BRITISH STANDARD

BS EN 50368:2003

Cable cleats for electrical installations

The European Standard EN 50368:2003 has the status of a British Standard

ICS 29.120.10

British Standards

National foreword

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The UK participation in its preparation was entrusted to Technical Committee PEL/213, Cable management, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

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Cable cleats for electrical installations

Brides de câbles pour installations électriques

Kabelhalter für elektrische Installationen

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CENELEC

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

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Foreword

This European Standard was prepared by the Technical Committee CENELEC TC 213, Cable management.

The text of the draft was submitted to the formal vote and was approved by CENELEC as EN 50368 on 2003-09-01.

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) 2004-09-01

- latest date by which the national standards conflicting with the EN have to be withdrawn (dow) 2006-09-01

Annexes designated "informative" are given for information only.
In this standard, Annexes A and B are informative.

Contents

1 Scope

This European Standard specifies requirements and tests for cable cleats used for cable fixing, retention and support in electrical installations up to 1 000 V a.c. and/or 1 500 V d.c. and which, if declared, provide resistance to electromechanical forces. This standard does not apply to cable glands, cable ties or devices that rely on the mounting surface for cable retention or devices covered by other standards.

Certain cable cleats may be suitable for use in association with cables operating outside the above-mentioned voltages; regard shall then be taken of extra requirements which may be necessary.

2 Normative references

This European Standard incorporates, by dated or undated references, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies (including amendments).

Publication	Year	Title
EN 60695-2-2	1994	Fire Hazard testing - Part 2: Test methods - Section 2: Needle-flame test (IEC 60695-2-2:1991)
EN 60909-0	2001	Short-circuit currents in three-phase a.c. systems - Part 0: Calculation of currents (IEC 60909-0:2001)
EN ISO 4287	1998	Geometrical product specification (GPS) - Surface texture: Profile method - Terms, definitions and surface texture parameters (ISO 4287:1997)
EN ISO 868	1997	Plastics and ebonite - Determination of indentation hardness by means of a durometer (Shore hardness) (ISO 868:1985)
IEC 61363-1	1998	Electrical installations of ships and mobile fixed offshore units - Part 1: Procedures for calculating short-circuit currents in three phase a.c.

3 Definitions

For the purpose of this European Standard, the following definitions apply:

3.1
cable cleat
a device designed to provide in itself, or with the system component(s) it is designed to fit to, retention and support of cables and installed at intervals along the length of the cable. A cable cleat is provided with a means of attachment to a mounting surface but does not rely on the mounting surface for the retention of the cables

3.2
intermediate restraint
a cable retaining device, which is designed to be used with cable cleats, that is not attached to the support structure and that holds the cables together

3.3
metallic cable cleat
a cable cleat consisting of metal only

3.4
non-metallic cable cleat
a cable cleat consisting of non-metallic material only

3.5
composite cable cleat
a cable cleat comprising metallic and non-metallic materials

3.6
non-flame propagating cable cleat
a cable cleat which may or may not ignite as a result of an applied flame but does not propagate fire

3.7
metallic intermediate restraint
an intermediate restraint consisting of metal only

3.8
non-metallic intermediate restraint
an intermediate restraint consisting of non-metallic material only

3.9
composite intermediate restraint
an intermediate restraint comprising metallic and non-metallic materials

3.10
non-flame propagating intermediate restraint
an intermediate restraint which may or may not ignite as a result of an applied flame but does not propagate fire

3.11
electrical fault
a circuit condition in which the current flows through an abnormal or unintended path. This may result from an insulation failure or the bridging of insulation. Conventionally, the impedance between live conductors or between live conductors and extraneous conductive parts at the fault position is considered negligible

3.12
fault current
a current resulting from an electrical fault

3.13
short-circuit current
an overcurrent resulting from an electrical fault of negligible impedance between live conductors or between a live conductor and an earth, having a difference in potential under normal operating conditions

3.14
peak short-circuit current i_p
the maximum possible instantaneous value of the short-circuit current (see Annex B)

3.15
initial RMS symmetrical short-circuit current I''_k
the RMS value of the a.c. symmetrical component of a short-circuit current, applicable at the instant of the short-circuit if the impedance remains at zero-time value (see Annex B)

3.16
decaying (aperiodic) component of short-circuit current $i_{d.c.}$
mean value between the top and bottom envelope of a short-circuit current decaying from an initial value to zero (see Annex B)

3.17
steady-state short-circuit current I_k
the RMS value of the short circuit current which remains after the decay of the transient phenomena (see Annex B)

3.18
trefoil formation
a symmetrical triangular arrangement of three cables which may be in contact with each other (see Figure 5)

3.19
side-by-side formation
an arrangement in which the cables are laid in a flat formation. The cables may be in contact (see Figure 6)

3.20
bundled formation
a group of four or more cables held together

3.21
electromechanical forces
the induced forces acting on current carrying conductors

3.22
retention
the ability of a cable cleat to limit the axial and lateral movement of the cable

3.23
environmental influences
the effect of corrosive or polluting substances or solar radiation, etc.

4 General requirements

4.1 Cable cleats shall be so designed and constructed that safe handling is ensured and that safe retention and support for the cable(s) is provided.

4.2 Intermediate restraints shall be so designed and constructed that safe handling is ensured and that a safe means is provided for holding cables together.

5 General notes on tests

5.1 Tests according to this standard are type tests. Where there are a number of sizes in the range, the manufacturer or responsible vendor may define classes (products of the same declared ability but varying dimensionally) and in this case, only the most critical size in each class shall be tested.

5.2 Unless otherwise specified, all tests shall be carried out on new samples with the cable cleats and intermediate restraints where used, assembled and installed according to the manufacturer's or responsible vendor's instructions.

