BS EN 61230:2008

BSI British Standards

Live working — Portable equipment for earthing or earthing and short-circuiting

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British Standards

National foreword

This British Standard is the UK implementation of EN 61230:2008. It is identical to IEC 61230:2008. It supersedes BS EN 61230:1996 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PEL/78, Tools for live working.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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ICS 13.260; 29.240.20; 29.260.99

Compliance with a British Standard cannot confer immunity from legal obligations.

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Amendments issued since publication

Amd. No.	Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 61230

November 2008

ICS 13.260; 29.240.20; 29.260.99

Supersedes EN 61230:1995 + A11:1999

English version

Live working - Portable equipment for earthing or earthing and short-circuiting
(IEC 61230:2008)

Travaux sous tension -
Equipements portables de mise à la terre ou de mise à la terre et en court-circuit
(CEI 61230:2008)

Arbeiten unter Spannung -
Ortsveränderliche Geräte zum Erden oder Erden und Kurzschließen
(IEC 61230:2008)

This European Standard was approved by CENELEC on 2008-10-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

CENELEC

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

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Ref. No. EN 61230:2008 E

Foreword

The text of document 78/741/FDIS, future edition 2 of IEC 61230, prepared by IEC TC 78, Live working, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61230 on 2008-10-01.

This European Standard supersedes EN 61230:1995 + A11:1999.

The major changes are:

- extension of the scope to cover the use of equipment on d.c. installations;
- extension of the use of aluminium to all conductive parts of the device;
- extension of the application to silicone rubber cables made by the revision of TC 20 document EN 61138;
- possibility of using this standard for separate components of the equipment;
- general revision of requirements and tests;
- deletion of the marking requirement of the double triangle to clarify that the products covered by the standard are not appropriate for performing live working;
- clarification and modification to the procedure for short-circuit test:
  - change of the number of devices submitted to test,
  - change of the pre-conditioning time to 48 h,
  - clarification of the test procedure for separate components;
- application of conformity assessment for products having completed the production phase, according to EN 61318:2008;
- revision of existing annexes;
- change of normative Annexes A and C into informative Annexes C and B with a reviewed wording;
- deletion of Annex B, not applicable according to EN 61318:2008;
- deletion of Annex D, its requirements and tests being now included in the body of the standard;
- introduction of a new informative Annex A on railway application;
- introduction of a new informative Annex D giving guidelines for determination of the equivalent r.m.s. value of a short-circuit current;
- revision of the list of type tests, which now appears in normative Annex E;
- introduction of a new normative Annex F on classification of defects.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2009-07-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2011-10-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61230:2008 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60071-1	NOTE Harmonized as EN 60071-1:2006 (not modified).
IEC 60071-2	NOTE Harmonized as EN 60071-2:1997 (not modified).
IEC 60228	NOTE Harmonized as EN 60228:2005 (not modified).
IEC 60743 + A1	NOTE Harmonized as EN 60743:2001 + A1:2008 (not modified).
IEC 60832	NOTE Harmonized as EN 60832:1996 (modified).
IEC 60855	NOTE Harmonized as EN 60855:1996 (modified).
IEC 60865-1	NOTE Harmonized as EN 60865-1:1993 (not modified).
IEC 60909-0	NOTE Harmonized as EN 60909-0:2001 (not modified).
IEC 61235	NOTE Harmonized as EN 61235:1995 (modified).
IEC 61472	NOTE Harmonized as EN 61472:2004 (not modified).
ISO 9000	NOTE Harmonized as EN ISO 9000:2005 (not modified).

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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

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

Publication	Year	Title	EN/HD	Year
IEC 60060-1	1989	High-voltage test techniques - Part 1: General definitions and test requirements	HD 588.1 S1	1991
IEC 60068-2-11	1981	Environmental testing - Part 2: Tests - Test Ka: Salt mist	EN 60068-2-11	1999
IEC 60068-2-42	2003	Environmental testing - Part 2-42: Tests - Test Kc: Sulphur dioxide test for contacts and connections	EN 60068-2-42	2003
IEC 60811-1-4 + corr. May + A1 A2	1985 1986 1993 2001	Common test methods for insulating and sheathing materials of electric cables - Part 1: Methods for general application - Section 4: Tests at low temperature	 EN 60811-1-4 A2	 1995 2001
IEC 60811-2-1 A1	1998 2001	Insulating and sheathing materials of electric and optical cables - Common test methods - Part 2-1: Methods specific to elastomeric compounds - Ozone resistance, hot set and mineral oil immersion tests	EN 60811-2-1 A1	1998 2001
IEC 60811-3-1 A1 A2	1985 1994 2001	Common test methods for insulating and sheathing materials of electric cables - Part 3: Methods specific to PVC compounds - Section 1: Pressure test at high temperature - Tests for resistance to cracking	EN 60811-3-1 A1 A2	1995 1996 2001
IEC 61138 (mod)	2007	Cables for portable earthing and short-circuiting equipment	EN 61138	2007
IEC 61318	2007	Live working - Conformity assessment applicable to tools, devices and equipment	EN 61318	2008
IEC 61477 A1 A2 (mod)	2001 2002 2004	Live working - Minimum requirements for the utilization of tools, devices and equipment	EN 61477 A1 A2	2002 2002 2005

CONTENTS

INTRODUCTION

This International Standard has been prepared in accordance with the requirements of IEC 61477.

An agreement may be made between manufacturer and customer for additional requirements, and tests. These additional requirements are prescribed in the customer's specification on the basis of an acceptance procedure.

LIVE WORKING – PORTABLE EQUIPMENT FOR EARTHING OR EARTHING AND SHORT-CIRCUITING

1 Scope

This International Standard is applicable to portable equipment, with or without matching connection points, for temporary earthing or earthing and short-circuiting of electrically isolated or de-energized a.c. and d.c. installations, distribution and transmission networks, whether they are overhead or underground or of low or high voltage.

NOTE Annex A provides guidance for application to railway systems.

This standard covers equipment comprising an earthing or a short-circuiting or an earthing and short-circuiting device and insulating component. An example is given in Figure 1a and Figure 1b.

It also covers:

– earthing or short-circuiting or earthing and short-circuiting devices intended to be installed with insulating means. An example of an earthing device is given in Figure 1c;

– separate components, such as conductive extension (see Figure 1b) or clamp or cable with end fittings.

The performance of equipment, devices and components covered by this standard is based on electro-dynamic and electro-thermal effects acting during short-circuit. The withstand capability of the devices and equipment is expressed by their rated values of current, time and peak factor. No rated voltage is given, but the geometrical dimensions of the equipment are also linked to the voltage of the installation.

Examples of connection diagrams of earthing and short-circuiting devices are given in Figures 2 and 3. Associated usual lengths of cables are given in Table 1.

Not covered in this standard are:

– insulating means, such as insulating sticks, telescopic sticks, insulating handles, insulating gloves, aerial devices with insulating booms, insulating ropes to be used to install the earthing and short-circuiting device;

– insulating components, except for basic safety requirements for the insulating element;

  NOTE Basic safety recommendations for earthing sticks are given in Annex B.

– devices meant only for the draining of induced currents;

– relevant working procedures for using portable equipment for earthing or earthing and short-circuiting.

NOTE The equipment complying with this standard should be used according to safe working procedures and according to local or national regulation, such as live working or dead working procedures.

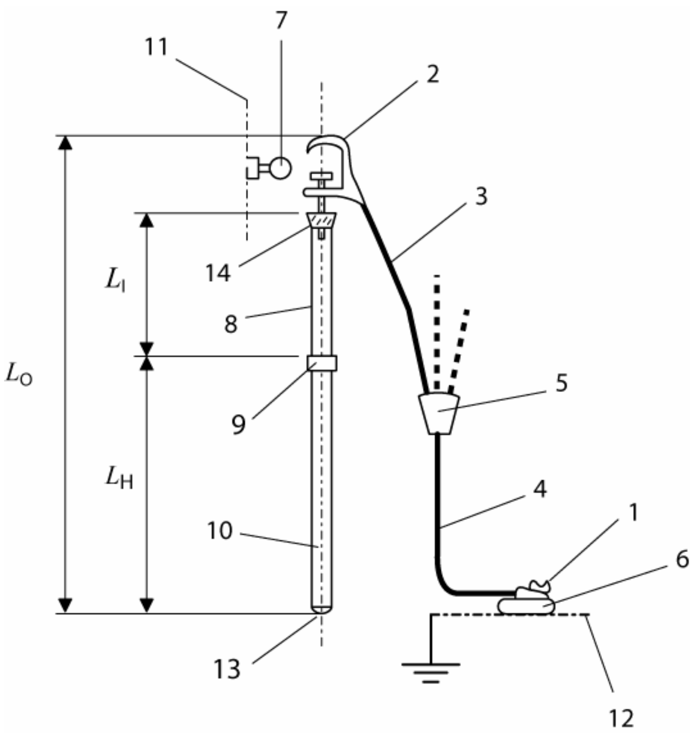


Figure 1a – Multi-phase equipment

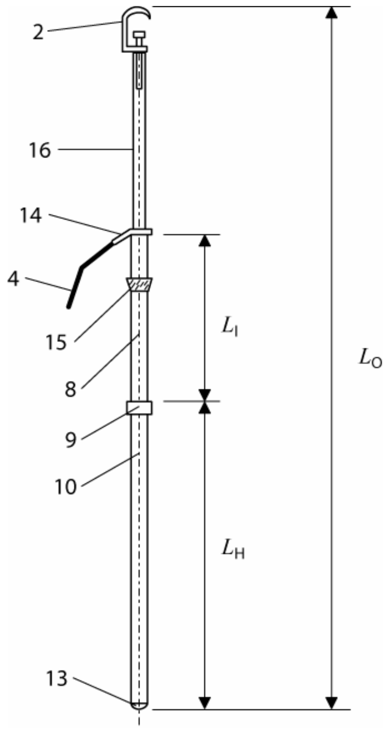
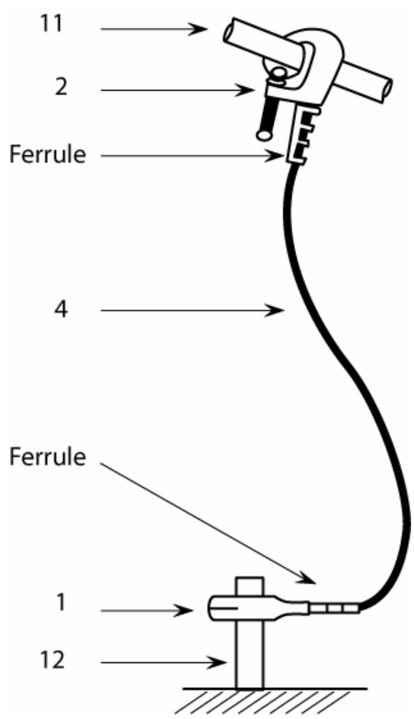


Figure 1b – Single-phase equipment with extension



NOTE The same device can also be used for short-circuiting.

Figure 1c – Earthing device

Key

1 Earth clamp or rail clamp
2 Line clamp or contact line clamp
3 Short-circuiting cable(s)
4 Earthing cable(s)
5 Connecting cluster
6 Earth permanent connection point or rail
7 Line permanent connection point or overhead contact line profile
8 Insulating element
9 Handle limit mark
10 Handle of earthing stick
11 Installation conductor or bar
12 Earthing system
13 End cap of stick
14 End fitting, permanent or detachable
15 Stick coupling, detachable for transport reasons
16 Conductive extension
L_I Length of insulating element
L_H Length of handle
L_O Overall length of earthing stick and conductive extension component

NOTE 1 The earthing and short-circuiting device comprises components 1, 2, 3, 4, 5 and 16.

NOTE 2 The earthing stick comprises components 8, 9, 10, 13, 14 and 15.

NOTE 3 The earthing device comprises components 1, 2 and 4.

Figure 1 – Examples of portable equipment and device for installations, network and railway systems application

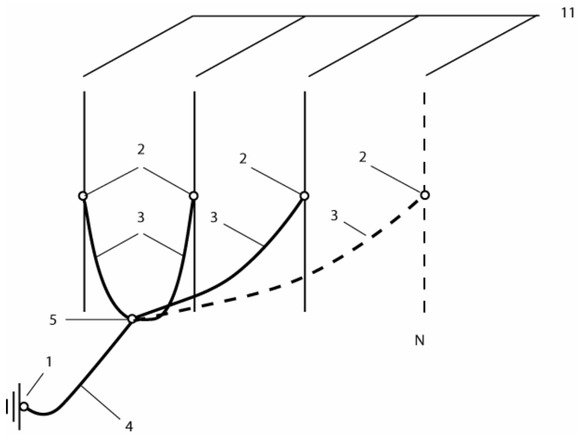


Figure 2a

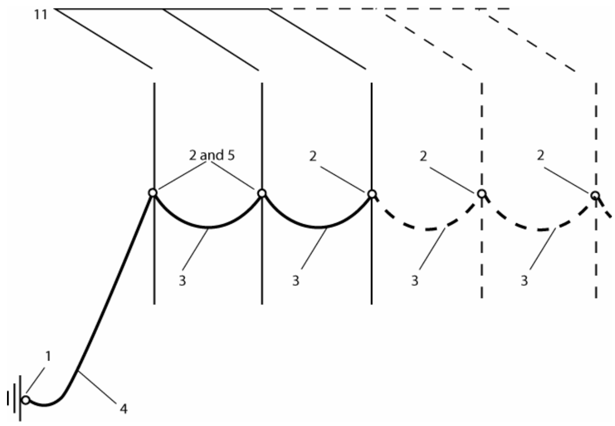


Figure 2b

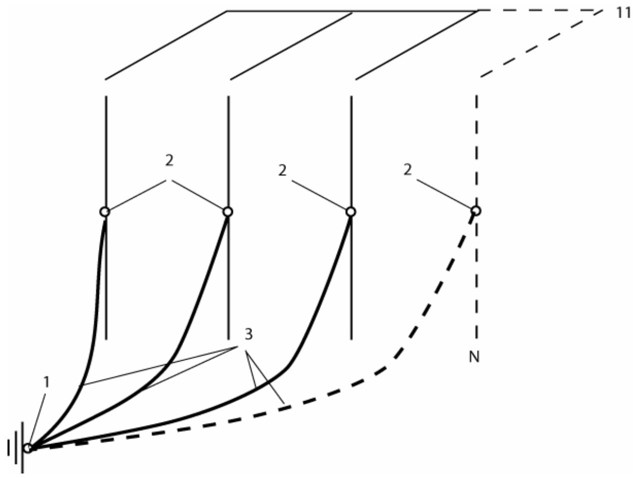


Figure 2c

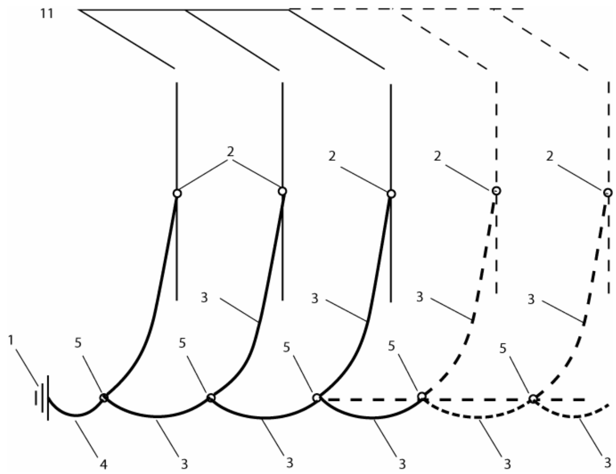
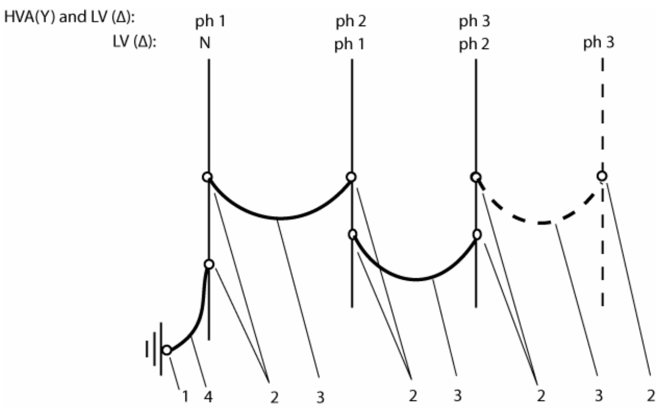


Figure 2d



HVA (Y) = High voltage distribution , Y Neutral system

LV (Δ) = Low voltage, Δ Neutral system

Figure 2e

Key

1	Earth clamp
2	Line clamp
3	Short-circuiting cable(s)
4	Earthing cable(s)
5	Connecting cluster
11	Installation conductor or bar
16	Conductive extension

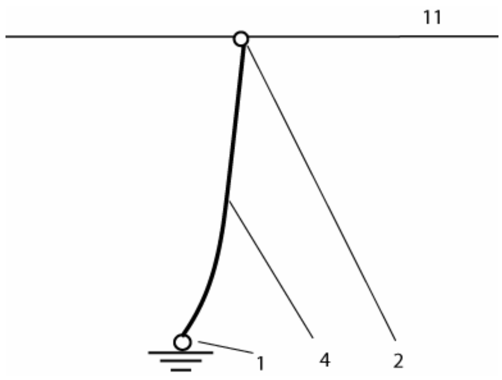


Figure 2f

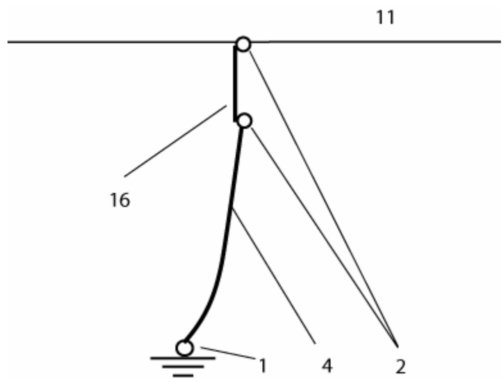


Figure 2g

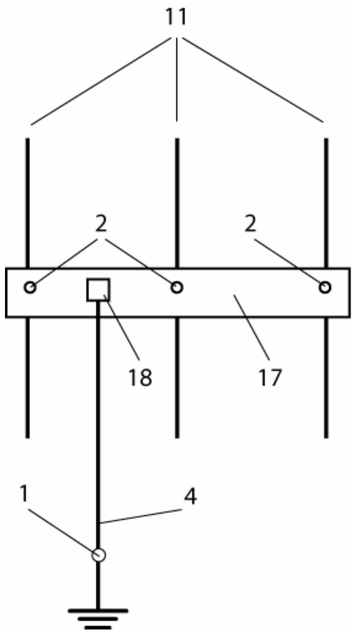
Figure 2 – Connection diagrams of single and multi-phase earthing and short-circuiting devices for network application

NOTE Figure 2 shows examples only of connection arrangements. Not all are suitable for all situations. It is the responsibility of the user to consider movement of connecting cables from magnetic forces. This has to be considered prior to a final connection.

