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Edition 2.0 2018-03

INTERNATIONAL STANDARD

GROUP SAFETY PUBLICATION

Tests for electric cables under fire conditions – Circuit integrity – Part 1: Test method for fire with shock at a temperature of at least 830 °C for cables of rated voltage up to and including 0,6/1,0 kV and with an overall diameter exceeding 20 mm

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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Part 1: Test method for fire with shock at a temperature of at least 830 °C for cables of rated voltage up to and including 0,6/1,0 kV and with an overall diameter exceeding 20 mm

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International Standard IEC 60331-1 has been prepared by IEC technical committee 20: Electric cables.

This second edition cancels and replaces the first edition published in 2009. It constitutes a technical revision.

The significant technical changes with respect to the previous edition are as follows:

– extension of the scope to include metallic data and telecom cables and optical fibre cables, although details for the specific point of failure, continuity checking arrangement, test sample, test procedure and test report relevant to metallic data and telecom cables and optical fibre cables are not given by IEC 60331-1;
– improved description of the test environment;

– modified steel test ladder with two extra vertical elements to accommodate the modified testing of single core cables without concentric metal layer and the testing of cables with a bending radius in normal use larger than approximately 400 mm;

– mandatory use of mass flow meters/controllers as the means of controlling accurately the input flow rates of fuel and air to the burner;

– improved description of the information to be included in the test report.

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

FDIS	Report on voting
20/1781A/FDIS	20/1792/RVD

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

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

It has the status of a group safety publication in accordance with IEC Guide 104.

A list of all parts of the IEC 60331 series, published under the title: *Tests for electric cables under fire conditions – Circuit integrity*, can be found on the IEC website.

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

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

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

IEC 60331 consists of the following parts under the general title: *Tests for electric cables under fire conditions – Circuit integrity:*

Part 1: *Test method for fire with shock at a temperature of at least 830 °C for cables of rated voltage up to and including 0,6/1,0 kV and with an overall diameter exceeding 20 mm*

Part 2: *Test method for fire with shock at a temperature of at least 830 °C for cables of rated voltage up to and including 0,6/1,0 kV and with an overall diameter not exceeding 20 mm*

Part 3: *Test method for fire with shock at a temperature of at least 830 °C for cables of rated voltage up to and including 0,6/1,0 kV tested in a metal enclosure*

Part 11: *Apparatus – Fire alone at a flame temperature of at least 750 °C*

Part 21: *Procedures and requirements – Cables of rated voltage up to and including 0,6/1,0 kV*

Part 23: *Procedures and requirements – Electric data cables*

Part 25: *Procedures and requirements – Optical fibre cables*

NOTE 1 Parts 21, 23 and 25 relate to fire-only conditions at a flame temperature of at least 750 °C.

NOTE 2 Parts 11, 21, 23 and 25 are no longer subject to maintenance. IEC 60331 Parts 1 and 2 are the recommended test procedures

Since its first edition (1970), IEC 60331 has been extended and has introduced a range of test apparatus in order that a test may be carried out on large and small power, control, data and optical fibre cables.

Successful tests carried out in accordance with this standard will enable an identification to be marked on the product.

TESTS FOR ELECTRIC CABLES UNDER FIRE CONDITIONS – CIRCUIT INTEGRITY –

Part 1: Test method for fire with shock at a temperature of at least 830 °C for cables of rated voltage up to and including 0,6/1,0 kV and with an overall diameter exceeding 20 mm

1 Scope

This part of IEC 60331 specifies the test method for cables which are required to maintain circuit integrity when subject to fire and mechanical shock under specified conditions.

This document is applicable to cables of rated voltage not exceeding 600 V/1 000 V, including those of rated voltage below 80 V, metallic data and telecom cables and optical fibre cables.

It is intended for use when testing cables of greater than 20 mm overall diameter.

Cables of smaller diameter are intended to be tested using the apparatus, procedure and requirements of IEC 60331-2.

This document includes details for the specific point of failure, continuity checking arrangement, test sample, test procedure and test report relevant to electric power and control cables with rated voltage up to and including 600 V/1 000 V. Details for the specific point of failure, continuity checking arrangement, test sample, test procedure and test report relevant to metallic data and telecom cables and optical fibre cables are not given by IEC 60331-1.

Although the scope is restricted to cables with rated voltage up to and including 0,6/1,0 kV, the procedure can be used, with the agreement of the manufacturer and the purchaser, for cables with rated voltage up to and including 1,8/3 (3,3) kV, provided that suitable fuses are used.

Annex A provides the method of verification of the burner and control system used for the test.

Requirements are stated for an identification that may optionally be marked on the cable to signify compliance with this document.

CAUTION – The test given in this standard may involve the use of dangerous voltages and temperatures. Suitable precautions should be taken against the risk of shock, burning, fire and explosion that may be involved, and against any noxious fumes that may be produced.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60584-1, *Thermocouples – Part 1: EMF specifications and tolerances*

IEC 60269-3, *Low-voltage fuses – Part 3: Supplementary requirements for fuses for use by unskilled persons (fuses mainly for household and similar applications) – Examples of standardized systems of fuses A to F*

3 Terms and definitions

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

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

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
circuit integrity
ability of an electric cable to continue to operate in a designated manner whilst subjected to a specified flame source for a specified period of time under specified conditions

3.2
draught-free environment
space in which the results of tests are not significantly affected by the local air speed

4 Test environment

The test shall be carried out in a draught-free environment within a suitable chamber, of minimum volume 20 m^3, with facilities for disposing of any noxious gases resulting from the burning. Sufficient ventilation shall be available to sustain the flame for the duration of the test. Air inlets and the exhaust chimney should be located in such a way that the burner flame remains stable during the verification procedure and test. If necessary, the burner shall be shielded from any draughts by the use of draught shields. Windows may be installed in the walls of the chamber in order to observe the behaviour of the cable during the test. Fume exhaust should be achieved by means of natural draught through a chimney located at least 1 m from the burner. A damper may be used for adjustment of ventilation conditions.

