

Compression and mechanical connectors for power cables for rated voltages up to 36 kV ($U_m = 42$ kV) —

Part 1: Test methods and requirements

The European Standard EN 61238-1:2003 has the status of a
British Standard

ICS 29.060.20

National foreword

This British Standard is the official English language version of EN 61238-1:2003. It was derived by CENELEC from IEC 61238-1:2003. It supersedes BS 4579-1:1970 and BS 4579-3:1976 which are withdrawn.

The CENELEC common modifications have been implemented at the appropriate places in the text and are indicated by tags (e.g. [C] [CI]).

The UK participation in its preparation was entrusted by Technical Committee GEL/20, Electric cables, to Subcommittee GEL/20/11, Cable accessories, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible 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.

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

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**Compression and mechanical connectors for power cables
for rated voltages up to 36 kV ($U_m = 42$ kV)
Part 1: Test methods and requirements
(IEC 61238-1:2003, modified)**

Raccords sertis et à serrage mécanique
pour câbles d'énergie de tensions
assignées inférieures ou égales
à 36 kV ($U_m = 42$ kV)
Partie 1: Méthodes et prescriptions
d'essais
(CEI 61238-1:2003, modifiée)

Pressverbinder und Schraubverbinder
für Starkstromkabel für Nennspannungen
bis einschließlich 36 kV ($U_m = 42$ kV)
Teil 1: Prüfverfahren und Anforderungen
(IEC 61238-1:2003, modifiziert)

This European Standard was approved by CENELEC on 2003-06-01. 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.

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

CENELEC

European Committee for Electrotechnical Standardization
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Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 20/599/FDIS, future edition 2 of IEC 61238-1, prepared by IEC TC 20, Electric cables, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61238-1 on 2003-06-01.

A draft amendment, prepared by the Technical Committee CENELEC TC 20, Electric cables, was submitted to the formal vote and was approved by CENELEC for inclusion into EN 61238-1 on 2003-06-01.

The following dates were fixed:

- latest date by which the EN has to be implemented
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national standard or by endorsement (dop) 2004-03-01
- latest date by which the national standards conflicting
with the EN have to be withdrawn (dow) 2006-06-01

Annexes designated "normative" are part of the body of the standard.

Annexes designated "informative" are given for information only.

In this standard, annexes A, B, E and ZA are normative and annexes C, D, F, G and H are informative.

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61238-1:2003 was approved by CENELEC as a European Standard with agreed common modifications.

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INTRODUCTION

This part of IEC 61238 deals with type tests for compression and mechanical connectors for use on copper or aluminium conductors of power cables for rated voltages up to $\sqrt{3}$ 36 kV ($U_m = 42$ kV). $\square$ When a design of connector meets the requirements of this standard, then it is expected that in service:

- a) the resistance of the connection will remain stable;
- b) the temperature of the connector will be of the same order or less than that of the conductor;
- c) the mechanical strength will be fit for the purpose;
- d) if the intended use demands it, application of short-circuit currents will not affect a) and b).

It should be stressed that, although the electrical and mechanical tests specified in this standard are to prove the suitability of connectors for most operating conditions, they do not necessarily apply to situations where a connector may be raised to a high temperature by virtue of connection to highly rated plant, or where the connector is subjected to excessive mechanical vibration or shock or to corrosive conditions. In these instances, the tests in this standard may need to be supplemented by special tests agreed between supplier and purchaser.

COMPRESSION AND MECHANICAL CONNECTORS FOR POWER CABLES FOR RATED VOLTAGES UP TO IEC 36 kV ($U_m = 42 \text{ kV}$) IEC –

Part 1: Test methods and requirements

1 Scope and object

This part of IEC 61238 applies to compression and mechanical connectors for power cables for rated voltages up to IEC 36 kV ($U_m = 42 \text{ kV}$) IEC , e.g. buried cables or cables installed in buildings, having

- a) conductors complying with IEC 60228 and IEC 60228A with cross-sectional areas 10 mm^2 and greater for copper and 16 mm^2 and greater for aluminium,
- b) a maximum continuous conductor temperature not exceeding 90°C .