Table 1 – Usual lengths of earthing and short-circuiting cables for different types of installations and different voltage levels

Classes of operating voltages	**Overhead line**	**Open air substation**	**Metal enclosed or indoor substation**
Low voltage [a]	Multi-phase Figures 2a, 2b, 2c, 2d key 3 = 0,5 m key 4 = 12 m to 16 m	Multi-phase Figure 2c ; key 3 = 0,5 m Figure 2a ; key 3 = 0,5 m and key 4 = 1 m to 10 m	Specific
	Single-phase Figure 2f key 4 = 0,5 m to 10 m		
Distribution [a]	Multi-phase Figures 2a, 2b, 2c, 2d key 3 = 2 m to 2,5 m key 4 = 8 m to 10 m	Multi-phase Figures 2a, 2b, 2c key 3 = 7,5m to 10 m key 4 = 2,5 m to 3 m	Multi-phase Figure 2a key 3 = 0,7 m key 4 = 2 m
	Multi-phase + 5 m extension Figure 2g key 4 = 8 m to 10 m		
	Single-phase Figure 2f key 4 = 8 m to 10 m	Single-phase Figure 2f key 4 = 10 m to 12 m	
Transmission [a]	Single-phase Figure 2f key 4 = 8 m	Single-phase Figure 2f key 4 = 10 m to 12 m	Multi-phase Figure 2a key 3 = 3 m key 4 = 3 m
		Single-phase + 2 m to 5 m extension Figure 2g key 4 = 7 m to 8 m	Single-phase Figure 2f key 4 = 3 m to 4 m

[a] The voltage limits for the different classes of operating voltage are conventional values and could be modified by national regulations or national practice.



Key

1	Earth clamp
2	Line clamp
4	Earthing cable(s)
11	Installation conductor
17	Short-circuiting bar
18	Earthing cable connection

Figure 3 – Illustration of a three-phase earthing and short-circuiting device with short-circuiting bar and earthing cable(s) for installation and network application

2 Normative references

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

IEC 60060-1:1989 *High voltage test techniques – Part 1: General definitions and test requirements* [1)]

IEC 60068-2-11:1981, *Environmental testing – Part 2: Tests – Test Ka: Salt mist*

IEC 60068-2-42:2003, *Environmental testing – Part 2-42: Tests – Test Kc: Sulphur dioxide test for contacts and connections*

IEC 60811-1-4:1985, *Common test methods for insulating and sheathing materials of electric cables – Part 1: Methods for general application – Section Four: Tests at low temperature*
Amendment 1 (1993)
Amendment 2 (2001)

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1) Under revision.

IEC 60811-2-1:1998, *Insulating and sheathing materials of electric and optical cables Common test methods – Part 2-1: Methods specific to elastomeric compounds – Ozone resistance, hot test and mineral oil immersion tests*
Amendment 1 (2001)[2)]

IEC 60811-3-1:1985, *Common test methods for insulating and sheathing materials of electric cables – Part 3: Methods specific to PVC compounds – Section One – Pressure test at high temperature – Tests for resistance to cracking*
Amendment 1 (1994)
Amendment 2 (2001)

IEC 61138:2007, *Cables for portable earthing and short-circuiting equipment*

IEC 61318:2007, *Live working – Conformity assessment applicable to tools, devices and equipment*

IEC 61477:2001, *Live working – Minimum requirements for the utilization of tools, devices and equipment*
Amendment 1 (2002)
Amendment 2 (2004)[3)]

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61318 and the following apply.

NOTE Further information on terminology is illustrated in Figures 1, 2 and 3.

3.1
conductive extension
rigid conductor forming an extension of an earthing or short-circuiting or earthing and short-circuiting device

NOTE The conductive extension can be installed between the end fitting of an earthing stick and a line clamp, or between a line clamp and connecting point.

[IEC 60743, definition 15.9, modified; IEV 651-14-11, modified]

3.2
connecting cluster
component of an earthing and short-circuiting device for connecting short-circuiting cables either directly or through connecting links, such as cable lugs, to each other and to the earthing cable(s) and/or the earth clamp

[IEC 60743, definition 15.5, modified; IEV 651-14-06, modified]

3.3
connecting point
part of installation or part of test set-up to which a clamp is connected

2) There exists a consolidated edition 2.1 (2001) that includes IEC 60811-2-1:1998 and its Amendment 1.

3) There exists a consolidated edition 1.2 (2005) that includes IEC 61447:2001 and its Amendments 1 and 2.

3.4
connection point
part of installation specially arranged for clamp connection (for example, ball pin, cylinder bolt, bow, hook, stirrup, stud)

[IEV 651-14-09 modified]

3.5
dead (in live working)
de-energized
at a potential equal to or not significantly different from that of earth at the worksite

NOTE In some countries, according to the dead procedures, the state dead is only considered after the earthing and short-circuiting equipment has been properly installed.

[IEV 651-01-15 modified]

3.6
earth clamp
clamp forming part of an earthing or earthing and short-circuiting device for connecting an earthing cable, or a connecting cluster to an earthing conductor or an earth electrode or a reference potential

[IEC 60743, definition 15.6, modified; IEV 651-14-07, modified]

3.7
earthing and short-circuiting device
assembly of components for interconnecting conductors for earthing or short-circuiting or earthing and short-circuiting installations and networks

NOTE 1 The earthing and short-circuiting device comprises clamps, cables or bars and possibly clusters.

NOTE 2 The earthing and short-circuiting device could be of single phase type or multi-phase type.

[IEC 60743, definition 15.2, modified; IEV 651-14-03, modified]

3.8
earthing cable
cable forming part of an earthing and short-circuiting device, which connects earth clamp to a line clamp of the electrical installation or earth clamp to connecting cluster

[IEC 60743, definition 15.1, modified; IEV 651-14-02, modified]

3.9
earthing stick
earth application stick
insulating component equipped with a permanent or detachable end fitting for installing clamps, short-circuiting bars or conductive extension components onto the electrical installation

NOTE The insulating element of the earthing stick is intended to provide the adequate safety distance and insulation to the worker.

[IEC 60743, definition 15.8, modified; IEV 651-14-10, modified]

3.10
energized (in live working)
at a potential significantly different from that of earth at the worksite and which presents an electrical hazard

NOTE A part is energized when it is electrically connected to a source of electric energy. It can also be energized when it is electrically charged under the influence of an electric or magnetic field.

[IEV 651-01-14]

3.11
induced current
electric current resulting from the displacement of charges carriers due to an induced tension or a magnetic field induction

[IEV 121-11-29 modified]

3.12
insulating element
element of an insulating component that provides adequate electrical insulation to the worker

NOTE For most of the insulating components used in the design of portable equipment for earthing or earthing and short-circuiting, the insulating element also provides adequate safety distance to the workers.

3.13
insulating component
hand-held insulating part of a portable equipment for earthing or earthing and short-circuiting, designed to bring and connect clamps to parts of electrical installations

NOTE An earthing stick is considered as an insulating component.

3.14
insulating means
insulating tool, equipment or device, manual or mechanical, complying with insulating properties and used for bringing and connecting clamps of earthing and short-circuiting devices to parts of electrical installations

NOTE An insulating glove, an insulating rope, an insulating handle, an insulating stick, an insulating telescopic stick, an aerial device with insulating boom, are insulating means.

3.15
insulating stick
insulating tool essentially made of an insulating tube and/or rod with end fittings

[IEV 651-02-01]

3.16
isolate
to disconnect completely a device or circuit from other devices or circuits, separating it physically, electrically and mechanically from all sources of electrical energy

NOTE Such separation may not eliminate all effects of electromagnetic or electrostatic induction.

[IEC 61328, definition 3.46, modified; IEC 61911, definition 3.39, modified]

3.17
line clamp
clamp forming part of an earthing and short-circuiting device, which is attached to a short-circuiting cable, a short-circuiting bar or conductive extension component, either directly or through connecting links, and used for the connection to line (line conductors, busbars or current-carrying conductors), or to the connection point

[IEC 60743, definition 15.7, modified; IEV 651-14-08, modified]

3.18
maintenance test
test carried out periodically on an item to verify that its performance remains within specified limits, after having made certain adjustments, if necessary

[IEV 151-16-25]

3.19
maximum peak current
$\hat{i}_{tm}$
peak value associated with the first major loop of the test short-circuit current determining the highest electro-dynamic mechanical stresses

3.20
portable equipment for earthing or earthing and short-circuiting
equipment, which is portable and is capable to be carried by one person and manually or mechanically connected with its insulating component to parts of an electrical installation for earthing or short-circuiting or earthing and short-circuiting purposes

NOTE 1 The portable equipment for earthing or earthing and short-circuiting comprises the earthing and short-circuiting device and one or more specific detachable or non-detachable insulating components.

NOTE 2 The use of insulating component is to safely connect the devices to the connecting points.

NOTE 3 The portable equipment for earthing or earthing and short-circuiting is installed temporarily on isolated power circuits for the purposes of potential equalization and to help protect the worker by conducting a short-circuit current for a specified duration (time).

NOTE 4 The aim of the earthing and short-circuiting of disconnected or isolated parts of installations is to provide a control path to the short-circuit current and secondly to prevent the voltage rise in the earth circuit.

[IEV 651-14-01 modified]

3.21
rated current and rated time
r.m.s value of current and time assigned to a device, or component, determining the highest mechanical and thermal stresses for a given peak factor

NOTE The values apply only to those parts designed to withstand short-circuit current.

[IEV 651-14-12 modified]

3.22
rated peak factor
ratio of the maximum peak current to its rated current

[IEV 101-14-57 modified]

3.23
safety distance
air clearance between the worker and a live part of the installation related to the voltage of the installation and to the working procedures, which is determined to prevent any electrical hazard to occur

3.24
short-circuiting bar
rigid conductor, such as a bar or tube, forming part of an earthing and short-circuiting device which connects together phases of the installation

[IEC 60743, definition 15.4, modified; IEV 651-14-05, modified]

3.25
short-circuiting cable
cable forming part of an earthing and short-circuiting device, which connects together clamps to a common electrical reference point such as a line clamp to another line clamp or to a connecting cluster

[IEC 60743, definition 15.3, modified; IEV 651-14-04, modified]

3.26
solidly earthed (neutral) system
system whose neutral point(s) is (are) earthed directly

[IEV 601-02-25]

3.27
supplier
organisation or person that provides a product

Example: Producer, distributor, retailer or vendor of a product, or provider of a service or information.

NOTE 1 A supplier can be internal or external to the organisation.

NOTE 2 In a contractual situation a supplier is sometimes called "contractor".

[ISO 9000, definition 3.3.6]

3.28
transit current
current which flows through the cables of the earthing and short-circuiting device when the device is completely connected to the electrical installation

NOTE 1 For HV installations or networks, the current may be a residual current (e.g. unbalanced load or induced current).

NOTE 2 For railway d.c. systems, the current flowing from the rail to the overhead contact line when the earthing cable is connected and when a train is running on an adjacent rail track.

4 Requirements

4.1 General

The equipment, devices and components shall be designed to contribute to the safety of the users provided the equipment, devices and components are used by skilled persons, in accordance with safe methods of work and the instructions for use (see 4.10).

NOTE 1 According to safe procedure, electrical installations are considered energized or live until all protective earthing and short-circuiting equipment have been properly installed.

NOTE 2 Where applicable, national or regional regulations should be followed, such as live working or dead working procedures.

Earthing and short-circuiting devices and their components shall be designed to withstand all the mechanical stresses to which they are submitted during normal use.

Devices and components shall withstand the maximum short-circuit current, time and Joule integral for which they are rated.

NOTE Devices and components should be designed in order to also accept transit current.

Earthing and short-circuiting devices, when installed according to instructions for use, shall be able to withstand all stresses from short-circuit currents for which they are designed without causing electrical, mechanical, chemical or thermal danger to persons.

NOTE 1 For indoor use and enclosed space, poisonous effects should be considered (see C.2.2).

NOTE 2 Highest possible temperature rise of cables is therefore adopted to reduce weight.

The manufacturer or the end assembler of all component parts of the equipment shall be responsible to ensure that the equipment meets all the requirements of this standard.

4.2 Electrical rating

Earthing and short-circuiting devices and their components shall be rated in terms of a short-circuit current (I_r), a time (t_r) and the corresponding peak factor.

For d.c. applications, the values shall be the same.

Most common values for the rated time are the following:

3 s, 2 s, 1 s, 0,75 s, 0,5 s, 0,25 s, 0,1 s

The rating of the complete device shall be expressed as rated current in kiloamperes, as rated time in seconds and rated peak factor (see 4.9).

NOTE In order to compare different rated values see Annex C.

Separate components of the equipment shall be provided with their rated values and their corresponding test configurations (see 4.10).

Compliance shall be verified by visual verification according to 5.2.

4.3 Cables for earthing and short-circuiting

Earthing and short-circuiting cables, whether they are made of aluminium or aluminium alloy or made of copper, shall be designed to meet the performance requirement of their rating.

NOTE For selection of the cable cross-section according to temperature rise during a short-circuit, curves or tables and guidance are given in Annex C.

Cables shall have adequate mechanical, chemical, environmental and electrical properties to meet all the requirements of this standard.

NOTE 1 It may be acceptable that the insulating covering of the cable may melt or burn according to the maximum accepted temperature rise during the flow of the short-circuit current and according to the applicable safety rules.

NOTE 2 Guidance for selection of cables taking into account transit current is given in Annex C.

4.3.1 Selection of cables

Cables for earthing and short-circuiting purposes (see Figures 1, 2, and 3) shall be flexible.

Cables shall be insulated for mechanical protection.

NOTE The customer may request additional resistance to mechanical shock onto a metallic structure. The cable with PVC insulation should meet the additional requirement and clashing test of 5.4 of IEC 61138.

The selection of the nature of the insulating material shall be made to fulfil chemical, environmental and temperature conditions met in practice.

For earthing and short-circuiting cables of a circular cross-section, electrical, mechanical and other requirements can be met by selecting cables according to IEC 61138.

Cables not complying with IEC 61138 can be used but shall fulfil the following tests:

– the flexibility shall be in accordance with 5.3 of IEC 61138, and with 8.2 of IEC 60811-1-4 for low temperature bending test,
– the physical integrity of the cover shall be in accordance with 5.1.3 of IEC 61138,
– the type of insulating material shall be in accordance with Clause 7 of IEC 61138,
– the resistance to mechanical shock shall be in accordance with 4.3.5 of IEC 61138.