Tests on non-metallic and composite cable cleats and intermediate restraints where used shall not commence earlier than 168 hours after manufacture.

5.3 Unless otherwise specified, the tests shall be carried out at an ambient temperature of (25 ± 5) °C and a relative humidity between 40 % and 60 %.

5.4 Unless otherwise specified, three samples are subjected to the tests and the requirements are satisfied if all the tests are met. If only one of the samples does not satisfy a test due to a manufacturing fault, then that test and any preceding one which may have influenced the results of the test shall be repeated and also the tests which follow shall be made in the same required sequence on another full set of samples, all of which shall comply with the requirements.

NOTE The applicant, when submitting the first set of samples, may also submit an additional set of samples which may be necessary should one sample fail. The test house shall then, without further request, test the additional set of samples and shall only reject if a further failure occurs. If the additional set of samples is not submitted at the same time, a failure of one sample shall entail rejection.

5.5 When toxic or hazardous processes are used, due regard shall be taken of the safety of persons within the test area.

6 Classification

6.1 According to material

6.1.1 Metallic

6.1.2 Non-metallic

6.1.3 Composite

6.2 According to resistance to impact

6.2.1 Very light

6.2.2 Light

6.2.3 Medium

6.2.4 Heavy

6.2.5 Very heavy

6.3 According to resistance to electromechanical forces

6.3.1 Non-resistant to electromechanical forces

6.3.2 Resistant to electromechanical forces

The manufacturer or responsible vendor shall declare the category of the cable cleat as follows:

6.3.2.1 capable of withstanding one short-circuit

6.3.2.2 capable of withstanding two short-circuits without any adjustment of the cleats and/or intermediate restraints between short-circuits

The manufacturer or responsible vendor shall also declare

– the peak short-circuit current and the initial RMS symmetrical short-circuit current,
– the arrangement showing the maximum spacing between cleats and intermediate restraints, where used.

6.4 According to temperature

Table 1 - Temperature for permanent application

A. Maximum temperature °C
+40
+60
+85
+105
+120
+150
+250
B. Minimum temperature °C
-5
-15
-25
-40
-60

NOTE For temperature values above 250 °C and below -60 °C, the manufacturer or responsible vendor may declare temperatures outside the values tabulated above.

6.5 According to flame application time

This is given in Table 2 for non-metallic and composite cable cleats and non-metallic and composite intermediate restraints.

Table 2 - Flame application time

Application time s
5
10
20
30
60
120

6.6 According to response to environmental influences

Under consideration.

7 Marking and documentation

7.1 Marking

Each cable cleat and intermediate restraint shall be marked with

- the manufacturer's or responsible vendor's name or logo or trademark,
- product identification or type.

Where it is not possible to make these marks directly onto the product, then the marks shall be on the smallest supplied package.

7.2 Durability and legibility

Marking on the product shall be durable and easily legible.

Compliance is checked by inspection and by rubbing the marking by hand for 15 seconds with a piece of cloth soaked with water and again for 15 seconds with a piece of cloth soaked with petroleum spirit.

Marking made by moulding, pressing or engraving is not subjected to this test.

After the test, the marking shall be legible.

NOTE 1 Petroleum spirit is defined as the aliphatic solvent hexane with a content of aromatics of maximum 0,1 % by volume, a kauri-butanol value of 29, initial boiling point of 65 °C, a dry point of 69 °C and a specific gravity of 0,68 kg/l.

NOTE 2 Marking may be applied, for example, by moulding, pressing, engraving, printing, adhesive labels, etc…

7.3 Documentation

The manufacturer or responsible vendor shall provide in his literature

- the classifications according to Clause 6,
- the maximum and minimum cable or bundle diameters,
- the method of assembly and installation (where appropriate),
- the maximum lateral load,
- the maximum axial movement load.

Compliance is checked by inspection.

8 Construction

The surface of the cable cleat and intermediate restraint, where used, shall be free from burrs, flash and similar inconsistencies which are likely to damage the cables or inflict injury to the installer or user.

Compliance is checked by visual and manual inspection.

9 Mechanical properties

9.1 Requirements

9.1.1 The cable cleat shall be

– capable of accepting the range of cable or cable bundle diameter declared by the manufacturer or responsible vendor.

  Compliance is checked by measurement and by visual and manual inspection.

– capable of supporting the lateral load at the maximum declared temperature.

  Compliance is checked by the test according to 9.2.

– resistant to impact at the minimum declared temperature.

  Compliance is checked by the test according to 9.3.

– resistant to electromechanical forces, where declared in 6.3.2.

  Compliance is checked by the test in 9.4.

– resistant to axial movement of the cable.

  Compliance is checked by the test in 9.5.

9.1.2 The intermediate restraint if used shall be

– capable of accepting the range of cable or bundle diameter declared by the manufacturer or responsible vendor.

  Compliance is checked by measurement and by visual and manual inspection.

– resistant to impact at the minimum declared temperature.

  Compliance is checked by the test according to 9.3.

– resistant to electromechanical forces, where declared in 6.3.2.

  Compliance is checked by the test in 9.4.

9.2 Lateral load test

The cable cleat is mounted on the test rig as shown in Figure 1. For the purpose of applying the load, an unsleeved mandrel of circular (example shown in Figure 2) or other appropriate cross-section is positioned within the cable-carrying aperture. Care is taken to ensure that the load acts through the centre line of the cable-carrying aperture. The mandrel size is the minimum for which the cleat is designed.

The test load as declared by the manufacturer or responsible vendor is applied in the direction according to the manufacturer's recommended application(s), if any.

For metallic cable cleats, the full test load is applied for a period of (5^{+1}_{0}) minutes.

