature (VST)*

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

ISO 4126-1, *Safety valves – Part 1: General requirements*

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

ANSI/NFPA 70 - National Electrical Code

ANSI/UL 94: 1991 - Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

ANSI/UL 498: 1991 - Attachment Plugs and Receptacles

ANSI/UL 746C: 1995 - Polymeric Materials -- Use in Electrical Equipment Evaluations

ANSI/UL 817: 1994 - Cord Sets and Power Supply Cords

ANSI/UL 1310: 1995 - Class 2 Power Units

CSA C22.1 - Canadian Electrical, Code Part I

CAN/CSA C22.2 No.0.17 - Evaluation of Properties of Polymeric Materials

CSA C22.2 No.21 - Cord Sets and Power Supply Cords

CSA C22.2 No.42 - General Use Receptacles, Attachment Plugs, and Similar Wiring Devices

CSA C22.2 No. 182.1 - Industrial Type, Special Use Attachment Plugs, Receptacles, and Connectors

CSA C22.2 No. 182.2 - Industrial Locking Type, Special Use Attachment Plugs, Receptacles, and Connectors

CSA C22.2 No. 182.3 - Special Use Attachment Plugs, Receptacles, and Connectors

CAN/CSA C22.2 No.223 - Power Supplies With Extra-Low Voltage Class 2 Outputs

3 Terms and definitions

For the purpose of this part of IEC 61010 the following definitions apply.

Unless otherwise specified, values of "voltage" and "current" are the r.m.s. values of an alternating, direct or composite voltage or current.

NOTE An index of defined terms is given in Annex H.

3.1 Equipment and states of equipment

3.1.1

fixed equipment

equipment fastened to a support, or otherwise secured in a specific location [IEV 826-07-07]

3.1.2

PERMANENTLY CONNECTED EQUIPMENT

equipment that is electrically connected to a supply by means of a permanent connection which can be detached only by the use of a TOOL

3.1.3

PORTABLE EQUIPMENT

equipment intended to be carried by hand

3.1.4

HAND-HELD EQUIPMENT

PORTABLE EQUIPMENT intended to be supported by one hand during NORMAL USE

3.1.5

TOOL

external device, including keys and coins, used to aid a person to perform a mechanical function

3.2 Parts and accessories

3.2.1

TERMINAL

a component provided for the connection of a device (equipment) to external conductors [IEV 151-01-03, modified]

NOTE TERMINALS can contain one or several contacts and the term therefore includes sockets, connectors, etc.

3.2.2

FUNCTIONAL EARTH TERMINAL

TERMINAL by which electrical connection is made direct to a point of a measuring or control circuit or to a screening part and which is intended to be earthed for any functional purpose other than safety

NOTE For measuring equipment, this TERMINAL is often termed measuring earth TERMINAL.

3.2.3

PROTECTIVE CONDUCTOR TERMINAL

TERMINAL which is bonded to conductive parts of an equipment for safety purposes and is intended to be connected to an external protective earthing system

3.2.4

ENCLOSURE

part providing protection of equipment against certain external influences and, in any direction, protection against direct contact

3.2.5

BARRIER

part providing protection against direct contact from any usual direction of access

NOTE ENCLOSURES and BARRIERS may provide protection against the spread of fire (see 9.2.1 b)).

3.3 Electrical quantities

3.3.1

RATED (value)

quantity value assigned, generally by a manufacturer, to a specified operating condition of a component, device or equipment [IEV 151-04-03]

3.3.2

RATING

set of RATED values and operating conditions [IEV 151-04-04]

3.3.3

WORKING VOLTAGE

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

NOTE 1 Transients are disregarded.

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

3.4 Tests

3.4.1

TYPE TEST

test of one or more samples of equipment (or parts of equipment) made to a particular design, to show that the design and construction meet one or more requirements of this standard [IEV 151-04-15, modified]

NOTE This is an amplification of the IEV 151-04-15 definition to cover both design and construction requirements.

3.4.2

ROUTINE TEST

test to which each individual device (equipment) is subjected during or after manufacture to ascertain whether it conforms to certain criteria [IEV 151-04-16, modified] (See Annex F)

3.5 Safety terms

3.5.1

ACCESSIBLE (of a part)

able to be touched with a standard test finger or test pin, when used as specified in 6.2

3.5.2

HAZARD

potential source of harm

3.5.3

HAZARDOUS LIVE

capable of rendering an electric shock or electric burn in NORMAL CONDITION or SINGLE FAULT CONDITION

NOTE See 6.3.1 for values applicable to NORMAL CONDITION and 6.3.2 for the higher values deemed to be appropriate in SINGLE FAULT CONDITION.

3.5.4

HIGH INTEGRITY

not liable to become defective in such a manner as to cause a risk of HAZARD; a HIGH INTEGRITY part is considered as not subject to failure when tests under fault conditions are made

3.5.5

MAINS

low-voltage electricity supply system (above the values of 6.3.2 a)) to which the equipment concerned is designed to be connected for the purpose of powering the equipment

NOTE Some measuring circuits may also be connected to the MAINS for measuring purposes.

3.5.6

MAINS CIRCUIT

circuit which is intended to be conductively connected to the MAINS for the purpose of powering the equipment

NOTE Measuring circuits and circuits that are inductively derived from MAINS CIRCUITS are not MAINS CIRCUITS.

3.5.7

PROTECTIVE IMPEDANCE

component, assembly of components or the combination of BASIC INSULATION and a current or voltage-limiting device, whose impedance, construction and reliability are such that, when connected between ACCESSIBLE conductive parts and parts which are HAZARDOUS LIVE, it provides protection to the extent required by this standard in NORMAL CONDITION and SINGLE FAULT CONDITION

3.5.8

PROTECTIVE BONDING

electrical connection of ACCESSIBLE conductive parts or protective screening to provide electrical continuity to the means for connection of an external protective conductor

3.5.9

NORMAL USE

operation, including stand-by, according to the instructions for use or for the obvious intended purpose

NOTE In most cases, NORMAL USE also implies NORMAL CONDITION, because the instructions for use will warn against using the equipment when it is not in NORMAL CONDITION.

3.5.10

NORMAL CONDITION

condition in which all means for protection against HAZARDS are intact

3.5.11

SINGLE FAULT CONDITION

condition in which one means for protection against HAZARD is defective or one fault is present which could cause a HAZARD

NOTE If a SINGLE FAULT CONDITION results unavoidably in another SINGLE FAULT CONDITION, the two failures are considered as one SINGLE FAULT CONDITION

3.5.12

OPERATOR

person operating equipment for its intended purpose

NOTE The OPERATOR should have received training appropriate for this purpose.

3.5.13

RESPONSIBLE BODY

individual or group responsible for the use and maintenance of equipment and for ensuring that OPERATORS are adequately trained

3.5.14

WET LOCATION

location where water or another conductive liquid may be present and is likely to cause reduced human body impedance due to wetting of the contact between the human body and the equipment, or wetting of the contact between the human body and the environment

3.6 Insulation

3.6.1

BASIC INSULATION

insulation, the failure of which could cause a risk of electric shock

NOTE BASIC INSULATION may serve also for functional purposes.

3.6.2

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

3.6.3

DOUBLE INSULATION

insulation comprising both BASIC INSULATION and SUPPLEMENTARY INSULATION

3.6.4

REINFORCED INSULATION

insulation which provides protection against electric shock not less than that provided by DOUBLE INSULATION. It may comprise several layers which cannot be tested singly as SUPPLEMENTARY INSULATION or BASIC INSULATION

3.6.5

POLLUTION

addition of foreign matter, solid, liquid or gaseous (ionized gases), that may produce a reduction of dielectric strength or surface resistivity

3.6.6

POLLUTION degree

for the purpose of evaluating spacings, the following degrees of POLLUTION in the micro-environment are defined

3.6.6.1

POLLUTION DEGREE 1

no POLLUTION or only dry, non-conductive POLLUTION occurs. The POLLUTION has no influence

3.6.6.2

POLLUTION DEGREE 2

normally only non-conductive POLLUTION occurs. Occasionally, however, a temporary conductivity caused by condensation must be expected

3.6.6.3

POLLUTION DEGREE 3

conductive POLLUTION occurs, or dry, non-conductive POLLUTION occurs which becomes conductive due to condensation which is expected

NOTE In such conditions, equipment is normally protected against exposure to direct sunlight, precipitation, and full wind pressure, but neither temperature nor humidity is controlled.

3.6.7

CLEARANCE

shortest distance in air between two conductive parts

3.6.8

CREEPAGE DISTANCE

shortest distance along the surface of the insulating material between two conductive parts
[IEV 151-03-37]

4 Tests

4.1 General

Tests in this standard are TYPE TESTS to be carried out on samples of equipment or parts. Their only purpose is to check that the design and construction ensure conformity with this standard. In addition, manufacturers shall perform the ROUTINE TESTS of Annex F on 100 % of equipment produced which has both HAZARDOUS LIVE parts and ACCESSIBLE conductive parts.

Tests on subassemblies of the equipment meeting the requirements of the relevant standards specified in this standard and used in accordance with them, need not be repeated during TYPE TESTS of the whole equipment.

Conformity with the requirements of this standard is checked by carrying out all applicable tests, except that a test may be omitted if examination of the equipment demonstrates conclusively that the equipment would pass the test. Tests are carried out under

- a) *reference test conditions (see 4.3);*
- b) *fault conditions (see 4.4).*

NOTE If when carrying out a conformity test, there is any uncertainty about the exact value of an applied or measured quantity (for example, voltage) due to the tolerance:

- *the manufacturer should ensure that at least the specified test value is applied;*
- *the test house should ensure that no more than the specified test value is applied.*

4.2 Sequence of tests

The sequence of tests is optional unless otherwise specified in this standard. The equipment under test shall be carefully inspected after each test. If the result of a test causes doubt whether any earlier tests would have been passed if the sequence had been reversed, these earlier tests shall be repeated. If tests under fault conditions may be destructive, these tests may follow those under reference test conditions.

4.3 Reference test conditions

4.3.1 Environmental conditions

Unless otherwise specified in this standard, the following environmental conditions shall exist in the test location:

- a) A temperature of 15 °C to 35 °C
- b) A relative humidity of not more than 75 %, but not exceeding the limits of 1.4.1 d)
- c) An air pressure of 75 kPa to 106 kPa
- d) No hoar-frost, dew, percolating water, rain, solar radiation, etc.

4.3.2 State of equipment

Unless otherwise specified, each test shall be carried out on the equipment assembled for NORMAL USE and under the least favourable combination of the conditions given in 4.3.2.1 to 4.3.2.13.

If dimensions or mass make it unsuitable to carry out particular tests on a complete equipment, tests on sub-assemblies are allowed, provided it is verified that the assembled equipment will meet the requirements of this standard.

Equipment intended to be built into a wall, recess, cabinet, etc., shall be installed as specified in the manufacturer's instructions.

4.3.2.1 Position of equipment

The equipment shall be in any position of NORMAL USE and with any ventilation unimpeded.

4.3.2.2 Accessories

Accessories and OPERATOR interchangeable parts available from, or recommended by, the manufacturer for use with the equipment under test shall be either connected or not connected.

4.3.2.3 Covers and removable parts

Covers or parts which can be removed without using a TOOL shall be removed or not removed.

4.3.2.4 MAINS supply

The following requirements apply:

- a) The supply voltage shall be between 90 % and 110 % of any RATED supply voltage for which the equipment can be set or, if the equipment is RATED for a greater fluctuation, at any supply voltage within the fluctuation range.
- b) The frequency shall be any RATED frequency.
- c) Equipment for both a.c. and d.c. shall be connected to an a.c. or d.c. supply.
- d) Equipment for d.c. or single-phase supply shall be connected both with normal and reverse polarity.
- e) Unless the equipment is specified for use only on a non-earthed MAINS supply, one pole of the reference test supply shall be at or near earth potential.
- f) If the means of connection permits reversal, battery-operated equipment shall be connected with both reverse and normal polarity.

4.3.2.5 Input and output voltages

Input and output voltages, including floating voltages but excluding the MAINS supply voltage, shall be set to any voltage within the RATED voltage range.

4.3.2.6 Earth TERMINALS

PROTECTIVE CONDUCTOR TERMINALS, if any, shall be connected to earth. FUNCTIONAL EARTH TERMINALS shall be connected or not connected to earth.

4.3.2.7 Controls

Controls which the OPERATOR can adjust by hand shall be set to any position except that

- a) MAINS selection devices shall be set to the correct value;
- b) combinations of settings shall not be made if they are prohibited by the manufacturer's marking on the equipment.

4.3.2.8 Connections

The equipment shall be connected for its intended purpose, or not connected.

4.3.2.9 Load on motors

Load conditions of motor-driven parts of equipment shall be in accordance with the intended purpose.

4.3.2.10 Output

For equipment giving an electrical output,

- a) the equipment shall be operated in such a way as to provide the RATED output power to the RATED load; and
- b) the RATED load impedance of any output shall be connected or not connected.

4.3.2.11 Duty cycle

Equipment for short-term or intermittent operation shall be operated for the longest period and shall have the shortest recovery period consistent with the manufacturer's instructions.

4.3.2.12 Loading and filling

Equipment intended to be loaded with a specific material in NORMAL USE shall be loaded with the least favourable quantity of the materials specified in the instructions for use, including not loaded (empty) if the instructions for use permit this in NORMAL USE.

NOTE 1 In case of doubt, tests should be performed in more than one loading condition.

NOTE 2 If the specified material could cause a HAZARD during test, another material may be used provided that it can be shown that the result of the test is not affected.

4.3.2.13 Heating equipment

When measuring temperatures to evaluate the spread of fire, heating equipment shall be tested in a test corner as required by 10.4.1.

4.4 Testing in SINGLE FAULT CONDITION

4.4.1 General

The following requirements apply.

- a) Examination of the equipment and its circuit diagram will generally show the fault conditions which are liable to result in HAZARDS and which, therefore, shall be applied.

- b) Fault tests shall be made unless it can be demonstrated that no HAZARD could arise from a particular fault condition, or specified alternative methods of checking conformity are chosen in place of fault testing (see clause 9 b) and c)).
- c) The equipment shall be operated under the least favourable combination of reference test conditions (see 4.3). These combinations may be different for different faults and they shall be recorded for each test.

4.4.2 Application of fault conditions

Fault conditions shall include those specified in 4.4.2.1 to 4.4.2.12. They shall be applied only one at a time and shall be applied in turn in any convenient order. Multiple simultaneous faults shall not be applied unless they are a consequence of an applied fault.

After each application of a fault condition, the equipment or part shall pass the applicable tests of 4.4.4.

4.4.2.1 PROTECTIVE IMPEDANCE

- a) If a PROTECTIVE IMPEDANCE is formed by a combination of components, each component shall be short-circuited or disconnected, whichever is less favourable.
- b) If a PROTECTIVE IMPEDANCE is formed by the combination of BASIC INSULATION and a current- or voltage-limiting device, both the BASIC INSULATION and the current- or voltage-limiting device shall be subjected to single faults, applied one at a time. BASIC INSULATION shall be bridged and the current- or voltage-limiting device shall be short-circuited or disconnected, whichever is less favourable.

Parts of PROTECTIVE IMPEDANCE which are HIGH-INTEGRITY components need not be short-circuited or disconnected (see 6.5.3 and 14.6).

4.4.2.2 Protective conductor

The protective conductor shall be interrupted, except for PERMANENTLY CONNECTED EQUIPMENT or equipment utilizing a connector in accordance with IEC 60309.

4.4.2.3 Equipment or parts for short-term or intermittent operation

These shall be operated continuously if continuous operation could occur in a SINGLE FAULT CONDITION. Individual parts may include motors, relays, other electromagnetic devices and heaters.

4.4.2.4 Motors

Motors shall be stopped while fully energized or prevented from starting, whichever is less favourable.

4.4.2.5 Capacitors

Capacitors (except for self-healing capacitors) in the auxiliary winding circuits of motors shall be short-circuited.

4.4.2.6 MAINS transformers

The secondary windings of MAINS transformers shall be short-circuited as specified in 4.4.2.6.1, and overloaded as specified in 4.4.2.6.2.

A transformer damaged during one test may be repaired or replaced before the next test.

Tests for MAINS transformers tested as separate components are specified in 14.7.

4.4.2.6.1 Short circuit

Each untapped output winding, and each section of a tapped output winding, which is loaded in NORMAL USE, shall be tested in turn, one at a time, to simulate short circuits in the load. Overcurrent protection devices remain fitted during the test. All other windings are loaded or not loaded, whichever load condition of NORMAL USE is less favourable.

4.4.2.6.2 Overload

Each untapped output winding, and each section of tapped output winding, is overloaded in turn one at a time. The other windings are loaded or not loaded, whichever load condition of NORMAL USE is less favourable. If any overloads arise from testing in the fault conditions of 4.4, secondary windings shall be subjected to those overloads.

Overloading is carried out by connecting a variable resistor across the winding. 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.

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. Before the test, the device is replaced by a link with negligible impedance. If this value cannot be derived from the specification, it is to be established by test.

For equipment in which the output voltage is designed to collapse when a specified overload current is reached, the overload is slowly increased to a point just before the point which causes the output voltage to collapse.

In all other cases, the loading is the maximum power output obtainable from the transformer.

Transformers with overtemperature protection which meets the requirements of 14.3 during the short-circuit test of 4.4.2.6.1 need not be subjected to overload tests.

4.4.2.7 Outputs

Outputs shall be short-circuited one at a time.

4.4.2.8 Equipment for more than one supply

Equipment which is designed to be operated from more than one type of supply shall be simultaneously connected to these supplies, unless this is prevented by the construction.

4.4.2.9 Cooling

Equipment cooling shall be restricted as follows, one fault at a time:

- a) Air-holes with filters shall be closed
- b) Forced cooling by motor-driven fans shall be stopped
- c) Cooling by circulation of water or other coolant shall be stopped

4.4.2.10 Heating devices

In equipment incorporating heating devices, the following faults shall be applied one at a time:

- a) Timers which limit the heating period shall be overridden to energize the heating circuit continuously.
- b) Temperature controllers, except for overtemperature protection devices meeting the requirements of 14.3, shall be overridden to energize the heating circuit continuously.
- c) Loss of cooling liquid shall be simulated.

4.4.2.11 Insulation between circuits and parts

Insulation between circuits and parts which is below the level specified for BASIC INSULATION shall be bridged to check against the spread of fire.

NOTE See clause 9 a) and b) for alternative methods of checking protection against spread of fire.

4.4.2.12 Interlocks

Each part of an interlock system for the protection of OPERATORS shall be short-circuited or open-circuited in turn if the system prevents access to HAZARDS when a cover, etc. is removed without the use of a TOOL.

HIGH INTEGRITY components of interlock systems (see 14.6 and 15.3) need not be short-circuited or open-circuited.

4.4.3 Duration of tests

4.4.3.1 The equipment shall be operated until further change as a result of the applied fault is unlikely. Each test is normally limited to 1 h since a secondary fault arising from a SINGLE FAULT CONDITION will usually manifest itself within that time. If there is an indication that a risk of electric shock, spread of fire or injury to persons may eventually occur, the test shall be continued until one of these HAZARDS does occur or for a maximum period of 4 h, unless a HAZARD occurs before then.

4.4.3.2 Where a device which interrupts or limits the current during operation is included to limit the temperature of parts which can easily be touched, the maximum temperature attained by the equipment shall be measured, whether the device operates or not.

4.4.3.3 If a fault is terminated by the opening of a fuse and if the fuse does not operate within approximately 1 s, the current through the fuse under the relevant fault condition shall be measured. Evaluation with the pre-arcing time/current characteristics shall be made to find out whether the minimum operating current of the fuse is reached or exceeded and what is the maximum time before the fuse operates. The current through the fuse may vary as a function of time.

If the minimum operating current of the fuse is not reached in the test, the equipment shall be operated for a period corresponding to the maximum fusing time or continuously for the duration specified in 4.4.3.1.

4.4.4 Conformity after application of fault conditions

4.4.4.1 *Conformity with requirements for protection against electric shock is checked after the application of single faults as follows:*

- a) *By making the measurements of 6.3.2 to check that no ACCESSIBLE conductive parts have become HAZARDOUS LIVE*
- b) *By performing a voltage test on DOUBLE INSULATION or REINFORCED INSULATION to check that there is still one level of protection by insulation. The voltage test is made as specified in 6.8 (without ~~conformity~~ Humidity preconditioning) with the test voltage for BASIC INSULATION.*
- c) *By measuring the temperature of transformer windings if the protection against electrical HAZARDS is achieved by DOUBLE INSULATION or REINFORCED INSULATION within the transformer. The temperatures of Table 16 shall not be exceeded.*

4.4.4.2 Conformity with requirements for temperature protection is checked by determining the temperature of the outer surface of the ENCLOSURE and of parts which can easily be touched.

Except for heated surfaces of heating equipment, the temperature of these parts shall not exceed 105 °C at an ambient temperature of 40 °C or the maximum RATED ambient temperature if higher.

This temperature is determined by measuring the temperature rise of the surface or part and adding it to 40 °C or the maximum RATED ambient temperature if higher.

4.4.4.3 Conformity with requirements for protection against the spread of fire is checked by placing the equipment on white tissue-paper covering a softwood surface and covering the equipment with cheesecloth. No molten metal, burning insulation, flaming particles, etc. shall fall on the surface on which the equipment stands and there shall be no charring, glowing, or flaming of the tissue paper or cheesecloth. Melting of insulation material shall be ignored if no HAZARD could arise.

4.4.4.4 Conformity with requirements for protection against other HAZARDS is checked as specified in clauses 7 and 8, and 11 to 16.

5 Marking and documentation

5.1 Marking

5.1.1 General

Equipment shall bear markings as specified in 5.1.2 to 5.2. Except for marking of internal parts, these markings shall be visible from the exterior, or be visible after removing a cover or opening a door without the aid of a TOOL, if the cover or door is intended to be removed or opened by an OPERATOR. Markings applying to the equipment as a whole shall not be put on parts which can be removed by an OPERATOR without the use of a TOOL.

For rack- or panel-mounted equipment, markings are permitted to be on a surface that becomes visible after removal of the equipment from the rack or panel.

Letter symbols for quantities and units shall be in accordance with IEC 60027. Graphic symbols shall be in accordance with Table 1 if applicable. There are no colour requirements for symbols. Graphic symbols shall be explained in the documentation.

NOTE 1 IEC or ISO symbols should be used if available.

NOTE 2 Markings should not be on the bottom of the equipment, except on HAND-HELD EQUIPMENT or where space is limited.

Conformity is checked by inspection.

5.1.2 Identification

The equipment shall, as a minimum, be marked with

- a) the name or trade mark of the manufacturer or supplier; and
- b) a model number, name or other means to identify the equipment. If equipment bearing the same distinctive designation (model number) is manufactured at more than one location, equipment from each manufacturing location shall be marked so that the location can be identified.

NOTE The marking of factory location may be in code and need not be on the equipment exterior.

Conformity is checked by inspection.

5.1.3 MAINS supply

The equipment shall be marked with the following information:

- a) Nature of supply
 - 1) a.c.: RATED MAINS frequency or range of frequencies
 - 2) d.c.: symbol 1 of Table 1

NOTE For information purposes it may be useful to mark

- equipment intended for a.c. with symbol 2 of Table 1;
- equipment suitable for both a.c. and d.c. with symbol 3 of Table 1;
- equipment for three-phase supply with symbol 4 of Table 1.

















- b) The RATED value(s) of the supply voltage(s) or the RATED range of the supply voltages

NOTE RATED voltage fluctuations may also be marked.

- c) The maximum RATED power in watts (active power) or volt-amperes (apparent power), or the maximum RATED input current, with all accessories or plug-in modules connected. If the equipment can be used on more than one voltage range, separate values shall be marked for each voltage range unless the maximum and minimum values do not differ by more than 20 % of the mean value.
- d) Equipment which the OPERATOR can set for different RATED supply voltages shall be provided with means for the indication of the voltage for which the equipment is set. For PORTABLE EQUIPMENT the indication shall be visible from the exterior. If the equipment is so constructed that the supply voltage setting can be altered without the use of a TOOL, the action of changing the setting shall also change the indication.
- e) Accessory MAINS socket-outlets accepting standard MAINS plugs shall be marked with the voltage if it is different from the MAINS supply voltage. If the outlet is for use only with specific equipment, it shall be marked to identify the equipment for which it is intended. If not, the maximum RATED current or power shall be marked, or symbol 14 of Table 1 placed beside the outlet with the full details included in the documentation.

Conformity is checked by inspection and by measurement of power or input current to check the marking of 5.1.3 c). The measurement is made after the current has reached a stationary stage (usually after 1 min) so as to exclude any initial inrush current. The equipment shall be in the condition of maximum power consumption. Transients are ignored. The measured value shall not exceed the marked value by more than 10 %.

Table 1 – Symbols

Number	Symbol	Reference	Description
1		IEC 60417 – 5031	Direct current
2		IEC 60417 – 5032	Alternating current
3		IEC 60417 – 5033	Both direct and alternating current
4			Three-phase alternating current
5		IEC 60417 – 5017	Earth (ground) TERMINAL
6		IEC 60417 – 5019	PROTECTIVE CONDUCTOR TERMINAL
7		IEC 60417 – 5020	Frame or chassis TERMINAL
8		IEC 60417 – 5021	Equipotentiality
9		IEC 60417 – 5007	On (Supply)
10		IEC 60417 – 5008	Off (Supply)
11		IEC 60417 – 5172	Equipment protected throughout by DOUBLE INSULATION or REINFORCED INSULATION
12			Caution, risk of electric shock
13		IEC 60417 – 5041	Caution, hot surface
14		ISO 7000 – 0434	Caution, risk of danger (See note.)
15		IEC 60417 – 5268	In position of a bi-stable push control
16		IEC 60417 – 5269	Out position of a bi-stable push control
NOTE See 5.4.1 which requires manufacturers to state that documentation must be consulted in all cases where this symbol is marked.			

5.1.4 Fuses

For any fuse which may be replaced by an OPERATOR, there shall be a marking beside the fuseholder, which will enable the OPERATOR to identify the correct replacement fuse (see 5.4.5).

Conformity is checked by inspection.

5.1.5 TERMINALS, connections and operating devices

If necessary for safety, an indication shall be given of the purpose of TERMINALS, connectors, controls, and indicators, including any connections for fluids such as gas, water and drainage. Where there is insufficient space, symbol 14 of Table 1 may be used.

NOTE 1 For additional information, see IEC 60445 and IEC 60447.

NOTE 2 Individual pins of multi-pin connectors need not be marked.

5.1.5.1 TERMINALS

TERMINALS for connection to the MAINS supply shall be identifiable.

The following TERMINALS shall be marked as follows:

- a) FUNCTIONAL EARTH TERMINALS with symbol 5 of Table 1
- b) PROTECTIVE CONDUCTOR TERMINALS with symbol 6 of Table 1, except when the PROTECTIVE CONDUCTOR TERMINAL is part of an approved MAINS appliance inlet. The symbol shall be placed close to, or on, the TERMINAL.
- c) TERMINALS of measuring and control circuits which are permitted by 6.6.3 to be connected to ACCESSIBLE conductive parts with symbol 7 of Table 1 if this connection is not self-evident.

NOTE This symbol may also be considered as a warning symbol in that it indicates that a HAZARDOUS LIVE voltage must not be connected to the TERMINAL. The symbol should also be used if it is likely that the OPERATOR could make such a connection inadvertently.
- d) TERMINALS supplied from the interior of the equipment and which are HAZARDOUS LIVE, with the voltage, current, charge or energy value or range, or with symbol 14 of Table 1. This requirement does not apply to MAINS supply outlets where a standard MAINS socket outlet is used.
- e) ACCESSIBLE FUNCTIONAL EARTH TERMINALS connected to ACCESSIBLE conductive parts, with an indication that this is the case, unless it is self-evident. Symbol 8 of Table 1 is acceptable for this marking.

Conformity is checked by inspection.

5.1.5.2 Measuring circuit TERMINALS

Unless a clear indication (see note below) is provided on a measuring instrument that voltage and current measuring circuit TERMINALS are not intended to be connected to voltages to earth above 50 V a.c. or 120 V d.c., the TERMINALS shall be marked as follows.

- a) Measuring circuit TERMINALS for measurements within measurement category I (see 6.7.4) shall be marked with the RATED voltage or current as applicable and with symbol 14 of Table 1 (see also 5.4.1 f) and g)).
- b) Measuring circuit TERMINALS for measurements within measurement categories II, III and IV (see 6.7.4) shall be marked with the RATED voltage or current as applicable and the relevant measurement category. The measurement category markings shall be "CAT II", "CAT III" or "CAT IV" as applicable.

NOTE Examples of acceptable indications that the inputs in all cases are intended to be less than 50 V a.c. or 120 V d.c. to earth include

- a) the full-scale deflection marking of a single-range indicating voltmeter or maximum marking of a multi-range voltmeter;
- b) the maximum range marking of a voltage selector switch; and
- c) the marked intended function of the instrument (for example, millivoltmeter).

Voltage and current measuring circuit TERMINALS that are permanently connected and not ACCESSIBLE need not be marked (see 5.4.3 i)). The measurement category and the RATED maximum WORKING VOLTAGE or RATED maximum current for such TERMINALS shall be stated in the equipment installation instructions (see 5.4.3).

An exception is also permitted for circuit TERMINALS (connectors) which are dedicated only for connection to specific TERMINALS of other equipment, provided that there is a means for identifying these TERMINALS.

Markings shall be placed adjacent to the TERMINALS. However, if there is insufficient space (as in multi-input equipment), it is permissible for the marking to be on the RATING plate or scale plate, or for the TERMINAL to be marked with symbol 14 of Table 1.

Conformity is checked by inspection.

5.1.6 Switches and circuit-breakers

If the power supply switch or circuit-breaker is used as the disconnecting device, the on-position or the off-position shall be clearly marked. Symbols 9 and 10 of Table 1 can, in some cases, also be suitable as the device identification (see 6.11.2.56.11.31). A lamp alone is not considered to be a satisfactory marking. Symbols 9 and 10 shall not be used for switches other than the power supply switch.

If a push-button switch is used as the power supply switch, symbols 9 and 15 of Table 1 may be used to indicate the on-position, or symbols 10 and 16 to indicate the off-position, with the pair of symbols (9 and 15, or 10 and 16) close together.

Conformity is checked by inspection.

5.1.7 Equipment protected by DOUBLE INSULATION or REINFORCED INSULATION

Equipment protected throughout by DOUBLE INSULATION or REINFORCED INSULATION shall be marked with symbol 11 of Table 1 unless it is provided with a PROTECTIVE CONDUCTOR TERMINAL.

Equipment which is only partially protected by DOUBLE INSULATION or REINFORCED INSULATION shall not bear symbol 11 of Table 1.

Conformity is checked by inspection.

5.1.8 Field-wiring TERMINAL boxes

If the temperature of the TERMINALS or the ENCLOSURE of a field-wiring TERMINAL box or compartment exceeds 60 °C in NORMAL CONDITION at an ambient temperature of 40 °C, or the maximum RATED ambient temperature if higher, there shall be a marking of the minimum temperature RATING of the cable to be connected to the TERMINALS. The marking shall be visible before and during connection, or be beside the TERMINALS.

Conformity, in case of doubt, is checked by measurement as specified in 10.3 a) and, if applicable, by inspection of markings.

5.2 Warning markings

Warning markings shall be visible when the equipment is ready for NORMAL USE. If a warning applies to a particular part of the equipment, the marking shall be placed on, or near to, this part.

The size of warning markings shall be as follows.

- a) Symbols shall be at least 2.75 mm high. Text shall be at least 1.5 mm high and contrast in colour with the background.
- b) Symbols or text moulded, stamped or engraved in a material shall be at least 2.0 mm high. If not contrasting in colour, they shall have a depth or raised height of at least 0.5 mm.

If it is necessary for the RESPONSIBLE BODY or OPERATOR to refer to the instruction manual to preserve the protection afforded by the equipment, the equipment shall be marked with symbol 14 of Table 1. Symbol 14 is not required to be used with symbols which are explained in the manual.

If the instructions for use state that an OPERATOR is permitted to gain access, using a TOOL, to a part which in NORMAL USE may be HAZARDOUS LIVE, there shall be a warning marking which states that the equipment must be isolated or disconnected from the HAZARDOUS LIVE voltage before access.

Warning markings are specified in 5.1.5.1 c), 6.1.2 b), 6.5.1.2 g), 6.6.2, 7.2 c), 7.3, 10.1, 13.2.2.

Conformity is checked by inspection.