Compliance for selection shall be verified by visual verification of the conformity to IEC 61138 or shall be verified by tests according to 5.3.2.

4.3.2 Earthing cables used on solidly earthed (neutral) systems

Earthing cables used on solidly earthed systems shall have the same cross-section as the associated short-circuiting cables or bars.

4.3.3 Earthing cables used on non-solidly earthed (neutral) systems

Earthing cables used on non-solidly earthed systems may have a cross-section less than the corresponding short-circuiting cables or bars, but never less than that given in Table 2. For values in between those listed in the first column, the value of the second column shall be the next higher size.

Table 2 – Minimum cross-section of earthing cables related to the cross-section of the short-circuiting cables and/or bars on non-solidly earthed (neutral) systems

Copper equivalent cross-section of short-circuiting cables and/or bars mm^2	**Minimum copper equivalent cross-section of earthing cables** mm^2
16	16
25	16
35	16
50	25
70	35
95	35
120	50
150	50

4.4 Short-circuiting bars

Short-circuiting bars, whether they are made of aluminium or aluminium alloy or made of copper, shall be designed to meet the performance requirement of their rating.

They shall be designed to be compatible with the installation on which they may be positioned. For this purpose, dimensions of short-circuiting bars are not standardised.

Compliance shall be verified by manual checking according to 5.2 and by test according to 5.7.

4.5 Connections of cables to rigid parts within devices

Excellent fatigue resistance is required for the connections of cables to rigid parts (ferrules, cable lugs, end fittings, clusters, etc.).

The connections shall be made with great care to ensure that the specified minimum characteristics of the cables are maintained. Soldered connections are not permitted.

The connection between end fittings and cables shall be protected from water penetration.

All attachments shall be protected against unintentional loosening. Single screws or nuts, if used, shall always be combined with a device, for instance lock washers, that positively prevents slippage or rotation.

Ferrules, cable lugs, end fittings, etc., shall have at least a current-carrying capacity equivalent to the associated cables.

Compliance shall be verified by visual verification according to 5.2 and by tests according to 5.4, 5.5 and 5.7.

4.6 Clamps

Clamps shall be designed to withstand the stresses for which they are rated. They shall provide reliable contact performance and shall withstand the thermal and mechanical stresses produced by the rated short-circuit currents.

Line and earth clamps shall be suitable for the surface and shape of the connecting point and shall permit easy and safe installation without causing damage to clamps and without danger for personnel.

For tightening type, the manufacturer or the end assembler shall provide a rated torque which shall be properly defined for the installation.

For other types such as spring clamps they shall not require an unusual force during the positioning and the removing operations.

NOTE More than one spring clamp may be put on the top end of an earthing stick for a quick and multiple operation. For this reason it is allowed to have specific or additional positioning device for holding many clamps.

Each different design of clamp of the same rating shall be type tested in the same conditions in order to be considered equivalent.

Compliance shall be verified by manual checking according to 5.2 and by tests according to 5.6 and 5.7.

4.7 Earthing and short-circuiting device

The different components of an earthing and short-circuiting device may come from the same manufacturer or from different manufacturers. The final assembly shall be made under the responsibility of the manufacturer or the end assembler of the device. Manufacturer or supplier of separate components shall give sufficient information in order to maintain the capability of the complete device. The final quality of the device after assembly relies only on its end assembler.

A earthing and short-circuiting device can use cables in parallel as short-circuiting or earthing cables.

For a multi-phase earthing and short-circuiting device, all cables exposed to a rated short-circuit current shall have the same cross-section, but the earthing cable(s) may have a smaller cross-section in case of use on non-solidly earthed system (see Table 2).

Compliance shall be verified by verification and checking according to 5.2 and by test according to 5.7.

4.8 Basic safety requirements for the insulating element(s) of the insulating component

The insulating elements(s) of the insulating component (earthing stick or other type) shall make use of insulating material(s) and shall be designed such as to provide basic electrical insulating properties to permit the workers to establish the appropriate electrical insulation when installing and removing the portable equipment for earthing or earthing and short-circuiting.

The manufacturer shall identify the design parameters associated with the basic insulating properties of the insulating element.

NOTE 1 Many parameters of a design of insulating element influence its overall insulating performance. Some parameters are under the control of the manufacturer. Others (ex: the length of insulating tube or rod) may be influenced by working procedures, regional or national regulations. The basic insulating properties are here associated with the design parameters controlled by the manufacturer.

NOTE 2 For example, when cylindrical tubes or rods are used as raw material for the design of the insulating element of an earthing stick, a design parameter associated with the basic electrical properties is the appropriate selection of tubes or rods according to IEC 60855 or IEC 61235.

Annex B provides guidance for selection of the insulating element of the earthing stick as a type of insulating component of complete equipment.

Compliance to the basic safety requirements shall be verified by verification according to 5.2.

4.9 Marking

4.9.1 General

The marking shall be clearly legible. It shall be durable and not removable.

Each device, cable and clamp shall be marked properly.

When a device is made of several components of different rating, the marking of the rated values of the device shall be the minimum of the rated capacity of each component and under the responsibility of the final assembler.

NOTE Additional recommendations are given in Annexes B and C.

Compliance shall be verified by visual verification according to 5.2 and by test according to 5.8.

4.9.2 Marking on earthing and short-circuiting device

The device itself or an additional non-removable label shall be marked where appropriate with at least the following items of marking:

– manufacturer's name or trade mark or end assembler's name;
– model or type reference for the device;
– year of manufacture;

– rated current I_r (kA), rated time t_r (s) of the device and value of the rated peak factor (for example 10 kA – 0,5 s – 2,6);

– number of the relevant IEC standard.

4.9.3 Marking on clamp

Clamp itself or an additional non-removable label shall be marked with at least the following items of marking:

– manufacturer's name or trademark;

– model or type reference for the clamp.

4.9.4 Marking on cable

For cables covered by IEC 61138, no other marking is required.

NOTE The reference number of the cable standard is given by the code designation.

For cables not covered by IEC 61138, the cable shall be marked with the following items:

– indication of the origin of the cable (see 4.4.1 of IEC 61138);

– cross-section or cable size;

– nature of the insulating covering (see Clause 7 of IEC 61138).

4.9.5 Marking on other components

Other components such as short-circuiting bars or conductive extension of the earthing and short-circuiting devices may be delivered separately. In that case they shall be marked similar to the clamps.

4.10 Instructions for use

Each device or equipment covered by this standard shall be supplied with manufacturer's written information and instructions for use and care. These instructions shall be prepared in accordance with the general provisions given in IEC 61477.

They shall include at least the following:

– instructions for assembling the complete device or equipment;

– limitation, if any, of the main characteristics such as rated values, temperature conditions, indoor use, etc.;

– rated values (current, time and peak factor) of the separate components;

– guidelines for maintenance, use, storage and inspection;

  NOTE Users should also refer to Annex C for additional information.

– torque and force values and instructions for securing of auxiliary fasteners, which may loosen during use;

– information about the use of aluminium for cables, clamps and other parts of the devices, if relevant;

– statement that "the devices shall be removed from service after exposure to short-circuit current" (see C.4);

– number of the relevant IEC standard and the year of publication with amendment, if any.

NOTE Additional instructions for use may be requested by the customer.

Compliance shall be checked by visual verification according to 5.2.

5 Tests

5.1 General

The present standard provides testing provisions to demonstrate compliance of the product to the requirements of Clause 4. These testing provisions are primarily intended to be used as type test for validation of the design input. Where relevant, alternative means (calculation, examination, tests, etc.) are specified within the test subclauses for the purpose of portable equipment for earthing or earthing and short-circuiting having completed the production phase.

The list of type tests to be performed with references to corresponding subclauses is specified in Table E.1 of Annex E.

Tests shall be carried out at the responsibility of the manufacturer or end supplier.

Tests shall be carried out at temperatures between –10 °C and +40 °C and regardless of humidity, unless otherwise specified.

NOTE 1 This broad range of climatic conditions is specified because outdoor testing may often be preferable or necessary.

NOTE 2 A maximum temperature of + 45 °C should be accepted in case of outdoors tests in countries where usual temperatures are very high.

Electrical tests shall be carried out using a single-phase a.c. voltage source in accordance with IEC 60060-1. The test circuit shall be complemented by adequate transformers and impedances to generate the test short-circuit current in order to fulfil the requirements of 5.7.

NOTE 1 It is recommended to consider IEC 62475 Ed.1 for high current test techniques (under development).

NOTE 2 For d.c. current tests there is no prescribed reference for the d.c. source. It is common practice to use the same rms a.c. value and set up.

Components evaluated by destructive tests shall not be re-used.

Visual verification shall be made either on complete equipment or device or separate components.

The manufacturer or the final assembler shall provide the test pieces. Test pieces intended to be used for destructive tests shall be prepared from complete equipment or device.

Unless otherwise specified, the type tests shall be carried out on three separate test pieces or complete devices.

The tests shall be considered as passed when all test pieces or the complete devices pass the tests.

NOTE For products having completed the production phase, the tests associated with critical, major and minor defects are specified in Annex F (also see Clause 6)

Acceptance tests are covered by IEC 61318.

5.2 Verification and checking

When visual verification is specified, it shall be understood to be visual verification by a person with normal or corrected vision without additional magnification.

Visual and dimensional verification, manual checking and other verification shall be made to check if the relevant requirements of Clause 4 are fulfilled.

The verification and checking shall be considered as passed if all the relevant requirements of Clause 4 are fulfilled.

5.3 Tests for the selection of cables

5.3.1 Cables complying with IEC 61138

In order to verify that cables comply with IEC 61138, visual verification shall be made on the marking of the cable.

5.3.2 Cables not complying with IEC 61138

5.3.2.1 Type tests

Cables not complying with IEC 61138 shall fulfil the following tests:

- for flexibility, 5.3 of IEC 61138, and with 8.2 of IEC 60811-1-4 for low temperature bending test,
- for the type of insulating material, Clause 7 of IEC 61138,
- for the resistance to mechanical shock:
  - for EPR, Clause 9 of IEC 60811-2-1,
  - for PVC, 9.2 of IEC 60811-3-1,
  - for PVC ST11, 9.2 of IEC 60811-3-1 and Table 7 of IEC 61138,
  - for SiR, Clause 9 of IEC 60811-2-1 and Table 8 of IEC 61138,
- for clashing, if required, 5.4 and Annex A of IEC 61138.

5.3.2.2 Alternative test for conformity assessment during production phase

The physical integrity of the cover shall be checked according 5.1.3 of IEC 61138.

5.4 Fatigue and humidity penetration tests on cable with end fittings

5.4.1 Fatigue test

Each type of cable with its end fittings shall be subjected to a combined bending and twisting test on three test pieces.

The test arrangement is shown in Figure 4. The metal bar or screw which forces the rotation shall be made either of steel, brass or aluminium alloy. The shape of the screw shall be made with care in order to obtain a uniform movement.

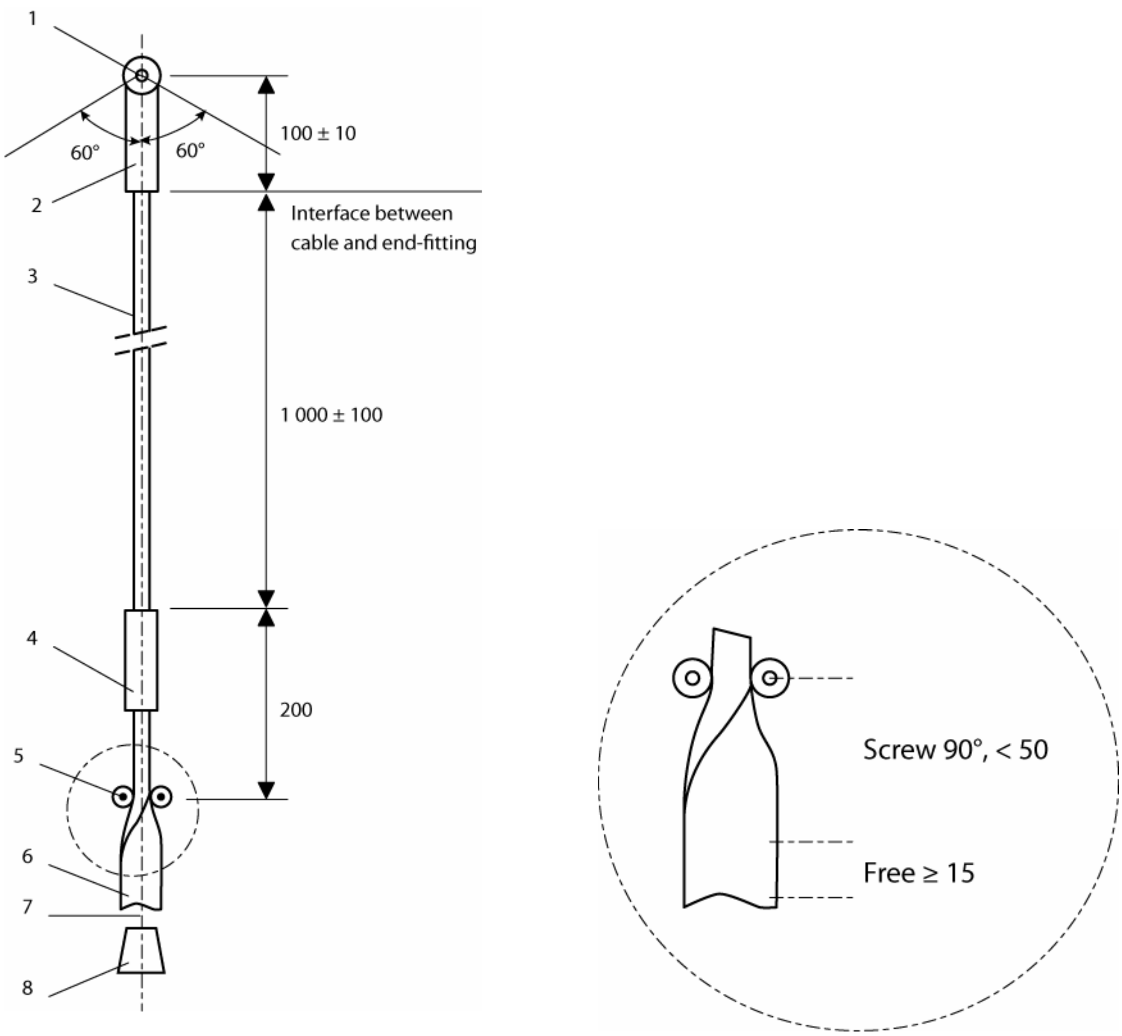
A test piece consists of a cable and end fittings. The free length of the cable shall be 1 000 mm ± 100 mm. The end fitting of the upper end of the cable shall be mounted vertically in a test apparatus so that it can be oscillated around a horizontal axis, at 60° in both directions from the vertical. The interface between the cable and the end fitting shall be 100 mm ± 10 mm from the axis (see Figure 4).

The lower end of the cable shall be attached to a vertical, guided screw and loaded with an appropriate mass in order to obtain a resulting force greater than or equal to 0,5 N per mm^2 of copper cable conductor cross section and 0,15 N per mm^2 of aluminium cable conductor cross section.

During one half-cycle of the test, the cable shall be twisted 90° in its unwinding direction, and back again. The duration of one cycle shall be at least 5 s. The test shall be terminated after 1 000 cycles. The starting position shall be vertical.

The humidity penetration test shall then be performed according to 5.4.2.

Dimensions in millimetres



Key

1	Axis of oscillation
2	End-fitting
3	Cable
4	End-fitting or tight connection between cable and item 6
5	Guide rolls, free distance 6 mm ± 1 mm
6	Metal bar, 40 mm × 5 mm
7	Wire
8	Weight to obtain a resulting force = 0,5 N per mm^2 of copper cable conductor cross section or 0,15 N per mm^2 of aluminium cable conductor cross section

Figure 4 – Apparatus for fatigue testing with bending and twisting

The sanction of the fatigue test shall be made after the humidity penetration test.

For verification of the conductor after test, the cable insulation of the upper end shall be removed and the conductor unwound into single strands, since damage to the conductor may start in the inner parts.

The fatigue test shall be considered as passed if:

– no cracks or wrinkles are observed on the cable insulation;
– no more than 1 % of the conductor strands are broken.

5.4.2 Humidity penetration test

The test shall be carried out after the fatigue test specified in 5.4.1 and using the same test pieces.

5.4.2.1 Test procedure

The test piece shall be completely immersed in a solution, which is specified in 5.4.2.2 for copper cables and in 5.4.2.3 for aluminium cables.

For copper cables the test piece shall be completely immersed for at least 45 min and be maintained for at least 15 min in each of three different positions similar to the two extreme positions and the middle position of the fatigue test.

For aluminium cables the test piece shall be completely immersed for at least 240 min and be maintained for at least 80 min in each three different positions similar to the two extreme positions and the middle position of the fatigue test.