This standard is not applicable to connectors for overhead conductors, which are designed for special mechanical requirements, or to separable connectors with a sliding contact or multi-core connectors (i.e. ring connectors).

Although it is not possible to define precisely the service conditions for all applications, two broad classes of connectors have been identified.

Class A

These are connectors intended for electricity distribution or industrial networks in which they can be subjected to short-circuits of relatively high intensity and duration. As a consequence, Class A connectors are suitable for the majority of applications.

Class B

These are connectors for networks in which overloads or short-circuits are rapidly cleared by the installed protective devices, e.g. fast-acting fuses.

Depending on the application, the connectors are subjected to the following tests:

Class A: heat cycle and short-circuit tests;

Class B: heat cycle tests only.

The object of this standard is to define the type test methods and requirements, which apply to compression and mechanical connectors for power cables with copper or aluminium conductors.

Formerly, approval for such products has been achieved on the basis of national standards and specifications and/or the demonstration of satisfactory service performance. The publication of this IEC standard does not invalidate existing approvals. However, products approved according to these earlier standards or specifications cannot claim approval to this IEC standard unless specifically tested to it.

After they have been made, these tests need not be repeated unless changes are made in the connector material, design or manufacturing process which might affect the performance characteristics.

2 Normative references

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

IEC 60050(461):1984, *International Electrotechnical Vocabulary (IEV) – Chapter 461: Electric cables*
Amendment 1 (1993)

IEC 60228:1978, *Conductors of insulated cables*

IEC 60228A:1982, First supplement – *Conductors of insulated cables – Guide to the dimensional limits of circular conductors*

IEC 60493-1:1974, *Guide for the statistical analysis of ageing test data – Part 1: Methods based on mean values of normally distributed test results*

3 Definitions

For the purposes of part of IEC 61238, the following definitions apply. Where possible, the definitions used are in accordance with IEC 60050(461).

3.1

connector (of cables)

metallic device for connecting a conductor to an equipment terminal or for connecting two or more conductors to each other

[IEV 461-17-03, modified]

3.2

through connector

metallic device for connecting two consecutive lengths of conductor

[IEV 461-17-04]

3.3

branch connector

metallic device for connecting a branch conductor to a main conductor at an intermediate point on the latter

[IEV 461-17-05]

3.4

(terminal) lug

metallic device to connect a cable conductor to other electrical equipment

[IEV 461-17-01]

3.5

palm (of terminal lug)

part of a terminal lug used to make the connection to electrical equipment

[IEV 461-17-07]

3.6

barrel (of terminal lug, of connector, etc.)

part of a device into which the conductor to be connected is introduced

[IEV 461-17-06]

3.7

reference conductor

length of unjointed bare conductor or conductor with the insulation removed, which is included in the test loop and which enables the reference temperature and reference resistance to be determined

3.8

equalizer

arrangement used in the test loop to ensure a point of equipotential in a stranded conductor

3.9

compression jointing

method of securing a connector to a conductor by using a special tool to produce permanent deformation of the connector and the conductor

3.10

mechanical jointing

method of securing a connector to a conductor, for example by means of a bolt or screw acting on the latter or by alternative methods

3.11

median connector

connector which during the first heat cycle records the third highest temperature of the six connectors in the test loop

3.12

insulation piercing connector (IPC)

connector in which electrical contact with the conductor is made by metallic protrusions which pierce the insulation of the cable core

[IEV 461-11-08]

NOTE The abbreviation IPC will be used throughout the standard.