5.3 Durability of markings

Markings in accordance with 5.1.2 to 5.2 shall remain clear and legible under conditions of NORMAL USE and resist the effects of cleaning agents specified by the manufacturer.

Conformity is checked by inspection and by performing the following test for durability of markings on the outside of the equipment. The markings are rubbed by hand, without undue pressure, for 30 s with a cloth soaked with the specified cleaning agent (or, if not specified, with isopropyl alcohol).

The markings shall be clearly legible after the above treatment, and adhesive labels shall not have worked loose or become curled at the edges

5.4 Documentation

5.4.1 General

Equipment shall be accompanied by documentation for safety purposes as follows:

- a) Intended use of the equipment
- b) Technical specification
- c) Instructions for use

- d) Name and address of manufacturer or supplier from whom technical assistance may be obtained
- e) The information specified in 5.4.2 to 5.4.5
- f) Definition of the relevant measurement category if marking of TERMINALS is required on the equipment (see 5.1.5.2)
- g) For equipment marked with measurement category I, a warning shall be given not to use the equipment for measurements within measurement categories II, III and IV, and a detailed RATING including the RATED transient overvoltages is given in the documentation.
- h) For equipment which for safety reasons requires specific probe assemblies, or probe assemblies with specific characteristics, the documentation shall indicate that probe assemblies which meet the manufacturer's specifications shall be used.
- i) For equipment intended to detect the presence of a hazardous voltage, the instructions shall provide guidance on how to determine that the equipment is functioning correctly.

If applicable, warning statements and a clear explanation of warning symbols marked on the equipment shall be provided in the documentation or shall be durably and legibly marked on the equipment. In particular, there shall be a statement that documentation needs to be consulted in all cases where symbol 14 of Table 1 is used, in order to find out the nature of the potential HAZARD and any actions which have to be taken.

NOTE If NORMAL USE involves the handling of hazardous substances, instruction should be given on correct use and safety provisions. If any hazardous substance is specified or supplied by the equipment manufacturer, the necessary information on its constituents and the correct disposal procedure should also be given.

Conformity is checked by inspection.

5.4.2 Equipment RATINGS

Documentation shall include the following:

- a) The supply voltage or voltage range, frequency or frequency range, and power or current RATING
- b) A description of all input and output connections
- c) The RATING of the insulation of external circuits, appropriate for SINGLE FAULT CONDITIONS, if such circuits are nowhere ACCESSIBLE (see 6.6.2)
- d) A statement of the range of environmental conditions for which the equipment is designed (see 1.4)
- e) A statement of the degree of protection, if the equipment is RATED according to IEC 60529

Conformity is checked by inspection.

5.4.3 Equipment installation

The documentation shall include installation and specific commissioning instructions (examples are listed below) and, if necessary for safety, warnings against HAZARDS which could arise during installation or commissioning of the equipment:

- a) Assembly, location and mounting requirements
- b) Instructions for protective earthing
- c) Connections to the supply
- d) For PERMANENTLY CONNECTED EQUIPMENT:

- 1) Supply wiring requirements
 - 2) Requirements for any external switch or circuit-breaker (see 6.11.2.1) and external overcurrent protection devices (see 9.5.1) and a recommendation that the switch or circuit-breaker be near the equipment;
- e) Ventilation requirements
 - f) Requirements for special services, for example, air, cooling liquid
 - g) The maximum sound power level produced by equipment which emits sound, if measurement is required by 12.5.1
 - h) Instructions relating to sound pressure level (see 12.5.1)
 - i) For voltage- and current-measuring circuit TERMINALS that are permanently connected and not ACCESSIBLE, information regarding the measurement category, RATED maximum WORKING VOLTAGE or RATED maximum current (see 5.1.5.2)

Conformity is checked by inspection.

5.4.4 Equipment operation

Instructions for use shall include, if applicable:

- a) Identification of operating controls and their use in all operating modes
- b) An instruction not to position the equipment so that it is difficult to operate the disconnecting device
- c) Instructions for interconnection to accessories and other equipment, including indication of suitable accessories, detachable parts and any special materials
- d) Specification of limits for intermittent operation
- e) An explanation of symbols related to safety which are used on the equipment
- f) Instructions for replacement of consumable materials
- g) Instructions for cleaning and decontamination
- h) A statement listing any potentially poisonous or injurious gases that can be liberated from the equipment, and possible quantities
- i) Detailed instructions about risk-reduction procedures relating to flammable liquids (see 9.4 c))

There shall be a statement in the instructions that, if the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

Conformity is checked by inspection.

5.4.5 Equipment maintenance

Instructions for the RESPONSIBLE BODY concerning preventive maintenance and inspection necessary for safety shall be given in sufficient detail. These shall include the inspection and replacement, if necessary, of any hoses or other parts containing liquids, if their failure could cause a HAZARD (See 11.7).

NOTE Instructions should advise the RESPONSIBLE BODY of any tests necessary to check that equipment is still in a safe condition. They should also warn against the repetition of any tests of this standard which could damage the equipment and reduce protection against HAZARDS.

For equipment using replaceable batteries, the specific battery type shall be stated.

The manufacturer shall specify any parts which are required to be examined or supplied only by the manufacturer or his agent.

The RATING and characteristics of replaceable fuses shall be stated.

Conformity is checked by inspection.

6 Protection against electric shock

6.1 General

6.1.1 Requirements

Protection against electric shock shall be maintained in NORMAL CONDITION (see 6.4) and SINGLE FAULT CONDITION (see 6.5). ACCESSIBLE parts of equipment shall not be HAZARDOUS LIVE (see 6.3).

Conformity is checked by the determination of ACCESSIBLE parts as specified in 6.2 and the measurements of the levels of 6.3, followed by the tests of 6.4 to 6.11.

6.1.2 Exceptions

If it is not feasible for operating reasons to prevent the following parts being both ACCESSIBLE and HAZARDOUS LIVE, they are permitted to be ACCESSIBLE to the OPERATOR during NORMAL USE while they are HAZARDOUS LIVE:

- a) Parts of lamps and lamp sockets after lamp removal
- b) Parts intended to be replaced by the OPERATOR (for example, batteries) and which may be HAZARDOUS LIVE during the replacement or other OPERATOR action, but only if they are ACCESSIBLE only by means of a TOOL and have a warning marking (see 5.2)
- c) Locking and screw-held type measuring TERMINALS, including TERMINALS which do not require the use of a TOOL

If any of the parts in a) and b) receive a charge from an internal capacitor, they shall not be HAZARDOUS LIVE 10 s after interruption of the supply.

If a charge is received from an internal capacitor, conformity is checked by the measurements of 6.3 to establish that the levels of 6.3.1 c) are not exceeded.

6.2 Determination of ACCESSIBLE parts

Unless obvious, determination of whether a part is ACCESSIBLE shall be made as specified in 6.2.1 to 6.2.3. Test fingers (see Annex B) and pins shall be applied without force unless a force is specified. Parts are considered to be ACCESSIBLE if they can be touched with a test finger or pin, or if they could be touched in the absence of a covering which is not considered to provide suitable insulation (see 6.9.1). For HAZARDOUS LIVE parts at a voltage to earth exceeding 1 kV r.m.s. or 1.5 kV d.c., a part is considered to be ACCESSIBLE if the test finger or pin reaches a point nearer to the HAZARDOUS LIVE part than the applicable CLEARANCE for BASIC INSULATION for the WORKING VOLTAGE.

If the OPERATOR is intended to perform any actions in NORMAL USE (with or without a TOOL) which will increase the accessibility of parts, such actions shall be taken before performing the examinations of 6.2.1 to 6.2.3. Examples include:

- a) Removing covers
- b) Opening doors
- c) Adjusting controls
- d) Replacing consumable material
- e) Removing parts

For rack- or panel-mounted equipment, the equipment is installed as specified in the manufacturer's instructions before making the examinations of 6.2.1 to 6.2.3. For such equipment, the OPERATOR is assumed to be in front of the panel.

6.2.1 Examination

The jointed test finger (see Figure B.2) is applied in every possible position. If a part could become ACCESSIBLE by applying a force, the rigid test finger (see Figure B.1) is applied with a force of 10 N. The force is exerted by the tip of the test finger so as to avoid wedge and lever action. The test is applied to all outer surfaces, including the bottom. However, on equipment accepting plug-in modules the tip of the jointed test finger is inserted only to a depth of 180 mm from the opening in the equipment.

6.2.2 Openings above parts that are HAZARDOUS LIVE

A metal test pin 100 mm long and 4 mm in diameter is inserted in any openings above parts which are HAZARDOUS LIVE. The test pin is suspended freely and allowed to penetrate up to 100 mm. The additional safety measures of 6.5 for protection in SINGLE FAULT CONDITION are not required solely because a part is ACCESSIBLE by this test only.

This test is not applied to TERMINALS.

6.2.3 Openings for pre-set controls

A metal test pin 3 mm in diameter is inserted through holes intended to give access to pre-set controls which require the use of a screwdriver or other TOOL. The test pin is applied in every possible direction through the hole. Penetration shall not exceed three times the distance from the ENCLOSURE surface to the control shaft or 100 mm, whichever is smaller.

6.3 Permissible limits for ACCESSIBLE parts

The voltage, current, charge or energy between an ACCESSIBLE part and reference test earth, or between any two ACCESSIBLE parts on the same piece of equipment within a distance of 1.8 m (over a surface or through air), shall not exceed the values of 6.3.1 in NORMAL CONDITION nor of 6.3.2 in SINGLE FAULT CONDITION.

6.3.1 Values in NORMAL CONDITION

Values above the following levels in NORMAL CONDITION are deemed to be HAZARDOUS LIVE. The limits of 6.3.1 b) and c) apply only if the voltage exceeds the values of 6.3.1 a).

- a) The voltage levels are 30 V r.m.s. and 42.4 V peak or 60 V d.c. ~~33 V r.m.s. and 46.7 V peak or 70 V d.c.~~ For equipment RATED for use in WET LOCATIONS, the voltage levels are 16 V r.m.s. and 22.6 V peak or 35 V d.c.
- b) The current levels are

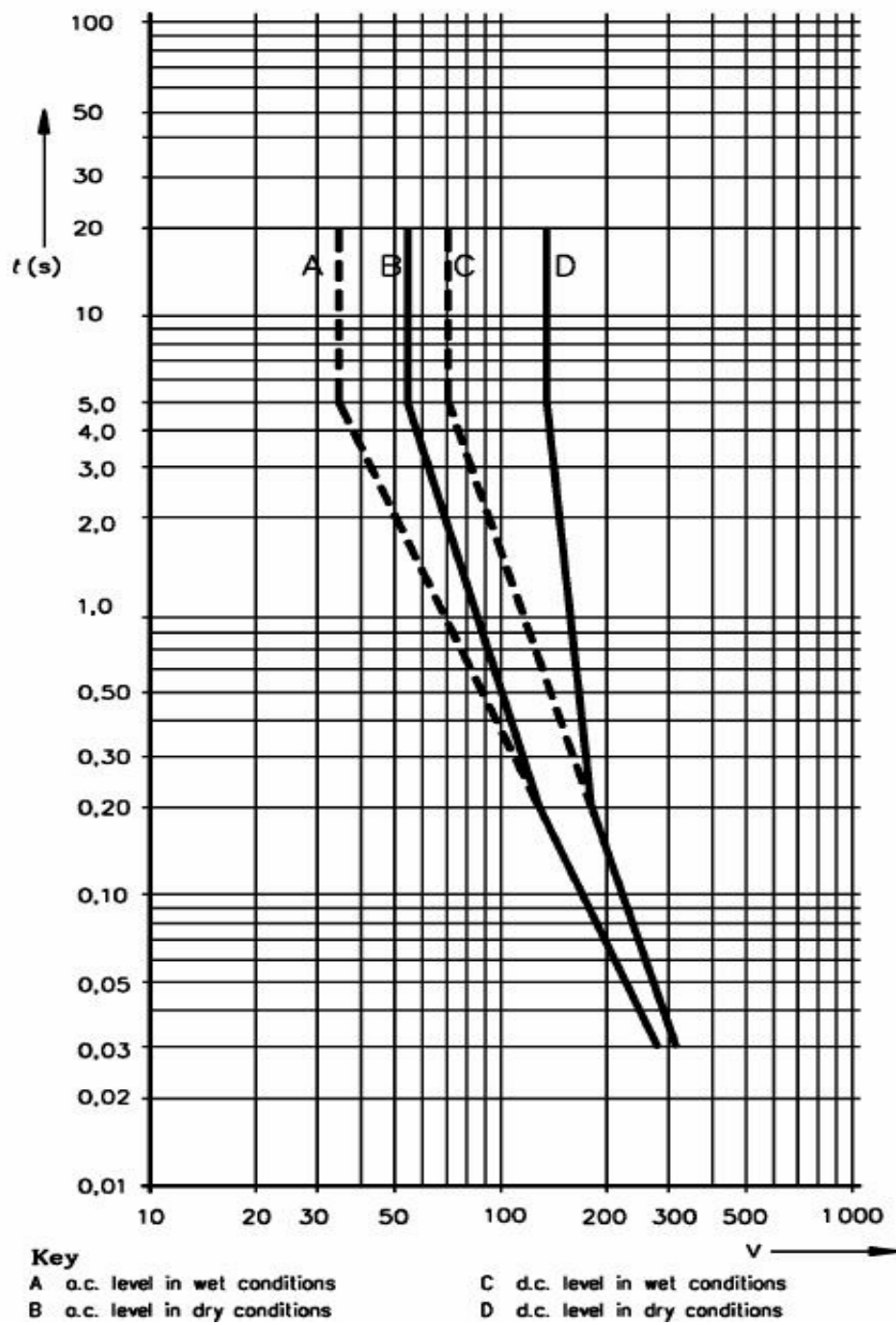
- 1) 0.5 mA r.m.s. for sinusoidal waveforms, 0.7 mA peak for non-sinusoidal waveform or mixed frequencies, or 2 mA d.c., when measured with the measuring circuit of Figure A.1. Alternatively, the measuring circuit of Figure A.2 can be used if the frequency does not exceed 100 Hz. The measuring circuit of Figure A.4 is used for equipment RATED for use in WET LOCATIONS.
- 2) 70 mA r.m.s. when measured with the measuring circuit of Figure A.3. This relates to possible burns at higher frequencies.
- c) The charge or energy of capacitance levels are
 - 1) 45 μ C charge for voltages up to 15 kV peak or d.c.; and
 - 2) 350 mJ stored energy for voltages above 15 kV peak or d.c.

See Figure 2.

6.3.2 Values in SINGLE FAULT CONDITION

Values above the following levels in SINGLE FAULT CONDITION are deemed to be HAZARDOUS LIVE. The limits of 6.3.2 b) and c) apply only if the voltage exceeds the values of 6.3.2 a).

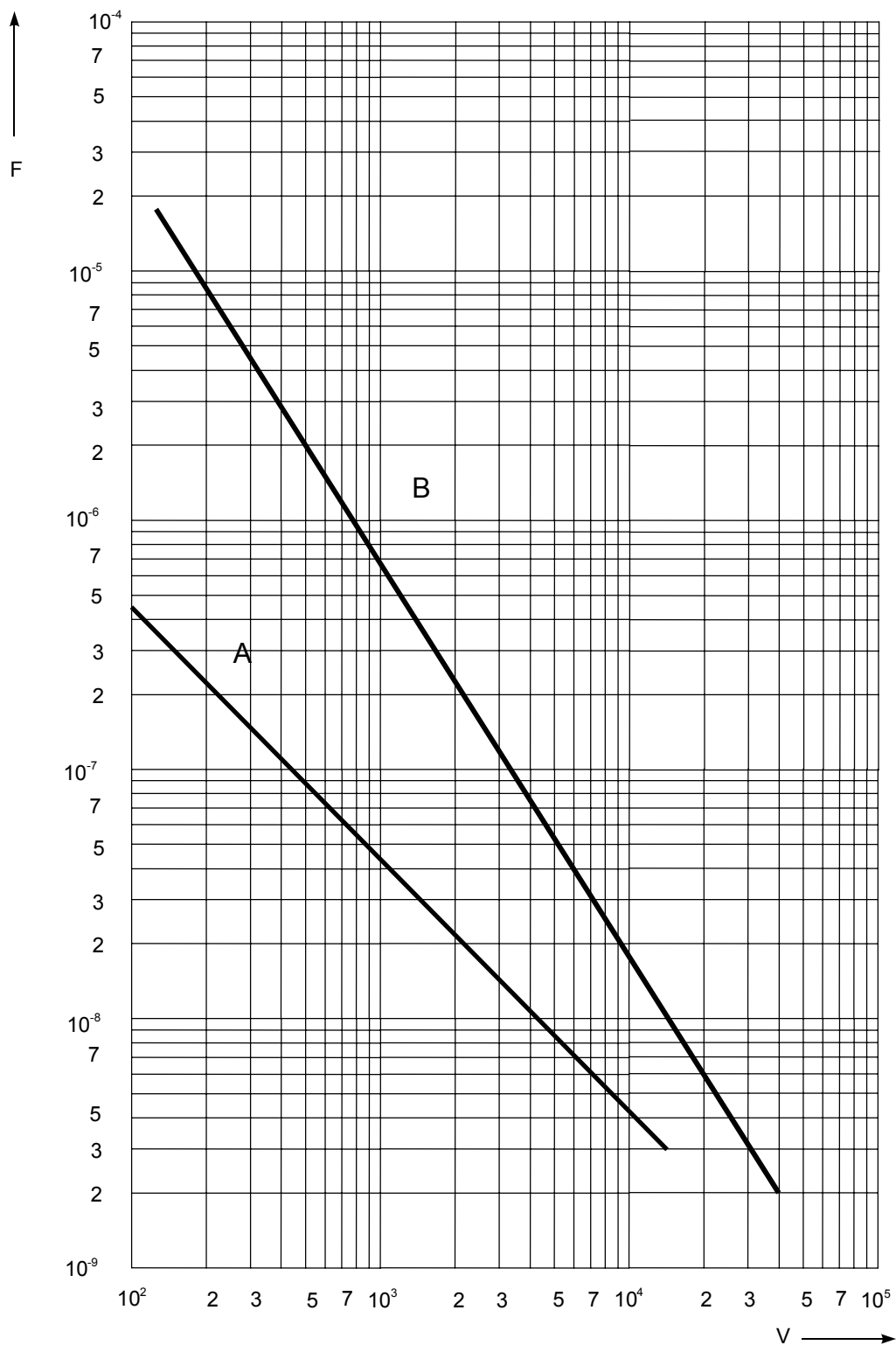
- a) The voltage levels are ~~50 V r.m.s. and 70 V peak or 120 V d.c.~~ ~~55 V r.m.s. and 78 V peak or 140 V d.c.~~ For equipment RATED for use in WET LOCATIONS, the voltage levels are 33 V r.m.s. and 46.7 V peak or 70 V d.c. For temporary voltages, the levels are those of Figure 1, measured across a 50 k Ω resistor.
- b) The current levels are
 - 1) 3.5 mA r.m.s. for sinusoidal waveforms, 5 mA peak for non-sinusoidal waveforms or mixed frequencies, or 15 mA d.c., when measured with the measuring circuit of Figure A.1. Alternatively, the measuring circuit of Figure A.2 can be used if the frequency does not exceed 100 Hz. The measuring circuit of Figure A.4 is used for equipment RATED for use in WET LOCATIONS;
 - 2) 500 mA r.m.s. when measured with the measuring circuit of Figure A.3. This relates to possible burns at higher frequencies.
- c) The capacitance level is that of Figure 2.

**Key**

A a.c. level in wet conditions
 B a.c. level in dry conditions

C d.c. level in wet conditions
 D d.c. level in dry conditions

**Figure 1 – Maximum duration of short-term temporary ACCESSIBLE voltages
 in SINGLE FAULT CONDITION (see 6.3.2 a))**

**Key**

- A NORMAL CONDITION
B SINGLE FAULT CONDITION

IEC 2734/2000

Figure 2 – Charged capacitance level in NORMAL CONDITION and SINGLE FAULT CONDITION
(see 6.3.1 c) and 6.3.2 c))

6.4 Protection in NORMAL CONDITION

ACCESSIBLE parts shall be prevented from becoming HAZARDOUS LIVE by one or more of the following means:

- a) BASIC INSULATION (see Annex D)
- b) Enclosures or barriers
- c) impedance

ENCLOSURES and BARRIERS shall meet the rigidity requirements of 8.1. If ENCLOSURES or BARRIERS provide protection by insulation, they shall meet the requirements of BASIC INSULATION.

CLEARANCES and CREEPAGE DISTANCES between ACCESSIBLE parts and HAZARDOUS LIVE parts shall meet the requirements of 6.7 and the applicable requirements for BASIC INSULATION.

Solid insulation between ACCESSIBLE parts and HAZARDOUS LIVE parts shall pass the voltage test of 6.8 for BASIC INSULATION.

NOTE There is no requirement for the minimum thickness of solid insulation, provided it is capable of passing the dielectric strength test of 6.8. However, under mechanical or thermal stress conditions, consideration needs to be given to the requirements of clauses 8, 9 and 10. Partial discharge testing for solid insulation is under consideration.

Conformity is checked by

- 1) *the determination of 6.2 and the measurements of 6.3.1, to establish that ACCESSIBLE conductive parts are not HAZARDOUS LIVE;*
- 2) *inspection or measurement of CLEARANCES and CREEPAGE DISTANCES as specified in 6.7;*
- 3) *the tests of 6.8 for dielectric strength of BASIC INSULATION; and*
- 4) *the test of 8.1 for rigidity of ENCLOSURES and BARRIERS.*

6.5 Protection in SINGLE FAULT CONDITION

Additional protection shall be provided to ensure that ACCESSIBLE parts are prevented from becoming HAZARDOUS LIVE in SINGLE FAULT CONDITION. The protection shall consist of one or more of the protective means specified in 6.5.1 to 6.5.3, or by automatic disconnection of the supply in case of a fault (see 6.5.4).

Conformity is checked as specified in 6.5.1 to 6.5.4.

6.5.1 PROTECTIVE BONDING

ACCESSIBLE conductive parts shall be bonded to the PROTECTIVE CONDUCTOR TERMINAL if they could become HAZARDOUS LIVE in case of a single fault of the primary protective means specified in 6.4. Alternatively, such ACCESSIBLE parts shall be separated from parts which are HAZARDOUS LIVE by a conductive protective screen or BARRIER bonded to the PROTECTIVE CONDUCTOR TERMINAL.

NOTE ACCESSIBLE conductive parts need not be bonded to the PROTECTIVE CONDUCTOR TERMINAL if they are separated from all HAZARDOUS LIVE parts by DOUBLE INSULATION or REINFORCED INSULATION.

Conformity is checked as specified in 6.5.1.1 to 6.5.1.5.

6.5.1.1 Integrity of protective bonding

The integrity of PROTECTIVE BONDING shall be assured by the following means.

- a) PROTECTIVE BONDING shall consist of direct connected structural parts or discrete conductors, or both. It shall withstand all thermal and dynamic stresses to which it could be subjected before one of the over-current protective means specified in 9.5 disconnects the equipment from the supply.
 - b) Soldered connections subject to mechanical stress shall be mechanically secured independently from the soldering. Such connections shall not be used for other purposes such as fixing constructional parts. Screw connections shall be secured against loosening.
 - c) If a part of the equipment is removable by the OPERATOR, the PROTECTIVE BONDING for the remainder of the equipment shall not be interrupted (except when that part also carries the MAINS input connection to the whole equipment).
 - d) Movable conductive connections, for example, hinges, slides, etc., shall not be the sole PROTECTIVE BONDING path unless they are specifically designed for electrical inter-connection and meet the requirements of 6.5.1.3.
 - e) The exterior metal braid of cables, even if connected to the PROTECTIVE CONDUCTOR TERMINAL, shall not be regarded as PROTECTIVE BONDING.
 - f) If power from the MAINS supply is passed through equipment for use by other equipment, means shall also be provided for passing the protective conductor through the equipment to protect the other equipment. The impedance to the protective conductor path through the equipment shall not exceed that specified in 6.5.1.3.
 - g) Protective conductors may be bare or insulated. Insulation shall be green-and-yellow, except in the following cases:
 - 1) For earthing braids, either green-and-yellow or colourless-transparent
 - 2) For internal protective conductors, and other conductors connected to the PROTECTIVE CONDUCTOR TERMINAL in assemblies such as ribbon cables, busbars, flexible printed wiring, etc., any colour may be used provided that no HAZARD is likely to arise from non-identification of the protective conductor. The bi-colour combination green-and-yellow shall be used only for identifying the protective conductor and for no other purpose.
- NOTE In some countries, the colour identification green for the protective conductor is used as equivalent to the two-colour combination green-and-yellow.
- h) Equipment using PROTECTIVE BONDING shall be provided with a TERMINAL meeting the requirements of 6.5.1.2 and suitable for connection to a protective conductor.

Conformity is checked by inspection.

6.5.1.2 PROTECTIVE CONDUCTOR TERMINAL

PROTECTIVE CONDUCTOR TERMINALS shall meet the following requirements.

- a) The contact surfaces shall be metal.

NOTE 1 Materials of PROTECTIVE BONDING systems should be chosen to minimize electro-chemical corrosion between the TERMINAL and the protective conductor, or any other metal in contact with them.
- b) The integral protective conductor connection of an appliance inlet shall be regarded as the PROTECTIVE CONDUCTOR TERMINAL.
- c) For equipment provided with a rewirable flexible cord and for PERMANENTLY CONNECTED EQUIPMENT, the PROTECTIVE CONDUCTOR TERMINAL shall be located close to the MAINS supply TERMINALS.

- d) If the equipment does not require connection to a MAINS supply, but nevertheless has a circuit or part which is required to be protectively earthed, the PROTECTIVE CONDUCTOR TERMINAL shall be located near to the TERMINALS of that circuit for which protective earthing is necessary. If this circuit has external TERMINALS, the PROTECTIVE CONDUCTOR TERMINAL shall also be external.
 - e) PROTECTIVE CONDUCTOR TERMINALS for MAINS CIRCUITS shall be at least equivalent in current-carrying capacity to the MAINS supply TERMINALS.
 - f) Plug-in type PROTECTIVE CONDUCTOR TERMINALS combined with other TERMINALS and intended to be connected and disconnected by hand, for example plugs and appliance couplers for MAINS cords or connector assemblies of plug-in units, shall be designed so that the protective conductor connection makes first and breaks last with respect to the other connections.
 - g) If the PROTECTIVE CONDUCTOR TERMINAL is also used for other bonding purposes, the protective conductor shall be applied first and secured independently of other connections. The protective conductor shall be connected in such a way that it is unlikely to be removed by servicing not involving the protective conductor or there shall be a warning marking (see 5.2) requiring the replacement of the protective conductor after removal.
 - h) For equipment in which the protective conductor is required for protection against a single fault in a measuring circuit, the following shall apply.
 - 1) The PROTECTIVE CONDUCTOR TERMINAL and protective conductor shall have at least the current RATING of the measuring TERMINALS.
 - 2) The PROTECTIVE BONDING shall not be interrupted by the presence of any switching or interrupting device. Devices used for indirect bonding in test and measurement equipment (see 6.5.1.5) are permitted to be part of the PROTECTIVE BONDING.
 - i) FUNCTIONAL EARTH TERMINALS (for example, measuring earth TERMINALS), if any, shall allow a connection which is independent from the connection of the protective conductor.
- NOTE 2 Equipment may be equipped with FUNCTIONAL EARTH TERMINALS, irrespective of the protective means taken.
- j) If the PROTECTIVE CONDUCTOR TERMINAL is a binding screw, it shall be of a suitable size for the bond wire, but no smaller than M 4 (No. 6), with at least three turns of the screw engaged. The contact pressure required for a bonding connection shall not be capable of being reduced by deformation of materials forming part of the connection.

Conformity is checked by inspection. Conformity for j) is also checked by the following test. The assembly of a screw in a metal part or nut, together with the least favourable grounding conductor to be secured, and any associated conductor securing means shall withstand, without mechanical failure, three operations of assembly and disassembly when using the tightening torques specified in Table 2.

Table 2 – Tightening torque for screw assemblies

Size of screw mm	4.0	5.0	6.0	8.0	10.0
Tightening torque N·m	1.2	2.0	3.0	6.0	10.0

6.5.1.3 Impedance of PROTECTIVE BONDING of plug-connected equipment

The impedance between the PROTECTIVE CONDUCTOR TERMINAL and each ACCESSIBLE part for which PROTECTIVE BONDING is specified shall not exceed 0.1 Ω . MAINS cord impedance does not form part of the specified bonding impedance.

Conformity is checked by applying a test current for 1 min and then calculating impedance. The test current is the greater of

- a) 25 A d.c. or a.c. r.m.s. at RATED MAINS frequency; and*
- b) a current equal to twice the RATED current of the equipment.*

If the equipment contains overcurrent protection devices for all poles of the MAINS supply, and if the wiring on the supply side of the overcurrent protection devices cannot become connected to ACCESSIBLE conductive parts in the case of a single fault, the test current need not be more than twice the RATED current of the internal overcurrent protection devices.

6.5.1.4 Bonding impedance of PERMANENTLY CONNECTED EQUIPMENT

Bonding of PERMANENTLY CONNECTED EQUIPMENT shall be of low impedance.

Conformity is checked by applying a test current of twice the value of the overcurrent protection means specified in the equipment installation instructions for the building supply MAINS CIRCUIT for 1 min between the PROTECTIVE CONDUCTOR TERMINAL and each ACCESSIBLE conductive part for which PROTECTIVE BONDING is required. The voltage between them shall not exceed 10 V a.c. r.m.s. or d.c. and shall not exceed 4 V a.c. r.m.s. or d.c. for certification to Canadian requirements (in accordance with Clause 3.4.2.1 of CSA C22.2 No. 0.4.)

If the equipment contains overcurrent protection devices for all poles of the MAINS supply, and if the wiring on the supply side of the overcurrent protection devices cannot become connected to ACCESSIBLE conductive parts in the case of a single fault, the test current need not be more than twice the RATED current of the internal overcurrent protection devices.

6.5.1.5 Indirect bonding for test and measurement equipment

Indirect bonding establishes a connection between the PROTECTIVE CONDUCTOR TERMINAL and ACCESSIBLE conductive parts if these become HAZARDOUS LIVE as a result of a fault. Devices to establish indirect bonding are

- a) voltage-limiting devices which become conductive when the voltage across them exceeds the relevant values of 6.3.2 a), with overcurrent protection to prevent breakdown of the device.

Conformity is checked by connecting the ACCESSIBLE conductive parts to the MAINS supply TERMINALS while the equipment is connected to the MAINS supply as in NORMAL USE. The voltage between the ACCESSIBLE conductive parts and the PROTECTIVE CONDUCTOR TERMINAL shall not exceed the relevant values of 6.3.2 a) for more than 0.2 s.

- b) voltage-sensitive tripping devices which interrupt all poles of the MAINS supply, and connect the ACCESSIBLE conductive parts to the PROTECTIVE CONDUCTOR TERMINAL whenever the voltage across them reaches the relevant values of 6.3.2 a).

Conformity is checked by applying the relevant voltage of 6.3.2 a) between the ACCESSIBLE conductive parts and the PROTECTIVE CONDUCTOR TERMINAL. The tripping action shall take place within 0.2 s.

6.5.2 DOUBLE INSULATION and REINFORCED INSULATION

CLEARANCES and CREEPAGE DISTANCES forming part of DOUBLE INSULATION or REINFORCED INSULATION shall meet the applicable requirements of 6.7 (see Annex D). ENCLOSURES shall meet the requirements of 6.9.2.

Solid insulation forming part of REINFORCED INSULATION shall pass the voltage test of 6.8 with the values for reinforced insulation.

Conformity is checked as specified in 6.7, 6.8 and 6.9.2. The parts of DOUBLE INSULATION are tested separately if this is possible; the tests for REINFORCED INSULATION are otherwise used. CLEARANCES and CREEPAGE DISTANCES necessary for safety can be checked by measurement.

6.5.3 PROTECTIVE IMPEDANCE

A PROTECTIVE IMPEDANCE which ensures that ACCESSIBLE conductive parts cannot become HAZARDOUS LIVE as a result of a SINGLE FAULT CONDITION shall be one or more of the following:

- a) An appropriate HIGH-INTEGRITY single component (see 14.6)
- b) A combination of components
- c) A combination of BASIC INSULATION and a current- or voltage-limiting device

Components, wires and connections shall be RATED for both NORMAL CONDITION and SINGLE FAULT CONDITION.

Conformity is checked by inspection and by the measurements of 6.3 in SINGLE FAULT CONDITION (see 4.4.2.1).