At the end of the humidity penetration test, the cable insulation of the upper end shall be removed for inspection.

The humidity penetration test shall be considered as passed if the copper conductor has not turned black or if the aluminium conductor has not turned brown.

5.4.2.2 Sodium sulphide solution for copper cable

The humidity penetration test for copper cables shall be carried out with a sodium sulphide solution, prepared as follows:

600 g of sodium sulphide ($Na\ S \cdot 9\ H_2O$) shall be dissolved in 3 l of water and stirred together with an excess quantity (at least 750 g) of flowers of sulphur for at least 6 h at a liquid temperature of 40 °C. Allow the un-dissolved sulphur to settle for at least a further 6 h and filter the solution. Adjust the density to 1,142 g/cm³ by adding distilled water or saturated sodium.

Before use, the quality of the sodium sulphide solution shall be verified. A piece of bare copper wire shall turn black in 5 s or less, when immersed in the solution.

5.4.2.3 Permanganate potassium solution for aluminium cable

The humidity penetration test for aluminium cables shall be carried out with a permanganate solution, prepared as follows:

3 g of permanganate shall be dissolved in 3 l of water and stirred together.

Before use, the quality of the permanganate solution shall be verified. A piece of bare aluminium shall turn brown in 4 h or less, when immersed in the solution.

5.5 Tension test on cable with end fittings

Each combination of cable to end fittings shall be tested using three test pieces.

Each test piece, with a free length of cable of 50 cm ± 5 cm and with its end fittings shall be subjected to a tension force increasing linearly during at least 10 s up to the corresponding value given in Table 3 (for example with a copper cable of 75 mm^2 rated conductor cross-section, the tension force N is: 80 × 75 = 6 000 N). The specified tension force shall be held for 30 s and then removed. The tension shall be applied along the cable axis.

The test shall be considered as passed if no connection has loosened.

Table 3 – Tension test force on cable with end fittings

Cross-section area of conductor **A**[a] mm^2	**Tension force Copper** N	**Tension force Aluminium** N
≤ 50	100 × A	60 × A
> 50	80 × A	50 × A

[a] "A" = the rated cross-section area of the conductor

5.6 Test on clamps, permanent connection points and connections

Clamps shall be tested by connecting them to fixed connection points or to conductors with dimensions, shapes and surfaces for which they are designed, using the connecting method recommended by the manufacturer.

The testing of clamps designed for a range of conductor sizes or for connection points shall consist of two tests with the largest and two tests with the smallest conductor or connection point.

5.6.1 Tests for tightening types

A torque shall be applied to the screw of the clamp progressively, up to a value of 1,25 times the rated tightening force T_r given by the manufacturer and then maintained at this value for a period not less than 1 min.

NOTE The rated value should be defined taking into account the most severe application.

The test shall be considered as passed if no damage such as cracks or deformation is seen on the clamp during visual verification after test.

5.6.2 Tests for non-tightening types

For non-tightening type of clamps, there is no test required. There is no way to overstress the clamp during installation.

5.7 Short-circuit current test

5.7.1 General

The electromagnetic forces on the device during a short-circuit depend on the configuration of the installation, the location of connecting points and, for cable devices, the cable length in relation to the distance between the connecting points. The short-circuit current test shall simulate the worst stresses that a device may be exposed to in practice.

The short-circuiting part of single phase or multi-phase earthing and short-circuiting devices shall be tested on test set-ups simulating phase to phase or phase to earth.

For devices used on non-solidly earthed (neutral) systems, the value of short-circuit current, corresponding to the earth fault, shall be applied to the earthing cable accordingly.

NOTE If required by the customer, the test may be made on a three-phase set-up corresponding to the installation to be earthed or in the real configuration of the installation. Three-phase sources may be used after agreement between manufacturer and customer with the frequency corresponding to the installation.

In case of equipment, the insulating component(s) that are detachable are not submitted to test while non-detachable insulating component(s) shall be submitted to test.

Depending on the design of the clamps, tests shall be performed in different ways:

a) When the device is designed for only one size of conductor or only one shape and dimension of connection point, the test shall be performed three times for this conductor or for this connection point, each time with a different test piece.

b) When the device is designed for a range of conductor sizes that a clamp may be attached to, four tests shall be performed each time with a different test piece. Two tests shall be performed with the maximum conductor size at the rated current of the device. Two tests shall be performed with the minimum conductor size at the rated current of the conductor of minimum size.

c) When the device is designed to be used for different shapes of connection points, the test shall be performed twice for each shape for which the clamp is designed, each time with a different test piece.

d) In case of clamps accommodating different shapes and different sizes of connection points, each shape and each size shall be tested twice on the maximum current and twice on the minimum current, each time with a different test piece. Examples of combinations are given in Figure 5.

All tests in standard test set-ups shall be performed with a.c. single-phase or single path current at a frequency selected between 45 Hz and 65 Hz for network and installation application.

NOTE A.C. short-circuit application is more severe than d.c. short-circuit. Consequently, a device or equipment tested in a.c. could be used in d.c. with the same value of rated current. After agreement between customer and manufacturer, the customer could require a d.c. test made according to his own specification.

All varieties of current paths between connecting points that may be exposed to short-circuit current shall be subjected to test at least twice. The total number of tests depends on the type of devices as explained above. Devices which are specified for use in solidly earthed systems shall thus be tested line to earth as well as line to line.

For multi-phase devices using cables connected in parallel, when a separate clamp is used for each cable, tests shall be performed with the clamps connected as close together as possible.

For separate components, they shall be assembled in a device test piece and submitted to short-circuit current test. The manufacturer shall provide documentation on the test set-ups used to qualify the separate components.

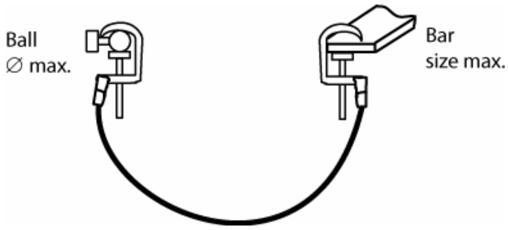


Figure 5a – Combination of ball and bar of maximum size

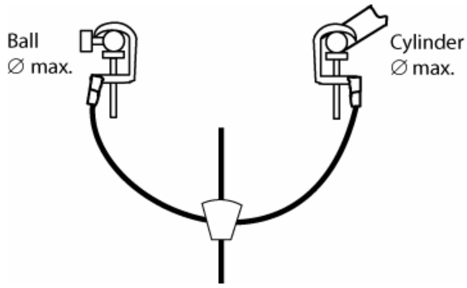


Figure 5b – Combination of ball and cylinder of maximum size

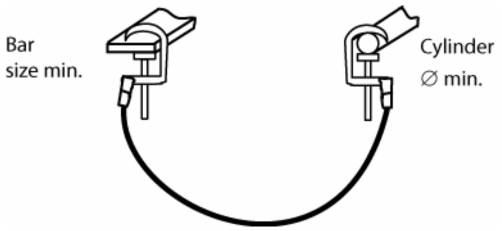


Figure 5c – Combination of bar and cylinder of minimum size

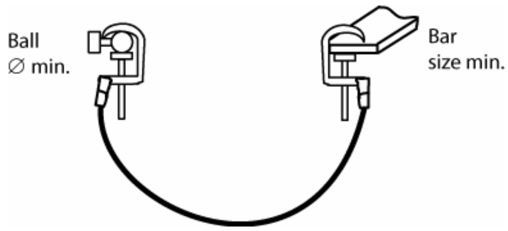


Figure 5d – Combination of ball and bar of minimum size

NOTE In Figures 5a, 5c and 5d, cables may be short-circuiting cables or earthing cables.

Figure 5 – Examples of multiple combinations of clamps accommodating different shapes and sizes of connection points

5.7.2 Preparation of test pieces

If the branches of multi-phase devices are not identical, the test shall be carried out with those having the greatest number of contacts in the current path, clamp to clamp. Other branches affecting the test, for instance using the same earth fixed connection point, shall also be included. A new test piece or a different test piece shall be used for each test. For example for three tests we need three test pieces.

5.7.2.1 Dimensions

Dimensions of test pieces are specified in Figures 6, 7 and 8. Dimensions could be according to Table 1 for specific use. Lengths of interconnecting cables and conductive extension, if any, exclude clamps and connecting clusters, unless specifically indicated. These lengths are considered as minimum.

5.7.2.2 Blind ends

Branches of the device carrying no current during the test shall be included in the test piece in the shape of blind ends of 300 mm long. If the length of the branch is less than 300 mm, for example for low voltage installations, the length of the blind end shall be the length given by the manufacturer. In all cases the length of the blind end is left free during the short circuit test but shall be insulated in order to prevent unintentional short-circuit.

5.7.2.3 Preconditioning of clamps and associated nuts and bolts

Clamps and associated nuts and bolts shall be preconditioned before the test. During the preconditioning, internal contacts of nuts and bolts shall be protected, for example with an assembly (cable end-fitting and clamps) similar to the final mounting.

Pre-conditioning shall be done by cleaning the contact surfaces with isopropanol (CH_3-$CH(OH)$-CH_3) and then drying them in air for 15 min. The clamp shall be then pre-conditioned for ageing purposes in a climatic chamber for 48 h in accordance with IEC 60068-2-11. The test pieces shall be positioned in the same position of the corresponding short-circuit current test.

NOTE It is the duty of an employer to ensure that the relevant legislation and safety requirements for the use of this chemical are complied with in their entirety.

After pre-conditioning, the test pieces shall be washed in running tap water for no more than 5 min, then shaken by hand or subjected to air blast to remove droplets of water. The parts of the clamp that will be in contact with parts of the test set-up (conductors and fixed connection points) shall be cleaned with a dry cloth in order to remove the remaining salt deposit.

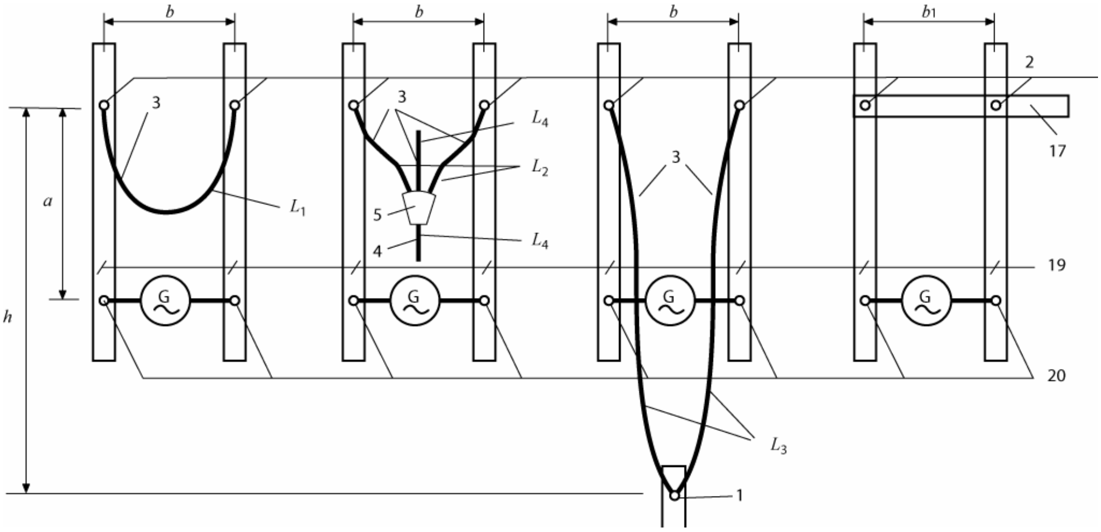


Figure 6a – For testing short-circuiting devices with cables according to Figures 2b and 2e

Figure 6b – For testing short-circuiting devices with cables according to Figure 2a

Figure 6c – For testing short-circuiting devices with cables according to Figures 2c and 2d

Figure 6d – For testing short-circuiting devices with bars according to Figure 3

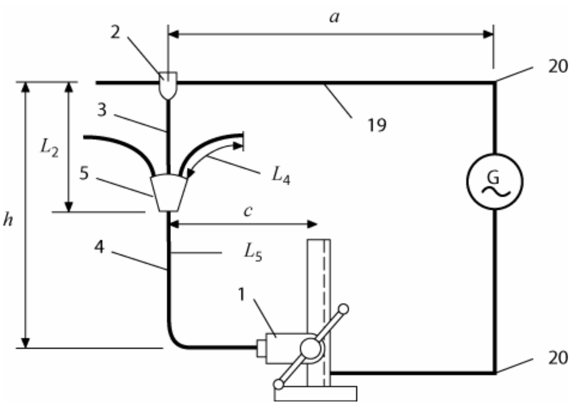


Figure 6e – For testing earthing cables according to Figure 2a

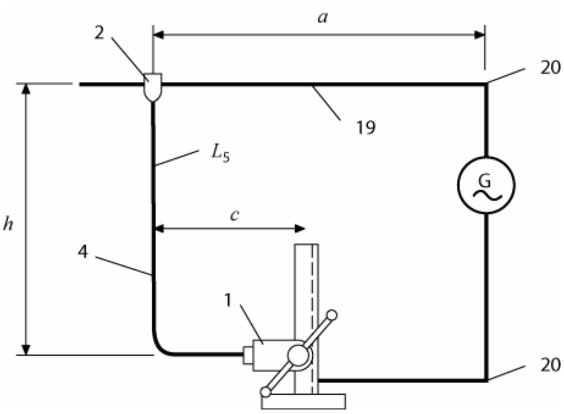


Figure 6f – For testing earthing cables according to Figure 3

Key

1	Earth clamp (electrically isolated in the test set-up)	*b*	Distance between line clamps, 500 mm (*)
2	Line clamp	b_1	Distance decided from case to case
3	Short-circuiting cable(s)	*c*	Horizontal distance between vertical cable(s) and earth clamp connection point, 1 000 mm (*)
4	Earthing cable(s)	*h*	Vertical distance between line and earth clamp connection points, 2 000 mm(*)
5	Connecting cluster	L_1	Cable length between clamps, 1 000 mm (*)
17	Short-circuiting bar	L_2	Cable length between line clamp and connecting cluster, 750 mm (*)
19	Test set-up rigid conductor of the type(s) for which the clamp to be tested is designed	L_3	Cable length between line clamp and earth clamp, 2 500 mm (*)
20	Test current feed-in point	L_4	Length of blind ends, 300 mm (*)
a	Distance between current feed-in point and line clamp or between current feed-in point and earthing cable(s) connection, minimum 2 000 mm (*)	L_5	Cable length between connecting cluster and earth clamp, 2 500 mm (*)
		(*)	Given lengths are standards lengths, the required length should be modified according to the real work site dimensions

Figure 6 – Test set-ups for testing multi-phase devices connected between rigid conductors for substations