For composite and non-metallic cable cleats, the full test load is applied for a period of (60^{+5}_{0}) minutes.

All tests are carried out after the oven temperature has reached and maintained the declared maximum temperature from Table 1 with a tolerance of $(^{+5}_{0})$ °C. The load is held without break for the prescribed period at the declared temperature. Any movement of the mandrel shall be limited to less than 50 % of the mandrel diameter.

9.3 Impact test

The impact test is carried out using a fall hammer as shown in Figure 3.

Before the test, the samples are assembled onto a test mandrel as defined in Figure 8, having a diameter equivalent to the maximum stated cable diameter for which the cable cleat is designed and mounted on a rigid support.

For cable cleats and intermediate restraints taking more than one cable, the appropriate number of mandrels is used.

For metallic cable cleats and intermediate restraints, the test is carried out at ambient temperature.

For composite and non-metallic cable cleats and intermediate restraints, the samples are conditioned at the declared lowest temperature according to Table 1 with a tolerance of $\left({}^{+3}_{0}\right)$ °C for a period of $\left(60^{+5}_{0}\right)$ minutes. The impact is applied within a period of $\left(10^{0}_{-2}\right)$ seconds after removal from the refrigerator.

Each sample is placed in position on the steel base as shown in Figure 3. The energy value of the hammer is as declared in Table 3.

The impact is applied at the weakest point of the cable cleat or intermediate restraint and the direction of impact is radial to the centre of the mandrel.

After the test, the samples shall show no signs of disintegration nor shall there be any cracks or damage, visible to normal or corrected vision without magnification, that are likely to impair normal use.

Table 3 - Minimum impact test values

Classification	Minimum impact energy J	Equivalent mass kg	Height mm (± 1%)
Very light	0,5	0,25	200
Light	1,0	0,25	400
Medium	2,0	0,5	400
Heavy	5,0	1,7	300
Very heavy	20,0	6,7	300

9.4 Test for resistance to electromechanical force

A short-circuit test is carried out as follows, using the manufacturer’s or responsible vendor's declared peak short-circuit current and initial RMS symmetrical short-circuit current values. Typical values are shown in Table 4.

The test is carried out at an ambient temperature of (20 ± 10) °C using an unarmoured single core 600 V / 1 000 V stranded copper conductor cable having an outside diameter as detailed in Table 4. The test is carried out on the declared arrangement at the declared short-circuit level. The cables are mounted according to the layout shown in Figure 4.

The arrangement of the cables is as shown in Figure 5 or Figure 6 or any other configuration as declared by the manufacturer or responsible vendor, with one end being connected to a three phase supply and the other end to a short-circuiting busbar, with all three phases being connected. The cable run is fixed to a rigid structure. The cable is restrained at a minimum of 5 equally spaced positions along the cable run with at least 4 cable cleats.

Care is taken to ensure the cross-sectional area of the cable is adequate for the magnitude and duration of the test current. Table 4 gives recommended maximum sizes for unarmoured single core stranded copper conductors, XLPE (Cross Linked Polyethylene) insulation, PVC (Polyvinyl Chloride) oversheath, 600 V / 1 000 V cable. Other cables may be used.

The manufacturer's or responsible vendor's catalogue references of the cable cleat and intermediate restraint (where used) and the arrangement details showing the spacing used in the test shall be recorded.

If the test station has to undertake a calibration test, action is taken to ensure that the test installation is not affected.

The test set-up is subjected to a three phase short-circuit of duration of not less than 0,1 seconds. The duration of the test and the ambient temperature is recorded.

For cable cleats and intermediate restraint(s), if used, as classified in 6.3.2.2, the test is repeated. In addition, a voltage withstand test is performed by applying a test voltage of 2,8 kV d.c. between the cable cores and the mounting frame.

NOTE 1 Care must be taken to ensure that there is adequate restraint for the cables at each end of the cable run to be tested.

NOTE 2 Any screens on individual cables shall be isolated from
- each other,
- the busbar,
- the earthing system.

NOTE 3 Annex B may be used to calculate the theoretical forces that may be created during short-circuits in order to plan testing.

For cable cleats and intermediate restraints classified in 6.3.2.1

– there shall be no failure that will affect the intended function of holding the cables in place.

For cable cleats and intermediate restraints classified in 6.3.2.2

– the cable cleats and, if used, the intermediate restraints shall be intact with no missing parts (minor deformation is acceptable),
– the cable cleats and, if used, the intermediate restraints shall be reusable,
– there shall be no cuts or damage to the outer sheath of the cable caused by the cable cleat or by the intermediate restraint, if used,
– the cables shall meet the requirements of the voltage withstand test.

Table 4 - Examples of typical peak short-circuit current, initial RMS symmetrical short-circuit current and recommended cables

Peak short-circuit current kA	**Initial RMS symmetrical short-circuit current** kA	**Maximum conductor area** mm²	**Nominal cable diameter range** mm
70	33	185	25,5 – 28,5
105	50	240	29,0 – 32,0
130	60	300	31,0 – 34,5
NOTE The initial RMS symmetrical short-circuit current shown in the table is the minimum value for the corresponding peak short-circuit current.			

9.5 Axial movement test

The test is carried out using a mandrel with an overall diameter equivalent to the minimum declared cable diameter for which the cable cleat is designed. Test mandrels shall consist of a metallic section with an elastomeric sleeving having a hardness of 65 Shore D ± 15 points in accordance with EN ISO 868, a surface roughness less than or equal to 7 µm R_a in accordance with EN ISO 4287 and a minimum sleeve thickness as shown in Figure 8. The complete test mandrel shall have a diametrical tolerance of ± 0,2 mm for mandrels up to and including 16 mm diameter and of ± 0,3 mm for larger diameters. In the case of non-circular cable, a profile is to be used simulating the outer dimension, as declared by the manufacturer or responsible vendor.