4 Symbols

A	nominal cross-sectional area of the conductor
D	change in the resistance factor of the connector
I	direct current flowing through a connection during resistance measurement
I_{rms}	equivalent r.m.s. short-circuit current
I_{N}	alternating current necessary to maintain the reference conductor at its equilibrium temperature
I_{r}	direct current flowing through the reference conductor/conductors during resistance measurement
k	connector resistance factor: ratio of the resistance of a connector to that of the resistance of the equivalent length of the reference conductor
$\ell_{\text{a}}, \ell_{\text{b}}, \ell_{\text{j}}$	lengths of the connector assembly associated with the measurement points after jointing
ℓ_{r}	length of the reference conductor between measurement points
t_1	heating time
t_2	time necessary for the connectors and the reference conductor to cool to a value equal to or less than 35 °C
U	potential difference between measurement points when current I is flowing
U_{r}	potential difference between measuring points on a reference conductor when current I_{r} is flowing
α	temperature coefficient of resistance at 20 °C
β	mean scatter of the connector resistance factors
δ	initial scatter of the connector resistance factors
λ	resistance factor ratio: change in the resistance factor of the connector, relative to its initial resistance factor
θ	temperature of a connector
θ_{max}	maximum temperature recorded on a connector over the total period of test
θ_{R}	temperature of the reference conductor determined in the first heat cycle
θ_{ref}	temperature of the reference conductor at the moment of measuring θ_{max}

NOTE Suffixes may be used to indicate values for the individual connector, see Annex F.

5 General

5.1 Conductor

The following information shall be recorded in the test report:

- conductor material;
- nominal cross-sectional area, dimensions and shape. It is recommended that the actual cross-sectional area should also be given;
- type of conductor, i.e. solid or stranded. In the case of stranded conductors, details of conductor constructions shall be given when known, or can be determined by inspection, e.g:
 - compacted;
 - non-compacted;
 - flexible (Class 5 and 6, according to IEC 60228);
 - number and arrangement of strands;
 - type of plating, if applicable;
 - type of impregnation, water blocking, etc., if applicable;
- approximate indication of hardness, e.g. annealed, half-hard, hard;
- in the case of insulation-piercing connectors, material and thickness of insulation.

5.2 Connectors and tooling

The following information shall be recorded in the test report:

- the assembly technique that is to be used;
- tooling, dies and necessary setting;
- bolts, nuts, washers, torque, etc.;
- preparation of contact surfaces, if applicable;
- type, reference number and any other identification of the connector;
- in the case of insulation piercing connectors, type of insulation and installation temperature.

5.3 Range of approval

In general, tests made on one type of connector/conductor combination apply to that arrangement only. However, to limit the number of tests the following is permitted:

- a connector which can be used on stranded round conductors or on stranded sector-shaped conductors which have been rounded, is approved for both types if satisfactory results are obtained on a compacted round conductor;
- a connector which covers a range of cross-sectional areas shall be approved, if satisfactory results are obtained on the smallest and the largest cross-sectional area (see Note 2 below);
- if a connector is a through connector for two conductors of different cross-sectional areas, shapes, or materials, and if the technique and the connector barrels used have already been tested separately for each cross-sectional area, no additional test is necessary. If not, and if it is required for bimetallic through connectors, additional tests shall be made using the conductor having the highest temperature of the two conductors, as reference conductor;

- if a manufacturer can clearly demonstrate that common and relevant connector design criteria were used for a family of connectors, conformity to this standard is achieved by successfully testing the largest, the smallest and two intermediate connector sizes;

Exception no.1: for a family of connectors consisting of five sizes, only the largest connector, the smallest connector, and one connector of a representative intermediate size need to be tested.

Exception no.2: for a family of connectors consisting of four sizes or less, only the largest connector and the smallest connector need to be tested.

- in the case of range-taking connectors, the maximum and minimum conductor cross-sectional area for the selected connectors shall be tested;
- satisfactory test results on insulation piercing connectors tested on PVC insulation at lower temperatures for heat cycles and for short-circuits shall give approval of such connectors for PVC insulation only;
- satisfactory test results of a connector on dry conductor shall give approval for its use on a conductor of the same type from an impregnated paper insulated cable;
- for connectors where one or both sides are designed for a range of cross-sectional areas, and a common clamping or crimping arrangement serves for the connection of the different cross-sectional areas, then mechanical tests on conductors with the largest and smallest cross-sectional areas shall be carried out according to Clause 7.

NOTE 1 Examples of relevant design criteria include

- compression reduction,
- number of contact screws or crimps,
- force per unit area of contact screw or crimp,
- ratio of amount of material of connector to that of conductor.