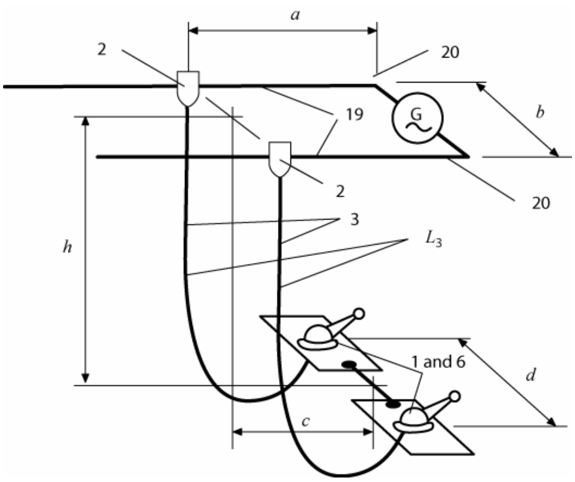


Figure 7a – For testing devices according to Figures 2c and 2d

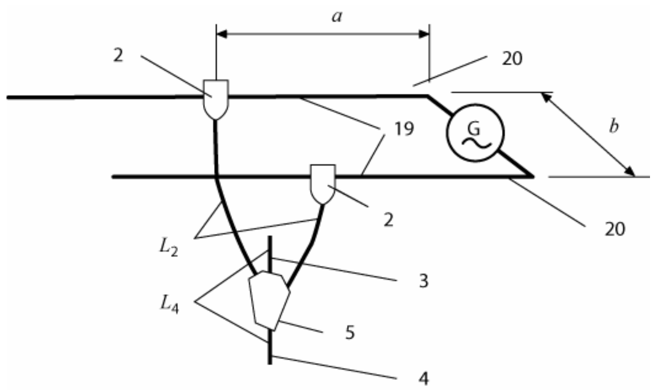


Figure 7b – For testing devices according to Figure 2a

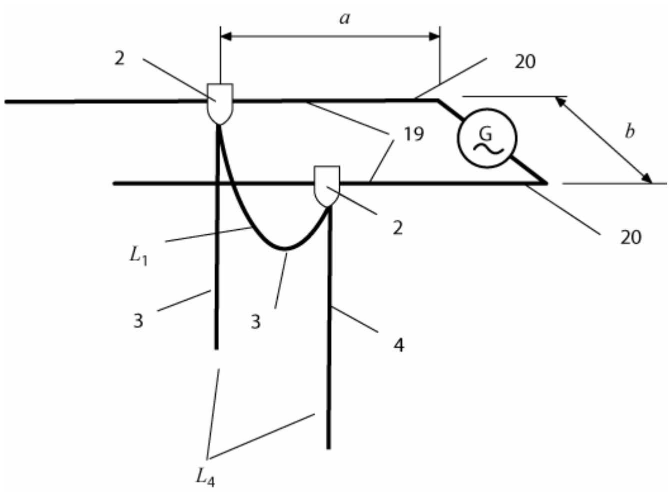


Figure 7c – For testing devices according to Figures 2b and 2e

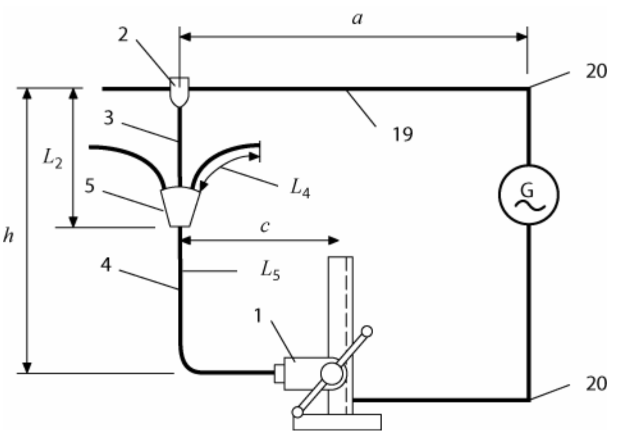


Figure 7d – For testing earthing cable according to Figure 2a

Key

1 Earth clamp (electrically isolated in the test set-up)
2 Line clamp
3 Short-circuiting cable(s)
4 Earthing cable(s)
5 Connecting cluster
6 Earth fixed connection point (electrically isolated in the test set-up)
19 Test set-up conductor of the type(s) for which the clamp to be tested is designed
20 Test current feed-in point
a Distance between current feed-in point and line clamp, minimum 2 000 mm (*) or less for LV installation
b Horizontal distance between test set-up conductors 1 000 mm (*)
c Horizontal distance between vertical cable(s) and earth clamp connection point, 1 000 mm (*)
d Minimum distance specified in the manufacturer's instruction. If no value is given, the test shall be performed with $d = 0$
h Vertical distance between line and earth connecting point, 4 000 mm (*)
L_1 Cable length between clamps, 2 000 mm (*)
L_2 Cable length between line clamp and connecting cluster, 1 500 mm (*)
L_3 Cable length between line clamp and earth clamp, 5 000 mm (*)
L_4 Length of blind ends, 300 mm (*)
L_5 Cable length between connecting cluster and earth clamp, 3 500 mm (*)
(*) Given length are standards lengths, the required length should be modified according to the real work site dimensions

Figure 7 – Test set-ups for testing multi-phase short-circuiting devices for overhead lines

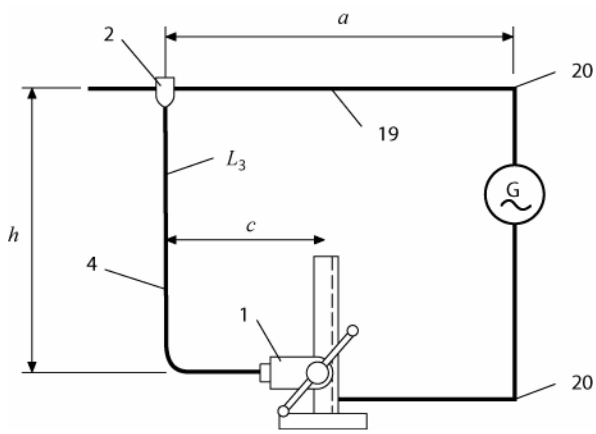


Figure 8a – For testing single-phase devices for overhead lines and for open air substations according to Figure 2f

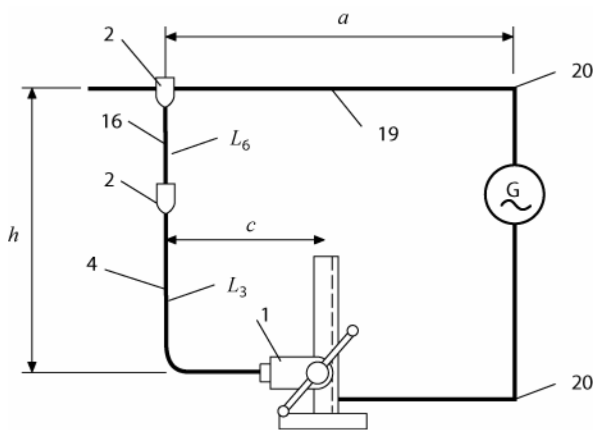


Figure 8b – For testing single-phase devices with conductive extension for overhead lines and for open air substations according to Figure 2g

Key

1	Earth clamp (electrically isolated in the test set-up)
2	Line clamp
3	Short-circuiting cable(s)
4	Earthing cable(s)
5	Connecting cluster
16	Conductive extension
19	Test set-up conductor rigid or not of the type(s) for which the clamp to be tested is designed
20	Test current feed-in point
a	Distance between current feed-in point and line clamp, minimum 2 000 mm
c	Horizontal distance between vertical cable(s) and earth clamp connection point, 1 000 mm
h	Vertical distance between line conductor and earth connection point, 4 000 mm or 8 000 mm
L_3	Cable length between line clamp and earth clamp, 5 000 mm
L_6	Length of conductive extension, 5 000 mm
(*)	Given lengths are standards lengths, the required length should be modified according to the real work site dimensions

Figure 8 – Test set-ups for testing single-phase devices for overhead lines and for open air substations

5.7.3 Test set-ups and test arrangements

A number of test set-ups are specified in Figures 6, 7 and 8. They shall be provided with suitable connection points or conductors with dimensions, shapes and surfaces for which the clamps of the device to be tested are designed.

Devices which do not fit into the standardized test set-up shall be tested in a special test set-up, built according to the principles of the standardized test set-ups or corresponding as closely as possible to the conditions of the installations for which they are designed.

Test set-ups for testing multi-phase earthing and short-circuiting devices for connection between rigid conductors and for substation applications are specified in Figure 6. A vertical arrangement with feed-in at the bottom is always used as representative of the worst conditions, as described in Figures 6, 7 and 8.

NOTE Three-phase test set-ups are not specified in this standard and are left open to an agreement between customer and manufacturer.

The test set-ups for testing multi-phase earthing and short-circuiting devices for overhead line application are specified in Figure 7.

Test set-ups for testing single-phase earthing and short-circuiting devices for open air substation and overhead line applications are specified in Figure 8. These test set-ups shall be used for testing earthing cables of multi-phase devices.

The tests shall be representative of the conditions under which the device is normally used. When line clamps are connected directly to the line conductor, aged conductor material shall be used. New copper, aluminium or aluminium-alloy conductors shall be aged artificially for ten days in accordance with IEC 60068-2-42.

Rubbing and polishing of the conductor or the connecting points is not permitted but cleaning the dust or salt deposit is necessary before test.

All clamp-to-clamp branches shall be tested and connected to the appropriate test set-up with arrangements according to Figures 6, 7, and 8.

For the test, clamps shall be tightened or positioned according to the manufacturer's or final assembler's instructions.

5.7.4 Test current, Joule integral and duration

5.7.4.1 A.C. component of the test current I_t

The a.c. component of the test current I_t shall be equal to 1,15 times the rated current I_r (I_t = 1,15 × I_r).

5.7.4.2 Test first loop peak current $\hat{\imath}_{tm}$

The test first loop peak current $\hat{\imath}_{tm}$ shall be not less than the a.c. component of the test current multiplied by the peak current factor n ($\hat{\imath}_{tm} \geq n \times I_t$).

For high voltage installations (> 1 000 V a.c.) a peak current factor of 2,5 shall be used for 50 Hz equipment and a peak current factor of 2,6 shall be used for 60 Hz equipment. For low voltage installations (≤ 1 000 V a.c.), a peak factor of 2 shall be used.

NOTE The peak current factor value of 2,5 for 50 Hz or 2,6 for 60 Hz was chosen as a common value for high voltage installations but could be higher according the characteristics of the installation (see C.5).

5.7.4.3 Test time t_t

The a.c. test current I_t shall be applied for a time t_t equal to or less then 1,15 times the rated time t_r.

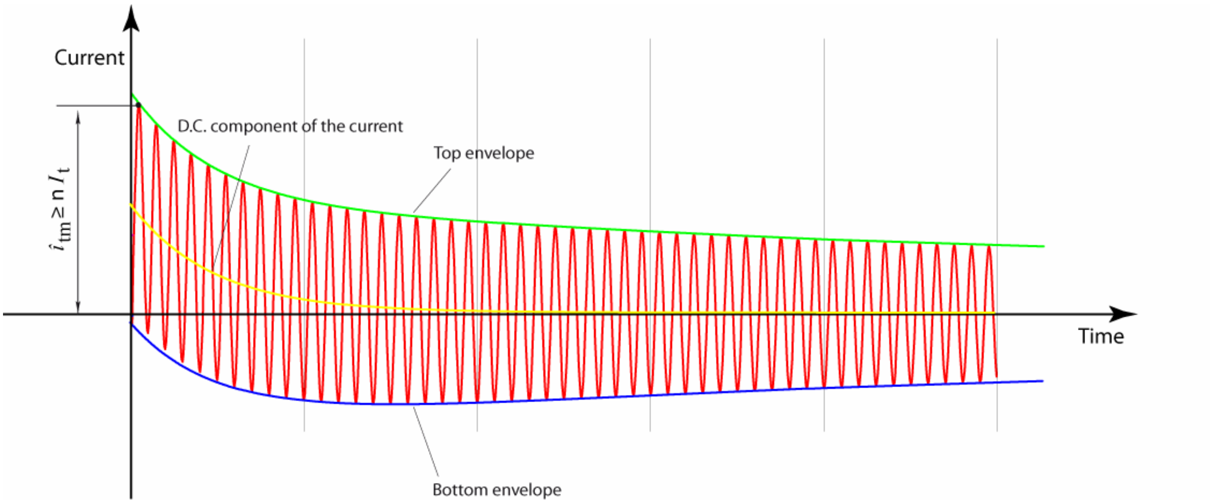
5.7.4.4 Joule integral

If the peak factor cannot be met with the available test installations, it is permitted to increase the a.c. component of the test current to a value $I_t^{'}$ in order to reach the first loop peak current specified in 5.7.4.2 ($\hat{\imath}_{tm} \geq n \times I_t$). In this case, the test duration t_t may be reduced in order to fulfill the Joule integral requirement defined hereafter.

The Joule integral $I_t^{'2} \times t_t$ shall be equal to or higher than $I_t^{2} \times t_r$.

The shape of the short-circuit current is illustrated in Figure 9.

If no other method to determine the value $I_t^2 \times t_t$ is available, then it shall be determined from the oscillogram using the method of evaluating I_t given in Annex D.



Key

$\hat{\imath}_{tm}$ Test first loop peak current

I_t A.C. component of the test current

Figure 9 – Shape of the short-circuit current during test

5.7.4.5 Tolerances

During the test, the applicable tolerances shall not exceed the following values without the consent of the manufacturer:

– + 5 % for the peak current;

– + 10 % for the Joule integral.

5.7.5 Documentation and evaluation of the test

During short-circuit current test, the voltage and the current curves shall be recorded. The recording shall be used to determine the peak current, Joule integral, test time and current at the end of the test time.

Moving, sliding or pivoting of the clamps on the connection points is allowed as long as the test current is not interrupted. Sparking is allowed as long as it is possible to remove the clamp after the test only with the aid of the dedicated insulating component (earthing stick or other) or the required insulating means.

A test report shall be drawn up which, beside the test results, shall give at least:

– a clear designation of the device or component tested;

– a description of the test arrangement, if necessary accompanied by photographs and/or drawings;

– a recording with time trace and scales for test voltage and test current.

The test shall be considered as passed if the recording indicates that:

– there is no current interruption during the test time;

– the values of peak current, Joule integral, test time and rms current measured are all in accordance with those prescribed in 5.7.4.

NOTE The test result is considered valid for cable lengths up to twice those of the tested device or for corresponding additional impedance between the connecting points of the short-circuiting device and the work location being protected. For the protection of the worker, if there is further additional impedance in the practical application, compliance with combination of IEC 60479-1 and IEC 61201, and need for additional tests should be evaluated by the customer.

5.7.6 Alternative means to short-circuit current test for conformity assessment during production phase

There is no real alternative test to the short-circuit test after completing the production phase for checking the conformity to the associated requirement. Nevertheless the manufacturer or end assembler shall prove that he has followed the same documented assembly procedure with identical components as per the type tested device (see Annex F).

5.8 Durability of marking

The durability of the marking shall be verified by thoroughly cleaning the marking for at least 1 min with a piece of lint-free cloth dampened with water and then rubbing it vigorously for a further minimum of 1 min with a piece of lint-free cloth dampened with isopropanol (CH_3-$CH(OH)$-CH_3).

The test shall be considered as passed if the marking remains legible and the letters do not smear.

The surface of the equipment or component may change. No signs of loosening shall be present for labels.

NOTE Marking made by moulding or engraving need not be subjected to this test.

6 Conformity assessment

For leading the conformity assessment during the production phase, IEC 61318 shall be used in conjunction with the present standard.

Annex F, issued from a risk analysis on the performance of the portable equipment for earthing or earthing and short-circuiting, provides the classification of defects and identifies the associated tests applicable after completion of production phase.

7 Modifications

Any change of components design or material that effects performance of the portable equipment for earthing or earthing and short-circuiting (or of any of its component) shall require the type tests to be repeated, in whole or in part, as well as a change in the reference literature.

Annex A
(informative)

Guidelines for portable equipment for earthing to be used on railway systems

A.1 General

This annex is given for guidance of application of the present standard on railway systems when the requirements of the customer are different from the standard requirements. The values required should be amended according to the site application. An agreement between customer and manufacturer should be made.

NOTE The references of clauses and subclauses between parenthesis are those of the body of this standard.

A.2 Definitions (3)

The terms and definitions of Clause 3 are applicable except for the following:

A.2.1 Earth clamp (3.6)

For railway systems, the earth clamp is replaced by the "rail clamp", the earthing conductor is the rail itself.

A.2.2 Line clamp (3.17)

For railway systems, the line clamp is replaced by "contact line clamp" and is connected to the contact line.

A.2.3 Portable equipment for earthing or earthing and short-circuiting (3.20)

For railway systems, the equipment is used for earthing only and is called “portable equipment for earthing.

A.3 Requirements (4)

A.3.1 Electrical rating (4.2)

For railway systems different data for rated time, rated current for short circuit and peak factor should be confirmed with the infrastructure manager, and special cycles for transit current (I_{tr}) in d.c. systems should be taken into account (see A.4.3 for corresponding test).

A.3.2 Cables for earthing (4.3)

Equipment for earthing of railways systems can be left installed or put along the track for later use during all the planned period. For this reason, cables with an adequate flexibility under cold conditions should be required.

A.3.3 Clamps (4.6)

Clamps should be submitted to transit current and short-circuit current. Clamps should be resistant to be used for a long period of time and adapted to the shape of rails and contact lines.

The contact line clamp should be of the tightening type or type sitting by gravity on the overhead contact line profile.

The rail clamp should be resistant to vibrations in case a train is on the adjacent track during the working period (see A.4.2 for corresponding test).

A.3.4 **Earthing device** (4.7)

For railway application, in addition, all conductors and connections of the device should resist to the d.c. transit current (see A.4.2 for corresponding test).

A.4 **Tests** (5)

NOTE The values given in the following subclauses are given as examples for guidance. They are not mandatory and should be adapted to the referred railways systems.

A.4.1 **Tests for the selection of cables** (5.3)

A.4.1.1 Clashing test

Railways equipment being under heavy operating conditions, the clashing test should be required (see IEC 61138).

A.4.1.2 Test for flexibility under cold conditions

If the flexibility of the cable under cold conditions according to IEC 61138 is not considered as sufficient, a new test defined by the customer should be submitted to the manufacturer.

A.4.2 **Test on clamps** (5.6)

For railway systems, the rail clamp should be tested in vibration because of the possibility of a running train on the adjacent track during working procedure.