The cable cleat is mounted on a rigid support and assembled in the test rig as shown in Figure 7. The declared load is applied, without jerking, and then held for (5_{0}^{+1}) minutes.

After the test, the displacement of the mandrel with respect to the cable cleat shall not be more than 5 mm.

10 Contribution to fire

Non-metallic and composite cable cleats and intermediate restraints shall have adequate resistance to flame application time as declared according to Table 2.

Compliance is checked by the following test.

The sample shall be installed on a solid steel mandrel of a diameter within the declared values for the cable cleat or intermediate restraint. Using an arrangement as shown in Figure 9, the sample shall be submitted to the needle-flame test as specified in EN 60695-2-2 with the following additional information:

– the flame shall be applied to the face of the sample;
– the underlying layer shall consist of three layers of tissue paper; and
– there shall be a single application of the flame.

The sample shall be deemed to have passed the test if

– 30 seconds after the test flame is removed, there is no flaming of the sample, and
– there is no ignition of the tissue paper.

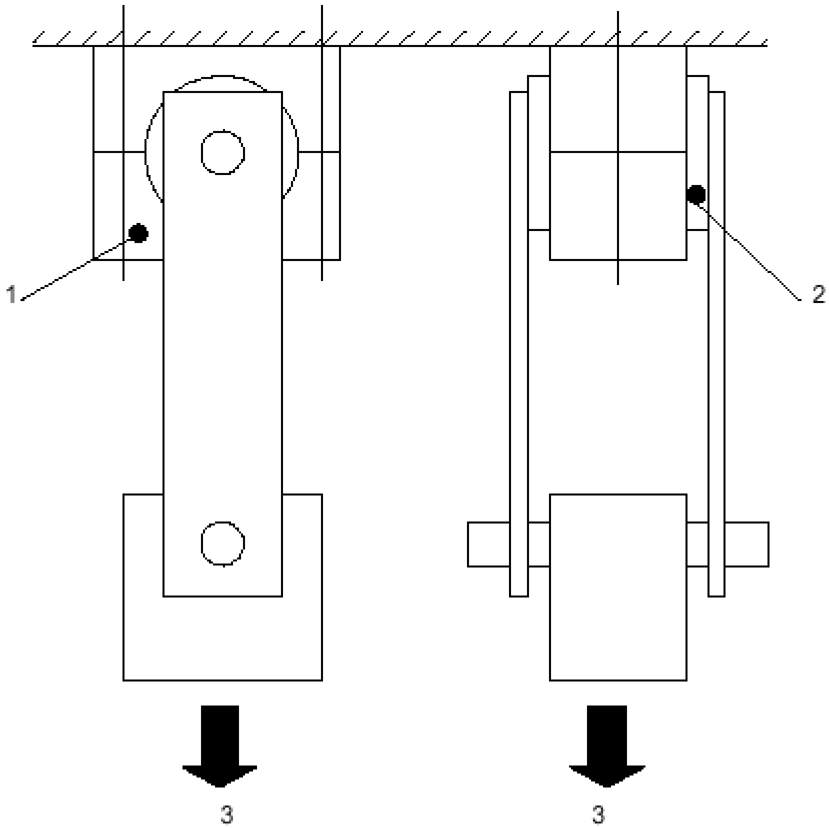
11 Environmental influences

Under consideration.

12 Electromagnetic compatibility

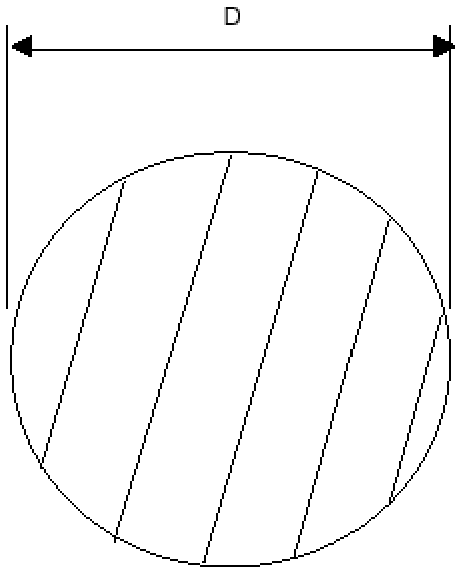
Products covered by this standard are, in normal use, passive in respect of electromagnetic influences (emission and immunity).

NOTE When products covered by this standard are installed as part of a wiring installation, the installation may emit or may be influenced by electromagnetic signals. The degree of influence will depend on the nature of the installation within its operating environment and the apparatus connected by the wiring.