NOTE 2 Different types of water blocking may affect the performance.

6 Electrical tests

6.1 Installation

All conductors of the same cross-sectional area in the test loop shall be taken from the same continuous core.

For each series of tests, six connectors shall be fitted in accordance with the manufacturer's instructions, on a bare conductor or on a conductor that has had the insulation removed before assembly, to form a test loop together with the corresponding reference conductor.

For stranded conductors, potential between the strands at measuring points can cause errors in measuring electrical resistance. Equalizers (see Annex A) shall be used to overcome this problem and to ensure uniform current distribution in the reference conductor and between connectors at the equalizer points.

In the case of insulation piercing connectors, the insulation shall be retained on the conductor under the connector and for a distance of at least 100 mm outside the connector. Reference conductor(s) with the insulation retained shall also be included in the test loop. If the connector is to be tested according to Class B, there is no need for bare reference conductors.

The test loop shall be installed in a location where the air is calm. The ambient temperature of the test location shall be between 15 °C and 30 °C.

For assembly of the IPC, the temperature shall be $(23 \pm 3) ^\circ\text{C}$.

In the case of solid conductors, the potential measuring points shall be as close as possible to the connector in order to reduce ℓ_a and ℓ_b close to zero.

The test loop may be of any shape provided that it is arranged in such a way that there is no adverse affect from the floor, walls and ceiling.

To permit the short-circuit tests (Class A connectors only) to be made easily, the loop can be made dismantable. In this case, the technology of the sectioning connections shall be such that they do not influence the measurements, particularly from the point of view of temperature.

Retightening of bolts or screws of the connectors under test is not permitted.

6.1.1 Through connectors and terminal lugs

The test loop is shown in Figure 1, which indicates the dimensions that shall be used.

Where terminal lugs are to be tested, the palms shall be bolted to linking bars in accordance with the manufacturer's instructions. These linking bars shall, at the point of connection, be of the same dimensions and thickness as the palm, and also of the same material.

It may be necessary to adjust the thermal characteristics of the linking bar outside the point of connection, to achieve the temperatures specified in 6.3. As an alternative to linking bars, tests can be made on terminal lugs with palm connected direct to palm. In case of disagreement, the method with linking bars shall be used.

If however it is requested that the terminal lug test includes an evaluation of the performance of the bolted palm when connected to a plant terminal, then linking bar ends, or an intermediate piece, shall be used of a material, size and surface coating agreed between the parties.

6.1.2 Branch connectors

When the branch connector is intended for a branch cross-sectional area equal to the main, or a cross-sectional area immediately above or below the main, it is treated as a through connector between the main and the branch, and the test method for through connectors is applicable. In other cases, the test loop shall be as shown in Figure 2. Where a type of connector makes it necessary for the main conductor to be cut, that part of the connector which acts as a through connector, shall also be tested as for through connectors.

6.2 Measurements

6.2.1 Electrical resistance measurements

Measurements of electrical resistance shall be made at stages throughout the test as specified in 6.3.

These measurements of resistance shall be made under steady temperature conditions of both the test loop and test location. The ambient temperature shall be between 15 °C and 30 °C.

The recommended method is to pass a direct current of up to 10 % of the heat cycling current, through the connectors and the reference conductor, without increasing the temperature and to measure the potential difference between specific potential points. The ratio of potential difference and direct current is the resistance between those points.

NOTE To improve the accuracy of the resistance measurement, it is recommended that the same direct current is used throughout the test programme.

For branch conductors assembled in accordance with Figure 2, the whole of the measuring current shall flow through that part of the connector whose potential difference is being measured. Switches or disconnect points may be provided for this purpose.

Thermoelectric voltages may affect the accuracy of low resistance measurements (of the order of 10 $\mu\Omega$). If this is suspected, two resistance measurements shall be taken with the direct measuring current reversed between readings. The mean of the two readings is then the actual resistance of the sample.