6.5.4 Automatic disconnection of the supply

If automatic disconnection of the supply is used for protection in SINGLE FAULT CONDITION, the automatic disconnection device shall meet all the following requirements.

- a) It shall be supplied with the equipment or the installation instruction shall specify the device to be fitted as part of the installation.
- b) It shall be RATED to disconnect the load within the time specified in Figure 1.
- c) It shall be RATED for the maximum RATED load conditions of the equipment.

Conformity is checked by inspection of the device specification and, if applicable, installation instructions. In case of doubt, the device is tested to check that it disconnects the supply within the required time.

6.6 Connections to external circuits

6.6.1 General

Connections to external circuits shall not

- a) cause ACCESSIBLE parts of the external circuits to become HAZARDOUS LIVE in NORMAL CONDITION or SINGLE FAULT CONDITION; nor
- b) cause ACCESSIBLE parts of the equipment to become HAZARDOUS LIVE in NORMAL CONDITION or SINGLE FAULT CONDITION.

Protection shall be achieved by separation of circuits, unless short-circuiting of the separation could not cause a HAZARD.

The manufacturer's instructions or equipment markings shall include the following information for each external TERMINAL as applicable for the purposes of the requirements above:

- 1) The RATED conditions at which the TERMINAL has been designed to operate while maintaining safety (maximum RATED input/output voltage, specific type of connector, designated use, etc.)

- 2) The RATING of the insulation required for the external circuit to conform to the requirements for protection against electric shock, in NORMAL CONDITION and SINGLE FAULT CONDITION, arising from the connection to the TERMINAL

For accessibility of TERMINALS, see 6.6.2.

Conformity is checked by:

- i) inspection;
- ii) the determinations of 6.2;
- iii) the measurements of 6.3 and 6.7; and
- iv) the dielectric strength tests of 6.8 (without humidity preconditioning).

6.6.2 TERMINALS for external circuits

TERMINALS which receive a charge from an internal capacitor shall not be HAZARDOUS LIVE 10 s after interruption of the supply.

TERMINALS which are energized from the interior, with HAZARDOUS LIVE voltage exceeding 1 kV r.m.s. or 1.5 kV d.c., or with floating voltage exceeding 1 kV r.m.s. or 1.5 kV d.c., shall not be ACCESSIBLE. Equipment with such TERMINALS shall be designed so that an ACCESSIBLE HAZARDOUS LIVE voltage is not present when connectors are not mated, or shall be marked with symbol 12 of Table 1 (see 5.2) to warn the OPERATOR of the possible presence of an ACCESSIBLE HAZARDOUS LIVE voltage.

Unmated measuring TERMINALS which are HAZARDOUS LIVE when the maximum RATED voltage is applied to the TERMINAL shall not be ACCESSIBLE.

NOTE For locking and screw-held TERMINALS, see 6.1.2 c).

Conformity is checked by inspection, and by the determination of ACCESSIBLE parts as specified in 6.2.

6.6.3 Circuits with TERMINALS which are HAZARDOUS LIVE

These circuits shall not be connected to ACCESSIBLE conductive parts, except for circuits which are not MAINS CIRCUITS, and which are designed to be operated with one TERMINAL contact at earth potential. In such cases, the ACCESSIBLE conductive parts shall not be HAZARDOUS LIVE.

If such a circuit is also designed to be operated with one ACCESSIBLE TERMINAL contact (signal low) floating at a voltage which is not HAZARDOUS LIVE, this TERMINAL contact is permitted to be connected to a common FUNCTIONAL EARTH TERMINAL or system (for example, a coaxial screening system). This common FUNCTIONAL EARTH TERMINAL or system is also permitted to be connected to other ACCESSIBLE conductive parts.

Conformity is checked by inspection.

6.6.4 ACCESSIBLE TERMINALS for stranded conductors

- a) ACCESSIBLE TERMINALS for stranded conductors shall be located or shielded so that there is no risk of accidental contact between HAZARDOUS LIVE parts of different polarity or between such parts and other ACCESSIBLE parts, even if a strand of a conductor escapes from a TERMINAL. Unless it is self-evident (which is preferable) ACCESSIBLE TERMINALS shall be

marked to show whether or not they are connected to ACCESSIBLE conductive parts (see 5.1.6 c)).

Conformity is checked by inspection after fully inserting a stranded conductor with an 8 mm length of insulation removed, with one of the strands free. The strand shall not touch parts of different polarity or other ACCESSIBLE parts, when bent in every possible direction, without tearing back the insulation or making sharp bends round BARRIERS.

- b) ACCESSIBLE TERMINALS of circuits carrying HAZARDOUS LIVE voltage or current shall be anchored, fitted or designed so that they will not work loose when they are tightened, loosened or when connections are made.

Conformity is checked by manual test and inspection.

6.7 CLEARANCES and CREEPAGE DISTANCES

CLEARANCES and CREEPAGE DISTANCES are specified in 6.7.1 to 6.7.4 so as to withstand the voltages that appear on the system for which the equipment is intended. They also take account of RATED environmental conditions and of any protective devices fitted within the equipment or required by the manufacturer's instructions.

Figure 2a is provided to assist in selecting the appropriate tables and equations used in determining CLEARANCES and CREEPAGE DISTANCES.

There are no CLEARANCE or CREEPAGE DISTANCE requirements for the interior of void-free moulded parts, including the inner layers of multi-layer printed circuit boards.

Conformity is checked by inspection and measurement. When determining a CLEARANCE or CREEPAGE DISTANCE to ACCESSIBLE parts, the ACCESSIBLE surface of an insulating ENCLOSURE is considered to be conductive as if it was covered by metal foil wherever it can be touched with a standard test finger (see Annex B). Conformity for homogeneous construction is checked as specified in 6.7.3.1 c).

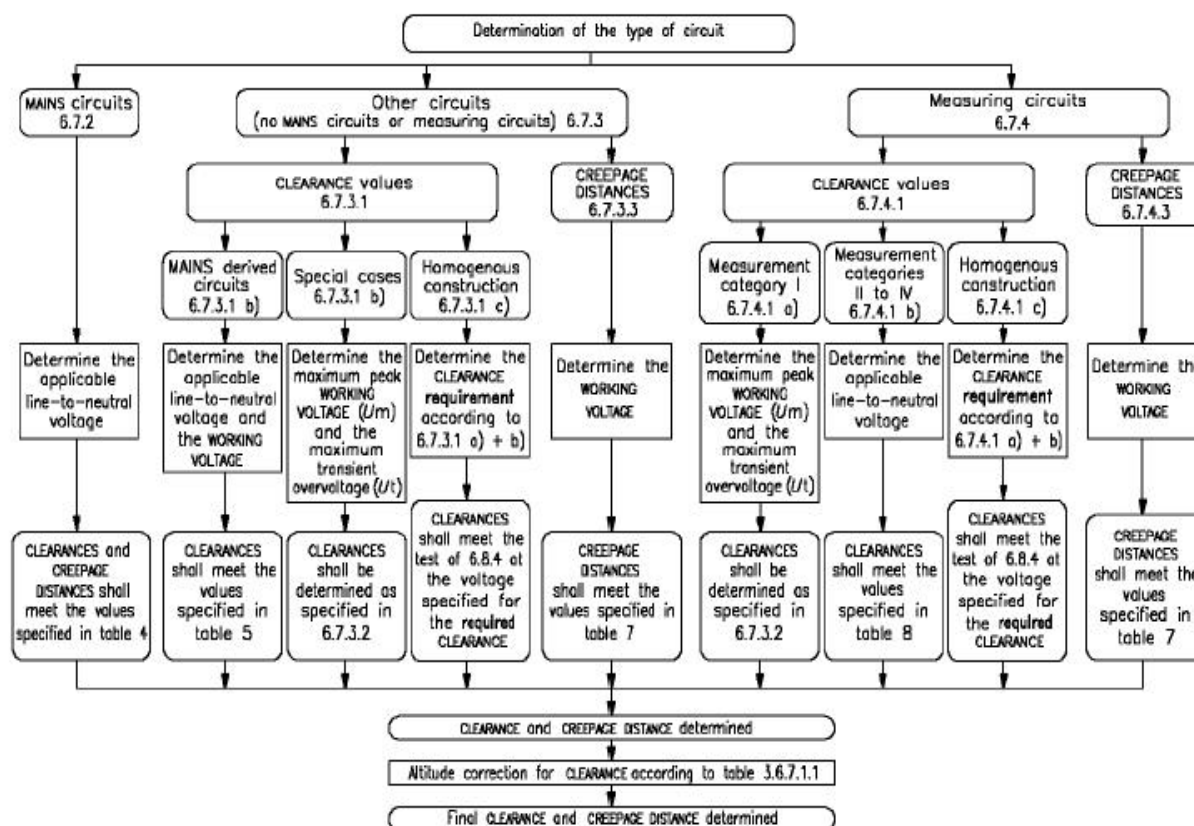


Figure 2a – Determination of spacings

6.7.1 General requirements

6.7.1.1 CLEARANCES

CLEARANCES are specified to withstand the maximum transient overvoltage that can be present on the circuit, either as a result of an external event (such as a lightning strike, or a switching transient), or as the result of the operation of the equipment. If transient overvoltages cannot occur, CLEARANCES are based on the maximum WORKING VOLTAGE.

The value for CLEARANCE depends on

- a) the type of insulation (basic insulation, reinforced insulation, etc.); and
- b) the POLLUTION degree of the micro-environment of the CLEARANCE.

In all cases, the minimum CLEARANCE for POLLUTION DEGREE 2 is 0.2 mm and for POLLUTION DEGREE 3 is 0.8 mm.

If the equipment is RATED to operate at an altitude greater than 2 000 m, the CLEARANCE is multiplied by a factor derived from Table 3. The factors are not applied to CREEPAGE DISTANCE, but CREEPAGE DISTANCE shall always be at least as large as the value specified for CLEARANCE.

Table 3 – Multiplication factors for CLEARANCE for altitudes up to 5 000 m

RATED operating altitude m	Multiplication factor
Up to 2 000	1.00
2 001 to 3 000	1.14
3 001 to 4 000	1.29
4 001 to 5 000	1.48

6.7.1.2 CREEPAGE DISTANCES

For CREEPAGE DISTANCES between two circuits, the actual WORKING VOLTAGE which stresses the insulation between the circuits shall be used. Linear interpolation of CREEPAGE DISTANCE is permissible. CREEPAGE DISTANCE shall always be at least as large as the value specified for CLEARANCE. If the calculated CREEPAGE DISTANCE is smaller than the CLEARANCE, the CREEPAGE DISTANCE shall be increased to the value of the CLEARANCE.

For coated printed wiring boards whose coatings meet the requirements of IEC 60664-3 for type A coatings, or of ANSI/UL 746C for conformal coatings, the values for POLLUTION DEGREE 1 apply

For REINFORCED INSULATION, the CREEPAGE DISTANCE shall be twice the value specified for BASIC INSULATION.

For the purposes of this subclause, materials are separated into four groups according to their CTI (Comparative Tracking Index) values, as follows:

Material group I	$600 \leq \text{CTI}$
Material group II	$400 \leq \text{CTI} < 600$
Material group IIIa	$175 \leq \text{CTI} < 400$
Material group IIIb	$100 \leq \text{CTI} < 175$

The CTI values above refer to values obtained, in accordance with IEC 60112, on samples specifically made for the purpose and tested with solution A.

For glass, ceramics or other inorganic insulating materials which do not track, CREEPAGE DISTANCES need not be greater than their associated CLEARANCE.

Annex E specifies measures which can be used to reduce the POLLUTION degree.

CREEPAGE DISTANCES are measured as specified in Annex C.

6.7.2 MAINS CIRCUITS

CLEARANCES and CREEPAGE DISTANCES shall meet the values specified in Table 4.

Table 4 – CLEARANCES and CREEPAGE DISTANCES for MAINS CIRCUITS

Voltage line-to- neutral a.c. r.m.s. or d.c. V	Values for CLEAR- ANCE (see note 1) Mm	Values for CREEPAGE DISTANCES								
		POLLUTION DEGREE 1		POLLUTION DEGREE 2				POLLUTION DEGREE 3		
		Printed wiring boards CTI ≥ 100 mm	All material groups CTI ≥ 100 mm	Printed wiring boards CTI ≥ 100 mm	Material group I CTI ≥ 600 mm	Material group II CTI ≥ 400 mm	Material group III CTI ≥ 100 mm	Material group I CTI ≥ 600 mm	Material group II CTI ≥ 400 mm	Material group III CTI ≥ 100 mm
>50 ≤100	0.1	0.1	0.25	0.16	0.71	1.0	1.4	1.8	2.0	2.2
>100 ≤150	0.5	0.5	0.5	0.5	0.8	1.1	1.6	2.0	2.2	2.5
>150 ≤300	1.5	1.5	1.5	1.5	1.5	2.1	3.0	3.8	4.1	4.7
>300 ≤600	3.0	3.0	3.0	3.0	3.0	4.3	6.0	7.5	8.3	9.4
NOTE 1 Minimum values for clearance for different POLLUTION DEGREES are POLLUTION DEGREE 2: 0.2 mm; POLLUTION DEGREE 3: 0.8 mm. NOTE 2 Values specified are for BASIC INSULATION or SUPPLEMENTARY INSULATION. Values for REINFORCED INSULATION are twice the values for basic insulation.										

6.7.3 Circuits other than MAINS CIRCUITS

6.7.3.1 CLEARANCE values – General

- a) For circuits derived from MAINS CIRCUITS, CLEARANCES shall have the values as specified in Table 5 except for the conditions specified in b) below.
- b) CLEARANCES for the following cases are specified in 6.7.3.2. Such cases include CLEARANCES where
 - 1) means have been taken within the equipment which limit overvoltages to levels below the applicable impulse withstand voltage of Table 5 (see 14.9);
 - 2) the maximum possible transient overvoltage is above the applicable impulse withstand voltage of Table 5; and
 - 3) the WORKING VOLTAGE is the sum of voltages from more than one circuit, or is a mixed voltage;
 - 4) it is controlled by the source (external to the equipment, but as specified by the manufacturer) to levels below the impulse withstand voltage of Table 5, provided that the equipment is not intended for connection to other sources which would permit higher impulse voltages.
- c) Reduced CLEARANCES may apply to homogeneous construction because the dielectric strength of an air gap is dependent on the shape of the electric field within the gap, as well as on the width of the gap. In homogeneous construction, conductive parts are shaped and arranged so that homogeneous or near-homogeneous electric field conditions exist between them. As a result, reduced CLEARANCES can be accepted between such conductive parts in circuits other than MAINS CIRCUITS.

No particular value can be specified for a reduced CLEARANCE for homogeneous construction, but it can be tested by a dielectric strength test. The test is an a.c. peak or d.c. test, using the test voltage (see Table 9) for the CLEARANCE value which would apply for inhomogeneous construction.

Table 5 – CLEARANCES for circuits derived from MAINS CIRCUITS

WORKING VOLTAGE	CLEARANCE			
AC r.m.s. or d.c.	MAINS voltage ≤100 V RATED impulse voltage 500 V	MAINS voltage >100 V ≤ 150 V RATED impulse voltage 800 V	MAINS voltage >150 V ≤ 300 V RATED impulse voltage 1 500 V	MAINS voltage >300 V ≤ 600 V RATED impulse voltage 2 500 V
V	mm	mm	mm	mm
50	0.05	0.12	0.53	1.51
100	0.07	0.13	0.61	1.57
150	0.10	0.16	0.69	1.64
300	0.24	0.39	0.94	1.83
600	0.79	1.01	1.61	2.41
1 000	1.66	1.92	2.52	3.45
1 250	2.23	2.50	3.16	4.16
1 600	3.08	3.39	4.11	5.21
2 000	4.17	4.49	5.30	6.48
2 500	5.64	6.02	6.91	8.05
3 200	7.98	8.37	9.16	10.2
4 000	10.6	10.9	11.6	12.8
5 000	13.7	14.0	14.9	16.1
6 300	17.8	18.2	19.1	20.3
8 000	23.5	23.9	24.7	26.0
10 000	30.3	30.7	31.6	32.9
12 500	39.1	39.6	40.5	41.9
16 000	52.0	52.5	53.5	54.9
20 000	67.4	67.9	68.9	70.5
25 000	87.4	87.9	89.0	90.6
32 000	117	117	118	120
40 000	151	151	153	154
50 000	196	196	198	199
63 000	258	258	260	261

6.7.3.2 CLEARANCE values where Table 5 does not apply and for circuits in measurement category I

CLEARANCES for BASIC INSULATION and SUPPLEMENTARY INSULATION are determined from the following formula:

$$\text{CLEARANCE} = D_1 + F(D_2 - D_1)$$

where

D_1 and D_2 are CLEARANCES taken from Table 6;

- D_1 is the CLEARANCE that would be applicable to the maximum voltage U_m if it consisted only of a $1.2 \times 50 \mu\text{s}$ impulse;
- D_2 is the CLEARANCE that would be applicable to the maximum voltage U_m if it consisted only of the peak WORKING VOLTAGE U_w , without any transient overvoltage;
- The maximum voltage (U_m) is the maximum peak WORKING VOLTAGE U_w plus the maximum transient overvoltage U_t ;
- F is a factor, determined from one of the equations:
- $$F = (1.25 U_w / U_m) - 0.25 \text{ if } 0.2 < U_w / U_m \leq 1$$
- $$F = 0 \text{ if } U_w / U_m \leq 0.2$$

CLEARANCES for REINFORCED INSULATION are calculated using the same formula, but using the values of D_1 and D_2 specified in Table 6 for a voltage 1.6 times the actual WORKING VOLTAGE.

NOTE The following are two examples.

- a) CLEARANCE for REINFORCED INSULATION for a peak WORKING VOLTAGE of 3 500 V and a maximum transient overvoltage of 4 500 V.

$$U_m = U_w + U_t = (3\,500 + 4\,500) \text{ V} = 8\,000 \text{ V}$$

$$F = (1.25 U_w / U_m) - 0.25 = (1.25 \times 3\,500 / 8\,000) - 0.25 = 0.3470.297$$

$$D_1 = 16.7 \text{ mm}; D_2 = 29.5 \text{ mm (values for } 8\,000 \times 1.6 = 12\,800 \text{ V)}$$

$$\text{CLEARANCE} = D_1 + F(D_2 - D_1) = 16.7 + 0.3470.297(29.5 - 16.7) = 17.7 + 4.4 = 24.1 \text{ mm} \underline{20.5 \text{ mm}}$$

- b) CLEARANCE for BASIC INSULATION for a secondary peak WORKING VOLTAGE of 400 V derived from a primary voltage of 230 V a.c., but with overvoltage controlled within the equipment to a maximum of 2 100 V.

$$U_m = U_w + U_t = (400 + 2\,100) = 2\,500 \text{ V}$$

$$(U_w / U_m) < 0.2, \text{ so } F = 0$$

$$\text{CLEARANCE} = D_1 = 1.45 \text{ mm.}$$

Table 6 – CLEARANCE values for the calculation of 6.7.3.2

\hat{U}_m	CLEARANCE		\hat{U}_m	CLEARANCE	
	D_1	D_2		D_1	D_2
V	mm	mm	V	mm	mm
14.1 to 266	0.010	0.010	4 000	2.93	6.05
283	0.010	0.013	4 530	3.53	7.29
330	0.010	0.020	5 660	4.92	10.1
354	0.013	0.025	6 000	5.37	10.8
453	0.027	0.052	7 070	6.86	13.1
500	0.036	0.071	8 000	8.25	15.2
566	0.052	0.10	8 910	9.69	17.2
707	0.081	0.20	11 300	12.9	22.8
800	0.099	0.29	14 100	16.7	29.5
891	0.12	0.41	17 700	21.8	38.5
1 130	0.19	0.83	22 600	29.0	51.2
1 410	0.38	1.27	28 300	37.8	66.7
1 500	0.45	1.40	35 400	49.1	86.7
1 770	0.75	1.79	45 300	65.5	116
2 260	1.25	2.58	56 600	85.0	150
2 500	1.45	3.00	70 700	110	195
2 830	1.74	3.61	89 100	145	255
3 540	2.44	5.04	100 000	165	290
NOTE 1 Interpolation of CLEARANCES is allowed.					
NOTE 2 Minimum CLEARANCE for POLLUTION DEGREE 2 is 0.2 mm, for POLLUTION DEGREE 3 is 0.8 mm.					

6.7.3.3 CREEPAGE DISTANCE values

Table 7 gives the CREEPAGE DISTANCES related to the WORKING VOLTAGE.

Table 7 – CREEPAGE DISTANCES

WORKING VOLTAGE r.m.s. or d.c. V	BASIC INSULATION OR SUPPLEMENTARY INSULATION								
	On printed wiring board		Other circuits						
	POLLUTION degree		POLLUTION degree						
	1	2	1	2			3		
	Material group			Material group			Material group		
IIIb	IIIa		I	II	IIIa-b	I	II	IIIa-b (see note)	
mm	mm	mm	mm	mm	mm	mm	mm	mm	
10	0.025	0.04	0.08	0.40	0.40	0.40	1.00	1.00	1.00
12.5	0.025	0.04	0.09	0.42	0.42	0.42	1.05	1.05	1.05
16	0.025	0.04	0.10	0.45	0.45	0.45	1.10	1.10	1.10
20	0.025	0.04	0.11	0.48	0.48	0.48	1.20	1.20	1.20
25	0.025	0.04	0.125	0.50	0.50	0.50	1.25	1.25	1.25
32	0.025	0.04	0.14	0.53	0.53	0.53	1.3	1.3	1.3
40	0.025	0.04	0.16	0.56	0.80	1.10	1.4	1.6	1.8
50	0.025	0.04	0.18	0.60	0.85	1.20	1.5	1.7	1.9
63	0.040	0.063	0.20	0.63	0.90	1.25	1.6	1.8	2.0
80	0.063	0.10	0.22	0.67	0.95	1.3	1.7	1.9	2.1
100	0.10	0.16	0.25	0.71	1.00	1.4	1.8	2.0	2.2
125	0.16	0.25	0.28	0.75	1.05	1.5	1.9	2.1	2.4
160	0.25	0.40	0.32	0.80	1.1	1.6	2.0	2.2	2.5
200	0.40	0.63	0.42	1.00	1.4	2.0	2.5	2.8	3.2
250	0.56	1.0	0.56	1.25	1.8	2.5	3.2	3.6	4.0
320	0.75	1.6	0.75	1.60	2.2	3.2	4.0	4.5	5.0
400	1.0	2.0	1.0	2.0	2.8	4.0	5.0	5.6	6.3
500	1.3	2.5	1.3	2.5	3.6	5.0	6.3	7.1	8.0
630	1.8	3.2	1.8	3.2	4.5	6.3	8.0	9.0	10.0
800	2.4	4.0	2.4	4.0	5.6	8.0	10.0	11	12.5
1 000	3.2	5.0	3.2	5.0	7.1	10.0	12.5	14	16
1 250	4.2	6.3	4.2	6.3	9.0	12.5	16	18	20
1 600	5.6	8.0	5.6	8.0	11	16	20	22	25
2 000	7.5	10.0	7.5	10.0	14	20	25	28	32
2 500	10.0	12.5	10.0	12.5	18	25	32	36	40
3 200	12.5	16	12.5	16	22	32	40	45	50
4 000	16	20	16	20	28	40	50	56	63
5 000	20	25	20	25	36	50	63	71	80
6 300	25	32	25	32	45	63	80	90	100
8 000	32	40	32	40	56	80	100	110	125
10 000	40	50	40	50	71	100	125	140	160
12 500	50	63	50	63	90	125			
16 000	63	80	63	80	110	160			
20 000	80	100	80	100	140	200			
25 000	100	125	100	125	180	250			
32 000	125	160	125	160	220	320			
40 000	160	200	160	200	280	400			
50 000	200	250	200	250	360	500			
63 000	250	320	250	320	450	600			

NOTE 1

NOTE 2

Material group IIIb is not recommended for application in POLLUTION DEGREE 3 above 630 V.
Interpolation of CREEPAGE DISTANCES is allowed.

6.7.4 Measuring circuits

Measuring circuits are subjected to WORKING VOLTAGES and transient stresses from the circuit to which they are connected during measurement or test. When the measuring circuit is used to measure MAINS, the transient stresses can be estimated by the location within the installation at which the measurement is performed. When the measuring circuit is used to measure any other electrical signal, the transient stresses must be considered by the user to assure that they do not exceed the capabilities of the measuring equipment. In this standard, circuits are divided into the following measurement categories:

Measurement category IV is for measurements performed at the source of the low-voltage installation.

NOTE Examples are electricity meters and measurements on primary overcurrent protection devices and ripple control units.

Measurement category III is for measurements performed in the building installation.

NOTE Examples are measurements on distribution boards, circuit-breakers, wiring, including cables, bus-bars, junction boxes, switches, socket-outlets in the fixed installation, and equipment for industrial use and some other equipment, for example, stationary motors with permanent connection to the fixed installation.

Measurement category II is for measurements performed on circuits directly connected to the low voltage installation.

NOTE Examples are measurements on household appliances, portable tools and similar equipment.

Measurement category I is for measurements performed on circuits not directly connected to MAINS.

NOTE Examples are measurements on circuits not derived from MAINS, and specially protected (internal) MAINS-derived circuits. In the latter case, transient stresses are variable; for that reason, 5.4.1 g) requires that the transient withstand capability of the equipment is made known to the user.

6.7.4.1 CLEARANCE values

CLEARANCES for measurement category I shall be calculated according to 6.7.3.2.

CLEARANCES for measurement category II, III and IV are specified in Table 8.

Table 8 – CLEARANCES for measurement categories II, III and IV

Nominal a.c. or d.c. line-to-neutral voltage of MAINS supply	BASIC INSULATION or SUPPLEMENTARY INSULATION			DOUBLE INSULATION or REINFORCED INSULATION		
	Measurement category			Measurement category		
	II	III	IV	II	III	IV
V	mm	mm	mm	mm	mm	mm
≤50	0.04	0.1	0.5	0.1	0.3	1.5
>50 ≤100	0.1	0.5	1.5	0.3	1.5	3.0
>100 ≤150	0.5	1.5	3.0	1.5	3.0	6.0
>150 ≤300	1.5	3.0	5.5	3.0	5.9	10.5
>300 ≤600	3.0	5.5	8	5.9	10.5	14.3
>600 ≤1 000	5.5	8	14	10.5	14.3	24.3

6.7.4.2 CREEPAGE DISTANCE values

Table 7 specifies the CREEPAGE DISTANCES related to the WORKING VOLTAGE.

6.8 Procedure for dielectric strength tests

6.8.1 Reference test earth

The reference test earth is the reference point for voltage tests. It is one or more of the following, bonded together if more than one:

- a) *Any PROTECTIVE CONDUCTOR TERMINAL OR FUNCTIONAL EARTH TERMINAL*
- b) *Any ACCESSIBLE conductive part, except for any live parts permitted to be ACCESSIBLE because they do not exceed the values of 6.3.1. Such live parts are bonded together but do not form part of the reference test earth. Also excluded are ACCESSIBLE conductive parts which are allowed to be HAZARDOUS LIVE by the exceptions of 6.1.2.*
- c) *Any ACCESSIBLE insulating part of the ENCLOSURE, covered with metal foil everywhere except around TERMINALS. For test voltages up to 10 kV a.c. peak or d.c., the distance from foil to TERMINAL is not more than 20 mm. For higher voltages the distance is the minimum to prevent flashover.*
- d) *ACCESSIBLE parts of controls with parts made of insulating material being wrapped in metal foil or having soft conductive material pressed against them.*

6.8.2 Humidity preconditioning

To ensure that equipment will not become hazardous in the humidity conditions of 1.4, it is subjected to humidity preconditioning before the voltage tests of 6.8.4. The equipment is not operated during preconditioning.

If wrapping in foil is required by 6.8.1, the foil is not applied until after humidity preconditioning and recovery.

Electrical components, covers, and other parts which can be removed by hand are removed and subjected to the humidity preconditioning together with the main part.

Preconditioning is carried out in a humidity chamber containing air with a humidity of 92.5 % RH \pm 2.5 % RH. The temperature of the air in the chamber is maintained at 40 °C \pm 2 °C.

Before applying humidity, the equipment is brought to a temperature of 42 °C \pm 2 °C, normally by keeping it at this temperature for at least 4 h before the humidity preconditioning.

The air in the chamber is stirred and the chamber is designed so that condensation will not precipitate on the equipment.

The equipment remains in the chamber for 48 h, after which it is removed and allowed a recovery period of 2 h under the environmental conditions of 4.3.1, with the covers of non-ventilated equipment removed.

6.8.3 Conduct of tests

The tests specified in 6.8.4 are performed and completed within 1 h of the end of the recovery period after humidity preconditioning. The equipment is not operated during the tests.

Voltage tests are not made between two circuits, or between a circuit and an ACCESSIBLE conductive part, if they are connected to each other or not separated from each other.

PROTECTIVE IMPEDANCE and voltage-limiting devices in parallel with the insulation to be tested may be disconnected.

Where two or more protective means are used in combination (see 6.5 and 6.6.1), the voltages specified for DOUBLE INSULATION and REINFORCED INSULATION could be applied to parts of circuits which are not required to withstand these voltages. To avoid this, such parts may be disconnected during the tests, or the parts of circuits where DOUBLE INSULATION or REINFORCED INSULATION is required may be tested separately.

6.8.4 Voltage tests

Voltage tests are applied, using the values specified in Table 9. No breakdown or repeated flashover shall occur. Corona effects and similar phenomena are disregarded.

For solid insulation, the a.c. and d.c. tests are alternative test methods. It is sufficient that the insulation passes either of the two. The tests are conducted with the voltage raised gradually over a period of 5 s or less to the specified value so that no appreciable transients occur, then maintained for 5 s.

The CLEARANCE in case of homogenous construction (see 6.7.1.1), is tested with an a.c., d.c. or peak impulse voltage with the peak value specified in Table 9 for the value of CLEARANCE specified for inhomogeneous construction. For simplicity a.c. may be chosen, or d.c. to avoid capacitive currents or the impulse test to reduce power dissipation in components.

Impulse tests are the 1.2/50 μ s test specified in IEC 60060, conducted for a minimum of three pulses of each polarity at 1 s minimum intervals. If a.c. or d.c. tests are chosen, they shall be conducted for a minimum of three cycles in the case of a.c., or three times with a duration of 10 ms in each polarity in the case of d.c.

The values for testing DOUBLE INSULATION or REINFORCED INSULATION are 1.6 times the values from Table 9 for BASIC INSULATION.

NOTE 1 When testing circuits, it may not be possible to separate tests of CLEARANCE from tests of solid insulation.

NOTE 2 The maximum test current of test equipment is usually limited to avoid HAZARDS arising from the test and damage to equipment which fails the test.

NOTE 3 It may be useful to make partial discharges within the insulation material perceptible (see IEC 60270).

NOTE 4 Care should be taken to discharge stored energy after test.