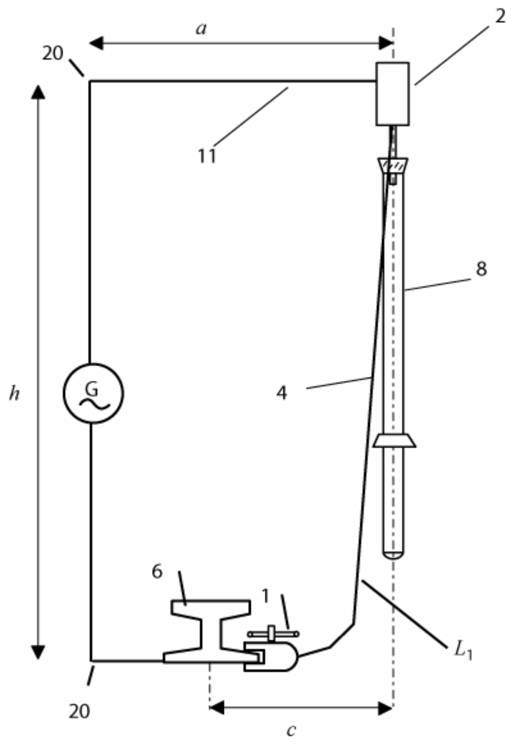
A.4.3 Short-circuit current test

A.4.3.1 **General** (5.7.1)

A.C. and d.c tests should be performed with single-phase test set-ups as required by the customer. For d.c tests, the source should be defined with the help of laboratories or test centres or be the railway network itself. For a.c. tests, the frequency range should be 16 Hz to 60 Hz.

A.4.3.2 **Test set-up and arrangement** (5.7.3)

Single-phase devices for railway systems should be used (see Figure A.1). Rail and overhead contact line profiles should be aged ones or pre-conditioned according to this standard. If different cross-sections of overhead contact line profile are used, for the test the smaller one should be always chosen.



Key

1	Rail (earthing) clamp
2	Contact line clamp
4	Earthing cable(s)
6	Rail
8	Insulating element of the earthing stick
11	Overhead contact line profile
20	Test current feed-in point
a	Distance between contact line clamp and feed-in point, minimum 2 000 mm (*)
h	Vertical distance between overhead contact line profile and rail connecting point, minimum 5 000 mm (*)
c	Horizontal distance between contact line and rail connecting points, 1 000 mm (*)
L_1	Length of earthing cable between contact line and rail clamps, 10 000 mm (*)
(*)	Given length are standards lengths, the required length should be modified according to the real work site dimensions

Figure A.1 – Test set-up for testing single phase equipment for railway systems

A.4.3.3 **Test values** (5.7.4)

Different values from those of this standard of rated current and time and peak factor, if any, should be applied according to the site application for the short-circuit current and for the transit current.

A.5 **Earthing stick** (B.3 and B.4)

For application to railway systems, an alternative bending test on the earthing stick should be required to simulate a worker walking with the stick carried out on his shoulder.

This test should replace the bending test of B.3 and the torsion test of B.4.

A.6 **Selection** (C.2)

Specific procedures for performing the work using the equipment with long cables should be developed prior to use.

Specific values of current and Joule integral for railway systems should be defined in accordance with railway regulation.

A.7 Selection of cable cross-section (C.2.2.1)

A calculation of short-circuit current value is given as follows as an example.

With an initial temperature of 20 °C and a final temperature of 450 °C, the current density should be of 225 A/mm^2 for the short-circuiting cable.

NOTE Due to transit current, initial temperature should be higher than 20 °C.

The correction factor for short-circuit time equal to or less than 0,12 s is 2,9.

$$I = 225\ \text{A/mm}^2 \times 35\ \text{mm}^2 \times 2{,}9 = 22{,}8\ \text{kA}$$

Other values are given in Table A.1.

Table A.1 – Short circuit values for copper cable with a maximum temperature of 450 °C

Cross section mm^2	**Current** **for short-circuit time ≤ 0,12 s** kA
16	10,4
25	16,3
35	22,8
50	32,8
70	45,7
95	62

NOTE The table does not take into account the re-closing consequences which could increase the temperature of cables.

Annex B
(informative)

Guidelines for earthing sticks

B.1 Recommendations

These recommendations are applicable to detachable or non-detachable earthing sticks corresponding to the insulating component of complete equipment.

The earthing stick, whether supplied by the manufacturer of the earthing and short-circuiting device or by a separate manufacturer, should be designed in accordance with the manufacturer or customer specification depending upon the working method.

The earthing stick should provide safety with respect to insulating properties, air clearances, handling and component weights.

No cable should permanently follow along the insulating element of the earthing stick, either outside or inside, unless the resulting insulating level of the paralleled cable and stick meets the requirements of sufficient insulation according to the operating voltage of the installation.

B.1.1 Insulation considerations

Safe insulation for the worker is achieved by correct design and length of insulating elements according to the relevant standards (IEC, regional or national such as EN 50508) or according to national regulation.

The length of an earthing stick is not usually determined by the need for insulation but for keeping the operator sufficiently distanced from un-earthed parts of installations during the earthing and short-circuiting procedure and for reaching the connecting point.

The air clearances specified in IEC 60071-1, IEC 60071-2 or IEC 61936-1, or calculated according to IEC 61472 (for 72,5 kV and above), give a base for determining minimum lengths of earthing sticks in this respect. An adequate length of insulating element should be required for safety, depending upon the nominal voltage of the installation and according to the working procedure. It could also be selected on an adequate estimated value of residual voltage after the beginning of the dead procedure (disconnection).

B.1.2 Mechanical considerations

The earthing stick and its couplings should withstand the bending and torsion stresses produced by the load and the tightening forces. The deflection should be minimised to avoid uncontrolled movements.

Selection of insulating elements with respect to deflection, bending and torsion qualities should be done according to IEC 60855 or IEC 61235. For live working applications, the selection of proper lengths of hollow tubes could be made in addition to the insulating element to obtain the adequate length of the stick.

Different attachments from those specified in IEC 60832 can be used to allow multiple uses.

The allowed min/max length and the mechanical and electrical limits of the composition of the stick which could be made of several parts or sections should be indicated in the instructions for use.

Bending and torsion forces, in normal use, should not cause damage to the earthing sticks. Compliance should be checked by test according to B.3 and B.4.

In case of earthing sticks of devices using gravity clamps or spring clamps (for which a value of pull-push traction is only needed), detachable end fittings between the earthing stick and the line clamp or conductive extension component (see Figure 1, item 14) or short-circuiting bar should allow fitting and removal of the earthing stick without using pulling or pushing forces exceeding 100 N. Moreover, the release force should not be less than 50 N. Compliance to the requirements is checked by measurement of the pulling and pushing forces.

B.2 Marking

Each earthing stick should carry at least the following items of marking:

– manufacturer's name or trade mark;
– model or type reference;
– year of manufacture;

If the stick is made with different components, each component should carry specific marking.

The marking should not affect the performance of the stick. If a removable label is used, the performance should not be affected by its removal.

Compliance should be verified by visual verification according to 5.2 and by test according to 5.8.

B.3 Bending test

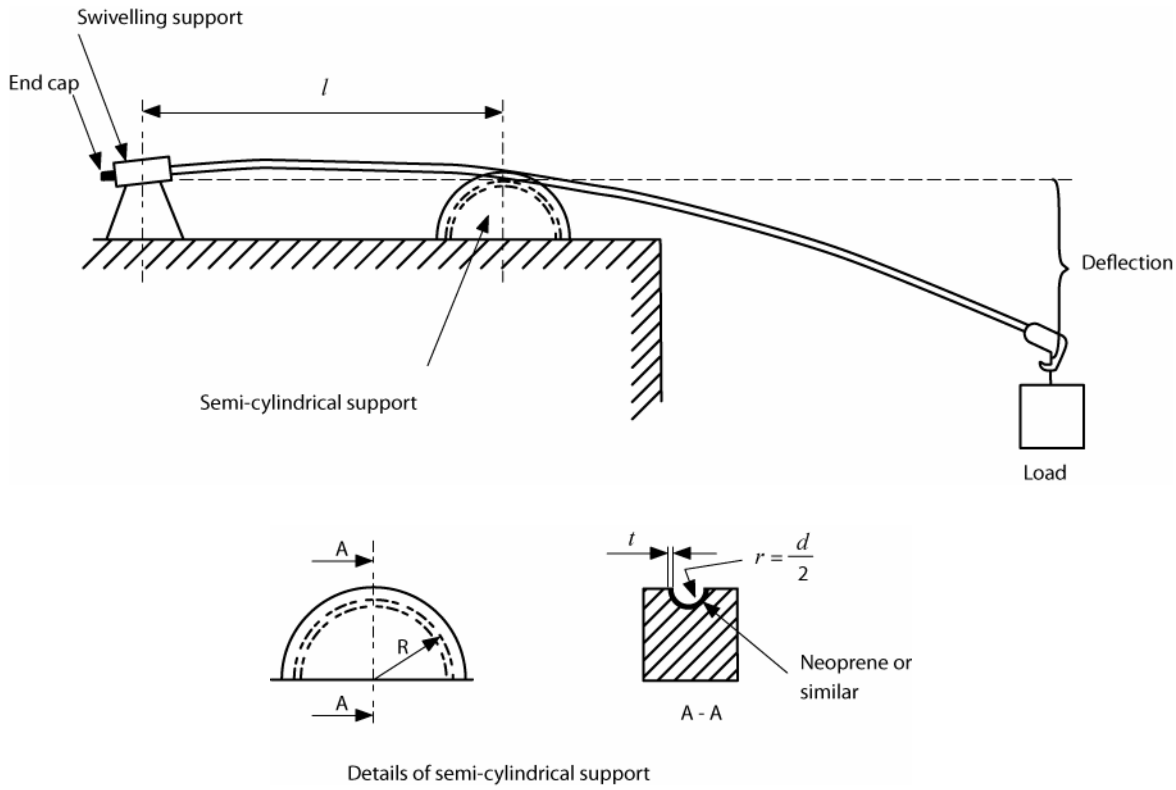
A test should be performed for sticks with a minimum total length of 2 m. The test should be performed for the longest combination of sections.

The following test is recommended for earthing sticks of circular cross-section.

The bending forces and maximum deflections are recommended for earthing sticks with a total length limited to 6 m and with a maximum of 3 joints or couplings. For longer sticks or more couplings, other bending forces and maximum deflections should be defined

The end of the stick at the handle section is fixed to a swivelling support. An intermediate part of the handle is supported freely by a semi-cylindrical horizontal surface. This semi-cylindrical surface should be provided with a groove, covered with neoprene or similar material with a degree of hardness of 40 IRHD to 50 IRHD (international rubber hardness degree) according to ISO 48 and a thickness of 6 mm.

The dimensions and general arrangement of the supports are given in Figure B.1. Since there are different possible designs of earthing sticks, the test set up should be such that it corresponds to the usual handling and load application of the stick under test. The swivelling support should be fixed as close as possible to the extremity of the stick and not over an end-cap, where available. If the hand guard interferes with the groove support it can be removed.



Key

l = 0,5 m for stick length ≤ 3 m

l = 1,0 m for stick length > 3 m

R = 100 mm

d diameter of the earthing stick in the support

t tolerance to permit an easy rotation

Figure B.1 – Arrangement for bending tests on earthing sticks of circular cross-section

The stick should be blocked in the swivelling support. Then a bending force of 5 daN, for sticks with a length up to 3 m, or 10 daN for sticks longer than 3 m, should be applied to the head of the earthing stick as close as possible to where the earthing and short-circuiting device is to be attached to this stick. The deflection is measured at the point of load application.

The test should be considered as passed if the deflection does not exceed the value of Table B.1.

Table B.1 – Maximum deflection

Total length of the stick (m)	**2**	**2,5**	**3**	**3,5**	**4**	**4,5**	**5**	**5,5**	**6**
Deflection (mm)	90	200	240	420	700	1 080	1 600	2 250	3 070

Immediately the bending force is increased up to 150 % and is maintained constant during 30 s.

The test should be considered as passed if the stick shows no signs of breakdown or mechanical damage.

B.4 Torsion test

Three complete sticks with couplings are tested.

The stick should be rigidly held by the lower end of the handle. A torque of T N·m, should be applied around the axis of the stick with the help of a test tool (see Annex C) appropriate to the type of head, as specified in Figure B.2.

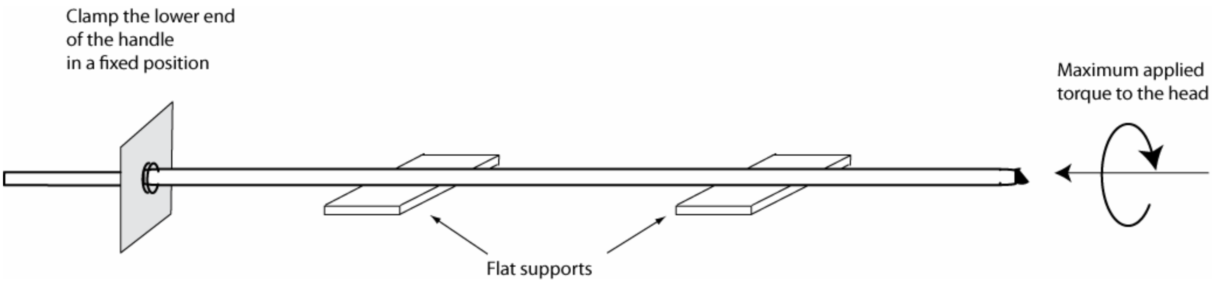


Figure B.2 – Arrangement for torsion tests on earthing sticks of circular cross-section

For a multiple section stick the test should be performed for the longest combination.

$$T\ (\text{N·m}) = \text{tube } \varnothing \text{ (measured in mm)}$$

For tubes with a diameter larger than 39 mm, 40 N·m will be applied.

The stick should not be exposed to bending forces during the test.

The torque should be applied in one direction for 1 min and then in the inverse direction for 1 min. The torsion angle in each direction will be measured.

The test should be considered as passed if the sum of the absolute values of the angles measured in both directions does not exceed 25°/ m of the total length of the stick.

Then the torque should be increased up to 1,2 T (N·m) for both directions and maintained for 30 s.

The test should be considered as passed if the stick shows no signs of mechanical damage. In case of telescopic earthing stick, the lock assemblies should continue to operate as designed.

Annex C
(informative)

Guidelines for selection, use and maintenance of portable earthing or earthing and short-circuiting equipment

C.1 General

C.1.1 Basic principles

Earthing (grounding) and short-circuiting of isolated or de-energized parts of electrical installations is carried out in order to help minimize dangerous voltages and arcs in the event that the installation is accidentally switched on again or when an energy induced by energized adjacent installation is still present (see IEEE 516 and IEEE 1048). Equipotential conditions should be achieved if practicable to avoid injury in the event of re-energization.

Earthing and short-circuiting equipment may also be used to achieve equipotential conditions in order to protect the worker when there is a steady state transit current or induced current in the work site.

In order to avoid dangerous voltage and arcing it is recommended to use earthing and short-circuiting equipment in accordance with this standard, that are correctly sized, selected for the field of application, connected according to instructions for use and kept in good condition. When submitted to a short-circuit current, minor or partial destruction of the earthing and short-circuiting device may occur.

Experience shows that this equipment should be easy to use. Maximum possible temperatures of the current-carrying parts are therefore permitted in order to keep the weight of the devices small. Touching a device shortly after short-circuit can result in personal injury in the form of burns.

The weight of the components of the equipment should be taken into account to ensure that the effort required to apply them to conductors is within the capability of workers.

C.1.2 Items for consideration

The following items should be considered by the customer and the manufacturer for the design of the proper equipment made according to this standard.

- information on the installations on which the equipment or device will be used:
  - type of installation(s);
  - length of cables or distances between phase and earth;
  - type of neutral of the installation (solid or not);
  - type of clamps and definition of fixed connection point;
- evaluation or estimation of the poisonous effect when the insulating cover of cables is burnt during indoor use;
- restriction, if any, for evacuation of personnel and consequently nature of the insulating material and value of the cross-section of the cables;
- information of temperature range of use;
- specification of the equipment or device:
  - rated time;
  - rated current;
  - rated peak factor;

- transit current;
- limitation if any of the temperature of the cables during short-circuit;
- choice of cable according to IEC 61138 or others;
- nature of the conductive parts (copper, aluminium or aluminium alloy);
- insulation of the cluster, if any;
- type of equipment, complete or separate:
  - if separate, type of insulating means (for the compatibility of the couplings, if needed);
  - if complete:
    - working method (live or dead);
    - type of insulating component needed;
    - specification of earthing stick, if any;
    - additional insulating parts of the device;

– risk of clashing on metallic structures;

– additional tests.