The potential points shall be as indicated in Figure 3, and Annex B, and the various lengths shown shall also be measured to enable the actual connector resistances to be determined. The temperature of connector and reference conductor shall be recorded when resistance measurements are made. For direct comparison, the resistance values shall be corrected to 20 °C. Information on the recommended method is also given in Annex B. Temperature measurements at these locations shall be made during the heat cycling test.

Indirect resistance readings:

- voltage measurements shall have an accuracy within $\pm 0,5$ % or ± 10 μV , whichever is the greater;
- current measurements shall have an accuracy within $\pm 0,5$ % or $\pm 0,1$ A, whichever is the greater.

Direct resistance readings:

Resistance measurements shall have an accuracy within ± 1 % or $\pm 0,5$ $\mu\Omega$, whichever is the greater when the instrument is calibrated against a certified standard resistance.

6.2.2 Temperature measurements

The temperature measurements shall be made at stages throughout the test, as specified in 6.3.

Temperatures of both connectors and reference conductors shall be measured at the points indicated in Figure 3. The recommended method of temperature measurement is to use thermocouples. Temperature readings shall have an accuracy within ± 2 K.

6.3 Heat cycle test

The heat cycling test shall be made with alternating current.

6.3.1 First heat cycle

The object of the first heat cycle is to determine the reference conductor temperature to be used for subsequent cycles and also to identify the median connector.

a) Non-IPC through connectors and terminal lugs

Current is circulated in the test loop, bringing the reference conductor to 120 °C at equilibrium.

Equilibrium is defined as the moment when the reference conductor and the connectors do not vary in temperature by more than ± 2 K for 15 min.

If the temperature of the median connector (see 3.11) is equal to or greater than $100\text{ }^{\circ}\text{C}$, the reference conductor temperature for subsequent heat cycles shall be deemed to be $120\text{ }^{\circ}\text{C}$. If not, then the current shall be increased until the median connector temperature reaches $100\text{ }^{\circ}\text{C}$ at equilibrium, subject to the reference conductor temperature not exceeding $140\text{ }^{\circ}\text{C}$. If the temperature of the median connector does not reach $100\text{ }^{\circ}\text{C}$, even with a reference conductor temperature of $140\text{ }^{\circ}\text{C}$, the test shall be continued at that temperature. The measured reference conductor temperature θ_R shall then be used for subsequent heat cycles ($120\text{ }^{\circ}\text{C} \leq \theta_R \leq 140\text{ }^{\circ}\text{C}$). The current I_N at equilibrium temperature shall be recorded in the test report.

NOTE 1 Where linking bars are used for terminal lugs, the temperature at the midpoint of the bar linking the palms should also be measured. This temperature should be equal to the temperature of the reference conductor θ_R , with a tolerance of ± 5 K.

b) Non-IPC branch connectors

Where it is necessary to use the circuit shown in Figure 2, current shall be circulated in the test loop, bringing the main reference conductor and the three branch reference conductors to $120\text{ }^{\circ}\text{C}$ at equilibrium. To achieve this, the currents in the three branches shall be adjusted by current injection or impedance control. If the median connector temperature (see 3.11) is then equal to or greater than $100\text{ }^{\circ}\text{C}$, the reference conductor temperature for subsequent heat cycles shall be deemed to be $120\text{ }^{\circ}\text{C}$. If not, then the current shall be increased in the loop until the median connector temperature reaches $100\text{ }^{\circ}\text{C}$ at equilibrium, provided the reference conductors do not exceed $140\text{ }^{\circ}\text{C}$. It may be necessary at this stage, and also at intervals throughout the test, to adjust the current in an individual branch so as to ensure that each branch reference temperature is the same as the main reference temperature. The measured reference conductor temperature θ_R on the main and branch conductors, shall then be used for subsequent heat cycles ($120\text{ }^{\circ}\text{C} \leq \theta_R \leq 140\text{ }^{\circ}\text{C}$). The current(s) I_N at equilibrium temperature in the main and branch conductors shall be recorded in the test report.

c) IPC

For tests of IPCs, the same test loop as in Figure 1 or 2 shall be used except that the insulated reference conductor(s) is (are) added in the circuit. During cycling, the temperature on the median connector shall be modified to be 10 K higher than the maximum conductor temperature in normal operation for which these type of connectors are intended. However, the circulated current shall be limited so that the temperature of the insulated reference conductor at equilibrium is not more than 10 K to 15 K above the maximum conductor temperature in normal operation. In the case of branch connectors, it may be necessary at intervals throughout the test, to adjust the current in an individual branch so as to ensure that each branch reference temperature is the same as the main reference temperature. The current(s) I_N at equilibrium temperature in the main and possible branch conductors shall be recorded in the test report.