Table 9 – Test voltages for BASIC INSULATION

CLEARANCE	Peak voltage for impulse testing 1.2/50 µs	Voltage a.c. r.m.s. 50/60 Hz	Voltage a.c. peak 50/60 Hz or d.c.	CLEARANCE	Peak voltage for impulse testing 1.2/50 µs	Voltage a.c. r.m.s. 50/60 Hz	Voltage a.c. peak 50/60 Hz or d.c.
Mm	V	V	V	mm	V	V	V
0.010	330	230	330	16.5	14 000	7 600	10 700
0.025	440	310	440	17.0	14 300	7 800	11 000
0.040	520	370	520	17.5	14 700	8 000	11 300
0.063	600	420	600	18.0	15 000	8 200	11 600
0.1	806	500	700	19	15 800	8 600	12 100
0.2	1 140	620	880	20	16 400	9 000	12 700
0.3	1 310	710	1 010	25	19 900	10 800	15 300
0.5	1 550	840	1 200	30	23 300	12 600	17 900
1.0	1 950	1 060	1 500	35	26 500	14 400	20 400
1.4	2 440	1 330	1 880	40	29 700	16 200	22 900
<u>1.5</u>	<u>2 560</u>	<u>1 390</u>	<u>1 970</u>	45	32 900	17 900	25 300
2.0	3 100	1 690	2 400	50	36 000	19 600	27 700
2.5	3 600	1 960	2 770	55	39 000	21 200	30 000
3.0	4 070	2 210	3 130	60	42 000	22 900	32 300
3.5	4 510	2 450	3 470	65	45 000	24 500	34 600
4.0	4 930	2 680	3 790	70	47 900	26 100	36 900
4.5	5 330	2 900	4 100	75	50 900	27 700	39 100
5.0	5 720	3 110	4 400	80	53 700	29 200	41 300
5.5	6 100	3 320	4 690	85	56 610	30 800	43 500
6.0	6 500	3 520	4 970	90	59 400	32 300	45 700
6.5	6 800	3 710	5 250	95	62 200	33 800	47 900
7.0	7 200	3 900	5 510	100	65 000	35 400	50 000
7.5	7 500	4 080	5 780	110	70 500	38 400	54 200
8.0	7 800	4 300	6 030	120	76 000	41 300	58 400
8.5	8 200	4 400	6 300	130	81 300	44 200	62 600
9.0	8 500	4 600	6 500	140	86 600	47 100	66 700
9.5	8 800	4 800	6 800	150	91 900	50 000	70 700
10.0	9 100	4 950	7 000	160	97 100	52 800	74 700
10.5	9 500	5 200	7 300	170	102 300	55 600	78 700
11.0	9 900	5 400	7 600	180	107 400	58 400	82 600
11.5	10 300	5 600	7 900	190	112 500	61 200	86 500
12.0	10 600	5 800	8 200	200	117 500	63 900	90 400
12.5	11 000	6 000	8 500	210	122 500	66 600	94 200
13.0	11 400	6 200	8 800	220	127 500	69 300	98 000
13.5	11 800	6 400	9 000	230	132 500	72 000	102 000
14.0	12 100	6 600	9 300	240	137 300	74 700	106 000
14.5	12 500	6 800	9 600	250	142 200	77 300	109 400
15.0	12 900	7 000	9 900	264	149 000	81 100	115 000
15.5	13 200	7 200	10 200				
16.0	13 600	7 400	10 500				
NOTE Interpolation of test voltages is allowed.							

6.8.4.1 Altitude correction of test voltages for checking CLEARANCES in homogeneous construction

If the test site is at an altitude different from 2 000 m, test voltages are multiplied by the appropriate factor of Table 10. The factors are used only for a voltage test to check a CLEARANCE in homogeneous construction. The corrected test voltage will apply the same voltage stress to a CLEARANCE at the test site as the original test voltage would at 2 000 m.

Table 10 – Correction factors for test voltage according to test site altitude

Test site altitude m	Altitude correction factors for ranges of test voltages			
	$327 V_{\text{peak}} \leq \hat{U}_{\text{test}} < 600 V_{\text{peak}}$ $231 V_{\text{r.m.s.}} < U_{\text{test}} < 424 V_{\text{r.m.s.}}$	$600 V_{\text{peak}} \leq \hat{U}_{\text{test}} < 3\,500 V_{\text{peak}}$ $424 V_{\text{r.m.s.}} < U_{\text{test}} < 2\,475 V_{\text{r.m.s.}}$	$3\,500 V_{\text{peak}} \leq \hat{U}_{\text{test}} < 25\text{ kV}_{\text{peak}}$ $2\,475 V_{\text{r.m.s.}} < U_{\text{test}} < 17.7\text{ kV}_{\text{r.m.s.}}$	$25\text{ kV}_{\text{peak}} \leq \hat{U}_{\text{test}}$ $17.7\text{ kV}_{\text{r.m.s.}} < U_{\text{test}}$
Sea-level	1.08	1.16	1.22	1.24
1 to 500	1.06	1.12	1.16	1.17
501 to 1 000	1.04	1.08	1.11	1.12
1 001 to 2 000	1.00	1.00	1.00	1.00
2 001 to 3 000	0.96	0.92	0.89	0.88
3 001 to 4 000	0.92	0.85	0.80	0.79
4 001 to 5 000	0.88	0.78	0.71	0.70

6.9 Constructional requirements for protection against electric shock

6.9.1 General

If a failure could cause a HAZARD,

- the security of wiring connections subject to mechanical stresses shall not depend on soldering;
- screws securing removable covers shall be captive if their length determines a CLEARANCE or CREEPAGE DISTANCE between ACCESSIBLE conductive parts and HAZARDOUS LIVE parts; and
- accidental loosening or freeing of the wiring, screws, etc., shall not cause ACCESSIBLE parts to become HAZARDOUS LIVE.

The following shall not be used as insulation for safety purposes:

- Materials which can easily be damaged (for example, lacquer, enamel, oxides, anodic films)
- Non-impregnated hygroscopic materials (for example, paper, fibres, fibrous materials).

Conformity is checked by inspection.

6.9.2 ENCLOSURES of equipment with DOUBLE INSULATION or REINFORCED INSULATION

Equipment protected throughout by DOUBLE INSULATION or REINFORCED INSULATION shall have an ENCLOSURE which surrounds all metal parts. This requirement does not apply to small metal parts such as name plates, screws or rivets, if they are separated from parts which are HAZARDOUS LIVE by REINFORCED INSULATION or its equivalent.

ENCLOSURES or parts of ENCLOSURES made of insulating material shall meet the requirements for DOUBLE INSULATION or REINFORCED INSULATION.

Protection for ENCLOSURES or parts of ENCLOSURES made of metal shall be provided by one of the following means, except for parts where PROTECTIVE IMPEDANCE is used.

- a) Provision on the inside of the ENCLOSURE of an insulating coating or BARRIER, which shall surround all metal parts and all places where loosening of a part which is HAZARDOUS LIVE might cause it to touch a metal part of the ENCLOSURE
- b) Ensuring that CLEARANCES and CREEPAGE DISTANCES between the ENCLOSURE and parts which are HAZARDOUS LIVE cannot be reduced below the values for BASIC INSULATION by loosening of parts or wires

Screws or nuts with lock washers are not regarded as liable to become loose, nor are wires which are mechanically secured by more than soldering alone.

Conformity is checked by inspection and measurement and by the tests of 6.8.

6.9.3 Over-range indication

If a HAZARD could arise from an OPERATOR's reliance on the value (for example, voltage) displayed by the equipment, the display shall give an unambiguous indication whenever the value is above the maximum positive value or below the minimum negative value of the range to which the instrument is set.

NOTE Examples of hazardous indications include the following, unless there is a separate unambiguous indication of an over-range value:

- a) Analogue meters with stops at the exact ends of the range
- b) Digital meters which show a low value when the true value is above the range maximum (for example 1 001.5 V displayed as 001.5 V)
- c) Chart recorders which print a trace at the edge of the chart, thus indicating a value at the range maximum when the true value is higher

Conformity is checked by inspection and, in case of doubt, by provoking an over-range value.

6.10 Connection to MAINS supply source and connections between parts of equipment

6.10.1 MAINS supply cords

The following requirements apply to non-detachable MAINS supply cords and to detachable MAINS supply cords supplied with the equipment:

- a) MAINS supply cords shall be RATED for the maximum current for the equipment ~~and the cable used shall meet the requirements of IEC 60227 or IEC 60245~~. MAINS supply cords certified or approved by a recognized testing authority are regarded as meeting this requirement;
- b) If a cord is likely to contact hot external parts of the equipment, it shall be made of suitably heat-resistant material.
- c) If the cord is detachable, both the cord and the appliance inlet shall have at least the highest temperature RATING for either part.

NOTE The requirement for an equal temperature RATING for both the cord and the appliance inlet ensures that cord sets of low temperature RATING cannot be used inadvertently.

- d) ~~Green- and yellow-covered conductors~~ (with or without yellow stripes) shall be used only for connection to PROTECTIVE CONDUCTOR TERMINALS.

Detachable MAINS supply cords with MAINS connectors according to IEC 60320 ~~shall either meet the requirements of IEC 60799, or~~ shall be RATED at least for the current RATING of the MAINS connector fitted to the cord.

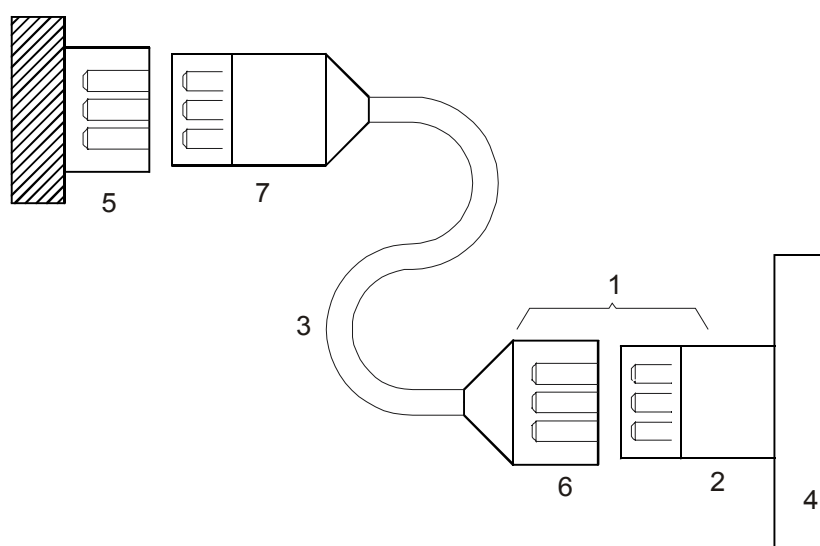
Requirements for MAINS cords or cord sets are contained in ANSI/UL 817 and CSA C22.2 No.21.

Requirements for general use receptacles, attachment plugs, and similar wiring devices are contained in ANSI/UL 498 and CSA C22.2 No. 42, CSA C22.2 No.182.1, CSA C22.2 No.182.2, CSA C22.2 No.182.3.

NOTE 6.10.1 only applies to cords connected to the external fixed MAINS socket-outlet and to external interconnecting mains cords. 6.10.1 does not apply to cords fully contained within the equipment enclosure.

The terminology for MAINS supply cords is given in Figure 3.

Conformity is checked by inspection and, where necessary, by measurement.



Key

- | | |
|--------------------------------|-----------------------------|
| 1 Appliance coupler | 4 Equipment |
| 2 Appliance inlet | 5 Fixed MAINS socket-outlet |
| 3 Detachable power supply cord | 6 MAINS connector |
| | 7 MAINS plug |

IEC 2735/2000

Figure 3 – Detachable MAINS supply cords and connection conditions

6.10.2 Fitting of non-detachable MAINS supply cords

MAINS supply cords shall be protected against abrasion and sharp bends at the point where the cord enters the equipment, by one of the following means;

- An inlet or bushing with a smoothly rounded opening
- A reliably fixed cord guard made of insulating material protruding beyond the inlet opening by at least five times the overall diameter of a cord with the largest cross-sectional area which can be fitted. For flat cords, the major overall cross-sectional dimension is taken as the overall diameter.

Conformity is by inspection, and if needed by measurement of dimensions.

The cord anchorage shall relieve the conductors of the cord from strain, including twisting, where they are connected within the equipment, and shall protect the insulation of the conductors from abrasion. The protective earth conductor, if any, shall be the last to take the strain if the cord slips in its anchorage.

Cord anchorages shall meet the following requirements.

- a) The cord shall not be clamped by a screw which bears direct on the cord.
- b) Knots in the cord shall not be used.
- c) It shall not be possible to push the cord into the equipment to an extent which could cause a HAZARD.
- d) Failure of the cord insulation in a cord anchorage which has metal parts shall not cause ACCESSIBLE conductive parts to become HAZARDOUS LIVE.
- e) A compression bushing shall not be used as a cord anchorage unless it has provision for clamping all types and sizes of MAINS supply cords which meet the requirements of 6.10.1 and are suitable for connection to the TERMINALS provided, or the bushing has been designed to terminate a screened MAINS supply cord.
- f) The cord anchorage shall be designed so that cord replacement does not cause a HAZARD and it shall be clear how the relief from strain is provided.

Conformity is checked by inspection and the following push-pull test: the cord is pushed into the equipment manually, as far as possible. It is then subjected 25 times to a steady pull of the value shown in Table 11, applied for 1 s each time in the least favourable direction. Immediately afterwards it is subjected for 1 min to a torque of the value shown in Table 11.

Table 11 – Physical tests on power supply cords

Mass of equipment kg	Pull N	Torque N·m
≤1	30	0.10
>1 ≤4	60	0.25
>4	100	0.35

After the tests

- 1) *the cord shall not have been damaged;*
- 2) *the cord shall not have been displaced longitudinally by more than 2 mm;*
- 3) *there shall be no signs of strain at the point where the anchorage clamps the cord;*
- 4) *CLEARANCES and CREEPAGE DISTANCES shall not have been reduced below the applicable values; and*
- 5) *the cord shall pass the voltage test of 6.8 (without humidity preconditioning).*

6.10.3 Plugs and connectors

- a) Plugs and connectors for connecting equipment to the MAINS supply, including appliance couplers used to connect detachable MAINS supply cords, shall conform to the relevant specifications for plugs, socket-outlets and connectors.
- b) If the equipment is designed to be supplied only at voltages below the level of 6.3.2 a) in NORMAL CONDITION or SINGLE FAULT CONDITION, or from a source used solely to supply that

equipment, the plugs of the MAINS supply cord shall not fit into the socket-outlets of MAINS supply systems at voltages above the RATED supply voltage of the equipment. Mains-type plugs and sockets shall not be used for purposes other than connection of a MAINS supply.

- c) If plug pins of cord-connected equipment receive a charge from an internal capacitor, the pins shall not be HAZARDOUS LIVE 5 s after disconnection of the supply.
- d) On equipment with accessory MAINS socket-outlets,
 - 1) if the outlet can accept a standard MAINS supply plug, there shall be a marking as specified in 5.1.3 e); and
 - 2) if the outlet has a TERMINAL contact for a protective earth conductor, the input MAINS supply connection to the equipment shall include a protective earth conductor connected to a PROTECTIVE CONDUCTOR TERMINAL.

Requirements for plugs of MAINS cords are contained in ANSI/UL 498 and CSA C22.2 No.42, CSA C22.2 No.182.1, CSA C22.2 No.182.2, CSA C22.2 No.182.3.

Conformity is checked by inspection. For plugs receiving a charge from an internal capacitor, the measurements of 6.3 are made to establish that the levels of 6.3.1 c) are not exceeded.

6.10.3ADV Permanently Connected Equipment*

6.10.3ADV.1 General

6.10.3ADV.1.1 Equipment intended for permanent connection to the MAINS shall have provision for connection of a wiring system in accordance with ANSI/NFPA 70, NEC, with CSA C22.1, CEC, Part I or with both as appropriate.

6.10.3ADV.1.2 Compliance is checked by inspection.

6.10.3ADV.1.3 PERMANENTLY CONNECTED EQUIPMENT shall be provided with TERMINALS or leads for the connection of conductors having an ampacity that, in accordance with the National Electrical Code and Canadian Electrical Code, Part I, is acceptable for the equipment.

6.10.3ADV.1.4 Compliance is checked by inspection.

6.10.3ADV.2 Wiring TERMINALS

6.10.3ADV.2.1 A TERMINAL or splice compartment shall be complete -- that is, the top, all sides, and a complete bottom are provided when the equipment is shipped from the factory -- and shall enclose all field-wiring TERMINALS and splices intended to be made in the field.

6.10.3ADV.2.2 Equipment with an ENCLOSURE that is complete need not be provided with a separate compartment.

6.10.3ADV.2.3 The TERMINAL or splice compartment in which MAINS connections to PERMANENTLY CONNECTED EQUIPMENT are made shall be located so that:

- a) internal wiring and electrical components are not exposed to mechanical damage or strain while connections are being made, and
- b) these connections may be readily inspected after the equipment is installed as intended.

* This section has been numbered in accordance with CSA and UL numbering.

6.10.3ADV.2.4 A wiring TERMINAL shall be provided in which connection is made by means of screws, nuts, or equally effective devices.

6.10.3ADV.2.5 Wire binding screws are permitted as follows:

- a) A No. 6 or M4 screw may be used to connect a 14 AWG (2.1 mm²) or smaller wire.
- b) A No. 8 or M4.5 screw may be used to connect a 12 AWG (3.3 mm²) or smaller wire.
- c) A No. 10 or M5 screw may be used to connect a 10 AWG (5.3 mm²) or smaller wire.

6.10.3ADV.2.6 Compliance with the requirements in this clause is checked by inspection.

6.10.3ADV.3 Leads

6.10.3ADV.3.1 The free length of a lead inside a wiring compartment shall be at least 6 inches (150 mm).

6.10.3ADV.3.2 Compliance is checked by inspection.

6.10.3ADV.4 TERMINAL and lead identification

6.10.3ADV.4.1 TERMINALS and leads shall be identified in a manner that will permit the equipment to be connected as intended by the manufacturer. Equipment containing either a MAINS-connected polarized convenience receptacle or a MAINS-connected polarized lamp socket must have an identified neutral (grounded) conductor.

6.10.3ADV.4.2 A wiring TERMINAL that is intended solely for connection of the neutral (grounded) MAINS conductor shall be readily distinguishable from all other TERMINALS. It shall be constructed of, or plated with, metal that is substantially white in color or shall be clearly identified in some other manner such as on a wiring diagram permanently attached to the equipment.

6.10.3ADV.4.3 A lead intended solely for field wiring connection to the neutral (grounded) MAINS conductor shall be readily distinguishable from all other leads by being finished to show a white or gray color.

6.10.3ADV.4.4 The protective grounding (earthing) TERMINAL shall be marked in accordance with 5.1.5.1 b) or marked "G," "GR," "GND," "GROUND," or "GROUNDING" or provided with a green-colored screw head that is hexagonal, slotted, or both.

6.10.3 ADV.4.5 A lead intended for field connection to the protective grounding conductor shall be readily distinguishable from all other leads by being finished to show a green color with or without one or more yellow stripes.

6.10.3 ADV.4.6 Compliance is checked by inspection.

6.10.3ADV.5 ENCLOSURE requirements for conduit entry

6.10.3ADV.5.1 An ENCLOSURE shall not pull apart or sustain damage such as cracking and breaking, and knockouts shall remain in place when subjected to pulling, torque, and bending, which are likely to occur.

6.10.3ADV.5.2 ENCLOSURES having sheet metal members with a thickness no less than 0.81 mm if of uncoated sheet steel, no less than 0.86 mm if of galvanized sheet steel, no less than 1.11 mm if of sheet aluminum, and no less than 1.09 mm if of sheet copper or sheet brass are presumed to pass these tests.

6.10.3ADV.5.3 Compliance is checked by performing the tests of 6.10.4.6

6.10.3ADV.6 Conduit ENCLOSURE entry tests

6.10.3ADV.6.1 General

6.10.3ADV.6.1.1 After each of the tests in 6.10.3ADV.6.2 - 6.10.3ADV.6.5, the equipment must meet the criteria defined in 6.10.3ADV.5.

NOTE Enclosures complying with ANSI/UL 50 are deemed to comply with 6.10.3ADV.6.2 and 6.10.3ADV.6.3.

6.10.3ADV.6.2 Conduit pull-out test

6.10.3ADV.6.2.1 The ENCLOSURE is to be suspended by a length of rigid conduit installed in one wall of the ENCLOSURE or mounted as intended in service, and a pulling force of 200 pounds (890 N) is to be applied for 5 minutes to a length of conduit installed in the opposite wall (or wall with conduit entry if ENCLOSURE is mounted rather than suspended).

6.10.3ADV.6.3 Conduit torque test

6.10.3ADV.6.3.1 The ENCLOSURE is to be securely mounted as intended in service. A torque in accordance with Table 6.10.3ADV.6.3.1.1 is to be applied to a length of installed conduit in a direction tending to tighten the connection. The lever arm is to be measured from the center of the conduit.

Table 6.10.3ADV.6.3.1.1 -- Tightening torque for conduit

<u>Trade size of conduit, in.</u>	<u>Tightening torque, inch-pounds (N m)</u>
<u>3/4 and smaller (end of line enclosure)</u>	<u>200 (22.6)</u>
<u>3/4 and smaller</u>	<u>800 (90.4)</u>
<u>1, 1-1/4, 1-1/2</u>	<u>1000 (113)</u>
<u>2 and larger</u>	<u>1600 (181)</u>
<u>Note - An end-of-line ENCLOSURE is an ENCLOSURE that is intended to be connected at the end of a run of conduit and has only one 3/4-inch maximum trade size opening for the connection of conduit.</u>	

6.10.3ADV.6.4 Bending

6.10.3ADV.6.4.1 A length of conduit at least 1 foot (300 mm) long of the intended size is to be installed:

- 1) in the center of the largest unreinforced surface, or
- 2) in a hub or an opening if provided as part of the ENCLOSURE.

The ENCLOSURE is to be securely mounted as intended in service, but positioned so that the installed conduit extends in a horizontal plane. A weight is to be suspended from the end of the conduit to produce the bending moment specified in Table 6.10.3ADV.6.4.1.1. The magnitude of the weight is to be determined from the equation:

$$W = (M - 0.5 \bullet C \bullet L) / L$$

In which

W is the weight, in pounds, to be hung at the end of the conduit;

L is the length of the conduit, in inches, from the wall of the ENCLOSURE to the point at which the weight is suspended;

C is the weight of the conduit, in pounds; and

M is the bending moment required in inch-pounds.

For the SI system of units, the equation is

$$W = (0.1 \bullet M - 0.5 \bullet C \bullet L) / L$$

In which

W and C are measured in kilograms;

M is measured in Newton-meters; and

L is measured in meters.

Table 6.10.3ADV.6.4.1.1 -- Bending moment for conduit openings

		Bending Moment (b),(c) inch-pounds (N-m)	
Normal Mounting Plane of ENCLOSURE Surface (a)	Conduit Size Inches	Metallic Conduit	Nonmetallic Conduit
Horizontal	All	300 (34)	300 (34)
Vertical	1/2 - 3/4	300 (34)	300 (34)
	1 - up	600 (68)	300 (34)

6.10.3ADV.6.4.2 If the ENCLOSURE surface may be installed in either a horizontal or a vertical plane, the vertical bending moment value shall be used.

6.10.3ADV.6.4.3 The test procedure may be terminated prior to attaining the values specified if the deflection of the conduit exceeds 10 inches (250 mm) for a 10 foot (3.05 m) length of conduit.

6.10.3ADV.6.4.4 For an end-of-line ENCLOSURE as defined in the note of Table 6.10.3ADV.6.3.1.1, the bending moment is to be 150 inch-pounds (17.0 N-m).

6.10.3ADV.6.5 Knockouts

6.10.3ADV.6.5.1 A knockout shall be subjected to a force of 20 pounds (89 N) applied at right angles by means of a mandrel with a 1/4-inch (6.4 mm) diameter flat end. The mandrel shall be applied at the point most likely to cause movement of the knockout.

6.10.3ADV.6.6 Continuity of bonding

6.10.3ADV.6.6.1 An enclosure made of insulating material, either wholly or in part, shall have an acceptable bonding means to provide continuity of bonding between all metallic conduits entering the enclosure.

6.11 Disconnection from supply source and maintaining polarity

6.11.1 General

Except as specified in 6.11.1.1, equipment shall be provided with a means for disconnecting it from each operating energy supply source, whether external or internal to the equipment. The disconnecting means shall disconnect all current-carrying conductors.

NOTE Equipment may also be provided with a switch or other disconnecting device for functional purposes.

Conformity is checked as specified in 6.11.1.1 to 6.11.3.2.

6.11.1.1 Exceptions

A disconnecting device is not required if a short circuit or overload cannot cause a HAZARD. Examples include

- a) equipment intended for supply only from a low energy source such as a small battery;
- b) equipment intended only for connection to an impedance protected supply. Such a supply is one having an impedance of such value that, if the equipment is subjected to an overload or short circuit, the RATED supply conditions are not exceeded and no HAZARD can arise; and
- c) equipment which constitutes an impedance protected load. Such a load is a component without discrete overcurrent or thermal protection, and of such impedance that the RATING is not exceeded if the circuit of which the component is a part is subjected to an overload or short circuit.

Conformity is checked by inspection. In case of doubt, a short circuit or overload is applied to check that no HAZARD can arise.

6.11.2 Requirements according to type of equipment

6.11.2.1 PERMANENTLY CONNECTED EQUIPMENT and multi-phase equipment

PERMANENTLY CONNECTED EQUIPMENT and multi-phase equipment shall employ a switch or circuit-breaker as the means for disconnection.

If a switch is not part of the equipment, documentation for equipment installation shall specify that

- a) a switch or circuit-breaker shall be included in the building installation;
- b) it shall be in close proximity to the equipment and within easy reach of the OPERATOR; and
- c) it shall be marked as the disconnecting device for the equipment.

Conformity is checked by inspection.

6.11.2.2 Single-phase cord-connected equipment

Single-phase cord-connected equipment shall have one of the following as a disconnecting device:

- a) A switch or circuit-breaker
- b) An appliance coupler which can be disconnected without the use of a TOOL
- c) A separable plug, without a locking device, to mate with a socket-outlet in the building

Conformity is checked by inspection.

6.11.2.3 HAZARDS arising from function

Equipment whose function may give rise to a HAZARD shall have an emergency switch, which need not disconnect auxiliary circuits (such as cooling) which are necessary for safety.

Equipment having ACCESSIBLE moving parts which could cause a HAZARD shall have an emergency switch for disconnection which shall not be more than 1 m from the moving part.

Conformity is checked by inspection.

6.11.3 Disconnecting devices

If a disconnecting device is part of the equipment, it shall be located electrically as close as practicable to the supply. Power-consuming components shall not be electrically located between the supply source and the disconnecting device.

Electromagnetic interference suppression circuits are permitted to be located on the supply side of the disconnecting device.

Conformity is checked by inspection.

6.11.3.1 Switches and circuit-breakers

An equipment switch or circuit-breaker employed as a disconnecting device shall meet the relevant requirements of IEC 60947-1 and IEC 60947-3 and be suitable for the application.

If a switch or a circuit-breaker is used as a disconnecting device, it shall be marked to indicate this function. If there is only one device – one switch or one circuit-breaker – symbols 9 and 10 of Table 1 are sufficient.

A switch shall not be incorporated in a MAINS supply cord.

A switch or circuit-breaker shall not interrupt a protective earth conductor.

A switch or circuit-breaker with contacts for disconnecting and other contacts for other purposes shall conform to the requirements of 6.6 and 6.7 for separation between circuits.

Conformity is checked by inspection.

6.11.3.2 Appliance couplers and plugs

If an appliance coupler or separable plug is used as the disconnecting device, it shall be readily identifiable and easily reached by the OPERATOR. For single-phase PORTABLE EQUIPMENT, a plug on a cord of length not greater than 3 m is considered to be easily reached. The protective earth conductor of an appliance coupler shall be connected before the supply conductors and disconnected after them.

Conformity is checked by inspection.

6.11.4 Polarity of connections

Any line-connected single-pole switch, any center contact of a lampholder, and any automatic control with a marked off position shall be connected to a TERMINAL or lead intended for connection to the ungrounded conductor of the supply circuit.

7 Protection against mechanical HAZARDS

7.1 General

Operation shall not lead to a mechanical HAZARD in NORMAL CONDITION or SINGLE FAULT CONDITION.

NOTE All easily touched edges, projections, corners, openings, guards, handles and the like, of the equipment ENCLOSURE, should be smooth and rounded so as not to cause injury during NORMAL USE of the equipment.

Conformity is checked as specified in 7.2 to 7.6.

7.2 Moving parts

Moving parts shall not be able to crush, cut or pierce parts of the body of an OPERATOR likely to contact them, nor severely pinch the OPERATOR's skin.

This requirement does not apply to easily touched moving parts which are obviously intended to operate on parts or materials external to the equipment, for example, drilling and mixing equipment. Such equipment should be designed to minimize inadvertent touching of such moving parts (for example, by fitting of guards or handles).

If, during routine maintenance outside NORMAL USE, it is unavoidable for technical reasons that an OPERATOR has to perform a function, such as adjustment, which requires access to moving parts which could cause a HAZARD, access is permitted if all of the following precautions have been taken:

- a) Access is not possible without the use of a TOOL
- b) The instructions for the RESPONSIBLE BODY include a statement that OPERATORS must be trained before being allowed to perform the hazardous operation
- c) There are warning markings (see 5.2) on any covers or parts which have to be removed to obtain access, prohibiting access by untrained OPERATORS. As an alternative, symbol 14 of Table 1 shall be placed on the covers or parts, with the warnings included in the documentation.

Conformity is checked by inspection.

7.3 Stability

Equipment and assemblies of equipment not secured to the building structure before operation shall be physically stable in NORMAL USE.

If means are provided to ensure that stability is maintained after the opening of drawers, etc. by an OPERATOR, either these means shall be automatic or there shall be a warning marking (see 5.2).

Conformity is checked by carrying out each of the following tests, if applicable. Containers contain the RATED amount of substance which provides the least favourable conditions of NORMAL USE. Castors are in their least favourable position of NORMAL USE. Doors, drawers, etc. are closed unless otherwise specified.

- a) *Equipment other than HAND-HELD EQUIPMENT, is tilted in each direction to an angle of 10° from its normal position.*
- b) *Equipment which has both a height of 1 m or more and a mass of 25 kg or more, and all floor-standing equipment, has a force applied at its top, or at a height of 2 m if the equipment has a height of more than 2 m. The force is 250 N, or 20 % of the weight of the equipment, whichever is less, and is applied in all directions except upwards. Jacks used in NORMAL USE, and doors, drawers, etc., intended to be opened by an OPERATOR, are in their least favourable positions.*
- c) *Floor-standing equipment has a force of 800 N applied downwards at the point of maximum moment to*
 - 1) *all horizontal working surfaces; and*

- 2) *other surfaces providing an obvious ledge and which are not more than 1 m above floor level.*

During the tests, the equipment shall not overbalance.

Conformity with the marking requirement is checked by inspection.

7.4 Provisions for lifting and carrying

If carrying handles or grips are fitted to, or supplied with, the equipment, they shall be capable of withstanding a force of four times the weight of the equipment.

Equipment or parts having a mass of 18 kg or more shall be provided with a means for lifting and carrying or directions shall be given in the manufacturer's documentation.

Conformity is checked by inspection and by the following test.

A single handle or grip is subjected to a force corresponding to four times the weight of the equipment. The force is applied uniformly over a 70 mm width at the centre of the handle or grip, without clamping. The force is steadily increased so that the test value is attained after 10 s and maintained for a period of 1 min.

If more than one handle or grip is fitted, the force is distributed between the handles or grips in the same proportion as in NORMAL USE. If the equipment is fitted with more than one handle or grip but is so designed that it may readily be carried by only one handle or grip, each handle or grip shall be capable of sustaining the total force.

The handles or grips shall not break loose from the equipment and there shall not be any permanent distortion, cracking or other evidence of failure.

7.5 Wall mounting

Mounting brackets on equipment intended to be mounted on a wall or ceiling shall withstand a force of four times the weight of the equipment.

Conformity is checked after mounting the equipment in accordance with the manufacturer's instructions, using the fasteners and wall construction specified. Adjustable brackets are adjusted to the position that will give the maximum projection from the wall.

If no wall construction is specified, a 10 mm ± 2 mm thick plaster board (drywall) on nominal 50 mm × 100 mm ± 10 mm studs at 400 mm ± 10 mm centres is to be used as the support surface. Fasteners are applied as specified in the instructions but, if not specified, are positioned in the plasterboard between the studs.

The mounting brackets are then subjected to the weight of the equipment plus a test weight of three times the weight of the equipment, acting vertically through the centre of gravity. The test weight is applied gradually and is increased from zero to full load in 5 s to 10 s, then maintained for 1 min.

After the test, there shall be no damage to the bracket or the mounting surface.

7.6 Expelled parts

Equipment shall contain or limit the energy of parts which could cause a HAZARD if expelled in the event of a fault.

The means of protection against expelled parts shall not be removable without the aid of a TOOL.

Conformity is checked by inspection after application of the relevant fault conditions of 4.4.

8 Mechanical resistance to shock and impact and resistance to UV radiation

Equipment shall not cause a HAZARD when subjected to shock and impact likely to occur in NORMAL USE. Equipment shall have adequate mechanical strength, components shall be reliably secured, and electrical connections shall be secure.

Conformity is checked by performing the tests of 8.1 and, except for FIXED EQUIPMENT, the appropriate test of 8.2. The equipment is not operated during the tests. Parts which do not form part of an ENCLOSURE are not subjected to the tests of 8.1.

After completion of the tests, the equipment shall pass the voltage tests of 6.8 (without humidity preconditioning) and is inspected to check that

- a) parts which are HAZARDOUS LIVE have not become ACCESSIBLE;*
- b) ENCLOSURES show no cracks which could cause a HAZARD;*
- c) CLEARANCES are not less than their permitted values and the insulation of internal wiring remains undamaged;*
- d) BARRIERS have not been damaged or loosened;*
- e) no moving parts are exposed, except as permitted by 7.2; and*
- f) there has been no damage which could cause spread of fire.*

Damage to the finish, small dents which do not reduce CREEPAGE DISTANCES or CLEARANCES below the values specified in this standard, and small chips which do not adversely affect the protection against electric shock or moisture, are ignored. Breakage of any part which is not part of an ENCLOSURE is ignored.