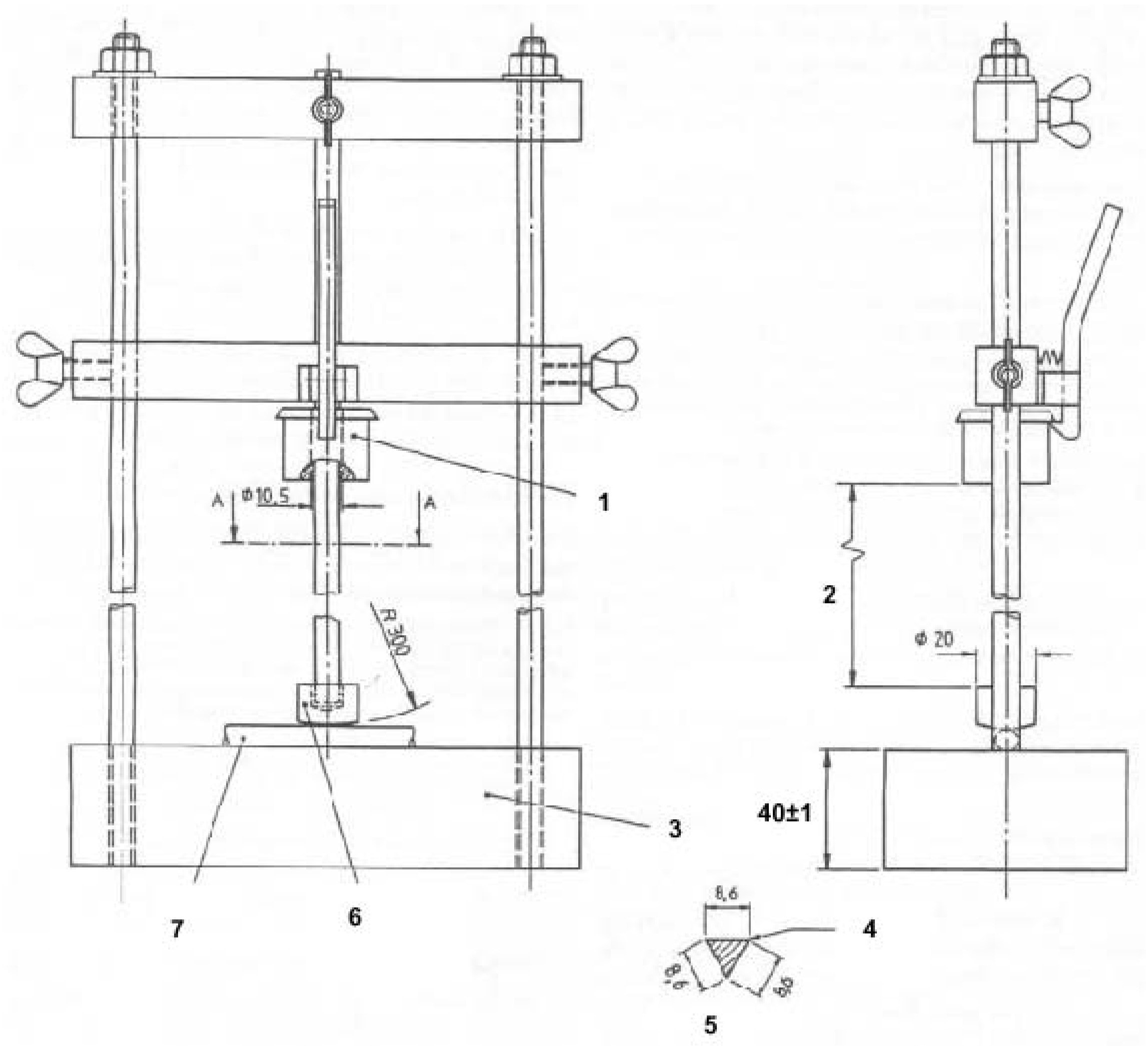
Key
1 Cleat
2 Mandrel
3 Load

Figure 1 - Typical arrangement for lateral load test



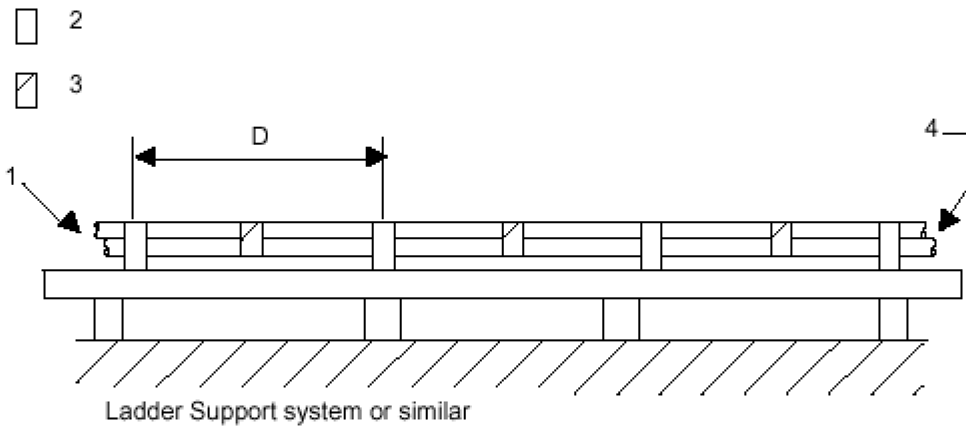
Key
D Minimum cable diameter

Figure 2 - Unsleeved mandrel



Key
1 Hammer
2 Fall height (see Table 3)
3 Steel base plate (minimum 10 kg)
4 Slightly rounded edges
5 Section A—A
6 Steel intermediate piece 100 g
7 Sample

Figure 3 - Typical arrangement for impact test



Key

1 Supply end
2 Cable cleats
3 Intermediate restraints (if used)
4 Short-circuit busbar end
D Distance between cable cleats on straight horizontal cable runs