NOTE 2 If a connector is used in an application where considerably higher temperatures are reached than the maximum conductor temperature in normal operation, additional tests at higher temperature of the test loop may be made, after agreement between manufacturer and user. The additional increase in temperature of the test loop should be achieved by the application of thermal insulation.

6.3.2 Second heat cycle

The object of this second heat cycle is to determine the heat cycle duration and temperature profile which will be used on the test loop for all subsequent heat cycles. Current is circulated in the loop until the main reference conductor temperature reaches the value θ_R determined in 6.3.1, with a tolerance of ${}^{+6}_0$ K and the median connector temperature is stable within a band of 2 K over a 10 min period.

An elevated current may be used to reduce the heating period. The duration of this elevated current is given in Table 1. The current shall thereafter be decreased or regulated to a mean value of the current close to I_N to ensure stable conditions during the median-connector control period. It may be necessary to use more than one cycle to determine the second heat cycle.

The reference conductor temperature shall be the control parameter, in order to keep the temperature profile during the heat cycle test. In this way, the fluctuation of the ambient temperature will not affect the temperature profile of the reference conductor.

Table 1 – Minimum elevated current heating time

Nominal conductor cross-sectional area, A	mm ²	Al	$16 \leq A \leq 50$	$50 < A \leq 150$	$150 < A \leq 630$	$A > 630$
		Cu	$10 \leq A \leq 35$	$35 < A \leq 95$	$95 < A \leq 400$	$A > 400$
Time	min		5	10	15	20

The reference temperature time (t_1) heating profile, see Figure 4, determined in this way shall be recorded and used for all subsequent cycles.

After the period t_1 , follows a period t_2 of cooling to bring the temperature of all connectors and the reference conductor to a value ≤ 35 °C.

It may be necessary in subsequent heat cycles to adjust t_2 to ensure that the temperature conditions are reached.

If accelerated cooling is used, it shall act on the whole of the loop, and use air within ambient temperature limits.

The total period $t_1 + t_2$ constitutes a heat cycle (see Figure 4).

6.3.3 Subsequent heat cycles

A total of 1000 heat cycles (as defined in 6.3.2) shall be made. After the cooling period of the cycles indicated below, the resistance and temperature of each connector and each reference conductor shall be recorded as indicated in 6.2. The maximum temperature of each connector during the cycle just prior to or following the resistance measurements shall also be recorded.

Measurements shall be made at the following cycles:

Class A

0 (before the first heat cycle, see 6.3.1)
 200, before short-circuit
 200, after short-circuit
 250
 Then every 75 cycles
 (in total 14 measurements)

Class B

0 (before the first heat cycle, see 6.3.1)
 250
 then every 75 cycles
 (in total 12 measurements)

A tolerance of ± 10 cycles may be used.

6.3.4 Short-circuit tests (for Class A connectors only)

Six short-circuits are applied after the 200th heat cycle.

The short-circuit current level shall be such that it raises the bare reference conductors from a temperature of ≤ 35 °C to a temperature between 250 °C and 270 °C.

However, for IPC connectors the short-circuit current shall be limited so that the temperature of the insulated reference conductor does not exceed the maximum permissible temperature of the insulation.

NOTE 1 The short-circuit current may be calculated according to Clause 3 of IEC 60949 and may be determined in accordance with Annex D of this standard as a method for selecting the current needed for a certain temperature rise, providing the actual conductor cross-sectional area is verified.

The maximum temperature, time and approximate current, or the actual current and time, used for the short-circuit test, shall be recorded and stated in the test report.