8.1 ENCLOSURE rigidity test

8.1.1 Static test

The equipment is held firmly against a rigid support and subjected to a force of 30 N applied by the hemispherical end of a hard rod of 12 mm diameter. The rod is applied to each part of the ENCLOSURE which is ACCESSIBLE when the equipment is ready for use, and which could cause a HAZARD if distorted, including any part of the bottom of PORTABLE EQUIPMENT.

In case of doubt whether a non-metallic ENCLOSURE will pass this test at an elevated temperature, this test is performed after the equipment is operated at an ambient temperature of 40 °C, or the maximum RATED ambient temperature if higher, until a steady-state condition is reached. The equipment is disconnected from the supply source before the test is performed.

8.1.2 Dynamic test

Bases, covers, etc., intended to be removed and replaced by the OPERATOR have their fixing screws tightened using a torque likely to be applied in NORMAL USE. The test is carried out with the equipment held firmly against a rigid support onto any point on surfaces which are ACCESSIBLE in NORMAL USE and which would be likely to cause a HAZARD if damaged.

Non-metallic ENCLOSURES of equipment with a minimum RATED ambient temperature below 2 °C are cooled to the minimum RATED ambient temperature, then tested within 10 min.

A maximum of three points is tested using a steel sphere. The energy level is 5 J.

The striking element is a 50 mm diameter steel sphere with a mass of 500 g \pm 25 g.

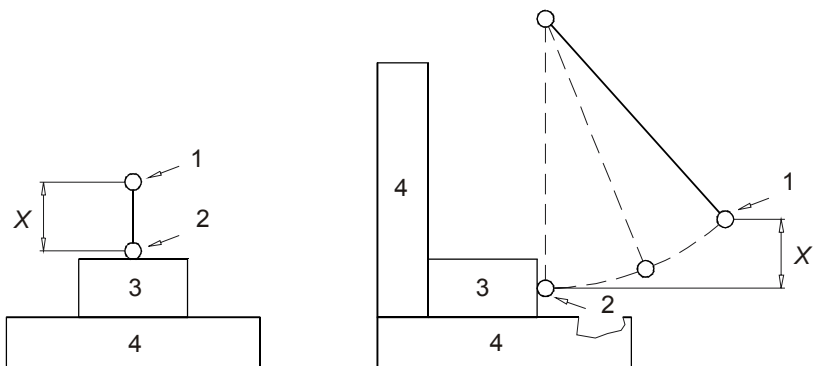
The test is performed as shown in Figure 4. The height X is 1 m for 5 J.

Alternatively, the drop test (see Figure 4 a)) can be performed with the element mounted at 90° to its normal position.

After the test, HAZARDOUS LIVE parts behind visibly damaged windows or displays shall not be ACCESSIBLE and other parts of the ENCLOSURE shall meet the requirements for BASIC INSULATION.

The following equipment and parts are not subjected to the test:

- a) *Panel meters*
- b) *HAND-HELD EQUIPMENT*
- c) *Direct plug-in equipment*
- d) *Components or windows not forming part of the ENCLOSURE*



IEC 2736/2000

Key

- 1 Sphere start position
- 2 Sphere impact position
- 3 Test sample
- 4 Rigid supporting surface

Figure 4 – Impact test using sphere

8.2 Drop test

8.2.1 Equipment other than HAND-HELD EQUIPMENT and direct plug-in equipment

The test is carried out as follows:

- a) *For equipment with a mass up to 20 kg, a corner drop test, as specified in 8.2.1.1*
- b) *For equipment with a mass over 20 kg but up to 100 kg, a face drop test, as specified in 8.2.1.2*
- c) *For FIXED EQUIPMENT and for equipment with a mass over 100 kg, no test is required.*

NOTE If the equipment consists of two or more units, the value for the mass refers to the mass of each individual unit. However, if one or more units are intended to be attached to, or supported by, another unit, these units are treated as a single unit.

The method of test shall not allow the equipment to topple onto the next face instead of falling back onto the test face as intended, nor roll around the next edge.

If the number of bottom edges exceeds four, the number of drops shall be limited to four edges.

8.2.1.1 Corner drop test

The equipment is placed in its position of NORMAL USE on a smooth, hard rigid surface of concrete or steel. One bottom edge is raised above the test surface by placing a wooden stud 10 mm high under one corner, and a 20 mm wooden stud under an adjacent corner. The equipment is then lifted above the test surface by rotating it about the edge on the two studs, until the other corner adjacent to the 10 mm stud is raised $100 \text{ mm} \pm 10 \text{ mm}$, or so that the angle made by the equipment and the test surface is 30° , whichever condition is less severe. It is then allowed to fall freely onto the test surface. The equipment is subjected to one drop on each of four bottom corners by applying the test along four bottom edges in turn.

8.2.1.2 Face drop test

The equipment is placed in its position of NORMAL USE on a smooth, hard, rigid surface of concrete or steel. It is then tilted about one bottom edge so that the distance between the opposite edge and the test surface is $25 \text{ mm} \pm 2.5 \text{ mm}$, or so that the angle made by the bottom and the test surface is 30° , whichever is less severe. It is then allowed to fall freely onto the test surface.

8.2.2 HAND-HELD EQUIPMENT and direct plug-in equipment

HAND-HELD EQUIPMENT and direct plug-in equipment is dropped once through a distance of 1 m on to a 50 mm thick hardwood board having a density of more than 700 kg/m^3 lying flat on a rigid base such as concrete block. The equipment is dropped so that it lands in the position expected to present the most severe condition.

Non-metallic ENCLOSURES of equipment with a minimum RATED ambient temperature below 2°C are cooled to the minimum RATED ambient temperature, then tested within 10 min.

8.3 Nonmetallic enclosures

Nonmetallic enclosures intended for outdoor use shall meet the UV resistance requirements of UL 746C or of C22.2 No. 0.17 or of both as appropriate.

Note: UL746, clause 27, has a 1000 hour UV/water exposure preconditioning using a Xenon-arc or alternatively, a 720 hour UV/water exposure preconditioning using twin carbon-arcs. CSA C22.2 No. 017, clause 5.9, only permits the 1000 hour UV/water exposure preconditioning.

9 Protection against the spread of fire

There shall be no spread of fire outside the equipment in NORMAL CONDITION or in SINGLE FAULT CONDITION. Figure 5 is a flow chart showing methods of conformity verification.

Conformity is checked by at least one of the following methods.

- a) Testing in the SINGLE FAULT CONDITIONS (see 4.4) that could cause the spread of fire outside the equipment. The conformity criteria of 4.4.4.3 shall be met.*
- b) Verifying elimination or reduction of the sources of ignition within the equipment as specified in 9.1*
- c) Verifying, as specified in 9.2, that if a fire occurs it will be contained within the equipment.*

These alternative methods can be applied throughout the equipment or individually for different sources of HAZARDS or for different areas of the equipment.

NOTE 1 Methods b) and c) are based on fulfilling specified design criteria, in contrast to method a) which relies entirely on testing in specified SINGLE FAULT CONDITIONS.

NOTE 2 See 13.2.2 concerning protection against fire caused by batteries.

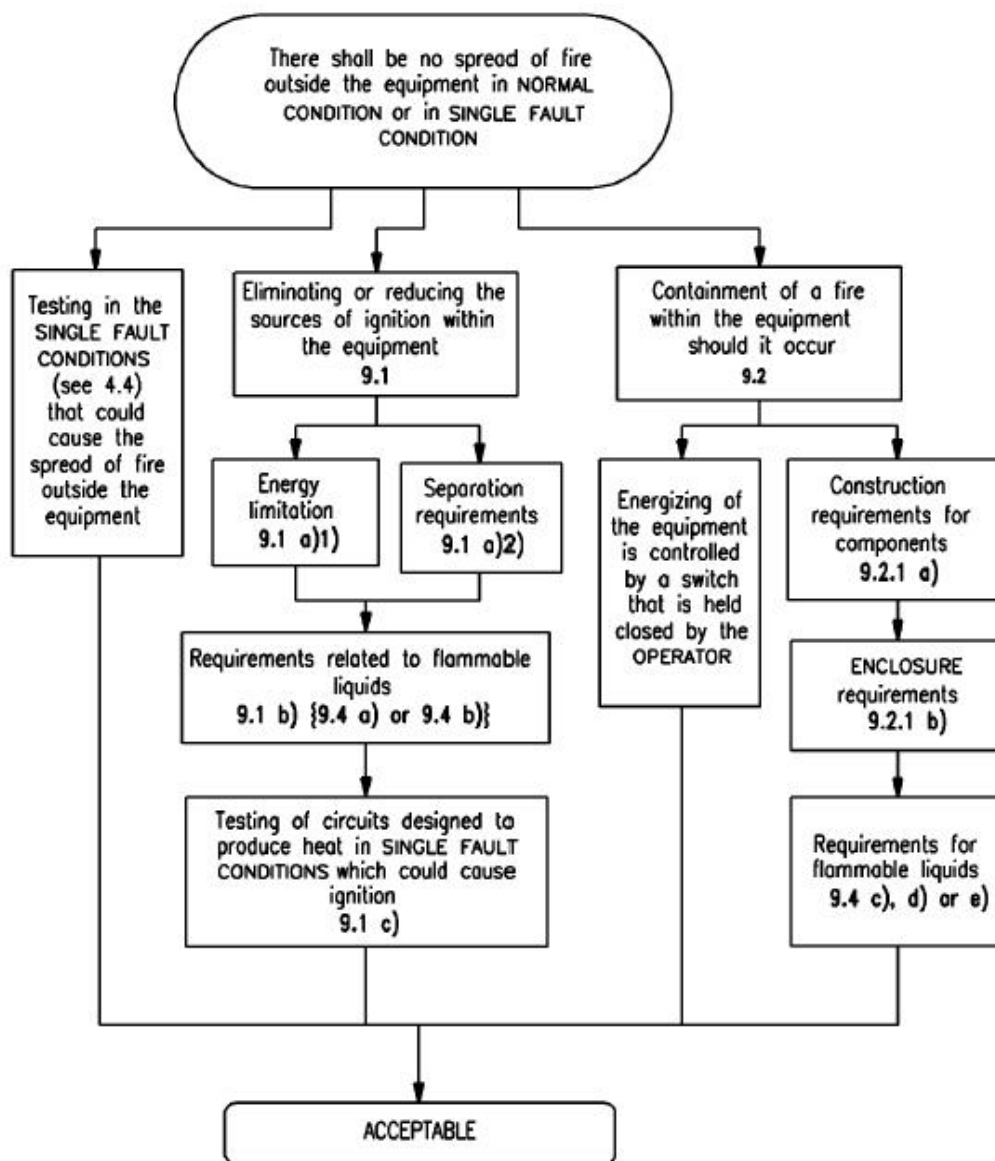


Figure 5 – Flow chart to explain the requirements for protection against the spread of fire

9.1 Eliminating or reducing the sources of ignition within the equipment

NOTE All circuits of the equipment which cannot be classified as limited-energy circuits (see 9.3) are considered to be an ignition source of fire, in which case either the method of 9 a) or the method of 9 c) is used.

The risk of ignition and occurrence of fire is considered to be reduced to a tolerable level if the following requirements are met for each source of ignition HAZARD.

a) Either 1) or 2):

- 1) The voltage, current and power available to the circuit or part of equipment is limited as specified in 9.3.

Conformity is checked by measurement of limited-energy values as specified in 9.3.

- 2) Insulation between parts at different potentials meets the requirements for BASIC INSULATION, or it can be demonstrated that bridging the insulation will not cause ignition.

Conformity is checked by inspection and in case of doubt by test.

b) Any ignition HAZARD related to flammable liquids is reduced to a tolerable level as specified in 9.4.

Conformity is checked as specified in 9.4.

c) In circuits designed to produce heat, no ignition occurs when tested in any SINGLE FAULT CONDITION (see 4.4) which could cause ignition.

Conformity is checked by the relevant tests of 4.4, applying the criteria of 4.4.4.3.

9.2 Containment of fire within the equipment, should it occur

The risk of the spread of fire outside the equipment is considered to be reduced to a tolerable level if the equipment meets one of the following constructional requirements.

- a) Energizing of the equipment is controlled by a switch that is held closed by the OPERATOR.
- b) The equipment and the equipment ENCLOSURE conform to the constructional requirements of 9.2.1 and the requirements of 9.4 b) or c) are met.

Conformity is checked by inspection and as specified in 9.2.1 and 9.4.

9.2.1 Constructional requirements

The following constructional requirements shall be met.

- a) Insulated wire shall have a flammability classification equivalent FV-1, or better, of IEC 60707, connectors and insulating material on which components are mounted shall have a flammability classification FV-2, or better, of IEC 60707. (Also see 14.8 for requirements for printed circuit boards.) Flame ratings of UL 94 V-0, V-1 and V-2 are equivalent to the flammability classifications of FV-0, FV-1 and FV-2 respectively.

~~Note — Flame ratings FT 1 of CSA C22.2 No. 0.3 and VW 1 ANSI/UL 1581 are considered acceptable for insulated wire and cable.~~

Conformity is checked by inspection of data on materials, or by performing the FV tests specified in IEC 60707 on three samples of the relevant parts. The samples may be any of the following:

- 1) Complete parts
- 2) Sections of a part, including the area with the least wall thickness and any ventilation openings
- 3) Specimens in accordance with IEC 60707

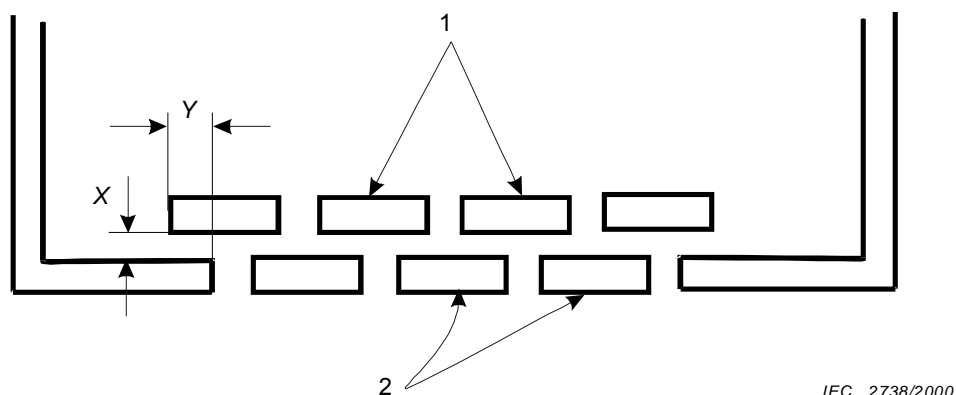
b) The ENCLOSURE shall meet the following requirements.

- 1) The bottom shall have no openings or, to the extent specified in Figure 7, shall be constructed with baffles as specified in Figure 6, or be made of metal, perforated as specified in Table 12, or be a metal screen with a mesh not exceeding 2 mm × 2 mm centre to centre and a wire diameter of at least 0.45 mm.
- 2) The sides shall have no openings within the area that is included within the inclined line C in Figure 7.
- 3) The ENCLOSURE, and any baffle or flame BARRIER, shall be made of metal (except magnesium) or of non-metallic materials having a flammability classification of FV-1 or better, of IEC 60707.
- 4) The ENCLOSURE, and any baffle or flame BARRIER, shall have adequate rigidity.

Conformity is checked by inspection. In case of doubt, the flammability classification of requirement b)3) is checked as in a).

Table 12 – Acceptable perforation of the bottom of an ENCLOSURE

Minimum thickness	Maximum diameter of holes	Minimum spacing of holes centre to centre
mm	mm	mm
0.66	1.14	1.70 (233 holes/645 mm ²)
0.66	1.19	2.36
0.76	1.15	1.70
0.76	1.19	2.36
0.81	1.91	3.18 (72 holes/645 mm ²)
0.89	1.90	3.18
0.91	1.60	2.77
0.91	1.98	3.18
1.00	1.60	2.77
1.00	2.00	3.00

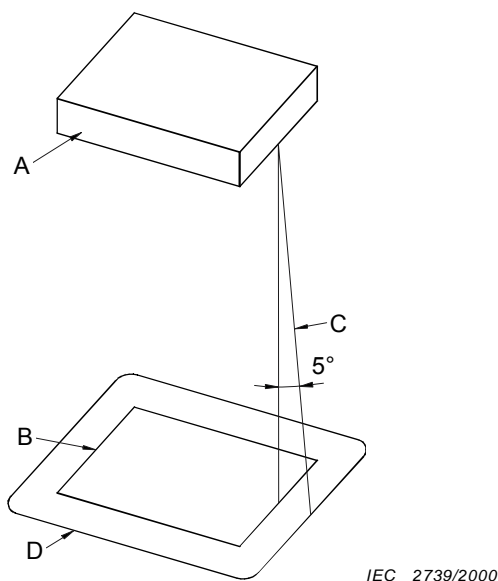


Y = twice X but never less than 25 mm

Key

- 1 Baffle plates (may be below the bottom of the ENCLOSURE)
- 2 Bottom of ENCLOSURE

Figure 6 – Baffle



Key

- A Part or component of the equipment that is considered to be a source of fire HAZARD. This consists of an entire component or part of the equipment if it is not otherwise shielded, or the unshielded portion of a component that is partially shielded by its casing.
- B Projection of the outline of A on the horizontal plane.
- C Inclined line that traces out the minimum area of the bottom and sides to be constructed as specified in 9.2.1 b)1) and 9.2.1 b)2). This line projects at a 5° angle from the vertical at every point around the perimeter of A and is oriented so as to trace out the maximum area.
- D Minimum area of the bottom to be constructed as specified in 9.2.1 b) 1).

Figure 7 – Area of the bottom of an ENCLOSURE to be constructed as specified in 9.2.1 b) 1)

9.3 Limited-energy circuit

A limited-energy circuit is a circuit that meets all the following criteria.

- a) The potential appearing in the circuit is not more than 30 V r.m.s. and 42.4 V peak, or 60 V d.c.
- b) The current that can appear in the circuit is limited by one of the following means:
 - 1) The maximum available current is limited inherently or by impedance so that it cannot exceed the relevant value of Table 13.
 - 2) Current is limited by an overcurrent protective device according to Table 14.
 - 3) A regulating network limits the maximum available current so that it cannot exceed the relevant value of Table 13 in NORMAL CONDITION or as a result of one fault in the regulating network.
- c) It is separated by at least BASIC INSULATION from other circuits that would result in energy values exceeding criteria a) and b) above.

If an overcurrent protective device is used, it shall be a fuse or a non-adjustable non-self-resetting electromechanical device.

Conformity is checked by inspection and by measuring the potentials appearing in the circuit, the maximum available current, under the following conditions:

- 1) *The potentials appearing in the circuit are measured in the load condition that maximizes the voltage.*
- 2) *Output current is measured after 60 s of operation, with the resistive load (including short circuit) which produces the highest value of current.*

Table 13 – Limits of maximum available current

Open-circuit output voltage (U) V			Maximum available current A
AC r.m.s.	DC	Peak (see note)	
≤20	≤20	≤28.3	8
20 < U ≤ 30	20 < U ≤ 30	28.3 < U ≤ 42.4	8
–	30 < U ≤ 60	–	150/U
NOTE The peak value applies to non-sinusoidal a.c. and to d.c. with ripple exceeding 10 %.			

Table 14 – Overcurrent protective device

Potential appearing in the circuit (U) V			Current that the protection device breaks after not more than 120 s (see notes 2 and 3) A
AC r.m.s.	DC	Peak (see note 1)	
≤20	≤20	≤28.3	10
20 < U ≤ 30	20 < U ≤ 60	28.3 < U ≤ 42.4	200/U
NOTE 1 The peak value applies to non-sinusoidal a.c. and to d.c. with ripple exceeding 10 %.			
NOTE 2 The evaluation shall be based on the specified time-current breaking characteristics of the protection device which is different from the rated breaking current. (For example, an ANSI/UL248-14 5 A fuse is specified to break 10 A or less at 120 s and an IEC 60127 T type 4 A fuse is specified to break at 8.4 A or less at 120 s.)			
NOTE 3 The breaking current of fuses is dependent on temperature, and this has to be taken into account if the ambient temperature of a fuse is significantly higher than the room ambient.			

9.4 Requirements for equipment containing or using flammable liquids

Flammable liquids contained in, or specified for use with, the equipment shall not cause the spread of fire in NORMAL CONDITION or in SINGLE FAULT CONDITION.

The risks arising from flammable liquids are considered to be reduced to a tolerable level if one of the following requirements is met.

- a) The temperature of the surface of the liquid and parts in contact with the surface, in NORMAL CONDITION and SINGLE FAULT CONDITION, is limited to a temperature not exceeding $t - 25\text{ °C}$, where t is the fire point of the liquid (see 10.3 b)).

NOTE Fire point is the temperature to which a liquid must be heated (under specified conditions) so that the vapour/air mixture at the surface will support a flame for at least 5 s when an external flame is applied and withdrawn.

- b) The quantity of liquid is limited to an amount that could not cause the spread of fire.
- c) If the liquid can be ignited, the flames are contained to prevent the spread of fire outside the equipment. Detailed instructions for use shall be provided to establish adequate risk-reduction procedures (see 5.4.4).

Conformity with a) and b) is checked by inspection and by temperature measurement as specified in 10.4.

Conformity with c) is checked as specified in 4.4.4.3.

NOTE For liquids with hazardous combustion products, it may be convenient to use a different liquid with similar burn characteristics.

9.5 Overcurrent protection

Equipment intended to be energized from, or connected to, a MAINS supply shall be protected by fuses, circuit-breakers, thermal cut-outs, impedance limiting circuits or similar means, to provide protection against excessive energy being drawn from the MAINS in case of a fault in the equipment. This limits the development of a fault and the probability of the start and spread of fire. Overcurrent protection devices may also provide protection against electric shock in case of fault.

Overcurrent protection devices shall not be fitted in the protective conductor. Fuses or single pole circuit-breakers shall not be fitted in the neutral conductor of multi-phase equipment.

NOTE 1 Overcurrent protection devices (for example, fuses) should preferably be fitted in all supply conductors. If fuses are used as overcurrent protection devices, the fuse holders should be mounted adjacent to each other. The fuses should be of the same RATING and characteristic. Overcurrent protection devices should preferably be located on the supply side of the MAINS CIRCUITS in the equipment, including any MAINS switch. It is recognized that, in equipment generating high frequencies, it is essential for the interference suppression components to be located between the MAINS supply and the overcurrent protection devices.

NOTE 2 In some equipment, the operation of the overcurrent protection device(s) may need to be detected and indicated.

9.5.1 PERMANENTLY CONNECTED EQUIPMENT

Overcurrent protection devices in the equipment are optional. If none is fitted, the manufacturer's instructions shall specify the overcurrent protection devices required in the building installation.

Conformity is checked by inspection.

9.5.2 Other equipment

If overcurrent protection is provided, it shall be within the equipment.

Conformity is checked by inspection.

9.6 Overcurrent Protective Devices

An overcurrent protective device shall be connected in the ungrounded supply conductor unless the overcurrent protective device or devices are so constructed as to interrupt both the neutral (grounded) and ungrounded conductors of the MAINS supply simultaneously. Where fuses are used as overcurrent protective devices in both the neutral (grounded) and ungrounded supply conductors, the fuseholders shall be mounted adjacent to each other and the fuses shall be of the same RATING and characteristics.

The screw shell of a plug fuseholder and the ACCESSIBLE contact of an extractor fuseholder connected to the ungrounded supply conductor shall be connected towards the load. The ACCESSIBLE contact or screw shell of fuseholders connected in the neutral (grounded) conductor shall be located towards the grounded supply line.

10 Equipment temperature limits and resistance to heat

10.1 Surface temperature limits for protection against burns

Easily touched surfaces shall not exceed the values of Table 15 in NORMAL CONDITION, or 105 °C in SINGLE FAULT CONDITION, at an ambient temperature of 40 °C, or the maximum RATED ambient temperature if higher.

If easily touched heated surfaces are necessary for functional reasons, they are permitted to exceed the values of Table 15 in NORMAL CONDITION and to exceed 105 °C in SINGLE FAULT CONDITION, provided that they are recognizable as such by appearance or function or are marked with symbol 13 of Table 1 (see 5.2).

Surfaces protected by guards that prevent them from being touched accidentally are not considered to be easily touched surfaces, provided that the guards cannot be removed without the use of a TOOL.

Table 15 – Surface temperature limits in NORMAL CONDITION

Part	Limit °C
1 Outer surface of ENCLOSURE	
a) metal	70
b) non-metallic	80
c) small areas that are not likely to be touched in NORMAL USE	100
2 Knobs and handles	
a) metal	55
b) non-metallic	70
c) non-metallic parts that in NORMAL USE are held only for short periods	85

Conformity is checked by measurement as specified in 10.4, and by inspection of guards to check that they protect against accidentally touching surfaces that are at temperatures above the values of Table 15, and that they cannot be removed without the aid of a TOOL.

10.2 Temperatures of windings

If a HAZARD could be caused by excessive temperature, the temperature of the insulating material of windings shall not exceed the values of Table 16 in NORMAL CONDITION or SINGLE FAULT CONDITION.

Conformity is checked by measurement as specified in 10.4, in NORMAL CONDITION and in the applicable SINGLE FAULT CONDITIONS of 4.4.2.4, 4.4.2.9 and 4.4.2.10, and also in any other SINGLE FAULT CONDITIONS that could cause a HAZARD as a result of excessive temperature.

Table 16 – Insulation material of windings

Class of insulation (see IEC 60085)	NORMAL CONDITION °C	SINGLE FAULT CONDITION °C
Class A	105	150
Class B	130	175
Class E	120	165
Class F	155	190
Class H	180	210

10.3 Other temperature measurements

The following other measurements are made, if applicable, for the purposes of other subclauses. Tests are made in NORMAL CONDITION unless stated.

- The temperature of a field-wiring TERMINAL box or compartment is measured if there is a possibility that it could exceed 60 °C at an ambient temperature of 40 °C, or the maximum RATED ambient temperature if higher (in connection with the marking requirement of 5.1.8).
- The temperature of the surface of flammable liquids, and parts in contact with the surface, is measured in the SINGLE FAULT CONDITIONS of 4.4.2.9 and 4.4.2.10 (in connection with 9.4 a)).
- The temperature of non-metallic ENCLOSURES is measured during the test of 10.5.1 (to establish a base temperature for the test of 10.5.2).
- The temperature of parts made of insulating material which are used to support parts connected to the MAINS supply (to establish a temperature for test a) of 10.5.3).
- The temperature of TERMINALS carrying a current exceeding 0.5 A and if substantial heat could be dissipated in case of poor contact (to establish a temperature for test a) of 10.5.3).

10.4 Conduct of temperature tests

Equipment is tested under reference test conditions. Unless a particular SINGLE FAULT CONDITION specifies otherwise, the manufacturer's instructions concerning ventilation, cooling liquid, limits for intermittent use, etc. are followed. Any cooling liquid shall be at the highest RATED temperature.

Maximum temperature can be determined by measuring the temperature rise under reference test conditions and adding this rise to 40 °C, or to the maximum RATED ambient temperature if higher.

The temperature of insulating material of windings is measured as the temperature of winding wire and of core lamination in contact with the insulating material. It can be determined by the resistance method or by using temperature sensors selected and positioned so that they have a negligible effect on the temperature of the winding. The latter method is used if the windings are non-uniform or if it is difficult to measure resistance.

Temperatures are measured when steady state has been reached.

10.4.1 Temperature measurement of heating equipment

Equipment intended to produce heat for functional purposes is tested in a test corner.

The test corner consists of two walls at right angles, a floor and, if necessary, a ceiling, all of plywood approximately 20 mm thick and painted matt black. The linear dimensions of the test corner should be at least 15 % greater than those of the equipment under test. Equipment is positioned at the distances from the walls, ceiling, or floor specified by the manufacturer. If no distances are specified then:

- a) equipment normally used on a floor or a table is placed as near to the walls as possible;*
- b) equipment normally fixed to a wall is mounted on one of the walls, as near to the other wall and to the floor or ceiling as is likely to occur in NORMAL USE; and*
- c) equipment normally fixed to a ceiling is fixed to the ceiling as near to the walls as is likely to occur in NORMAL USE.*

10.4.2 Equipment intended for installation in a cabinet or a wall

Such equipment is built in as specified in the installation instructions, using walls of plywood painted matt black, approximately 10 mm thick when representing the walls of a cabinet, approximately 20 mm thick when representing the walls of a building.

10.5 Resistance to heat

10.5.1 Integrity of CLEARANCES and CREEPAGE DISTANCES

CLEARANCES and CREEPAGE DISTANCES shall meet the requirements of 6.7 when the equipment is operated at an ambient temperature of 40 °C, or the maximum RATED ambient temperature if higher.

Conformity, in cases of doubt if the equipment produces an appreciable amount of heat, is checked by operating the equipment under the reference test conditions of 4.3, except that the ambient temperature is 40 °C, or the maximum RATED ambient temperature if higher. After this test, CLEARANCES and CREEPAGE DISTANCES shall not have been reduced below the requirements of 6.7.

If the ENCLOSURE is non-metallic, the temperature of parts of the ENCLOSURE is measured during the above test for the purposes of 10.5.2.

10.5.2 Non-metallic ENCLOSURES

ENCLOSURES of non-metallic material shall be resistant to elevated temperatures.

Conformity is checked by test, after one of the following treatments.

- a) A non-operative treatment, in which the equipment, not energized, is stored for 7 h at 70 °C ± 2 °C, or at 10 °C ± 2 °C above the temperature measured during the test of 10.5.1, whichever is higher. If the equipment contains components that might be damaged by this treatment, an empty ENCLOSURE may be treated, followed by assembly of the equipment at the end of the treatment.*
- b) An operative treatment, in which the equipment is operated under the reference test conditions of 4.3, except that the ambient temperature is 20 °C ± 2 °C above 40 °C, or above the maximum RATED ambient temperature if higher than 40 °C.*

After the treatment, no HAZARDOUS LIVE PARTS shall be ACCESSIBLE, the equipment shall pass the tests of 8.1 and 8.2 and, in case of doubt, additionally the tests of 6.8 (without humidity preconditioning).

10.5.3 Insulating material

Insulating material shall have adequate resistance to heat.

- a) Parts that are made of insulating material, and which are used to support other parts that are connected to the MAINS supply, shall be made of insulating materials that will not cause a HAZARD if short circuits occur inside the equipment.
- b) If in NORMAL USE, TERMINALS carry a current exceeding 0.5 A and if substantial heat could be dissipated in case of poor contact, the insulation which supports the TERMINALS shall be made of material that will not soften to an extent that could cause a HAZARD or further short circuits.

In case of doubt, conformity is checked by examination of material data. If the material data is not conclusive, one of the following tests is performed.

- 1) *A sample of the insulating material, at least 2.5 mm thick, is subjected to a ball-pressure test using the test apparatus of Figure 8. The test is made in a heating cabinet at the temperature measured as specified in 10.3 d) or 10.3 e) ± 2 °C, or at 125 °C ± 2 °C, whichever is higher. The part to be tested is supported so that its upper surface is horizontal, and the spherical part of the apparatus is pressed against this surface with a force of 20 N. After 1 h the apparatus is removed and the sample is cooled within 10 s to approximately room temperature by immersion in cold water. The diameter of the impression caused by the ball shall not exceed 2 mm.*

NOTE 1 If necessary, the required thickness may be obtained by using two or more sections of the part.

NOTE 2 For bobbins, only those parts that support or retain TERMINALS in position are subjected to the test.

- 2) *The Vicat softening test of ISO 306, method A. The Vicat softening temperature shall be at least 130 °C.*

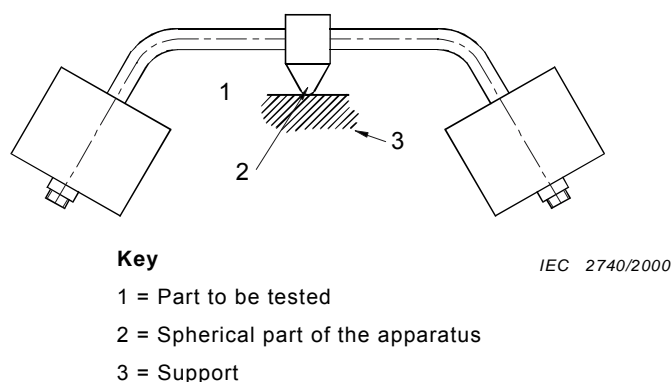


Figure 8 – Ball-pressure test apparatus

11 Protection against HAZARDS from fluids

11.1 General

Equipment containing fluids, or to be used in measurements of processes on fluids, shall be designed to give protection to the OPERATOR and surrounding area against HAZARDS from fluids encountered in NORMAL USE.