Figure 4 - Typical arrangement for short-circuit test

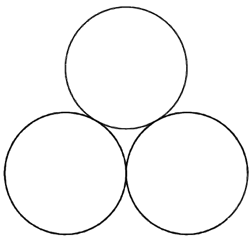


Figure 5 - Typical arrangement of three cables in trefoil formation

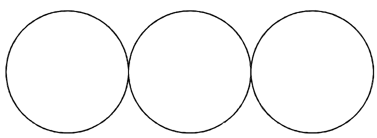
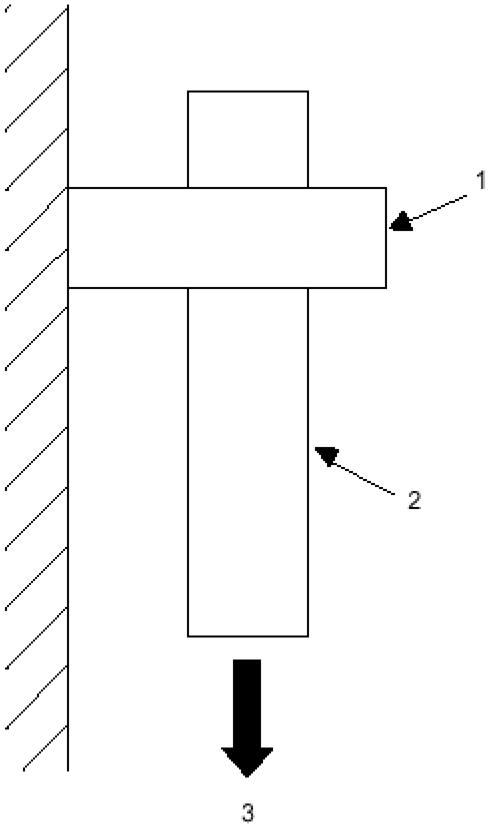
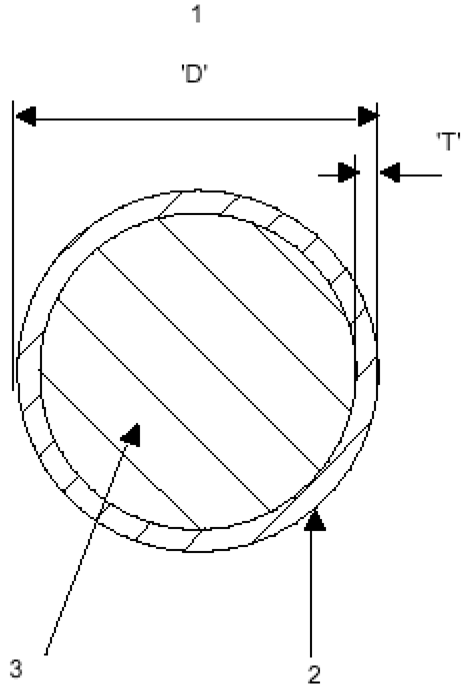


Figure 6 - Typical arrangement of cables in side-by-side formation



Key
1 Cleat
2 Mandrel
3 Direction of load

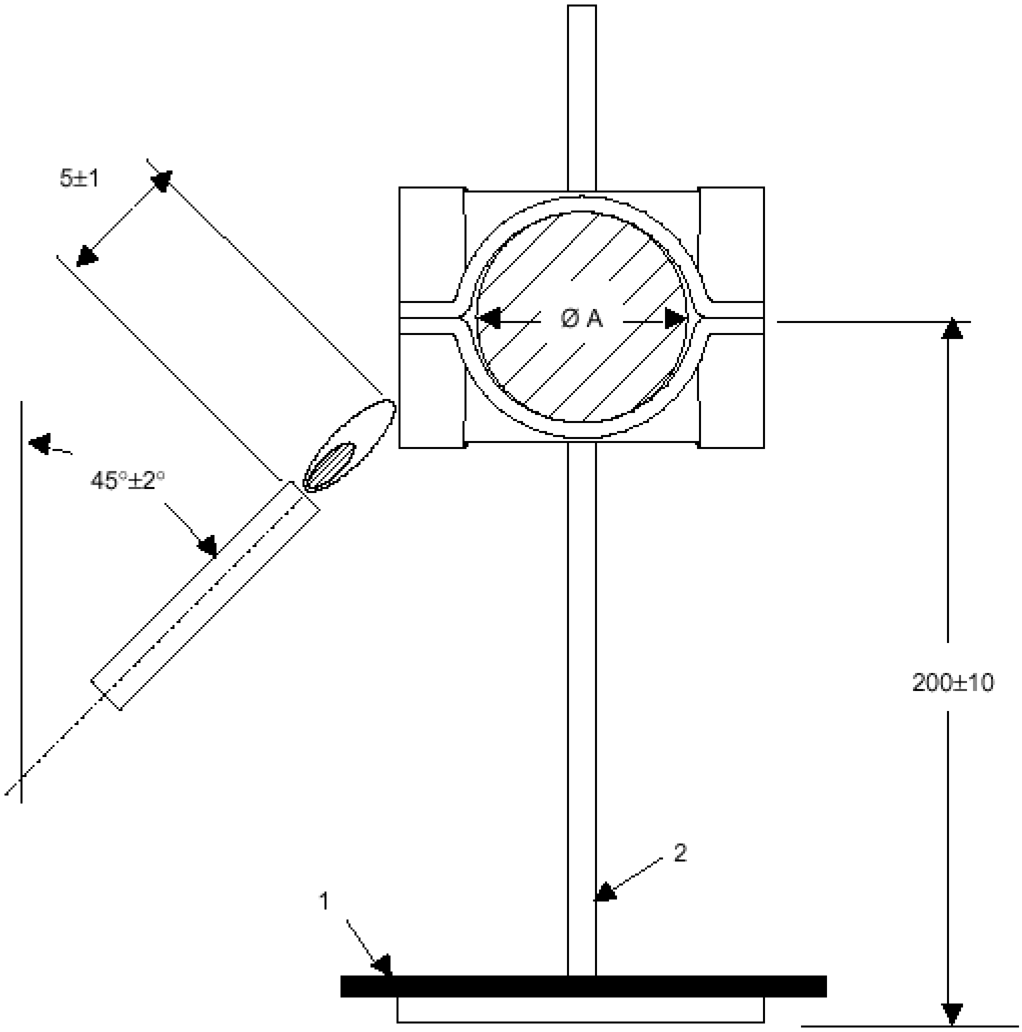
Figure 7 - Typical arrangement for axial movement test



Key
1 Section through mandrel
2 Elastomeric sleeve
3 Solid core
D Mandrel diameter
T Sleeving thickness

NOTE The relationship of diameter 'D' to thickness 'T' is
0 mm < D ≤ 4 mm : a non-metallic mandrel can be used,
4 mm < D ≤ 8 mm : T = 1 mm (minimum),
8 mm < D : T = 2 mm (minimum).