C.2 Selection

Different characteristics of the equipment (weight of components, length of insulating element, design of clamps, etc.) should be taken into consideration to validate the adequacy of use.

The device should have adequate insulation to ensure that temporary contact between parts of the device, or between these parts and surrounding structures, does not cause arcing when in use.

NOTE 1 Depending on the information supplied by the customer (see C.1.2), clusters could be insulated or not. A non-insulated cluster should be mechanically restrained if there is a possibility of contact with conductive structure.

NOTE 2 Non-insulated conductive extensions could be used in spaces clear from conductive structures.

C.2.1 Selection of clamps

Clamps should be selected to permit easy connection to the connection points. The connection points should be selected to correspond to the rating of the equipment.

Clamps should be designed to avoid any accidental separation from the positioning devices or end fitting of the earthing stick during the installation and the removal, and while they remain positioned on the conductor in order to avoid accident to personnel. The connection between clamp and positioning device should be verified by manual check.

C.2.2 Selection of cables

Earthing and short-circuiting cables should be selected according to 4.3 and according to the heating curve shown here after. The cable conductors should have standard nominal cross-sectional area according to IEC 60228 or according to national or regional standards such as ASTM F855. Table C.1 compares different standard values of nominal cross-section. At the request of the customer, non-standard values of cross-section may be used.

Table C.1 – Comparison of different standard values of nominal cross-sections

Copper equivalent cross-section of short-circuiting cable and/or bar mm²	
IEC 60228	**ASTM F855**
35	(33,63 = #2 AWG)
50	(53,48 = 1/0 AWG)
70	(67,42 = 2/0 AWG)
85 [a]	(85,03 = 3/0 AWG)
95	(107,2 = 4/0 AWG)
185	(177,36 = 350 kcmil)
240	(253 = 500 kcmil) [a]

[a] non-standard cross-section

For indoor use, temperature restrictions for the selected insulating material may call for special dimensioning.

Insulating materials that generate poisonous and/or corrosive by-products are acceptable for indoor use provided appropriate considerations are given to the following restrictions:

– evacuation of personnel is not impeded by poor visibility or by irritation of eyes or breathing;
– no serious poisoning occurs by short exposure;
– installations and buildings do not run the risk of permanent damage.

The user could either select a different insulating material for the covering of the cables or use a cable with a nominal cross-section larger than the one required for complying with the rated values for short-circuit, to reduce the temperature rise. For example: use of a cross-section of 50 mm^2 instead of 35 mm^2.

Earthing and short-circuiting cables should be of minimal weight in order to be easy to operate. The highest possible temperature rises of cables are therefore adopted to reduce weight.

The lengths of the earthing and short-circuiting cables should correspond to installation dimensions and distances between connection points.

Cable lengths less than 1,2 times the distance between the connection points may lead to more severe conditions than met during the tests specified in this standard and should be avoided. Too long cables (1,5 times) will entail unacceptable tension and movements. The cable may be anchored by reliable means, for example using insulating rope attached to a wood pole.

The selection of aluminium cable should be made carefully and include precautions for storage and inspection before use.

C.2.2.1 Selection of cable cross-section

Different methods may be used for selecting the cross-section of short-circuiting cables and earthing cables.

C.2.2.1.1 Example based on the application of IEC 60865-1

With an initial temperature of 20 °C and a final temperature of 300 °C, according to Figure 13 of IEC 60865-1, for a short-circuit time of 1 s, the current density for copper short-circuiting cable is 190 A/mm^2.

NOTE Figure 13 of IEC 60865-1 gives values that do not destroy the device; it involves only the adiabatic process.

The correction factor for short-circuit time less than 0,5 s is equal to 1,41.

The calculated value of the short-circuit current is:

$$I = 190 \text{ A/mm}^2 \times 35 \text{ mm}^2 \times 1{,}41 = 9{,}4 \text{ kA}$$

The correction factor for short-circuit time of 2 s is equal to $\sqrt{(1 \text{ s}/ 2 \text{ s})} = 0{,}71$

The calculated value of the short-circuit current is:

$$I = 190 \text{ A/mm}^2 \times 35 \text{ mm}^2 \times 0{,}71 = 4{,}7 \text{ kA}$$

For copper cables, the values of Table C.2, related to thermal effect, should be used for short-circuit sites close to the generator (see Clause 4 of IEC 60909-0).

Table C.2 – Short-circuit close to generator – Short-circuit current values in kA for copper cables with a maximum temperature of 300 °C

Cross section mm^2	**Short-circuit time** s				
	0,5 [a]	**1**	**2**	**5**	**10**
16	4,3	3,0	2,1	1,4	1,0
25	6,7	4,8	3,3	2,1	1,5
35	9,4	6,7	4,7	3,0	2,1
50	13,4	9,5	6,7	4,3	3,0
70	18,8	13,3	9,3	6,0	4,3
95	25,5	18,1	12,7	8,1	5,8
120	32,1	22,8	15,9	10,2	7,3
150	40,2	28,5	20,0	12,8	9,1

[a] Below 0,5 s, the calculation is not applicable

For short-circuits far from the generator, the values of Table C.2 should be multiplied by the factor 1,19, rounded to 1,20 (see Figure 12a and Figure 12b of IEC 60865-1). For example, for a cable with a cross-section of 35 mm^2 and a short-circuit time of 0,5 s, the calculated value of the short-circuit current is

$$I = 9{,}4 \text{ kA} \times 1{,}2 = 11{,}3 \text{ kA}$$

For aluminium cable, the current density given for copper (190 A/mm^2) has to be replaced by 125 A/mm^2 for the calculation of the short-circuit current.

C.2.2.1.2 Example based on the use of temperature heating curves according to Figure C.1

The curves of Figure C.1 give the temperature increase of a material when a current is flowing through it for a short time. They are based on the physical law of the heating of materials.

They have to be completed by the following formula:

$$I = \sqrt{\frac{\left(J^2 t\right) \times A^2}{t}}$$

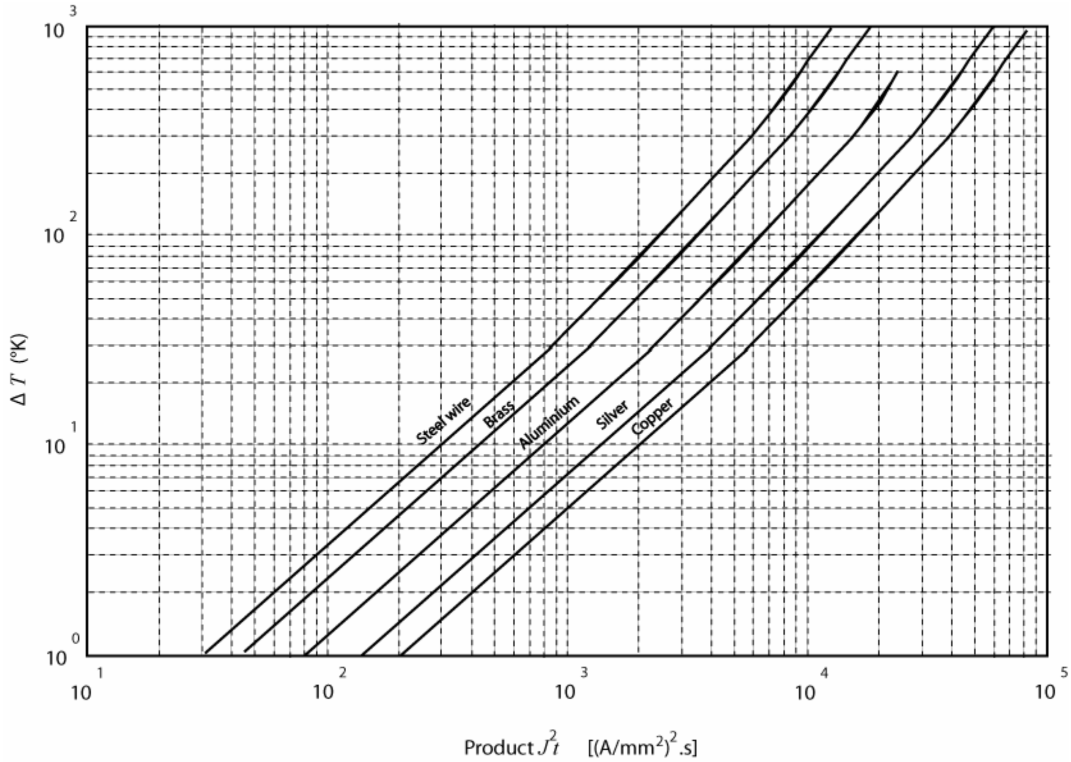


Figure C.1 – Curves representing the temperature heating of different nature of conductors related to the value of the Joule integral J^2t

<u>Hypothesis:</u>

- no thermal exchange with the outside,
- the value of the current is stable during the time it is running through the material,
- the initial temperature of the material is 20°C when the current appears.

<u>Data:</u>

I is the current running through the material (rms value) in A,

A is the cross-section of the material in mm^2,

J is the current density in A/mm^2 ($J=I/A$),

t is the time during which the current is running in s,

ΔT is the increase of temperature of the material (at the end of the time t) in °K.

<u>Case of use 1:</u>

What is the temperature reached by a known conductor having a cross-section A when a current I is running through it during a time t ?

The formula gives:

$$J^2t = \frac{I^2t}{A^2}$$

Then the curve corresponding to the conductor material gives ΔT from J^2t.

Example:

- copper cable with a cross-section A = 120 mm^2;
- short-circuit current I = 23 000 A;
- time t = 1 s

$$J^2t = \frac{I^2t}{A^2} = \frac{23\ 000^2 \times 1}{120^2} = 36\ 736\ (\text{A/mm}^2)^2.\text{s}$$

The corresponding curve of Figure C.2 gives an increase of temperature ΔT = 250 °K.

So this conductor will reach approximately (with ΔT = 250 °K) ΔT + 20 °C = 270 °C at the end of the time equal to 1 s.

NOTE 20 °C is the initial temperature when the short-circuit current appears.

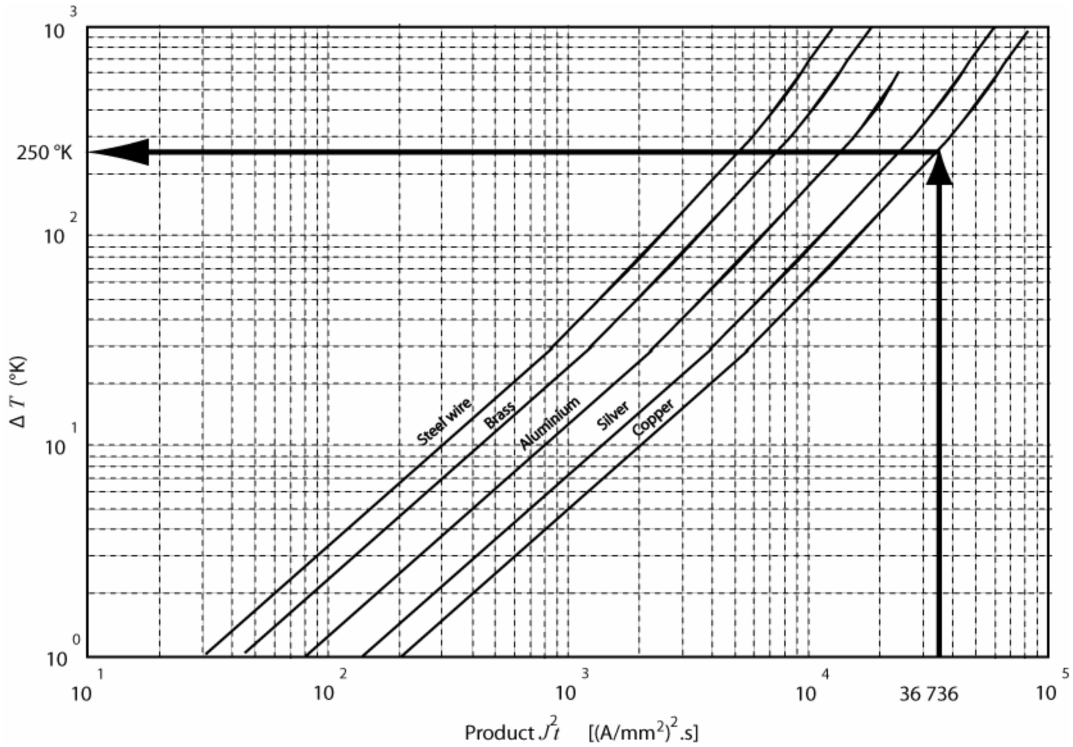


Figure C.2 – Determination of conductor temperature from heating

<u>Case of use 2:</u>

What cross-section of a known material cable should be used if a defined temperature should not be exceeded when a defined short-circuit current is flowing through it during a known time?

The curve corresponding to the conductor material gives J^2t from ΔT. Then, the formula gives:

$$A = \sqrt{\frac{I^2 t}{J^2 t}}$$

Example:

- aluminium cable
- short-circuit current I = 17 500 A
- time t = 2 s
- maximum reached temperature ΔT + 20 °C = 550 °C, so ΔT = 530 °K

The aluminium curve of Figure C.3 gives $J^2 t \approx$ 22 500 (A/mm²)².s.

$$A = \sqrt{\frac{I^2 t}{J^2 t}} = \sqrt{\frac{17\,500^2 \times 2}{22\,500}} = 165 \text{ mm}^2$$

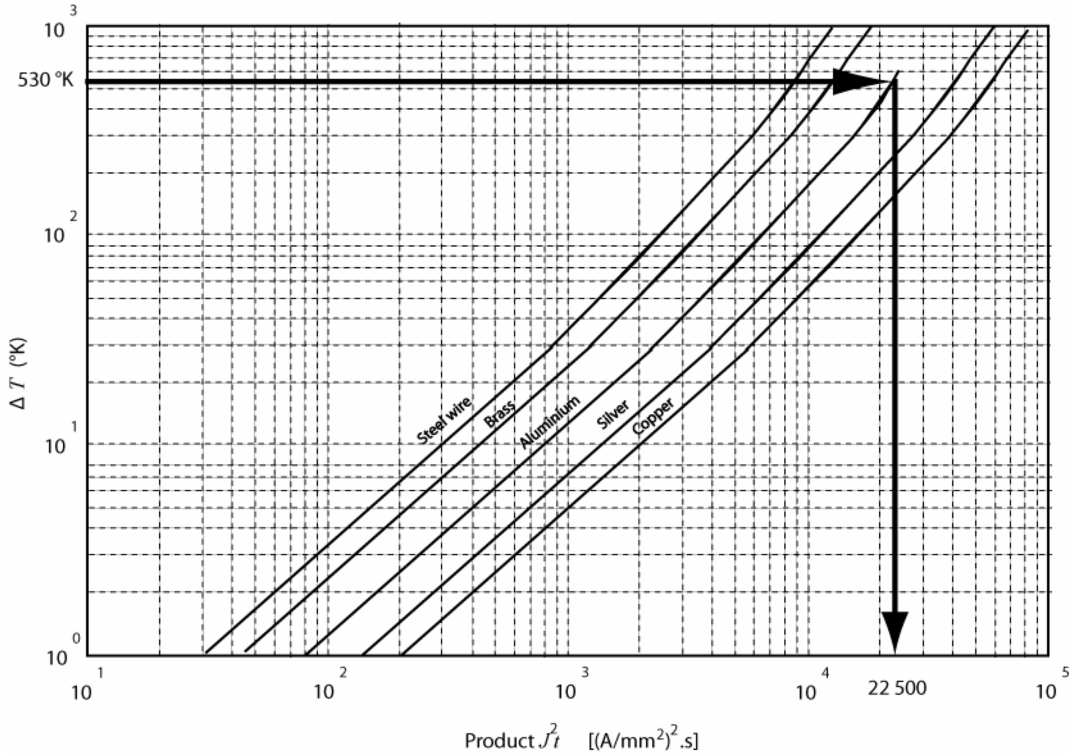


Figure C.3 – Determination of $J^2 t$

The method gives a minimal cross-section of 165 mm². The standardized cross-section immediately above should be used. In this case, there is none given by this standard but 185 mm² could be used .

C.2.2.1.3 Example based on North American practice

ASTM F855-04 provides guidance to users in selecting the cross section area of earthing and short-circuiting (grounding) copper cables, based on the required time and current. The cable selection is based on the fusing (melting) point of copper. The user should recognize that the ultimate capacity of cable is the calculated capacity of the cable at which melting or failure will occur. A suitable safety margin should be maintained in selecting the cable size.

The rationalization for detailing the earthing and short-circuiting (grounding) cable ratings in the manner in which it is presented is that it enables the user to choose which cable and which rating are required for the user's system and company's philosophy.

For further information and specific details refer to ASTM F855-04.

C.2.3 Selection of earthing stick

For guidance on the selection of earthing stick see Annex B.