NOTE Fluids likely to be encountered fall into three categories,

- a) those having continuous contact, for example, in vessels intended to contain them;
- b) those having occasional contact, for example, cleaning fluids; and
- c) those having accidental (unexpected) contact. The manufacturer cannot safeguard against such cases.

Fluids such as cleaning fluids (except those specified by the manufacturer) and beverages are not considered.

Conformity is checked by the treatment and tests of 11.2 to 11.5.

11.2 Cleaning

If a cleaning or decontamination process is specified by the manufacturer, this shall not cause a direct HAZARD, nor an electrical HAZARD, nor a HAZARD resulting from corrosion or other weakening of structural parts relied upon for safety.

Conformity is checked by cleaning the equipment three times if a cleaning process is specified and decontaminating the equipment once if a decontamination process is specified, in accordance with the manufacturer's instructions. If, immediately after this treatment, there are any signs of wetting of parts likely to cause a HAZARD, the equipment shall pass the voltage test of 6.8 (without humidity preconditioning) and ACCESSIBLE parts shall not exceed the limits of 6.3.1.

11.3 Spillage

If, in NORMAL USE, liquid is likely to be spilt into the equipment, the equipment shall be designed so that no HAZARD will occur, for example as a result of the wetting of insulation or of internal uninsulated parts that are HAZARDOUS LIVE.

Conformity shall be checked by inspection. In case of doubt, 0.2 l of water is poured steadily from a height of 0.1 m over a period of 15 s onto each point in turn where liquid might gain access to electrical parts. Immediately after this treatment, the equipment shall pass the voltage test of 6.8 (without humidity preconditioning) and ACCESSIBLE parts shall not exceed the limits of 6.3.1.

11.4 Overflow

Liquid overflowing from any container in the equipment which can be overfilled shall not cause a HAZARD during NORMAL USE, for example as a result of the wetting of insulation or of internal uninsulated parts that are HAZARDOUS LIVE.

Equipment likely to be moved while a container is full of liquid shall be protected against liquid surging out from the container.

Conformity is checked by the following treatment and tests. The liquid container is completely filled. A further quantity of liquid equal to 15 % of the capacity of the container or 0.25 l, whichever is the greater, is then poured in steadily over a period of 60 s. If equipment is likely to be moved while a container is full of liquid, it is then tilted 15° in the least favourable direction from the position of NORMAL USE, the container being refilled if it is necessary to do this in more than one direction. Immediately after this treatment, the equipment shall pass the voltage test of 6.8 (without humidity preconditioning) and ACCESSIBLE parts shall not exceed the limits of 6.3.1.

11.5 Battery electrolyte

Batteries shall be so mounted that safety cannot be impaired by leakage of their electrolyte.

Conformity is checked by inspection.

11.6 Specially protected equipment

If the equipment is RATED and marked by the manufacturer as conforming to one of the stated degrees of protection of IEC 60529, it shall resist the entry of water to the extent specified.

Conformity is checked by inspection and by subjecting the equipment to the appropriate treatment of IEC 60529, after which the equipment shall pass the voltage test of 6.8 (without humidity preconditioning) and ACCESSIBLE parts shall not exceed the limits of 6.3.1.

11.7 Fluid pressure and leakage

Annex G is normative and replaces the requirements of 11.7.2 to 11.7.4.

NOTE Equipment meeting the requirements of this subclause may not be accepted as conforming to national requirements relating to high pressures. Annex G describes requirements and tests which are accepted as evidence of conformity with national regulations in the USA, in Canada, and in some other countries.

11.7.1 Maximum pressure

The maximum pressure to which a part of the equipment can be subjected in NORMAL USE or SINGLE FAULT CONDITION shall not exceed the RATED maximum working pressure (P_{RATED}) for the part.

The maximum pressure shall be considered to be the highest of the following:

- a) The RATED maximum supply pressure specified for an external source
- b) The pressure setting of an overpressure safety device provided as part of the assembly
- c) The maximum pressure that can be developed by an air compressor that is part of the assembly, unless the pressure is limited by an overpressure safety device

Conformity is checked by inspection of the RATINGS of the parts and, if necessary, by measuring pressures.

11.7.2 Leakage and rupture at high pressure

Fluid-containing parts of equipment which in NORMAL USE have both of the following characteristics shall not cause a HAZARD through rupture or leakage:

- a) A product of pressure and volume greater than 200 kPa·l

b) A pressure greater than 50 kPa

Conformity is checked by the following hydraulic test.

The test pressure is the maximum permissible working pressure multiplied by a factor obtained from Figure 9. Any overpressure safety device which is used to limit the maximum working pressure is to be inactivated during the test.

The pressure is raised gradually to the specified test value and is held at that value for 1 min. The sample is not to burst, suffer from permanent (plastic) deformation, or leak. Leakage at a gasket during this test is not considered to constitute failure unless it occurs at a pressure below 40 % of the required test value, or below the maximum permissible working pressure, whichever is the greater.

No leakage is allowed from fluid-containing parts intended for toxic, flammable, or otherwise hazardous substances.

If unmarked fluid-containing parts and pipes cannot be hydraulically tested, integrity is to be verified by other suitable tests, for example, pneumatic tests using suitable media, at the same test pressure as for the hydraulic test.

As an exception to the above requirements, fluid-containing parts of refrigeration systems are to meet the relevant requirements of IEC 60335.

11.7.3 Leakage from low-pressure parts

Leakage from fluid-containing parts at lower pressures shall not cause a HAZARD. See also 5.4.5.

Conformity is checked by inspection of the RATINGS of parts and, if necessary, by subjecting the parts to a fluid pressure of two times the maximum pressure in NORMAL USE. No leakage is to occur which could cause a HAZARD.

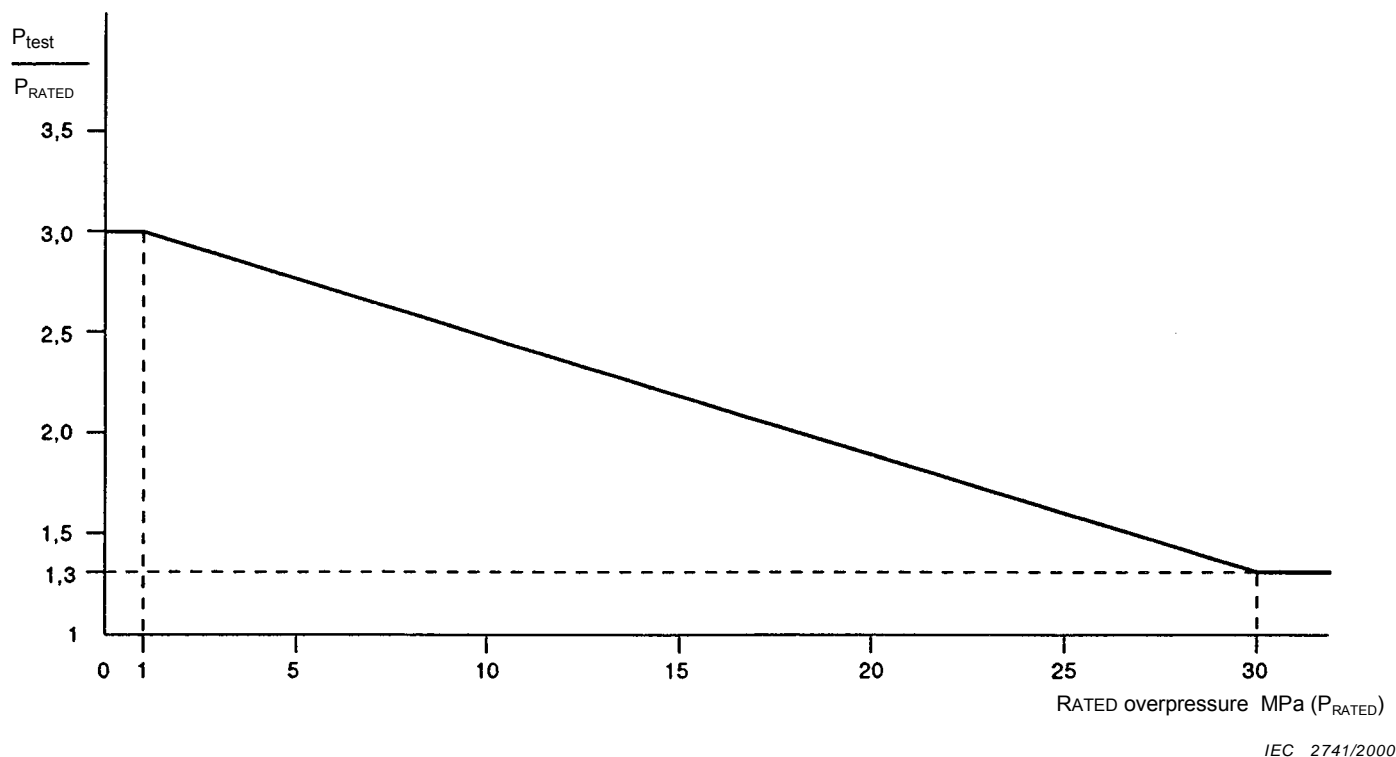


Figure 9 – Ratio between hydraulic test pressure and RATED maximum working pressure

11.7.4 Overpressure safety device

An overpressure safety device shall not operate in NORMAL USE, shall conform to the requirements of ISO 4126-1, and to the following requirements.

- a) It shall be connected as close as possible to the fluid-containing parts of the system that it is intended to protect.
- b) It shall be installed so as to provide easy access for inspection, maintenance and repair.
- c) It shall not be capable of being adjusted without the use of a TOOL.
- d) It shall have its discharge opening so located and directed that the released material is not directed towards any person.
- e) It shall have its discharge opening so located and directed that operation of the device will not deposit material on parts that may cause a HAZARD.
- f) It shall have adequate discharge capacity to ensure that, in the event of a failure of the supply pressure control, the pressure does not exceed the RATED maximum working pressure of the system.
- g) There shall be no shut-off valve between an overpressure safety device and the parts that it is intended to protect.

Conformity is checked by inspection and test.

12 Protection against radiation, including laser sources, and against sonic and ultrasonic pressure

12.1 General

The equipment shall provide protection against the effects of internally generated ultraviolet, ionizing and microwave radiation; laser sources, and sonic and ultrasonic pressure.

Conformity tests are carried out if the equipment is likely to cause such HAZARDS.

12.2 Equipment producing ionizing radiation

12.2.1 Ionizing radiation

For equipment containing radioactive substances and intended to emit ionizing radiation outside the ENCLOSURE, the effective dose rate at any easily reached point 100 mm from the outer surface of the equipment shall not exceed 1 $\mu\text{Sv/h}$.

For other equipment, the effective dose rate of unintended stray radiation at any easily reached point 50 mm from the outer surface of the equipment shall not exceed 5 $\mu\text{Sv/h}$. This includes cathode ray tubes and equipment in which electrons are accelerated by voltages exceeding 5 kV, as well as equipment containing radioactive substances and not intended to emit ionizing radiation outside the ENCLOSURE.

NOTE 1 See IEC 60405, for further information on the requirements for equipment which utilizes ionizing radiation.

NOTE 2 For X-ray and gamma radiation: 1 $\mu\text{Sv/h}$ = 0.1 mR/h and 5 $\mu\text{Sv/h}$ = 0.5 mR/h.

Conformity is checked by measuring the amount of radiation in the conditions that will produce maximum radiation. The method of determining the amount of radiation shall be effective over the range of possible radiation energies.

Equipment containing cathode-ray tubes is tested while displaying a pattern from each beam not exceeding 30 mm \times 30 mm or the smallest possible display, whichever is smaller. Displays are positioned so as to produce maximum radiation.

12.2.2 Accelerated electrons

The equipment shall be so constructed that compartments in which electrons are accelerated by voltages exceeding 5 kV cannot be opened without the use of a TOOL.

Conformity is checked by inspection.

12.3 Ultraviolet (UV) radiation

Nonmetallic parts subject to UV radiation shall be tested in accordance with 8.3 if failure could result in a hazard.

Equipment containing a UV source not designed to provide external UV illumination shall not permit unintentional escape of UV radiation that could cause a HAZARD.

NOTE Limits of maximum exposure to UV-B and UV-C are given by the IRPA Guidelines on protection against non-ionizing radiation.

Conformity is checked by inspection or by measuring to verify the limits in Annex DVC are not exceeded.

12.4 Microwave radiation

At all points in the vicinity of the apparatus, the power density of spurious microwave radiation at frequencies between 1 GHz and 100 GHz shall not exceed 10 W/m² at any point 50 mm away under reference test conditions. This requirement does not apply to parts of the apparatus where microwave radiation is propagated intentionally, for example, at waveguide output ports.

Conformity is checked by test.

12.5 Sonic and ultrasonic pressure

12.5.1 Sound level

If equipment produces noise at a level which could cause a HAZARD, the manufacturer shall measure the maximum sound pressure level which the equipment can produce (except that sound from alarms and from parts located remotely are not included) and shall calculate the maximum sound power level in accordance with ISO 3746 or ISO 9614-1.

Installation instructions shall specify how the RESPONSIBLE BODY can ensure that the sound pressure level from equipment, at its point of use after installation, will not reach a value which could cause a HAZARD. These instructions shall identify readily available and practicable protective materials or measures which may be used, including the fitting of noise-reducing baffles or hoods.

NOTE 1 A sound pressure level of 85 dBA above a reference sound pressure of 20 µPa is at present regarded by many authorities as the threshold at which a HAZARD may be caused. Special means, such as the use of protective earpieces, can make a higher level non-hazardous to the OPERATOR.

NOTE 2 The instructions for use should recommend that the sound pressure level be measured or calculated by the RESPONSIBLE BODY both at the OPERATOR'S position in NORMAL USE and at whatever point 1 m from the ENCLOSURE of the equipment has the highest sound pressure level.

Conformity is checked by measuring the maximum A-weighted sound pressure level at the OPERATOR'S position and at bystander positions, and if necessary, calculating the maximum A-weighted sound power level produced by the equipment, in accordance with either ISO 3746 or ISO 9614-1. The following conditions apply.

- a) *During measurement, any part necessary for the correct operation of the equipment and supplied by the manufacturer as an integral part of such equipment, for example, a pump, is fitted and operated as in NORMAL USE.*
- b) *Sound level meters used in the measurement conform either to type 1 of IEC 60651 or, if an integrated sound level meter, to type 1 of IEC 60804.*
- c) *The test room is semi-reverberant, with a hard reflecting floor. The distance between any wall or any other object and the surface of the equipment is not less than 3 m.*
- d) *The equipment is tested with the combination of load and other operating conditions (for example, pressure, flow, temperature) which creates the maximum sound pressure level.*

12.5.2 Ultrasonic pressure

If equipment produces ultrasound at a level which could cause a HAZARD, the manufacturer shall measure the maximum ultrasonic pressure level which the equipment can produce. When measured both at the OPERATOR'S normal position and at 1 m from the position on the equipment with the highest pressure level, the ultrasonic pressure shall not exceed 110 dB above the reference pressure value of 20 µPa, for frequencies between 20 kHz and 100 kHz.

Conformity is checked by measuring the pressure under reference test conditions.

12.6 Laser sources

Equipment employing laser sources shall meet the requirements of IEC 60825-1.

Conformity is checked as specified in IEC 60825-1.

13 Protection against liberated gases, explosion and implosion

13.1 Poisonous and injurious gases

Equipment shall not liberate dangerous amounts of poisonous or injurious gases in NORMAL CONDITION.

The manufacturer's documentation shall state which potentially poisonous or injurious gases can be liberated, and the quantities.

Conformity is checked by inspection of the manufacturer's documentation. The wide variety of gases makes it impossible to specify conformity tests based on limit values, so reference should be made to tables of occupational threshold limit values.

13.2 Explosion and implosion

13.2.1 Components

If components liable to explode if overheated or overcharged are not provided with a pressure release device, protection for the OPERATOR shall be incorporated in the apparatus (see 7.6 concerning expelled parts).

Pressure release devices shall be located so that a discharge will not cause danger to the OPERATOR. The construction shall be such that any pressure release device shall not be obstructed.

Conformity is checked by inspection.

13.2.2 Batteries and battery charging

Batteries shall not cause explosion or produce a fire HAZARD as a result of excessive charge or discharge, or if a battery is installed with incorrect polarity. If necessary, protection shall be incorporated in the equipment, unless the manufacturer's instructions specify that it is for use only with batteries which have built-in protection.

If an explosion or fire HAZARD could occur through fitting a battery of the wrong type (for example, if a battery with built-in protection is specified) there shall be a warning marking (see 5.2) on or near the battery compartment or mounting and a warning in the manufacturer's instructions. An acceptable marking is symbol 14 of Table 1.

If equipment has means for charging rechargeable batteries, and if non-rechargeable cells could be fitted and connected in the battery compartment, there shall be a marking (see 5.2) in or near the compartment. The marking shall warn against the charging of non-rechargeable batteries and indicate the type of rechargeable battery that can be used with the recharging circuit. An acceptable marking is symbol 14 of Table 1.

The battery compartment shall be designed so that there is no possibility of explosion or fire caused by build-up of flammable gases.

Also see 11.5.

Conformity is checked by inspection, including inspection of battery data, to establish that failure of a single component cannot lead to an explosion or fire HAZARD. If necessary, a short circuit and an open circuit is made on any single component (except the battery itself) whose failure could lead to such a HAZARD.

For batteries intended to be replaced by the OPERATOR, an attempt is made to install a battery with its polarity reversed. No HAZARD shall arise.

13.2.3 Implosion of cathode ray tubes

Cathode-ray tubes with a maximum face dimension exceeding 160 mm, shall be intrinsically protected against the effects of implosion and against mechanical impact, unless an ENCLOSURE provides adequate protection.

A non-intrinsically protected tube shall be provided with an effective protective screen which cannot be removed without the use of a TOOL. If a separate screen of glass is used, it shall not be in contact with the surface of the tube.

A cathode-ray tube is considered to be intrinsically protected with respect to the effects of implosion if no additional protection is necessary when it is correctly mounted.

Conformity for cathode-ray tubes is checked as specified in IEC 60065.

13.2.4 Equipment RATED for high pressures

See 11.7.

14 Components

14.1 General

Where safety is involved, components shall comply with applicable safety requirements specified in relevant ANSI, CAN, IEC, ISO or UL standards as appropriate.

If safety is involved, components shall be used in accordance with their specified RATINGS unless a specific exception is made. They shall conform to one of the following:

- a) Applicable safety requirements of a relevant IEC standard. Conformity with other requirements of the component standard is not required. If necessary for the application, components shall be subjected to the tests of this standard, except that it is not necessary to carry out identical or equivalent tests already performed to check conformity with the component standard.
- b) The requirements of this standard and, where necessary for the application, any additional applicable safety requirements of the relevant IEC component standard
- c) If there is no relevant IEC standard, the requirements of this standard

- d) Applicable safety requirements of a non-IEC standard which are at least as high as those of the relevant IEC standard, provided that the component has been approved to the non-IEC standard by a recognized testing authority. Annex DVA provides applicable safety requirements.

NOTE Tests performed by a recognized testing authority which confirm conformity with applicable safety requirements need not be retested, even if the tests were performed using a standard other than an IEC standard.

Figure 10 is a flow chart showing methods of conformity verification.

Conformity is checked by inspection and, if necessary, by test. No further tests are required for motors and transformers that have passed the applicable tests of 4.4.2.4, 4.4.2.6, 14.2 and 14.7.

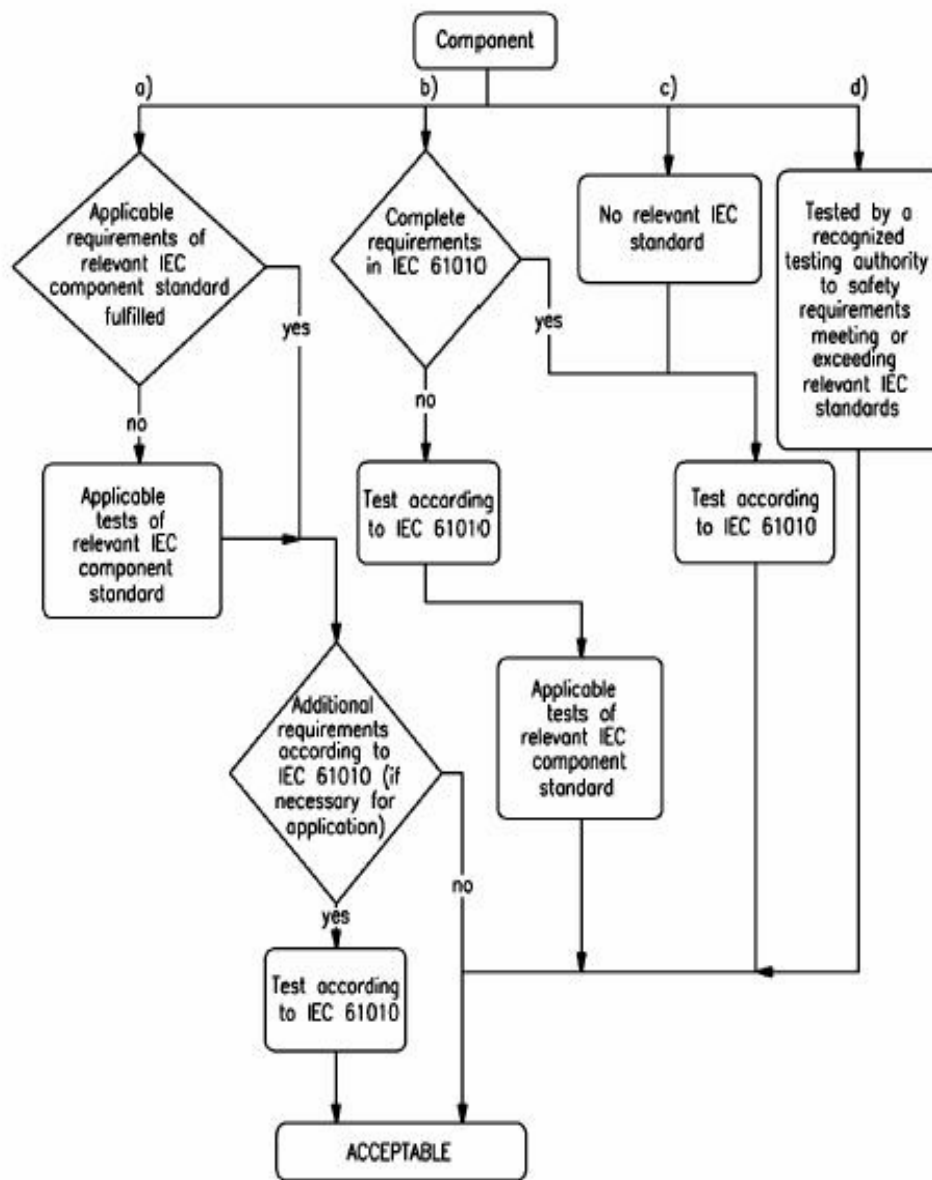


Figure 10 – Flow chart for conformity options 14.1 a), b), c) and d)

14.2 Motors

14.2.1 Motor temperatures

Motors which, when stopped or prevented from starting (see 4.4.2.4), would present an electric shock HAZARD, a temperature HAZARD, or a fire HAZARD, shall be protected by an overtemperature or thermal protection device meeting the requirements of 14.3.

Conformity is checked in the fault condition of 4.4.2.4 by measurement of the temperature in SINGLE FAULT CONDITION as specified in 10.2.

14.2.2 Series excitation motors

Series excitation motors shall be connected direct to the devices driven by them if an overspeeding motor could cause a HAZARD.

Conformity is checked by inspection.

14.3 Overtemperature protection devices

Overtemperature protection devices are devices operating in SINGLE FAULT CONDITION and shall meet all of the following requirements:

- a) Be constructed so that reliable function is ensured
- b) Be RATED to interrupt the maximum voltage and current of the circuit in which they are employed
- c) Not operate in NORMAL USE

Overtemperature protection devices which operate in case of failure of a temperature control system shall be self-resetting only if the protected part of the equipment cannot continue to function.

Conformity is checked by studying the operating principle of the device and by the following tests, with the equipment operated in SINGLE FAULT CONDITION (see 4.4). The number of operations is as follows.

- 1) *Self-resetting overtemperature protection devices are caused to operate 200 times.*
- 2) *Non-self-resetting overtemperature protection devices, except thermal fuses, are reset after each operation and thus caused to operate 10 times.*
- 3) *Non-resetting overtemperature protective devices are caused to operate once.*

NOTE Forced cooling and resting periods may be introduced to prevent damage to the equipment.

During the test, resetting devices shall operate each time the SINGLE FAULT CONDITION is applied and non-resetting devices shall operate once. After the test, resetting devices shall show no sign of damage which could prevent their operation in a further SINGLE FAULT CONDITION.

14.4 Fuse holders

Fuse holders with fuses intended to be replaceable by an OPERATOR shall not permit access to parts which are HAZARDOUS LIVE during fuse replacement.

Conformity is checked by testing with the jointed test finger (see Figure B.2) applied without force.

14.5 MAINS voltage selecting devices

Devices shall be constructed so that a change from one voltage or one type of supply to another cannot occur accidentally. The marking of voltage selecting devices is specified in 5.1.3 d).

Conformity is checked by inspection and manual test.

14.6 HIGH INTEGRITY components

If, in SINGLE FAULT CONDITION, a short circuit or an open circuit of a component could cause a HAZARD, HIGH-INTEGRITY components shall be used. HIGH-INTEGRITY components shall be constructed, dimensioned and tested in accordance with an applicable IEC standard, so that safety and reliability for the expected application is assured. They may be regarded as fault-free in relation to the safety requirements of this standard.

NOTE Examples of such requirements and tests are

- a) dielectric strength tests appropriate for DOUBLE INSULATION or REINFORCED INSULATION;
- b) dimensioning for at least twice the dissipation (resistor);
- c) climatic tests and endurance tests to ensure reliability for the expected life of the equipment; and
- d) surge tests for resistors, see IEC 60065.

A single electronic device which employs electron conduction in a vacuum, gas or semiconductor is not regarded as a HIGH-INTEGRITY component.

Conformity is checked by performing the relevant tests.

14.7 MAINS transformers tested outside equipment

MAINS transformers tested outside the equipment (see 4.4.2.6) shall be tested in the same conditions as exist inside the equipment if these could affect the test results.

Conformity is checked by the short-circuit and overload tests specified in 4.4.2.6, followed by the test of 4.4.4.1 b) and c). If there is any doubt whether a transformer would pass the other tests specified in 4.4.4 and 10.2 when installed in the equipment, the tests are repeated with the transformer installed in the equipment.

14.8 Printed circuit boards

Printed circuit boards shall be made of material with a flammability classification of FV-1 of IEC 60707 or better. Flame ratings of ANSI/UL 94 and CAN/CSA C22.2 No. 0.17, V-0, V-1 and V-2 are equivalent to the flammability classifications of FV-0, FV-1 and FV-2 respectively.

This requirement does not apply to thin-film flexible printed circuit boards which contain limited-energy circuits meeting the requirements of 9.3.

Conformity of the flammability RATING is checked by inspection of data on the materials. Alternatively, conformity is checked by performing the FV tests specified in IEC 60707 on three samples of the relevant parts. The samples may be any of the following:

- a) Complete parts

- b) *Sections of the part, including the area with the least wall thickness and any ventilation openings*
- c) *Specimens in accordance with IEC 60707*

14.9 Circuits or components used as transient overvoltage limiting devices

If control of transient overvoltage is employed in the equipment, any overvoltage limiting component or circuit shall withstand 10 positive and 10 negative impulses with the applicable impulse withstand voltage of Table 17, spaced up to 1 min apart, from a 1.2/50 μ s impulse generator (see IEC 60060). The generator shall produce an open-circuit voltage waveform of 1.2/50 μ s, a short-circuit current waveform of 8/20 μ s, with an output impedance (peak open-circuit voltage divided by peak short-circuit current) as specified in Table 18.

For measuring circuits, the test voltage is specified in Table 17. For other circuits, the test voltage is the same as that specified for measurement category II.

Table 17 – Impulse withstand voltages

Nominal a.c. or d.c. line-to-neutral voltage of MAINS supply	Specified impulse withstand voltage		
	Measurement category		
	II V	III V	IV V
50	500	800	1 500
100	800	1 500	2 500
150	1 500	2 500	4 000
300	2 500	4 000	6 000
600	4 000	6 000	8 000
1 000	6 000	8 000	12 000

Table 18 – Output impedance for impulse generators

Measurement category	Output impedance Ω
III and IV	2
II	12 (see note)
NOTE Resistance can be added in series with a lower impedance generator to raise the impedance to the appropriate value.	

Conformity is checked by the above test. After the test there shall be no sign of overload, nor degradation of performance of a component.

NOTE Circuits or components used to control the temporary overvoltages described in IEC 60364-4-442 cannot be tested by the above test.

14.9ADV EMC Materials*

14.9ADV.1 Conductive coatings

14.9ADV.1.1 The bond of a conductive (metallic) coating applied to a polymeric part shall be evaluated.

14.9ADV.1.2 Compliance with the requirements in 14.9ADV.1 is checked by:

- a) Evaluating the bond in accordance with the requirements for "Adhesives" in the Standard for Polymeric Materials--Use in Electrical Equipment Evaluations, UL 746C and CSA C22.2 No.0.17, or
- b) Evaluating the product to determine that peeling or flaking of the coating would not reduce spacings or bridge live parts so as to introduce a risk of fire or electric shock.

14.9ADV.2 Conductive shield or tape

14.9ADV.2.1 If peeling of the conductive shield or tape may introduce a risk of fire or electric shock, the bond between a conductive shield or tape and any other surface shall be investigated.

14.9ADV.2.2 Compliance with the requirements in this Clause is checked by inspection.

14.9BDV Direct Plug-in Transformers

Direct plug-in transformer units are subjected to additional requirements found in ANSI/UL 1310, CAN/CSA C22.2 No.223 or in both standards.

15 Protection by interlocks

15.1 General

Interlocks used to protect OPERATORS from HAZARDS shall prevent the OPERATOR from being exposed to the HAZARD before the HAZARD is removed and shall meet the requirements of 15.2 and 15.3.

Conformity is checked by inspection and by performing all relevant tests of this standard.

15.2 Prevention of reactivating

An interlock for the protection of an OPERATOR shall prevent the HAZARD being re-established by reactivating by hand until the action which caused the interlock to operate has been reversed or cancelled.

Conformity is checked by inspection and, if necessary, by attempting to operate by hand any interlock part which can be touched by the jointed test finger (see Figure B.2).

15.3 Reliability

An interlock system for the protection of OPERATORS shall ensure that a single fault is either unlikely to occur during the expected life of the equipment, or cannot cause a HAZARD.

* This section has been numbered in accordance with CSA and UL numbering.

Conformity is checked by assessment of the system. In case of doubt, the interlock system or relevant parts of the system are cycled to switch the least favourable load in NORMAL USE. The number of cycles is twice the maximum number likely to occur during the expected life of the equipment. Switches are tested for at least 10 000 cycles of operation. Parts passing this test are considered to be HIGH-INTEGRITY components.

16 Test and measurement equipment

16.1 Current measuring circuits

Equipment with current measuring circuits intended for connection to current transformers without internal protection shall be adequately protected to prevent a HAZARD arising from interruption of these circuits during operation. Current measuring circuits shall be so designed that, when range changing takes place, there shall be no interruption which could cause a HAZARD.

Conformity is checked by inspection and overload tests at 10 times the maximum RATED current for 1 s. No interruption which could cause a HAZARD shall occur during the test.

A range-change switch or similar device in a current measuring circuit is checked by inspection, and by causing the device to switch the maximum RATED current 6 000 times. Upon completion of the 6 000 cycles of operation, there shall be no electrical or mechanical breakdown of the switching device or any undue pitting or burning of contacts.

16.2 Multifunction meters and similar equipment

Multifunction meters and similar equipment shall not cause a HAZARD in any possible combination of RATED input voltages, and settings of function and range controls. Possible HAZARDS include electric shock, fire, arcing and explosion.

Conformity is checked by the following test.