Figure 8 - Details of mandrel



Key
1 Tissue paper
2 Stand

Figure 9 - Typical arrangement of the needle-flame test

Annex A
(informative)

Examples of cable cleats

Figure A.1

Figure A.2

Figure A.3

Figure A.4

Figure A.5

Figure A.6

Figure A.7

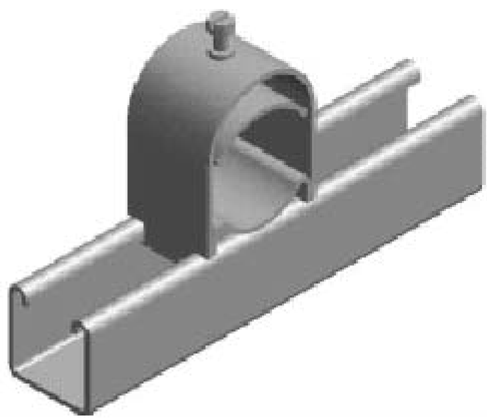


Figure A.8

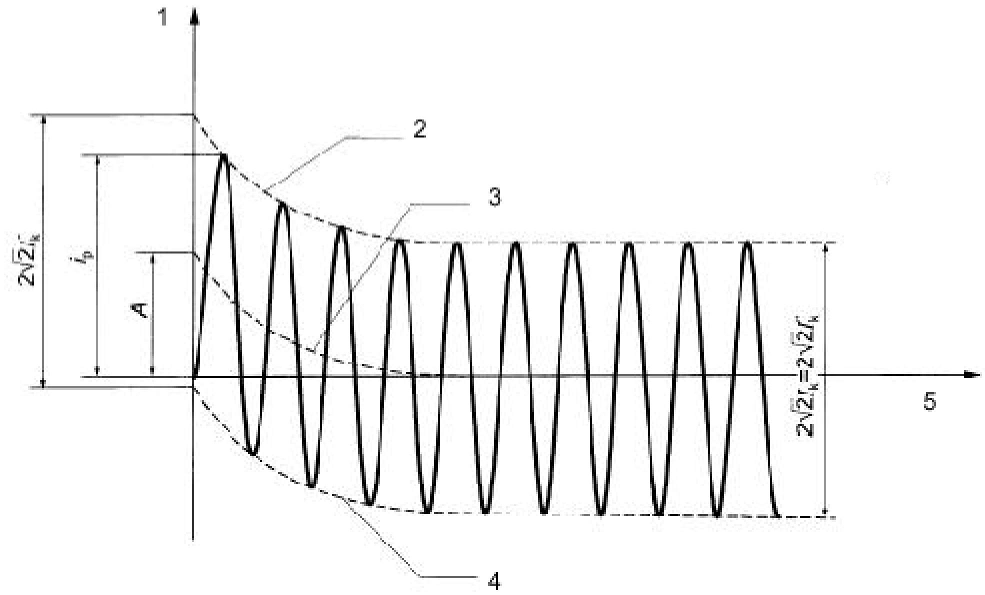
Annex B
(informative)

Calculation of forces caused by short-circuit currents

B.1 Characteristics

Recommendations for the calculation of short-circuit currents are given in EN 60909 and IEC 61363-1. The latter covers ships and offshore units. The information below is based on EN 60909-0.

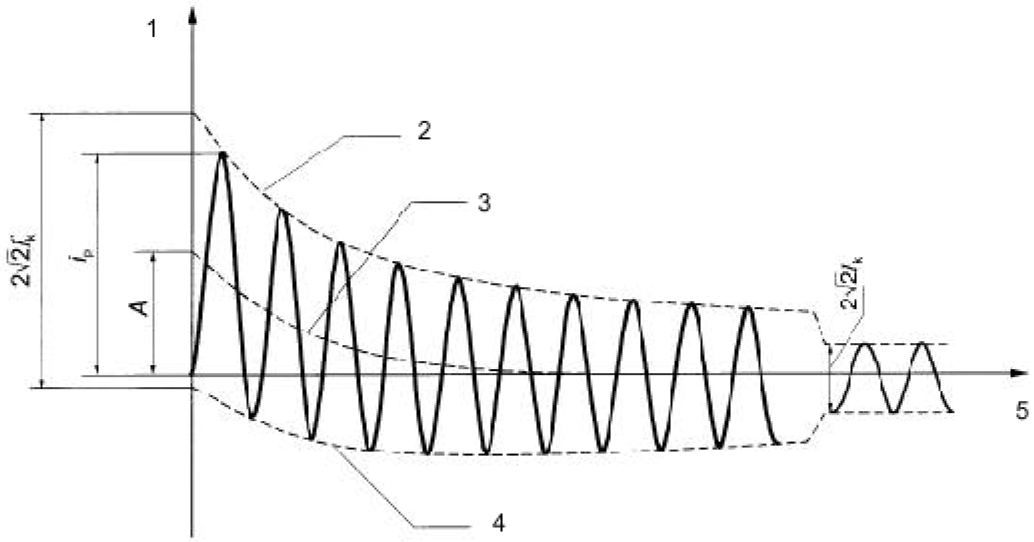
The characteristics of the current during a short-circuit depend on a number of factors, including the electrical separation from the generator. Figure B.1 shows a current vs. time characteristic typical of a far-from-generator short-circuit. The a.c. component in this case has a constant amplitude ($I''_k = I_k$) and is superimposed on a decaying d.c. component, $i_{d.c.}$ This falls from an initial value, A, to zero.