C.2.4 Selection of the device

The customer should decide if the selection of rated time of the device is in accordance with the duration of the maximum short-circuit current which is linked to the tripping time of main or back-up protection. If automatic re-closing is not effectively prevented after re-closure against short-circuit, the consequences of a second short-circuit should be evaluated.

In order to select properly the device to be used in a defined installation, two criteria should be followed:

- electromagnetic forces should not exceed the forces for which the device is rated;
- Joule heating should not exceed the heating for which the device is rated.

The first criterion is satisfied when the product of the short-circuit rms a.c. current and the peak factor of the installation is not greater than the product of the rms a.c. rated current and the rated peak factor (n_{rated}) of the device. This criterion is related to the maximum dynamic stress. The device can be used in installations that produce a higher or lower short-circuit current than the rated short-circuit current of the device, provided that the peak factor of the installation is accordingly lower or higher:

$$I_{\text{short-circuit installation}} \times n_{\text{installation}} \leq I_{\text{rated}} \times n_{\text{rated}}$$

The second criterion is satisfied when the maximum thermal stress expressed by the Joule integral of the installation is not higher than the Joule integral of the device calculated from the rated values:

$$I^2_{\text{short-circuit installation}} \times t_{\text{installation}} \leq I^2_{\text{rated}} \times t_{\text{rated}}$$

As long as the equivalence in the Joule integral is kept, the short-circuit duration can be increased (up to 5 s) by reducing the current accordingly to get the same adiabatic condition. There is no additional need for the customer to specify the short-circuit duration.

For short-circuit duration less than the rated time, the first criterion should be used.

For a device with rated current and time of 1 000 A and 1 s and a constant peak factor, Figure C.4 illustrates the usable time and current region under the adiabatic boundary of the second criterion and the dynamic boundary of the first criterion.

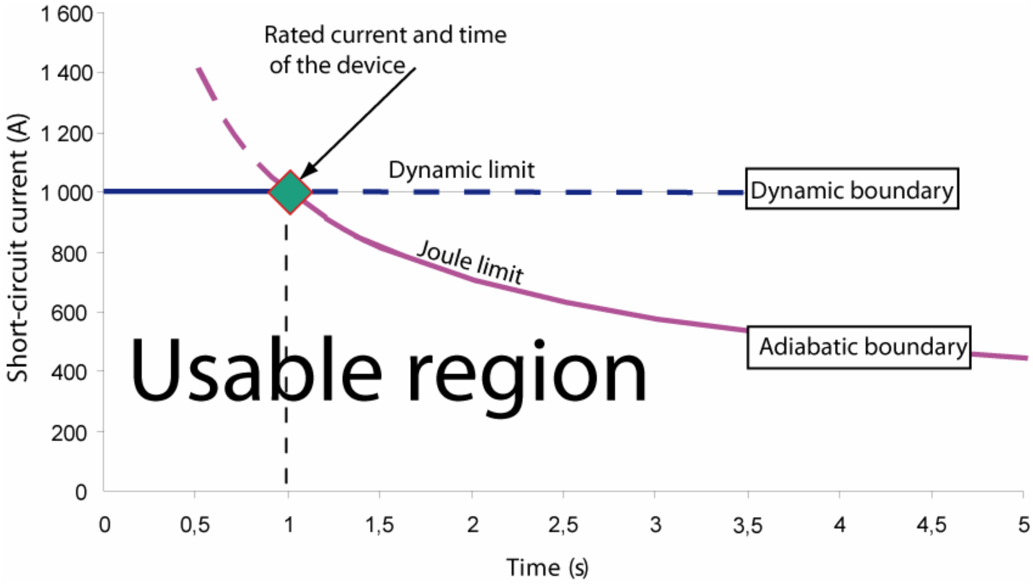


Figure C.4 – Example of the usable region for a device

C.3 Use of the equipment

C.3.1 General

To avoid danger from residual voltage while connecting the earthing and short-circuiting device, it has to be connected first to the earthing system. If the worker is not at the earth potential, he should use either an insulating component (earthing stick or other) or insulating means to connect the earth clamp first.

Further connections should be carried out by use of an insulating component (earthing stick or other) or insulating means until the connection of the device is completed.

To avoid danger from residual voltage while disconnecting the earthing and short-circuiting device, the line clamp(s) has (have) to be disconnected first by the use of insulating component (earthing stick or other) or insulating means until the disconnection of all line clamps is completed, then the earth clamp is removed.

If the worker is not at the earth potential, he should use either an insulating component (earthing stick or other) or insulating means to disconnect the earth clamp.

When connecting or disconnecting the line clamp(s), small sparks may occur and should be accepted.

When exposed to a short-circuit current, the device may produce violent movements. This may occur particularly when the cables are long. Since thermal utilisation of conductor material is high for weight optimisation, the device will reach a high temperature shortly after short-circuit.

C.3.2 Verification

C.3.2.1 Verification before use

For safety reasons, earthing and short-circuiting equipment should be handled with great care. It should be thoroughly inspected visually before each use.

Visible damage to clamps, connections, cable insulation or the exposure of bare conductor should be regarded as serious defects and the equipment should be removed from use.

Before use, inspection of the surface contact of the clamps should be done and the contact of the connection point should be cleaned by brushing all deposit remaining in order to obtain good electrical contact either for transit current or for short-circuit current.

C.3.2.2 Periodic inspection and in-service testing

The users should develop their own guidelines for proving the integrity of the device and define the according time interval for periodic inspection which may include the in-service testing of the equipment.

The following are examples of methods that may be used.

Example 1:

The pass/fail criterion for testing of portable earthing or earthing and short-circuiting equipment as it is used in ASTM F2249, is based on the resistance value of the earthing and short-circuiting device (cable, ferrules and clamps) which is higher than the initial established resistance value. This increase in resistance accounts for the expected normal deterioration of the assembly due to aging, contamination and corrosion particularly in the contact areas of the cable ferrules and clamps. The allowable increase in resistance is such as to permit the portable earthing or earthing and short-circuiting equipment to perform safely during electrical short-circuits.

The electrical resistance value for the pass/fail criterion is made up of two parts, the cable resistance and the resistance of the two ends containing short cable sections, ferrules and clamps. When earthing and short-circuiting devices are tested with a d.c. source, the d.c. resistance of the assembly is used for the pass or fail evaluation. With an a.c. source, the impedance of the cable and the impedance of the ends (ferrules and clamps) are used to determine if the portable equipment fails or passes the test. In order to make good resistance measurements it is recommended to use a current in excess of 10 A. The resolution of the measurement instrument should be 1 μΩ or better and the range of ambient temperature should be considered in order to obtain a good and comparable measurement.

The specific pass/fail resistance values as well as the other information on in-service inspection and maintenance are given in ASTM F 2249.

Example 2:

The cables may be inspected every five years or less for outdoor use and ten years or less for indoor use, by cutting the end fittings from the cable and visually inspecting the cable ends for corrosion. If there is an indication of corrosion or other problems (strand breakage, annealed copper strands, etc.), the equipment should be disposed of. If there is no indication of problems, new fittings should be installed and the equipment returned to service. The failure rate should be used to determine the frequency of this type of inspection, either inspecting more or less frequently.

C.4 Maintenance, storage, repair and disposal

The maintenance tests are not covered by this standard but may be made according to national or regional regulations or customer requirements.

C.4.1 Maintenance and storage

In order to maintain its capacity of protecting the workers, the earthing or earthing and short-circuiting equipment should be maintained and stored in good condition by the user. The manufacturer's or final assembler's instructions for use should be a reference document in that respect.

C.4.2 Repair

If reassembled, after cutting off exposed cable zones, it should be made in full agreement with the type designation. The repair should be made by the manufacturer or under the directive of the manufacturer or final assembler. But it is not advisable to repair the equipment in case of exposure to short-circuit.

C.4.3 Disposal

A device or equipment that has been exposed to short-circuit current should be disposed of, unless it is proved by thorough investigation, calculation and inspection that the exposure has been too moderate to give any negative mechanical or thermal effects. If there is any doubt as to the perfect condition of the device or equipment, it should be disposed of.

C.5 Effect of asymmetrical currents

The presence of asymmetrical currents on installations and on earthing or earthing and short-circuiting equipment should be determined before use. Useful references are IEC 60909-0, IEC 60909-1, IEC 60865-1, IEC 60865-2 and ASTM F855 (see also Figure 9).

The increasing value of the short-circuit currents noted in the locations with high inductive reactance relative to the resistance value produces an increase of the asymmetrical effect giving important mechanical effects.

The increasing ratio results in higher peak current during the first few cycles, mechanical forces increase as the square of the current and large ratios may double the current and increase the force by a factor of four times. The equipment should be dimensioned accordingly.

In this standard the peak factors retained were 2 for low voltage and 2,5 at 50 Hz (or 2,6 at 60 Hz) for high voltage but in some sites the peak factor could be greater, such as 2,7 due to the corresponding value of the X/R ratio and current initiating point on the voltage wave.

The variation in X/R values and the current initiating points result in substantially different asymmetrical currents. The greater the X/R, the greater the instantaneous peak current, and the longer the time required for the asymmetrical current to return to a symmetrical form.

Annex D
(informative)

Guideline for determination of the equivalent r.m.s. value of a short-time current during a short-circuit of a given duration

The method illustrated in Figure D.1 should be used to determine the short-time current I_t (refer to 5.7.4) for the calculation of the Joule integral $I^2{}_t \times t_t$.

The total time t_t of the test is divided into ten equal parts by verticals 0 – 0,1 ... 1 and the r.m.s. value of the a.c. component of the current is measured at these verticals.

These values are designated:

$$Z_0, Z_1 \ldots Z_{10}$$

where:

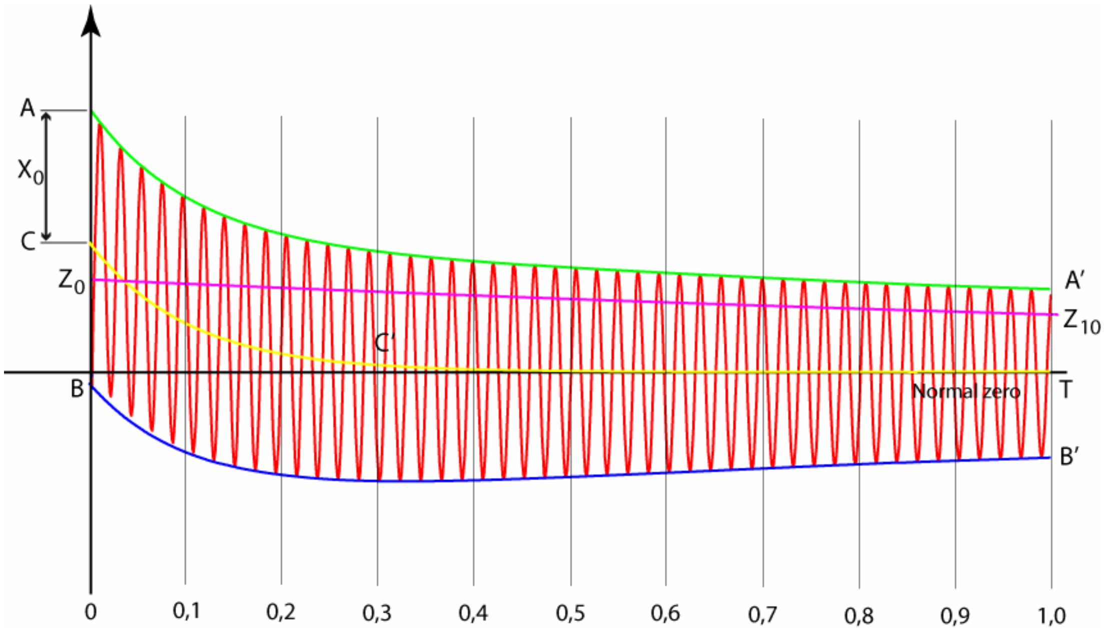
$Z = X / \sqrt{2}$ and X is the zero-line-to-peak value of a.c. component of current.

The equivalent r.m.s. current during the time t_t is given by:

$$I_t = \sqrt{\frac{1}{30}\left[Z_0^2 + 4\left(Z_1^2 + Z_3^2 + Z_5^2 + Z_7^2 + Z_9^2\right) + 2\left(Z_2^2 + Z_4^2 + Z_6^2 + Z_8^2\right) + Z_{10}^2\right]}$$

The d.c. component of current represented by CC' is not taken into account.

NOTE The d.c. component CC′ can be neglected for short-circuit durations of 1 s and above. For durations of 0,5 s it is necessary to increase the values for the short-circuit current by 4 % when calculating the Joule integral. For very short durations below 0,2 s the d.c. component cannot be neglected and the described method is not applicable.



Key

AA′	Top envelope of current wave
BB′	Bottom envelope of current wave
CC′	D.C. component; displacement of current wave zero line from normal zero line at any instant; it is given by half of the vertical distance between top envelope and bottom envelope
$Z_0 \ldots Z_{10}$	r.m.s. value of a.c. component of current at any instant measured from normal zero; d.c. component is neglected
X_o	Peak value of a.c. component of current at instant of initiating short-circuit; it is given by half of the vertical distance between top envelope and bottom envelope at point 0
X_i	Peak values given by the half of the vertical distance between top envelope and bottom envelope at the equal spreaded points 0,1 to 1
BT	Duration of short-circuit, t_t

Figure D.1 – Determination of short-time current

Annex E
(normative)

List of type tests

Table E.1 – List of type tests referred to subclauses

Nature of test	Subclauses		Description	Test method
	Requirements	Tests		
Non-destructive	4.1, 4.2, 4.3	5.2	Check that components of the devices are suitable for the temperature conditions and fields of application	Visual verification
Non-destructive	4.5, 4.7	5.2	Check the complete assembly of the connections and the complete device	Visual verification
Destructive	4.5	5.4.1	Fatigue test on cable with end fittings	Testing [a]
Destructive	4.5	5.4.2	Humidity penetration test on cable with end fittings	Testing [a]
Destructive	4.5	5.5	Tension test on cable with end fittings	Testing [a]
Non-destructive	4.6	5.2	Suitability of clamps to connection points	Manual checking
Destructive	4.5, 4.6	5.6	Test on clamps, fixed connection points and connections within devices	Testing [a]
Destructive	4.5, 4.6, 4.7	5.7.1 to 5.7.5	Short-circuit current test	Testing [a]
Non-destructive	4.9	5.2	Check of marking	Visual verification
Non-destructive	4.9	5.8	Testing durability of marking	Testing
Non-destructive	4.8	5.2	Verify the insulating element	Verification
Non-destructive	4.10	5.2	Check that the manufacturer's or end-assembler's instructions are made in accordance with requirements	Visual verification
Destructive and not	4.3.1	List of tests of 5.3.2.1	For cables not complying with IEC 61138	

[a] Test performed on test pieces.

Annex F
(normative)

Classification of defects

F.1 General

This annex was developed to address in a consistent manner the level of defects (critical, major and minor) of portable equipment and devices for earthing or earthing and short-circuiting as well as separate components, having completed the production phase (see IEC 61318).

Table F.1 identifies the requirements and tests with associated defects for the complete equipment. For separate component, Table F.1 shall be reduced to the corresponding component.

Table F.1 – Classification of defects and associated requirements and tests

Description of requirements		Type of defects			Tests
		Critical	Major	Minor	Subclauses
4.1	General (withstand the short-circuit current) (mechanical resistance)	 X	 X		 5.7.6 5.7.6
4.2	Electrical rating		X		5.2 visual verification
4.3	Cables for earthing and short-circuiting (according to IEC 61138) Cables not according to IEC 61138 (mechanical protection)		 X X X		 5.3.1 5.3.2.2 5.7.6
4.4	Short-circuiting bars (withstand the short-circuit current) (compatibility with the installation)	 X	 X		 5.7.6 5.2 manual
4.5	Connections of cables to rigid parts within devices (tension set) (fatigue and humidity) (current-carrying capacity) (quality of connections)	 X	 X	 X X	 5.5 5.4 (1) 5.7.6 (1)
4.6	Clamps (withstand the short-circuit current) (tightening clamps - torque) (suitability) (electrical rating) Spring clamps (installation and removing)	 X X	 X X	 X	 5.7.6 5.6.1 5.2 manual 5.7.6 (1) 5.2 manual
4.7	Earthing and short-circuiting device (withstand the short-circuit current) (design)	 X	 X		 5.7.6 5.2 visual
4.8	Insulating element of insulating component	X			5.2 verification (2)
4.9	Marking (durability) (absence) (incorrect marking)	 X	 X	 X	 5.8 5.2 visual 5.2 visual
4.10	Instruction for use (absence)		 X		 5.2 visual
(1) The test associated to the quality of connections will also check for the current-carrying capacity. (2) Based on manufacturer declaration.					

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