The maximum RATED voltage specified for any function is applied to each pair of TERMINALS in turn, in every combination of function and range controls. The test source connected to the equipment measuring TERMINALS during this test is limited to 3.6 kVA for measurement category I or measurement category II. For measurement category III or measurement category IV, the test circuit has to be capable of delivering 30 kVA.

During and after the tests, no HAZARD shall arise.

Multifunction meters and similar equipment are to be tested by changing the Function/Range Selector to all possible settings while connected to the maximum rated source.”

NOTE If test probes are provided with the equipment being tested then they are to be used for the test.

Compliance is checked by testing to verify no hazard occurs when switching selector settings.

Annex A (normative) — Measuring circuits for ACCESSIBLE current (see 6.3)

NOTE This annex is based on IEC 60990, which specifies procedures for measuring ACCESSIBLE current, and also specifies the characteristics for test voltmeters.

A.1 Measuring circuits for a.c. with frequencies up to 1 MHz and for d.c.

The current is measured using the circuit of Figure A.1. The current is calculated from:

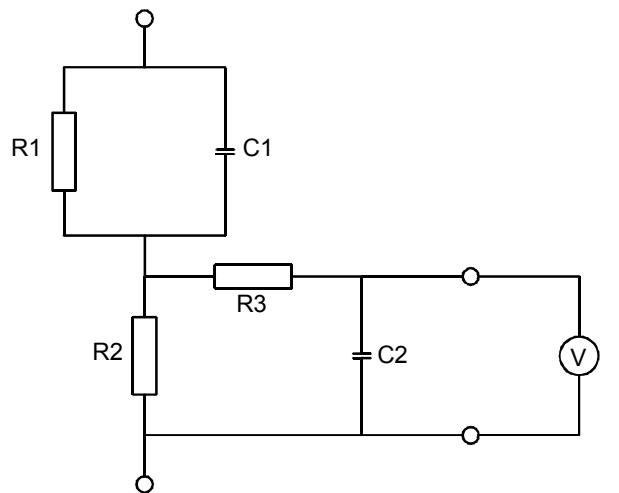
$$I = \frac{U}{500}$$

where

I is the current, in amperes;

U is the voltage, in volts, indicated by the voltmeter.

This circuit represents the impedance of the body and compensates for the change of physiological response of the body with frequency.



IEC 2743/2000

$R1 = 1\,500\ \Omega$

$R2 = 500\ \Omega$

$R3 = 10\ \text{k}\Omega$

$C1 = 0.22\ \mu\text{F}$

$C2 = 0.022\ \mu\text{F}$

Figure A.1 – Measuring circuit for a.c. with frequencies up to 1 MHz and for d.c.

A.2 Measuring circuits for a.c. with sinusoidal frequencies up to 100 Hz and for d.c.

If the frequency does not exceed 100 Hz, the current may be measured using either of the circuits of Figure A.2. When using the voltmeter, the current is calculated from:

$$I = \frac{U}{2\,000}$$

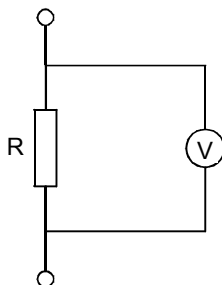
where

I is the current in amperes;

U is the voltage, in volts, indicated by the voltmeter.

The circuit represents the impedance of the body for frequencies not exceeding 100 Hz.

NOTE The value 2 000 Ω includes the impedance of the measuring instrument.



$R = 2\,000\ \Omega$

IEC 2744/2000

Figure A.2 – Measuring circuits for a.c. with sinusoidal frequencies up to 100 Hz and for d.c.

A.3 Current measuring circuit for electrical burns at high frequencies

The current is measured using the circuit of Figure A.3. The current is calculated from:

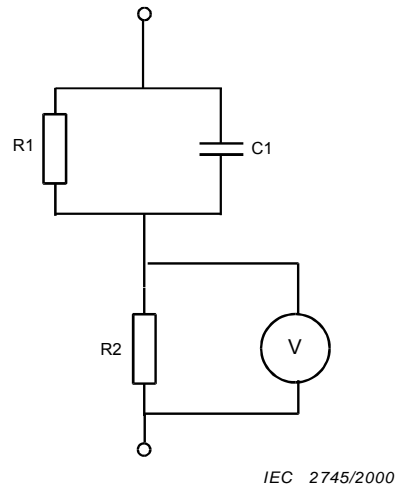
$$I = \frac{U}{500}$$

where

I is the current in amperes;

U is the voltage, in volts, indicated by the voltmeter.

This circuit compensates for the effects of high frequency on the physiological response of the body.



$R1 = 1\,500\ \Omega$

$R2 = 500\ \Omega$

$C1 = 0.22\ \mu\text{F}$

Figure A.3 – Current measuring circuit for electrical burns

A.4 Current measuring circuit for wet contact

For wet contact the current is measured using the circuit of Figure A.4. The current is calculated from:

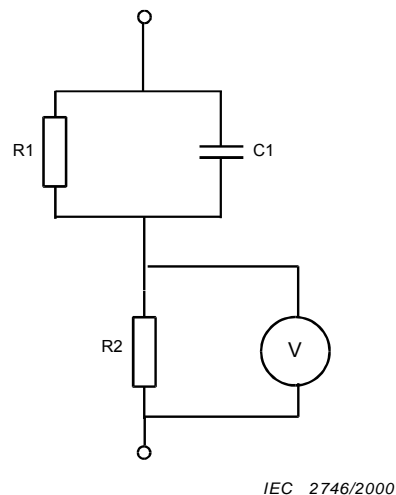
$$I = \frac{U}{500}$$

where

I is the current in amperes;

U is the voltage, in volts, indicated by the voltmeter.

This circuit represents the impedance of the body when there is no skin contact resistance.



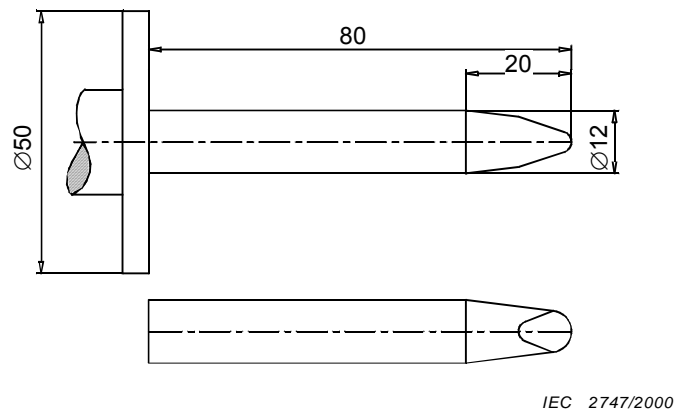
$R1 = 375\ \Omega$

$R2 = 500\ \Omega$

$C1 = 0.22\ \mu\text{F}$

Figure A.4 – Current measuring circuit for wet contact

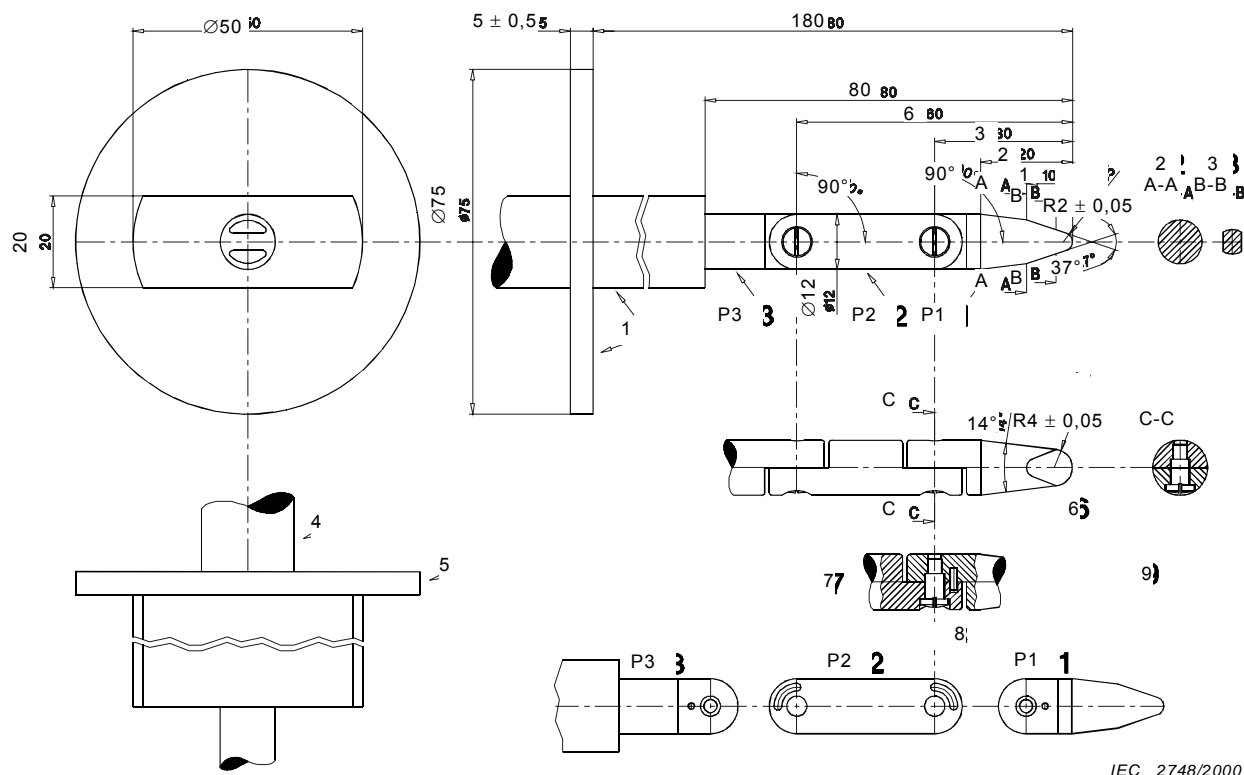
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Annex B (normative) — Standard test finger (see 6.2)

Dimensions in millimetres

For tolerances and dimensions of the fingertip, see Figure B.2.

Figure B.1 – Rigid test finger (test probe 11 of IEC 61032)



Key

1 = insulating material

2 = section AA

3 = section BB

4 = handle

5 = stop plate

6 = spherical

7 = detail x (example)

8 = side view

9 = chamfer all edges

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 $(90^{+10}_0)^\circ$ but in one plane 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 $(90^{+10}_0)^\circ$ bending angle.

Figure B.2 – Jointed test finger (test probe B of IEC 61032)

Annex C (normative) — Measurement of CLEARANCES and CREEPAGE DISTANCES

The width X of grooves specified in examples 1 to 11 apply to all examples as a function of the POLLUTION degrees as follows.

The dimension X specified in the following examples has a minimum value depending on the POLLUTION degree as given in Table C.1.

Table C.1

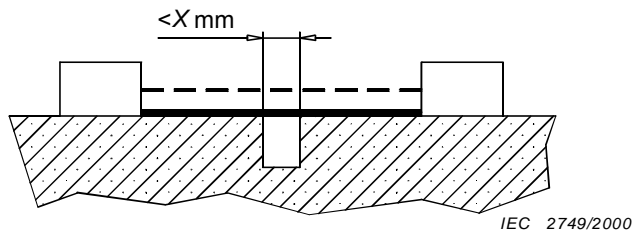
POLLUTION degree	Dimension X minimum value mm
1	0.25
2	1.0
3	1.5

If the associated CLEARANCE is less than 3 mm, the minimum dimension X may be reduced to one-third of this CLEARANCE.

The methods of measuring CLEARANCES and CREEPAGE DISTANCES are indicated in the following examples 1 to 11. These cases do not differentiate between gaps and grooves or between types of insulation.

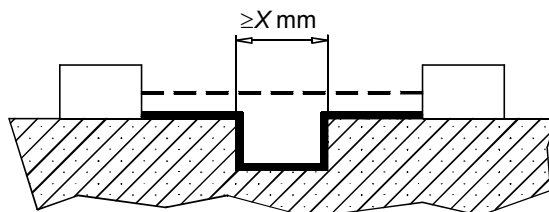
The following assumptions are made:

- Where the distance across a groove is equal to or larger than X , the CREEPAGE DISTANCE is measured along the contours of the groove (see example 2)
- Any recess is assumed to be bridged with an insulating link having a length equal to X and being placed in the least favourable position (see example 3)
- CLEARANCES and CREEPAGE DISTANCES measured between parts which can assume different positions in relation to each other are measured when these parts are in their least favourable position.



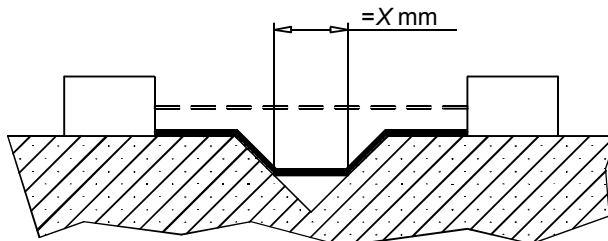
EXAMPLE 1 The path includes a parallel- or converging-sided groove of any depth with a width less than X .

The CLEARANCE and the CREEPAGE DISTANCE are measured directly across the groove as shown.



EXAMPLE 2 The path includes a parallel-sided groove of any depth and equal to or more than X .

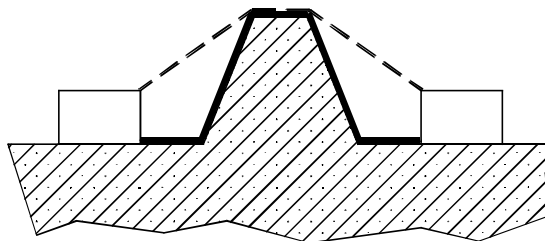
The CLEARANCE is the “line-of-sight” distance. The CREEPAGE DISTANCE follows the contour of the groove.



EXAMPLE 3 The path includes a V-shaped groove with a width greater than X .

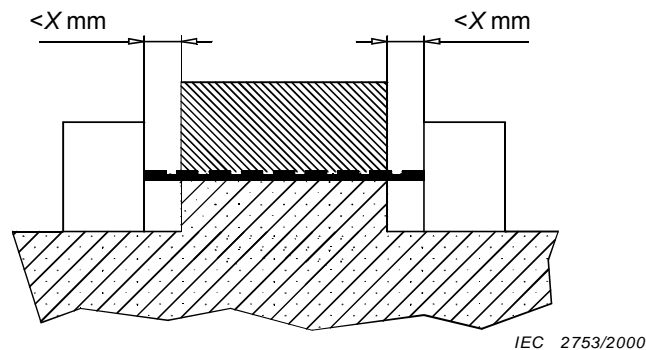
The CLEARANCE is the “line-of-sight” distance.

The CREEPAGE DISTANCE follows the contour of the groove but “short-circuits” the bottom of the groove by X link.

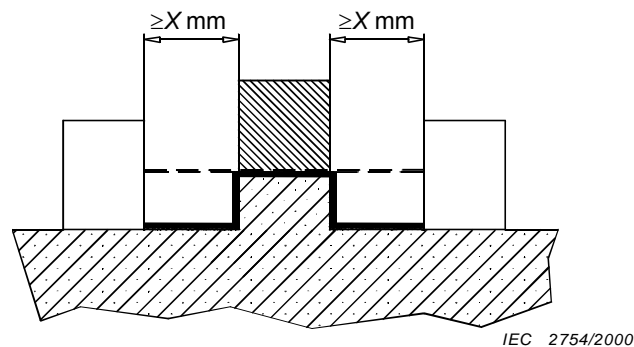


EXAMPLE 4 The path includes a rib.

The CLEARANCE is the shortest direct air path over the top of the rib. The CREEPAGE DISTANCE follows the contour of the rib.

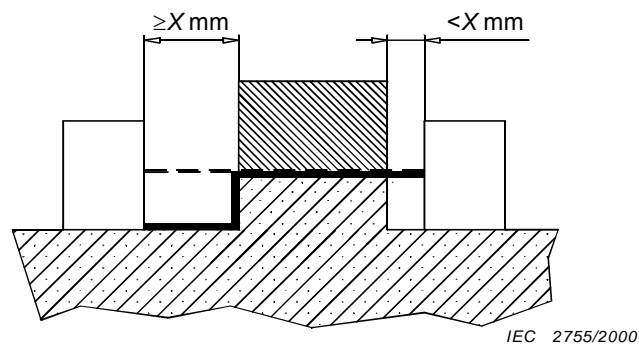
**EXAMPLE 5** The path includes an uncemented joint with grooves less than X wide on each side.

The CLEARANCE and the CREEPAGE DISTANCE path is the “line-of-sight” distance shown.

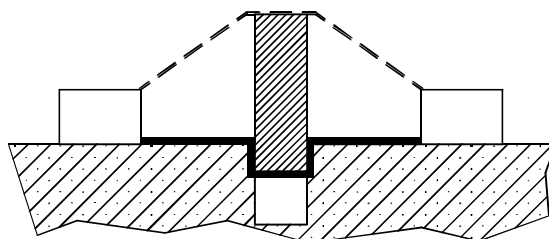
**EXAMPLE 6** The path includes an uncemented joint with grooves equal to, or more than, X .

The CLEARANCE is the “line-of-sight” distance.

The CREEPAGE DISTANCE follows the contour of the grooves.

**EXAMPLE 7** The path includes an uncemented joint with a groove on one side less than X wide and the groove on the other side equal to, or more than, X wide.

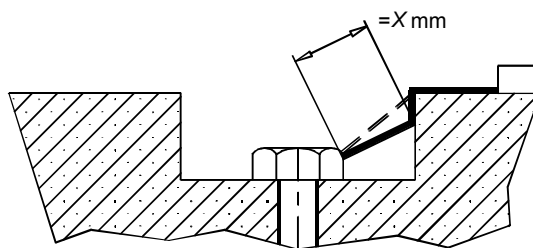
The CLEARANCE and the CREEPAGE DISTANCE are as shown.



IEC 2756/2000

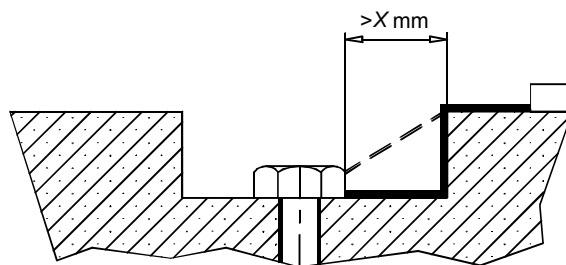
EXAMPLE 8 The CREEPAGE DISTANCE through the uncemented joint is less than the CREEPAGE DISTANCE over the BARRIER.

The CLEARANCE is the shortest direct air path over the top of the BARRIER.



IEC 2757/2000

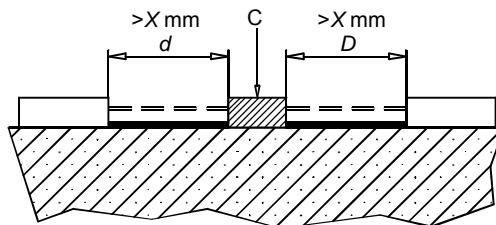
EXAMPLE 9 The gap between the head of the screw and the wall of the recess too narrow to be taken into account.



IEC 2758/2000

EXAMPLE 10 The gap between the head of the screw and the wall of the recess wide enough to be taken into account.

Measurement of the CREEPAGE DISTANCE is from screw to wall when the distance is equal to X.



IEC 2759/2000

EXAMPLE 11 $C = \text{floating part}$

The CLEARANCE is the distance $d + D$. The CREEPAGE DISTANCE is also $d + D$.

———— CREEPAGE DISTANCE

- - - - CLEARANCE

Figure C.1 – Examples of methods of measuring CLEARANCE and CREEPAGE DISTANCES

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Annex D (normative) — Parts between which insulation requirements are specified (see 6.4 and 6.5.2)

The following symbols are used in Figures D.1 to D.3 to indicate:

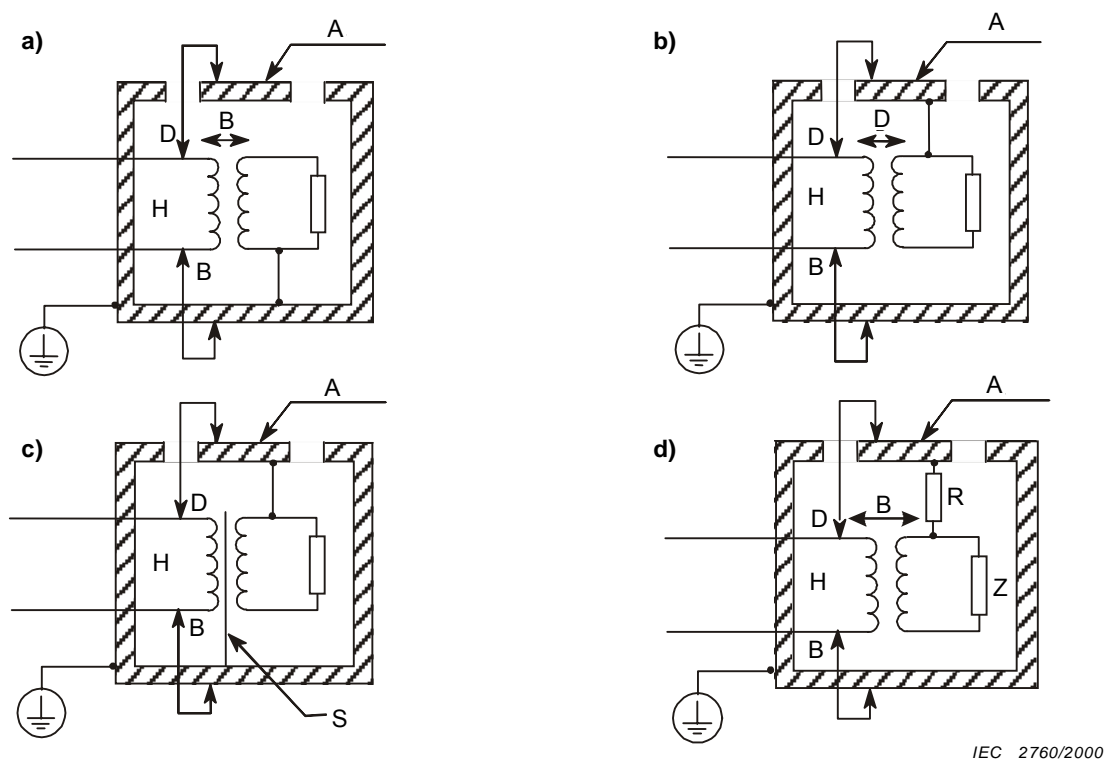
a) Requirements:

- B basic insulation is required
- D double insulation or reinforced insulation is required

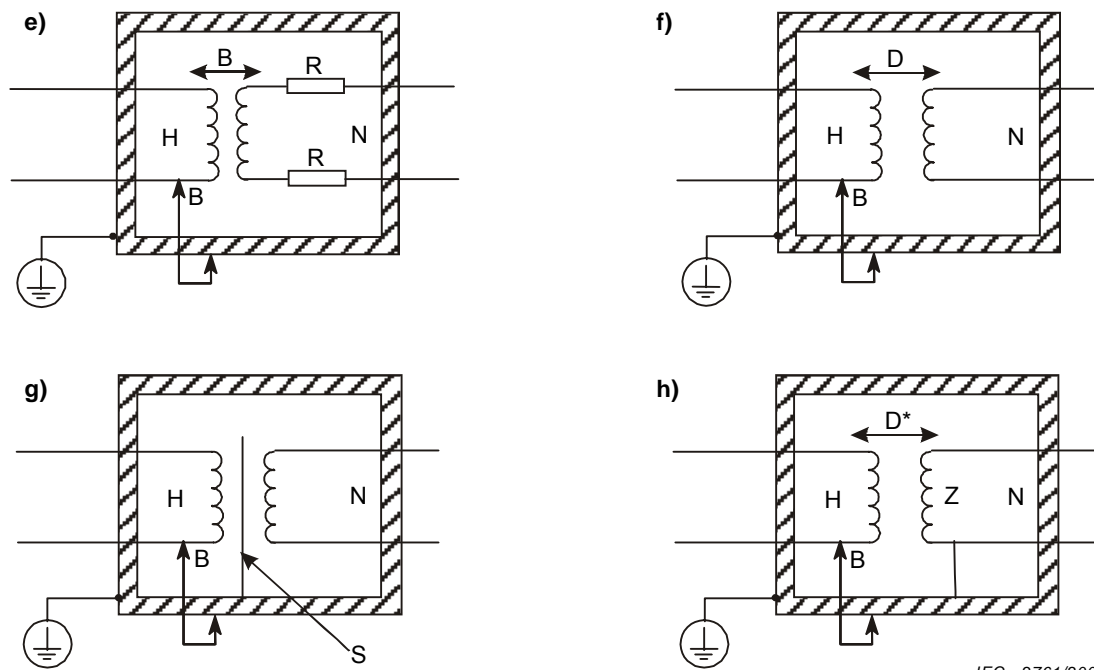
b) Circuits and parts:

- A accessible part, not bonded to the protective conductor terminal
- H circuit that is hazardous live in normal condition
- N circuit which does not exceed the values of 6.3.2 in NORMAL CONDITION
- R high impedance which, in combination with BASIC INSULATION, forms a PROTECTIVE IMPEDANCE (see 6.5.3 c))
- S protective screen
- T ACCESSIBLE external TERMINAL
- Z impedance of secondary circuit

The secondary circuits shown may also be regarded merely as parts.



Figures D.1 a) to D.1 d) – Protection between HAZARDOUS LIVE circuits and circuits not exceeding the values of 6.3.2 in NORMAL CONDITION and having external TERMINALS of ACCESSIBLE parts



IEC 2761/2000

D* may be B if Z is sufficiently low (see 6.6.1)

Figures D.1 e) to D.1 h) – Protection between HAZARDOUS LIVE circuits and other circuits which do not exceed the values of 6.3.2 in NORMAL CONDITION and which have external TERMINALS

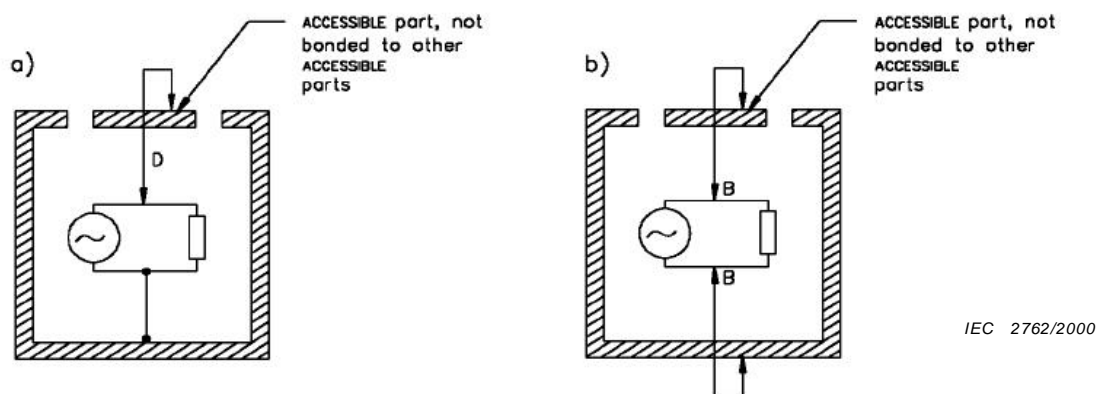


Figure D.2 a) and D.2 b) – Protection from a HAZARDOUS LIVE internal circuit for an ACCESSIBLE part which is not bonded to other ACCESSIBLE parts

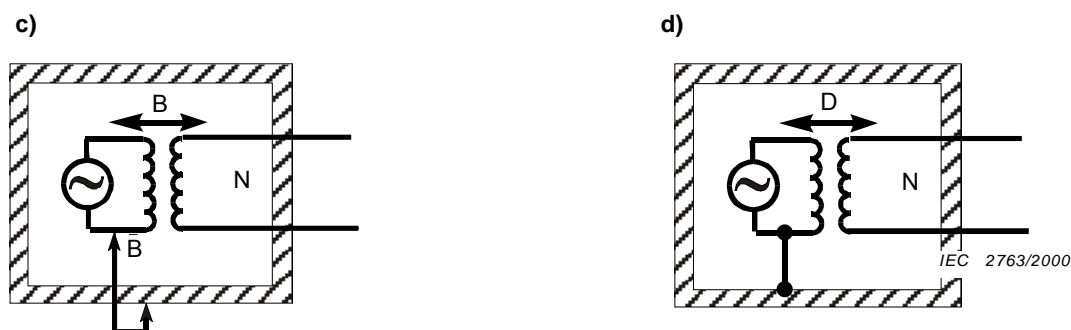


Figure D.2 c) and D.2 d) – Protection from a HAZARDOUS LIVE primary circuit for ACCESSIBLE TERMINALS of a secondary circuit which does not exceed the values of 6.3.2 in NORMAL CONDITION

NOTE Other means of protection are also possible for the circuits shown in Figures D.2 c) and D.2 d), such as protective screening, PROTECTIVE BONDING of circuits (see 6.5.1) and PROTECTIVE IMPEDANCE (see 6.5.3).

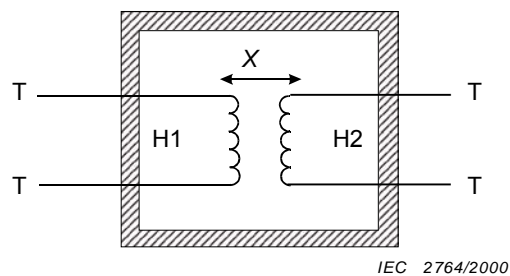


Figure D.3 – Protection of external ACCESSIBLE TERMINALS of two HAZARDOUS LIVE circuits

NOTE The requirement for insulation between an accessible part not bonded to the protective conductor terminal and either of the two hazardous live circuits is as shown in D.1 a) to D.1 d).

The test voltage for X is the most severe of the following:

B (basic) – if HAZARDOUS LIVE 1 and HAZARDOUS LIVE 2 are both connected, the test voltage is based on the highest RATED WORKING VOLTAGE that stresses the insulation between the circuits;

D (double) – if HAZARDOUS LIVE 1 is connected and the TERMINALS for HAZARDOUS LIVE 2 are ACCESSIBLE for connection purposes, the test voltage is based on the highest RATED WORKING VOLTAGE that stresses the insulation of HAZARDOUS LIVE 1;

D (double) – if HAZARDOUS LIVE 2 is connected and the TERMINALS for HAZARDOUS LIVE 1 are ACCESSIBLE for connection purposes, the test voltage is based on the highest RATED WORKING VOLTAGE that stresses the insulation of HAZARDOUS LIVE 2.

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Annex E (normative) — Reduction of POLLUTION degrees

Table E.1 shows the reduction in the POLLUTION degree of the environment through the use of additional protection.

Table E.1 – Reduction of the POLLUTION degree of internal environment through the use of additional protection

Additional protection	From POLLUTION DEGREE 2 of external environment to:	From POLLUTION DEGREE 3 of external environment to:
ENCLOSURE IPX4 of IEC 60529	2	2
ENCLOSURE IPX5 or IPX6 of IEC 60529	2	2
ENCLOSURE IPX7 or IPX8 of IEC 60529	2 (see note)	2 (see note)
Hermetically sealed ENCLOSURE	1	1
Constantly heated	1	1
Encapsulated	1	1
Coated	1	2
NOTE Reduction can be to POLLUTION DEGREE 1, if the equipment is manufactured with a low internal humidity and the manufacturer's instructions specify that, after opening the enclosure, closing must be carried out in a controlled humidity environment or a desiccant must be used.		

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Annex F (normative) — ROUTINE TESTS

The manufacturer shall perform the tests of F.1 to F.3 on 100 % of equipment produced which has both HAZARDOUS LIVE parts and ACCESSIBLE conductive parts.

Unless it can be clearly shown that the result of the tests cannot be invalidated by subsequent manufacturing stages, tests shall be made with equipment fully assembled. The equipment shall not be unwired, modified or disassembled for the test, but snap-on covers and friction-fit knobs may be removed if they would interfere with the tests. The equipment shall not be energized during the tests, but the MAINS switch shall be in the on-position.

Wrapping the equipment in foil is not required, nor is humidity preconditioning necessary.

F.1 Protective earth

A continuity test is made between the earth pin of the appliance inlet or the MAINS plug of plug-connected equipment, or the PROTECTIVE CONDUCTOR TERMINAL of PERMANENTLY CONNECTED EQUIPMENT on the one side, and all ACCESSIBLE conductive parts which are required by 6.5.1 to be connected to the PROTECTIVE CONDUCTOR TERMINAL on the other side.

NOTE No value is specified for the test current.