Key
1 Current
2 Top envelope
3 Decaying d.c. component, $i_{d.c.}$ of the short-circuit current
4 Bottom envelope
5 Time
A Initial value of the d.c. component, $i_{d.c.}$ of the short-circuit current

Figure B.1 – Short-circuit current of a far-from-generator short circuit with constant a.c. component

For near-to-generator short-circuits, the a.c. component has a decaying amplitude ($I''_k > I_k$) and is also superimposed on a decaying d.c. component, $i_{d.c.}$ that falls from an initial value, A, to zero. Figure B.2 shows a typical current vs. time characteristic for a near-to-generator short-circuit.



Key
1 Current
2 Top envelope
3 Decaying d.c. component, $i_{d.c.}$ of the short-circuit current
4 Bottom envelope
5 Time
A Initial value of the d.c. component, $i_{d.c.}$ of the short-circuit current

Figure B.2 – Short-circuit current of a near-to-generator short circuit with decaying a.c. component

B.2 Specification of the test current

A complete specification of short-circuit currents should give the currents as a function of time at the short-circuit location from the initiation of the short-circuit up to its end. In most practical cases, this is not necessary. It is usually sufficient to know the peak current, i_p, and the values of the initial RMS symmetrical, I''_k, and steady state, I_k, currents.

In order to specify the current used in a short-circuit test the following are quoted:

– the peak current, i_p
– the initial RMS symmetrical current, I''_k
– the steady state current, I_k
– the short-circuit duration, t

B.3 Calculation of the mechanical forces between conductors

The electromagnetic force acting on a conductor is determined by the current in the conductor and the magnetic field from the neighbouring conductors. In cable installations, the distances between the cables are normally small and hence the forces may be considerable.

In the case of two parallel conductors, the electromagnetic force on a conductor can be derived from Equation 1:

$$F(t) = B(t) \cdot i(t) \cdot l \qquad (1)$$

- l - length
- $F(t)$ - the momentary electromagnetic force on a conductor
- $B(t)$ - the momentary magnetic field from the neighbouring conductor
- $i(t)$ - the momentary current in the neighbouring conductor

If the d.c. component of the fault current is disregarded, the momentary force has a sinusoidal variation with a frequency twice the frequency of the currents (Equation 1). The d.c. component gives a decaying force-component with a frequency the same as the system frequency.

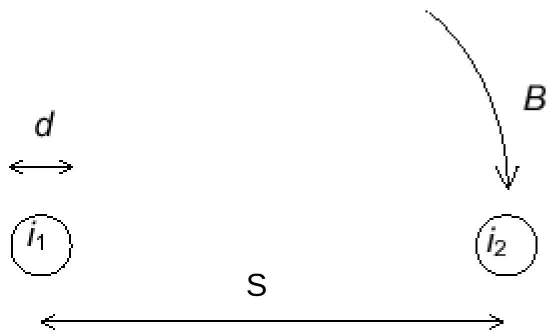


Figure B.3 - Two parallel conductors

For the two parallel conductors in Figure B.3., the magnetic field from current i_1, at the location of the other conductor is

$$B = \mu_0 \cdot H = \mu_0 \cdot i_1 / 2 \cdot \pi \cdot S \qquad (2)$$

where $\mu_o = 4 \cdot \pi \cdot 10^{-7}$ (H/m)

and the mechanical force is:

$$F = i_2 \times B = i_2 \cdot \mu_0 \cdot i_1 / 2 \cdot \pi \cdot S \qquad (3)$$

This equation is usually written as:

$$F_s = 0{,}2 \cdot i_1 \cdot i_2 / S \qquad (4)$$

In this equation, the force is given in N/m, *i* in kA and *S* in metres. The evaluation of Equation 4 requires $S >> d$ but gives an acceptable accuracy when the current distribution is uniform (or symmetrical) within the conductors.

The vector Equation 3 confirms that two parallel conductors are repelled if the two currents have a difference in phase angle of 180^o and that the force is directed towards the other conductor for currents that have the same phase angle.

In a three phase system, the magnetic field in Equation 2 is the resulting momentary vector value from the other two phases.

For a three phase short-circuit with the conductors in flat configuration, the forces on the two outer conductors are always directed outwards from the central conductor. The force on the central conductor is oscillating. The maximum force on the outer conductors in flat formation can be calculated by:

$$F_{fo} = 0{,}16 \cdot i_p^{\ 2} / S \qquad (5)$$

The maximum force on the middle conductor in flat formation can be calculated by:

$$F_{fm} = 0{,}17 \cdot i_p^{\ 2} / S \qquad (6)$$

For a three phase short-circuit with the cables in a trefoil configuration the maximum force on the conductor is:

$$F_t = 0{,}17 \cdot i_p^{\ 2} / S \qquad (7)$$

where

- F_s - maximum force on the cable conductor in flat formation for a single phase short-circuit [N/m],
- F_{fo} - maximum force on the outer cable conductors in flat formation for a three phase short- circuit [N/m],
- F_{fm} - maximum force on the centre cable conductor in flat formation for a three phase short-circuit [N/m],
- F_t - maximum force on the cable conductor in a trefoil configuration for a three phase short-circuit [N/m],
- i_p - the peak short-circuit current [kA],
- d - external diameter of the conductor [m],
- S - centre to centre distance between two neighbouring conductors [m].

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