The duration of the short-circuit current shall be $(1^{+0,5}_{-0,1})$ s with a maximum current of 25 kA.

If the required short-circuit current exceeds this value a longer duration ≤ 5 s with a current between 25 kA and 45 kA shall be used.

After each short-circuit, the test loop shall be cooled to a temperature ≤ 35 °C.

NOTE 2 For large cross-sectional areas, pre-heating up to 90 °C may be used. However, for cross-sectional areas exceeding 630 mm² copper or 1000 mm² aluminium, the above parameters (45 kA and 5 s) are insufficient to reach 250 °C.

As stated in 6.1, the test loop may be dismantled for these tests. Since the short-circuit test is intended to reproduce the thermal effects of high currents only, the recommended method is to use a concentric return conductor in order to reduce the electro-dynamic forces. The test arrangements shall be recorded.

NOTE 3 It should be noted that bending or vibrations during assembly, transport and handling may give rise to mechanical forces which affect the contact resistance of the test objects and should thus be avoided. Where tests are required to reproduce, e.g. forces that occur on terminal lugs bolted to a terminal plant, then the mechanical arrangement of the test loop should be agreed between the parties concerned.

NOTE 4 For special applications, other short-circuit conditions may be adopted.

NOTE 5 For branch connectors, the reference conductor is that associated with the branch.

6.4 Assessment of results

An individual connector resistance factor k enables a common method of connector assessment to be made over the range of conductor cross-sectional areas applicable to this standard. The parameters listed below are calculated (see Annex E).

- The connector resistance factor k shall be calculated according to Clause E.2, for each of the six connectors at all the measurement intervals listed in 6.3.3.
- The initial scatter δ , between the six initial values of k , measured at heat cycle 0, shall be calculated according to Clause E.3.
- The mean scatter β , between the six values of k , averaged over the last 11 measurement intervals, shall be calculated according to Clause E.4.
- The change in resistance factor D for each of the six connectors shall be calculated according to Clause E.5. D is the change in the value of k taken over the last 11 measurement intervals, calculated as a fraction of the mean value of k in this interval.
- The resistance factor ratio λ shall be calculated according to Clause E.6.
- The maximum temperature $\theta_{\max}$ on each connector shall be recorded according to Clause E.7.

6.5 Requirements

The six connectors shall satisfy the requirements shown in Table 2. If one connector out of the six does not satisfy one or more of the requirements, a re-test may be carried out. In this event, all six new connectors shall satisfy the requirements.

If more than one connector out of the six do not satisfy one or more of the requirements, no re-test is permitted and the type of connector shall be deemed as not conforming to this standard.

Table 2 – Electrical test requirements

Parameter	Designation	Text reference	Maximum value
Initial scatter	δ	E.3	0,30
Mean scatter	β	E.4	0,30
Change in resistance factor	D	E.5	0,15
Resistance factor ratio	λ	E.6	2,0
Maximum temperature	$\theta_{\max}$	E.7	θ_{ref}
NOTE Values given in this table are based on experience.			

7 Mechanical tests

The purpose of these tests is to ensure an acceptable mechanical strength for the connections to the conductors of power cables.

NOTE The pull-out force does not give any reliable indication of the electrical quality of the connector.

7.1 Method

The test shall be made on three additional connectors identical to those used for the electrical test. The connectors are fitted as for the electrical test of 6.1. The conductor lengths, between connectors or between connector and tensile test machine jaws, shall be ≥ 500 mm. The rate of application of the load shall not exceed 10 N per square millimetre of cross-sectional area and per second up to the value in Table 3, which is then maintained for 1 min.

If the connector is tested electrically for conductors with a different cross-sectional area, the different connectors shall be tested individually, in accordance with Table 3.

Table 3 – Tensile force for mechanical tests

Conductor material	Tensile force N
Aluminium	$40 \times A^a$; maximum 20 000
Copper	$60 \times A^a$; maximum 20 000
^a A = nominal cross-sectional area (mm ²).	

7.2 Requirements

No slipping shall occur during the last minute of the test.