F.2 MAINS CIRCUITS

A test voltage as specified in 6.8 (without humidity preconditioning) for BASIC INSULATION is applied between the MAINS TERMINALS connected together on the one side, and all ACCESSIBLE conductive parts connected together on the other. For this test, the contacts of any output TERMINAL intended to be connected to circuits of other equipment which are not HAZARDOUS LIVE are considered to be ACCESSIBLE conductive parts.

The test voltage is raised to its specified value within 2 s and maintained for at least 2 s.

No breakdown or repeated flashover shall occur. Corona effects and similar phenomena are disregarded.

F.3 Other circuits

A test voltage is applied between the TERMINALS of floating input circuits, which can be HAZARDOUS LIVE in NORMAL USE, connected together on the one side, and ACCESSIBLE conductive parts connected together on the other.

A test voltage is also applied between the TERMINALS of floating output circuits, which can be HAZARDOUS LIVE in NORMAL USE, connected together on the one side, and ACCESSIBLE conductive parts connected on the other.

The value of the applied voltage in each case is 1.5 times the WORKING VOLTAGE. If voltage-limiting (clamping) devices operate below 1.5 times the WORKING VOLTAGE, the value of the applied voltage is 0.9 times the clamping voltage, but not less than that of the WORKING VOLTAGE.

NOTE In equipment which has ACCESSIBLE conductive parts connected to the PROTECTIVE CONDUCTOR TERMINAL, a connection can be made to the earth pin of the appliance inlet or MAINS plug. During this test, the equipment should be electrically isolated from any external earthing means.

No breakdown or repeated flashover shall occur. Corona effects and similar phenomena are disregarded.

Annex G (normative) — Leakage and rupture from fluids under pressure

The requirements and tests of this annex are accepted in the USA, Canada, and in some other countries, as proof of conformity with national regulations relating to high pressures.

G.1 General

Fluid-containing parts of equipment under pressure shall not cause a HAZARD through rupture or leakage in NORMAL CONDITION or SINGLE FAULT CONDITION.

Conformity is checked as specified in G.2 to G.4.

G.2 Pressures above 2 MPa and a product pressure and volume greater than 200 kPa·l

G.2.1 General

Fluid-containing parts of equipment which in NORMAL USE have both of the following characteristics shall not cause a HAZARD through rupture or leakage:

- a) a product of pressure and volume greater than 200 kPa·l;
- b) a pressure above 2 MPa.

NOTE Such equipment includes fluid-pressure-actuated equipment employing flexible bellows, diaphragms, Bourdon tubes, etc. and equipment such as flowmeters that are connected to process pressures RATED at or above 2 MPa.

Conformity is checked by inspection and by performing the hydrostatic tests of G.2.2 to G.2.6. Any overpressure safety device which is used to limit the maximum working pressure is inactivated during the tests.

Figure G.1 is a flow chart showing methods of conformity verification.

*Test not valid for equipment intended for toxic, flammable, or otherwise hazardous material

Subclause references for tests A to F:

- | | |
|--------------|--------------|
| A = G.2.3 a) | D = G.2.5 b) |
| B = G.2.3 b) | E = G.2.5 c) |
| C = G.2.5 a) | F = G.2.6 |

P_{RATED} = RATED pressure

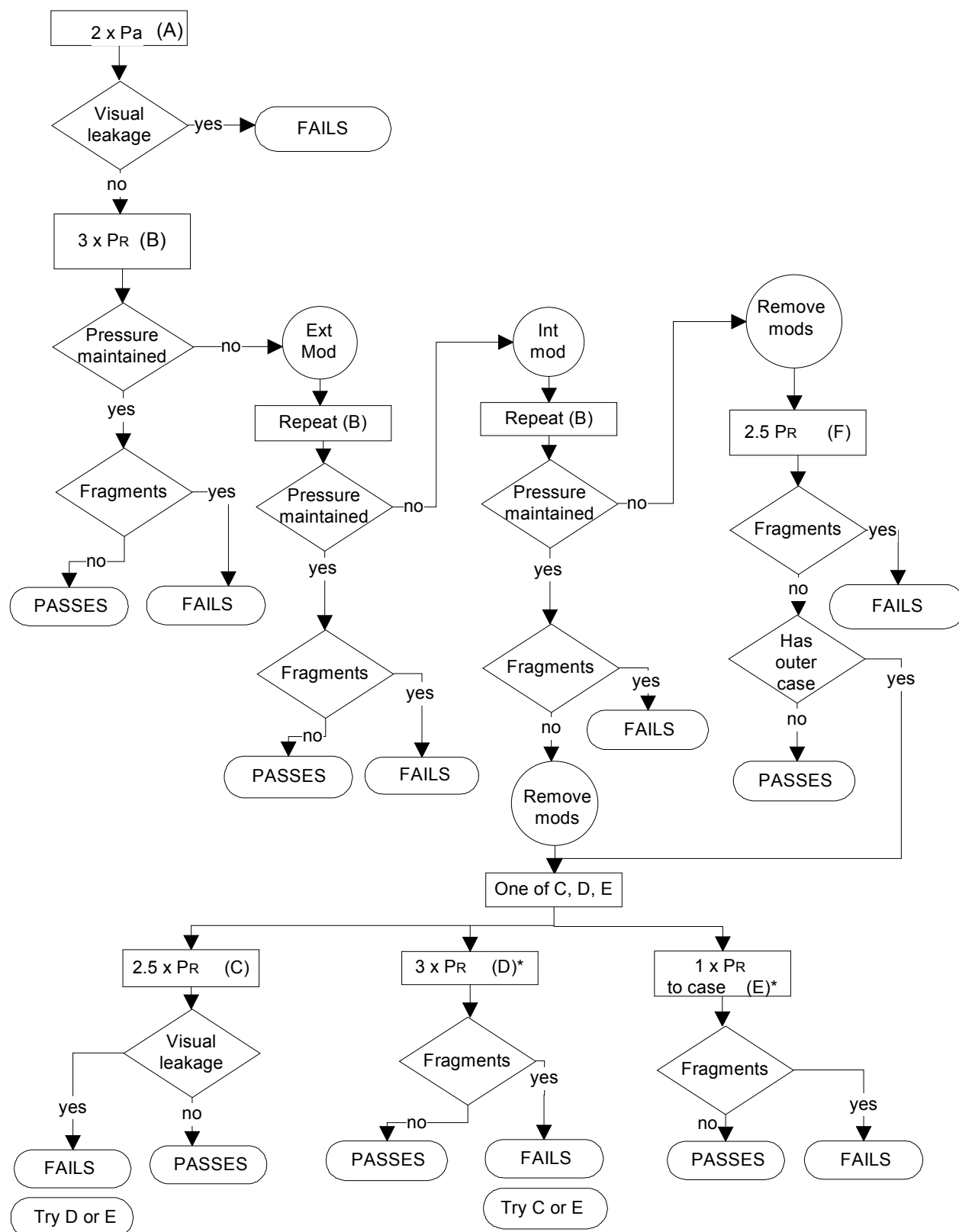


Figure G.1 – Conformity verification process (see G.2)

G.2.2 Conduct of hydrostatic tests for G.2.1

The part of the equipment that is normally subjected to the fluid pressure is filled with a suitable liquid, such as water, to exclude air, and is then connected to a hydraulic pump. The pressure is raised gradually to the specified test pressure.

Those portions of the equipment which normally receive indirect pressure loading, as in hydraulically coupled systems, are subjected to the test pressure at the same time, either through the original hydraulic filling fluid or, in its absence, by filling with the test liquid.

Test pressure values are based on RATED pressure (P_{RATED}). This is the maximum pressure as marked on the equipment or, if the value is marked, the maximum transient overpressure (maximum pressure which may be applied without permanent change in performance). In the case of differential pressure equipment, the RATED pressure is the higher of the working pressure and the static pressure.

Test pressure values specified in G.2.3 to G.2.6 apply to equipment with RATED pressure up to 14 MPa. For higher RATED pressures the values of Table G.1 apply.

If it is specified that pressure is applied to “the equipment”, this refers to that part of the equipment that is subjected to pressure in NORMAL USE. If it is specified that pressure is applied to “the outer casing” this refers to any unpressurized case, cover or housing that encloses all or part of the pressurized equipment, but that is not itself subjected to pressure in NORMAL USE.

G.2.3 Initial tests

The following tests are performed.

- a) A pressure of $2 \times P_{RATED}$ is applied to the equipment for 1 min without any visible leakage.*
- b) A pressure of $3 \times P_{RATED}$ is applied to the equipment for 1 min without any rupture or failure which results in fragments flying outside the equipment.*

During test b), leakage may occur because of splits in Bourdon tubes, diaphragms, or bellows, or because of joint or gasket failure. These are not considered to be test failures if the pressure can be maintained for 1 min. However, if leakage is at a rate which prevents pressure being maintained for 1 min, the modifications specified in G.2.4 may be made, and the test repeated.

- 1) If the equipment passes the test of G.2.3 b) after modification only as specified in G.2.4 a), no further tests are performed.*
- 2) If the equipment passes the test of G.2.3 b) after modification as specified in G.2.4 b), the modifications are removed, and one of the tests of G.2.5 is performed.*
- 3) If the equipment again fails the test of G.2.3 b), the modifications are removed and the test of G.2.6 is performed.*

G.2.4 Modifications to minimize leakage

The following modifications may be made.

- a) *External fittings may be modified to reduce leakage.*
- b) *A leaking gasket or a flexible seal (not part of the measuring element) which forms a structural partition between the part of the equipment that is under pressure in NORMAL USE and the outer casing may be replaced by a stronger non-functional member to reduce leakage.*

G.2.5 Additional tests if modification succeeded in minimizing leakage

If any modification as specified in G.2.4 b) was made before successfully repeating the test of G.2.3 b), the equipment is restored to its original state, and one of tests a), b) or c) below is performed on the unmodified equipment. For equipment intended for toxic, flammable or otherwise hazardous substances, test a) is performed.

- a) *A pressure of $2.5 \times P_{RATED}$ is applied to the equipment for 1 min without any visible leakage.*
- b) *A pressure of $3 \times P_{RATED}$ is applied to the equipment for 1 min without any rupture or failure which results in fragments flying outside the outer casing.*

NOTE In this case, even if the pressure of $3 \times P_{RATED}$ cannot be maintained within the equipment, leakage from the outer casing takes place at a rate which prevents a build-up of hazardous pressure.

- c) *If the equipment has an outer casing capable of being pressurized, it is subjected to a pressure of P_{RATED} for 1 min without any rupture or failure which results in fragments flying outside the outer casing.*

NOTE In this case, rupture and flying fragments are prevented by the capability of the outer casing to resist pressure.

G.2.6 Additional test if modifications failed to reduce leakage

If the equipment failed the test of G.2.3 b) after the modifications of G.2.4, but the leakage serves as a pressure relief mechanism, the equipment conforms to the requirements of G.2.3 b) if, after removal of the modifications, it passes the test specified below and, if the equipment has an outer casing, also passes one of tests a), b), and c) of G.2.5.

A pressure of $2.5 \times P_{RATED}$ is applied to the equipment for 1 min without any rupture or failure which results in fragments flying outside the equipment.

Table G.1 – Test pressures for equipment with pressures above 14 MPa

P_{RATED}	Pressure for test of G.2.5 c)	Pressure for test of G.2.3 a)	Pressure for tests of G.2.5 a) and G.2.6	Pressure for tests of G.2.3 b) and G.2.5 b)
$> 14 \leq 70$ MPa	P_{RATED}	$1.75 \times P_{RATED}$ plus 3.5 MPa	$2.0 \times P_{RATED}$ plus 7 MPa	$2.5 \times P_{RATED}$ plus 7 MPa
> 70 MPa	P_{RATED}	$1.3 \times P_{RATED}$ plus 35 MPa	$1.5 \times P_{RATED}$ plus 42 MPa	$2.0 \times P_{RATED}$ plus 42 MPa

G.3 Pressures between 50 kPa and 2 MPa, and pressure times volume above 200 kPa·l

Fluid-containing parts of equipment which in NORMAL USE have both of the following characteristics shall not cause a HAZARD through rupture or leakage:

- a) a product of pressure and volume greater than 200 kPa·l;
- b) a pressure between 50 kPa and 2 MPa.

Conformity is checked by a hydrostatic test conducted as specified in G.2.2. Any overpressure safety device which is used to limit the maximum working pressure is inactivated during the test.

A pressure of $3 \times P_{RATED}$ is applied to the equipment for 1 min without leakage, permanent (plastic) deformation, or bursting. However, for equipment not intended for use with toxic, flammable, or otherwise hazardous substances, leakage at a gasket at a pressure above $1.2 \times P_{RATED}$ is acceptable.

If a hydrostatic test cannot be performed on unmarked fluid-containing parts or pipes, their integrity is verified by suitable equivalent tests, such as pneumatic tests at $3 \times P_{RATED}$.

As an exception to the above method of conformity verification, conformity of fluid-containing parts of refrigeration systems is checked as specified in IEC 60335.

G.4 Pressures below 50 kPa, or pressure times volume below 200 kPa·l

Leakage from fluid-containing parts at lower pressures, or with a product of pressure and volume below 200 kPa·l, shall not cause a HAZARD.

Conformity is checked by inspection of the RATINGS of parts and, if necessary, by subjecting the parts to a fluid pressure of twice the maximum pressure in NORMAL USE. The pressure is applied for 1 min. No leakage is to occur which could cause a HAZARD.

G.5 Overpressure safety devices

An overpressure safety device shall not operate in NORMAL USE and shall conform to all the following requirements.

- a) It shall be connected as close as possible to the fluid-containing parts of the system that it is intended to protect.
- b) It shall be installed so as to provide easy access for inspection, maintenance and repair.
- c) It shall not be capable of being adjusted without the use of a TOOL.
- d) It shall have its discharge outlet located and directed so that the released material is not directed towards any person.
- e) It shall have its discharge outlet located and directed so that operation of the device will not cause a HAZARD by depositing material that could cause deterioration of parts.

- f) It shall have sufficient discharge capacity to ensure that the pressure will not exceed $1.1 \times P_{\text{RATED}}$ if there is a failure of the supply pressure control.
- g) There shall be no shut-off valve between any overpressure safety device and the parts that it is intended to protect.

Also see 11.7.4.

Conformity is checked by inspection and test.

Annex H (informative) — Index of defined terms

Term	Definition
ACCESSIBLE (OF A PART)	3.5.1
BARRIER	3.2.5
BASIC INSULATION	3.6.1
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TYPE TEST	3.4.1
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Annex DVA (informative) —CSA, UL, and IEC cross reference

The following is a matrix that provides a cross reference between CSA, UL, and IEC standards for components. This cross-reference is not meant to infer that the standards are equivalent.

Component	UL	CSA (C22.2)	IEC
Cabinets and boxes, electrical	50	No. 94	60529
Capacitors	810	252	
Circuit breakers	489	No. 5.1	60947 Pt 2
Double Insulation Systems	2097	No. 0.1	
Flexible Cord and Fixture Wire	62	No. 21	60227-5
			245-4
Fuse holders	512	No. 39	60257
Fuses, low voltage	248 series	No. 248 series	60127 series
Fuses, Plug	248-1	No. 59.1	
Lamp holders, Edison Base	496	No. 43	60238
Marking and Labeling Systems	969	No. 0.15	
Motors	1004	No. 100	60034.1
Motors, Impedance Protected	2111	No. 77	
Overheating protection for Motors, Thermal	52111	No. 235	60730 Pt 2-2
Polymeric Materials - Fabricated Parts	746D	No. 0.17	
Polymeric Materials - Long-term Property	746B	No. 0.17	60216
Polymeric Materials - Short-term Property	746A	No. 0.17	60216
Power Supplies	1012	No. 107.1	
Power Supplies (ITE)	60950-1	No. 60950-1	60950-1

Component	UL Std	CSA Std (C22.2)	IEC Std
Printed Wiring Boards	796	DIR. 010/1	
Switches, Clock-Operated	917	No. 177	
Switches, Enclosed	98	No. 4	61020
Switches, Snap, General Use	20	No. 111	61020 Pt 2
Switches, Special Use	1054	No. 55	61058
Systems of Insulating Material	1446		60085
Tapes, Insulating	510	No. 197	60454
Temperature Indicating & Regulating Equipment	873	No. 24	
Terminal Blocks	1059	No. 158	60947 Pt 7-1
Terminals, Quick Connect	310	No. 153	60760
Transformers, Specialty	506	No. 66	60742
Tubing, Extruded Insulating	224	No. 198.1	
Wire Connectors and Soldering Lugs	486A	No. 65	60998 series
Wire Connectors for Aluminum Conductors	486B	No. 65	60998 series
Wires and Cables, Rubber Insulated	44		60245
Wires and Cables, Thermoplastic Insulated	83	No. 75	60227

Annex DVB (informative) — Clauses affected by National Differences

<u>Foreword</u>	<u>Revised</u>
<u>Introduction</u>	<u>Revised</u>
<u>1.1.1 a)</u>	<u>added reference that scope includes automated test equipment</u>
<u>1.1.3ADV</u>	<u>added reference to National Electrical Codes</u>
<u>2</u>	<u>Added applicable North American standards</u>
<u>5.4.1 h)</u>	<u>Added documentation requirement for multifunction meters</u>
<u>5.4.1 i)</u>	<u>Added documentation requirement for equipment intended to detect hazardous voltages</u>
<u>6.3.1 a)</u>	<u>Revised hazardous voltage levels to IEC 61010-1 Edition 1 values</u>
<u>6.3.2 a)</u>	<u>Revised hazardous voltage levels to IEC 61010-1 Edition 1 values</u>
<u>6.5.1.4</u>	<u>Added Canadian requirement for bonding voltage drop to be 4 V max (not 10 V)</u>
<u>6.7</u>	<u>Added flow diagram for determining spacings</u>
<u>6.7.1.2</u>	<u>Added alternate circuit board coating</u>
<u>6.10.1 a)</u>	<u>Added alternate requirements for MAINS cords</u>
<u>6.10.3</u>	<u>Added alternate requirements for MAINS connectors</u>
<u>6.10.ADV</u>	<u>Added requirements for PERMANENTLY CONNECTED EQUIPMENT</u>
<u>6.11.3ADV</u>	<u>Added requirement for maintaining polarity</u>
<u>8.2ADV</u>	<u>Added requirement for enclosure resistance to UV</u>
<u>9.2.1 a)</u>	<u>Added alternate flame rating designations</u>
<u>9.5ADV</u>	<u>Added requirement for connections to overcurrent device</u>
<u>11.7</u>	<u>Added requirement that Annex G on hydrostatic testing is mandatory</u>
<u>12.3</u>	<u>Added requirements for UV testing of some nonmetallic parts</u>
<u>12.3</u>	<u>Added conformity statement to Annex DVC limits for UV emissions.</u>
<u>14.1</u>	<u>Added requirements to comply with standards where safety is involved</u>
<u>14.1 d)</u>	<u>Added that component standards are identified in Annex DVA</u>
<u>14.8</u>	<u>Added alternate flame rating designations</u>
<u>14.9ADV</u>	<u>Added requirements for EMC coatings, shield and tape</u>
<u>14.9BDV</u>	<u>Added requirements for direct plug-in transformers</u>
<u>16.2</u>	<u>Added requirements for multimeters with function/range switch</u>

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Annex DVC (normative) — UV radiation limits: Guidelines from the American Conference of Governmental Industrial Hygienists (ACGIH)

DVC.1 General

DVC.1.1 These Threshold Limit Values (TLVs) refer to ultraviolet (UV) radiation in the spectral region between 180 and 400 nm and represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse health effects. These values for exposure of the eye or the skin apply to UV radiation from arcs gas and vapor discharges, fluorescent and incandescent sources, and solar radiation, but they do not apply to UV lasers (see the TLVs for Lasers). These values do not apply to UV radiation exposure of photosensitive individuals or of individuals concomitantly exposed to photosensitizing agents. These exposures to the eye do not apply to aphakics. (See Light and Near-Infrared Radiation TLVs). These values should be used as guides in the control of exposure to continuous sources where the exposure durations shall not be less than 0.1 sec.

DVC.1.2 These values should be used as guides in the control of exposure to UV sources and should not be regarded as a fine line between safe and dangerous levels.

DVC.2 Recommended Values

DVC.2.1 The TLVs for occupational exposure to UV radiation incident upon skin or eye where irradiance values are known and exposure time is controlled are as follows:

a) For the near UV spectral region (320 to 400 nm), total irradiance incident upon the unprotected eye should not exceed 1.0 mW/cm² for periods greater than 10³ seconds (approximately 16 minutes) and for exposure times less than 10³ seconds should not exceed 1.0 J/cm².

b) The UV radiant exposure incident upon the unprotected skin or eye should not exceed the values given in Table DVC.4.1 or Figure DVC.4.1 within an 8 hour period.

c) To determine the effective irradiance of a broad band source weighted against the peak of the spectral effectiveness curve (270 nm), the following weighting formula should be used:

$$\underline{E_{eff} = \sum E_{\lambda} S_{\lambda} \Delta\lambda}$$

In which

E_{eff} = effective irradiance relative to a monochromatic source at 270 nm in W/cm² [J/(s•cm²)]

E_λ = spectral irradiance in W/(cm²•nm)

S_λ = relative spectral effectiveness (unitless)

Δλ = band width in nm

d) For most white-light sources and all open arcs, the weighting of spectral irradiance between 200 and 315 nm should suffice to determine the effective irradiance. Only specialized UV sources designed to emit UV-A radiation would normally require spectral weighting from 315 to 400 nm.

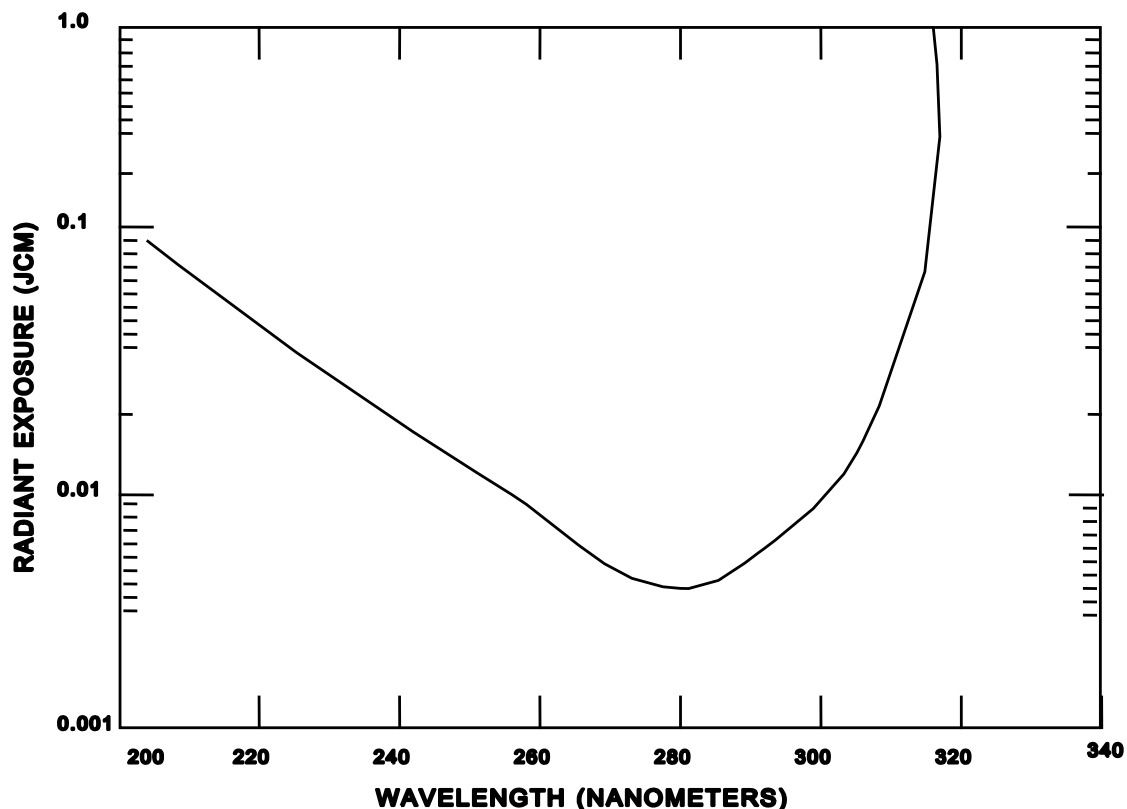


Figure DVC4.1 - Threshold Limit Values (TLV) for Ultraviolet Radiation

e) Permissible exposure time in seconds for exposure to actinic UV radiation incident upon the unprotected skin or eye may be computed by dividing 0.003 J/cm^2 by E_{eff} in W/cm^2 . The exposure time may also be determined using Table DVC4.2 which provides exposure times corresponding to effective irradiances in $\mu\text{W/cm}^2$.

f) All of the preceding TLVs for UV energy apply to sources which subtend an angle less than 80° . Sources which subtend a greater angle need to be measured only over an angle of 80° .

DVC.2.2 Conditioned (tanned) individuals can tolerate skin exposure in excess of the TLV without erythral effects. However, such conditioning may not protect persons against skin cancer.

DVC.2.3 Ozone (O_3) is produced in air by sources emitting UV radiation at wavelengths below 250 nm. Refer to Chemical Substances TLV for ozone.

TABLE DVC.4.1 Ultraviolet Radiation Exposure TLV and Spectral Weighting Function

<u>Wavelength[†]</u> <u>(nm)</u>	<u>TLV</u> <u>(J/m²)</u>	<u>TLV</u> <u>(mJ/cm²)</u>	<u>Relative Spectral</u> <u>Effectiveness, S_λ</u>
<u>180</u>	<u>2500</u>	<u>250</u>	<u>0.012</u>
<u>190</u>	<u>1600</u>	<u>160</u>	<u>0.019</u>
<u>200</u>	<u>100</u>	<u>100</u>	<u>0.030</u>
<u>205</u>	<u>590</u>	<u>59</u>	<u>0.051</u>
<u>210</u>	<u>400</u>	<u>40</u>	<u>0.075</u>
<u>215</u>	<u>320</u>	<u>32</u>	<u>0.095</u>
<u>220</u>	<u>250</u>	<u>25</u>	<u>0.120</u>
<u>225</u>	<u>200</u>	<u>20</u>	<u>0.150</u>
<u>230</u>	<u>160</u>	<u>16</u>	<u>0.190</u>
<u>235</u>	<u>130</u>	<u>13</u>	<u>0.240</u>
<u>240</u>	<u>100</u>	<u>10</u>	<u>0.300</u>
<u>245</u>	<u>83</u>	<u>8.3</u>	<u>0.360</u>
<u>250</u>	<u>70</u>	<u>7.0</u>	<u>0.430</u>
<u>254*</u>	<u>60</u>	<u>6.0</u>	<u>0.500</u>
<u>255</u>	<u>58</u>	<u>5.8</u>	<u>0.520</u>
<u>260</u>	<u>46</u>	<u>4.6</u>	<u>0.650</u>
<u>265</u>	<u>37</u>	<u>3.7</u>	<u>0.810</u>
<u>270</u>	<u>30</u>	<u>3.0</u>	<u>1.000</u>
<u>275</u>	<u>31</u>	<u>3.1</u>	<u>0.960</u>
<u>280*</u>	<u>34</u>	<u>3.4</u>	<u>0.880</u>
<u>285</u>	<u>39</u>	<u>3.9</u>	<u>0.770</u>
<u>290</u>	<u>47</u>	<u>4.7</u>	<u>0.640</u>
<u>295</u>	<u>56</u>	<u>5.6</u>	<u>0.540</u>
<u>297*</u>	<u>65</u>	<u>6.5</u>	<u>0.460</u>
<u>300</u>	<u>100</u>	<u>10</u>	<u>0.300</u>
<u>303*</u>	<u>250</u>	<u>25</u>	<u>0.120</u>
<u>305</u>	<u>500</u>	<u>50</u>	<u>0.060</u>
<u>308</u>	<u>1200</u>	<u>120</u>	<u>0.026</u>
<u>310</u>	<u>2000</u>	<u>200</u>	<u>0.015</u>
<u>313*</u>	<u>1500</u>	<u>500</u>	<u>0.006</u>
<u>315</u>	<u>1.0 x 10⁴</u>	<u>1.0 x 10³</u>	<u>0.003</u>
<u>316</u>	<u>1.3 x 10⁴</u>	<u>1.3 x 10³</u>	<u>0.0024</u>
<u>317</u>	<u>1.5 x 10⁴</u>	<u>1.5 x 10³</u>	<u>0.0020</u>
<u>318</u>	<u>1.9 x 10⁴</u>	<u>1.9 x 10³</u>	<u>0.0016</u>

<u>Wavelength☼</u> <u>(nm)</u>	<u>TLV</u> <u>(J/m²)</u>	<u>TLV</u> <u>(mJ/cm²)</u>	<u>Relative Spectral</u> <u>Effectiveness, S_λ</u>
<u>319</u>	<u>2.5 x 10⁴</u>	<u>2.5 x 10³</u>	<u>0.0012</u>
<u>320</u>	<u>2.9 x 10⁴</u>	<u>2.9 x 10³</u>	<u>0.0010</u>
<u>322</u>	<u>4.5 x 10⁴</u>	<u>4.5 x 10³</u>	<u>0.00067</u>
<u>323</u>	<u>5.6 x 10⁴</u>	<u>5.6 x 10³</u>	<u>0.00054</u>
<u>325</u>	<u>6.0 x 10⁴</u>	<u>6.0 x 10³</u>	<u>0.00050</u>
<u>328</u>	<u>6.8 x 10⁴</u>	<u>6.8 x 10³</u>	<u>0.00044</u>
<u>330</u>	<u>7.3 x 10⁴</u>	<u>7.3 x 10³</u>	<u>0.00041</u>
<u>333</u>	<u>8.1 x 10⁴</u>	<u>8.1 x 10³</u>	<u>0.00037</u>
<u>335</u>	<u>8.8 x 10⁴</u>	<u>8.8 x 10³</u>	<u>0.00034</u>
<u>340</u>	<u>1.1 x 10⁵</u>	<u>1.1 x 10⁴</u>	<u>0.00028</u>
<u>345</u>	<u>1.3 x 10⁵</u>	<u>1.3 x 10⁴</u>	<u>0.00024</u>
<u>350</u>	<u>1.5 x 10⁵</u>	<u>1.5 x 10⁴</u>	<u>0.00020</u>
<u>355</u>	<u>1.9 x 10⁵</u>	<u>1.9 x 10⁴</u>	<u>0.00016</u>
<u>360</u>	<u>2.3 x 10⁵</u>	<u>2.3 x 10⁴</u>	<u>0.00013</u>
<u>365*</u>	<u>2.7 x 10⁵</u>	<u>2.7 x 10⁴</u>	<u>0.00011</u>
<u>370</u>	<u>3.2 x 10⁵</u>	<u>3.2 x 10⁴</u>	<u>0.000093</u>
<u>375</u>	<u>3.9 x 10⁵</u>	<u>3.9 x 10⁴</u>	<u>0.000077</u>
<u>380</u>	<u>4.7 x 10⁵</u>	<u>4.7 x 10⁴</u>	<u>0.000064</u>
<u>385</u>	<u>5.7 x 10⁵</u>	<u>5.7 x 10⁴</u>	<u>0.000053</u>
<u>390</u>	<u>6.8 x 10⁵</u>	<u>6.8 x 10⁴</u>	<u>0.000044</u>
<u>395</u>	<u>8.3 x 10⁵</u>	<u>8.3 x 10⁴</u>	<u>0.000036</u>
<u>400</u>	<u>1.0 x 10⁶</u>	<u>1.0 x 10⁵</u>	<u>0.000030</u>

☼ Wavelengths chosen are representative; other values should be interpolated at intermediate wavelengths.

* Emission lines of a mercury discharge spectrum.

TABLE AC2 Permissible Ultraviolet Exposures

Duration of Exposure Per Day	Effective Irradiance, E_{eff} ($\mu\text{W}/\text{cm}^2$)
<u>8 hrs</u>	<u>0.1</u>
<u>4 hr</u>	<u>0.2</u>
<u>2 hrs</u>	<u>0.4</u>
<u>1 hr</u>	<u>0.8</u>
<u>30 min</u>	<u>1.7</u>
<u>15 min</u>	<u>3.3</u>
<u>10 min</u>	<u>5</u>
<u>5 min</u>	<u>10</u>
<u>1 min</u>	<u>50</u>
<u>30 sec</u>	<u>100</u>
<u>10 sec</u>	<u>300</u>
<u>1 sec</u>	<u>3000</u>
<u>0.5 sec</u>	<u>6000</u>
<u>0.1 sec</u>	<u>30000</u>

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