NOTE Experience has shown a chamber similar to the "3 m cube" specified in IEC 61034-1 to be suitable.

The chamber and test apparatus shall be at a temperature of between 10 °C and 40 °C at the start of each test.

The same ventilation and shielding conditions shall be used in the chamber during both the verification and cable test procedures.

5 Test apparatus

5.1 Test equipment

The test equipment shall consist of the following:

a) a test ladder, on to which the test specimen is mounted, comprising a steel framework fastened to a rigid support as described in 5.2;

b) a source of heat comprising a horizontally mounted ribbon burner as described in 5.3;

c) a shock-producing device as described in 5.4;

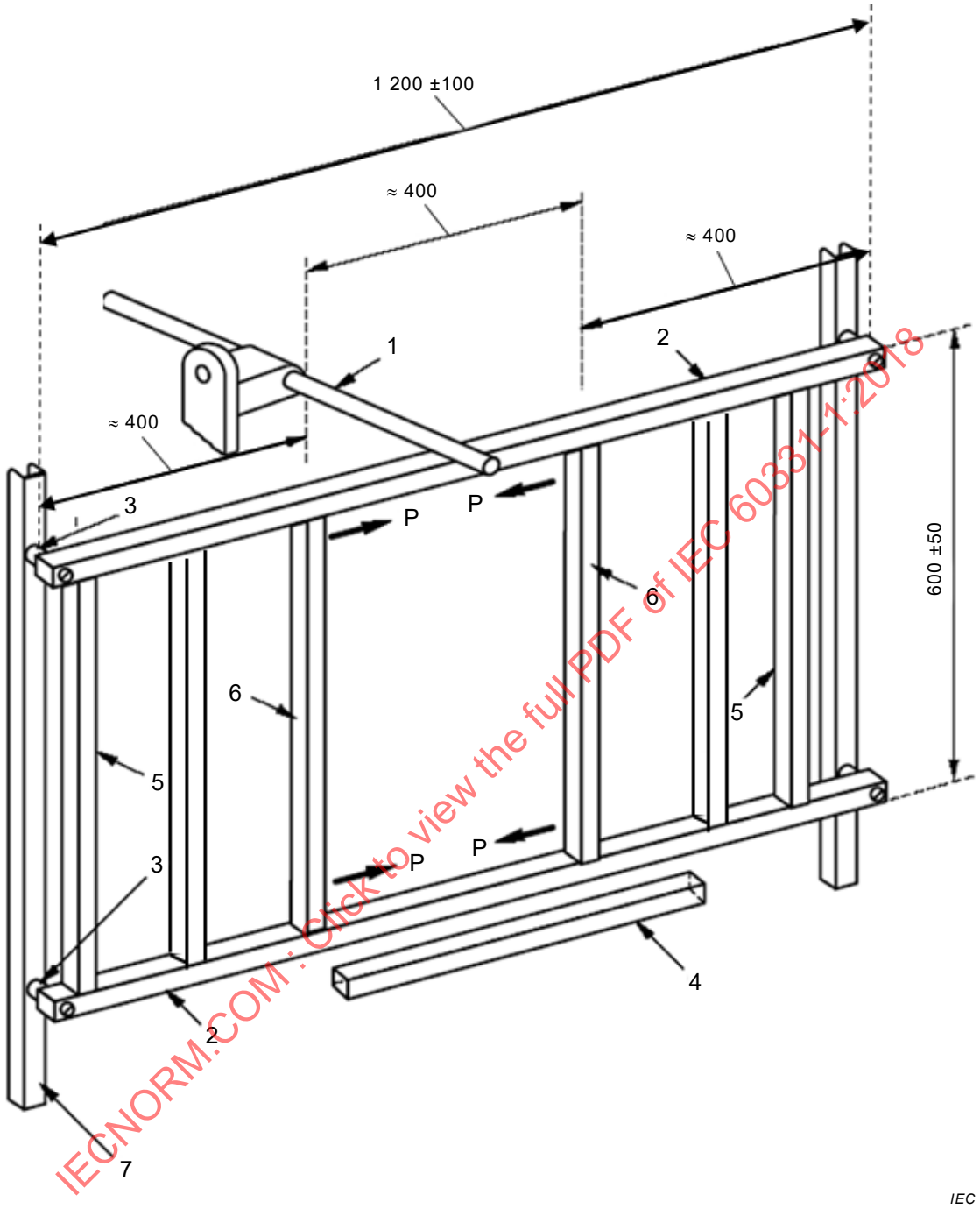
d) a test wall equipped with thermocouples for verification of the source of heat as described in Annex A;

e) a continuity checking arrangement as described in 5.6;

f) fuses as described in 5.7.

A general arrangement of the test equipment is shown in Figure 1, Figure 2 and Figure 3.

Dimensions in millimetres

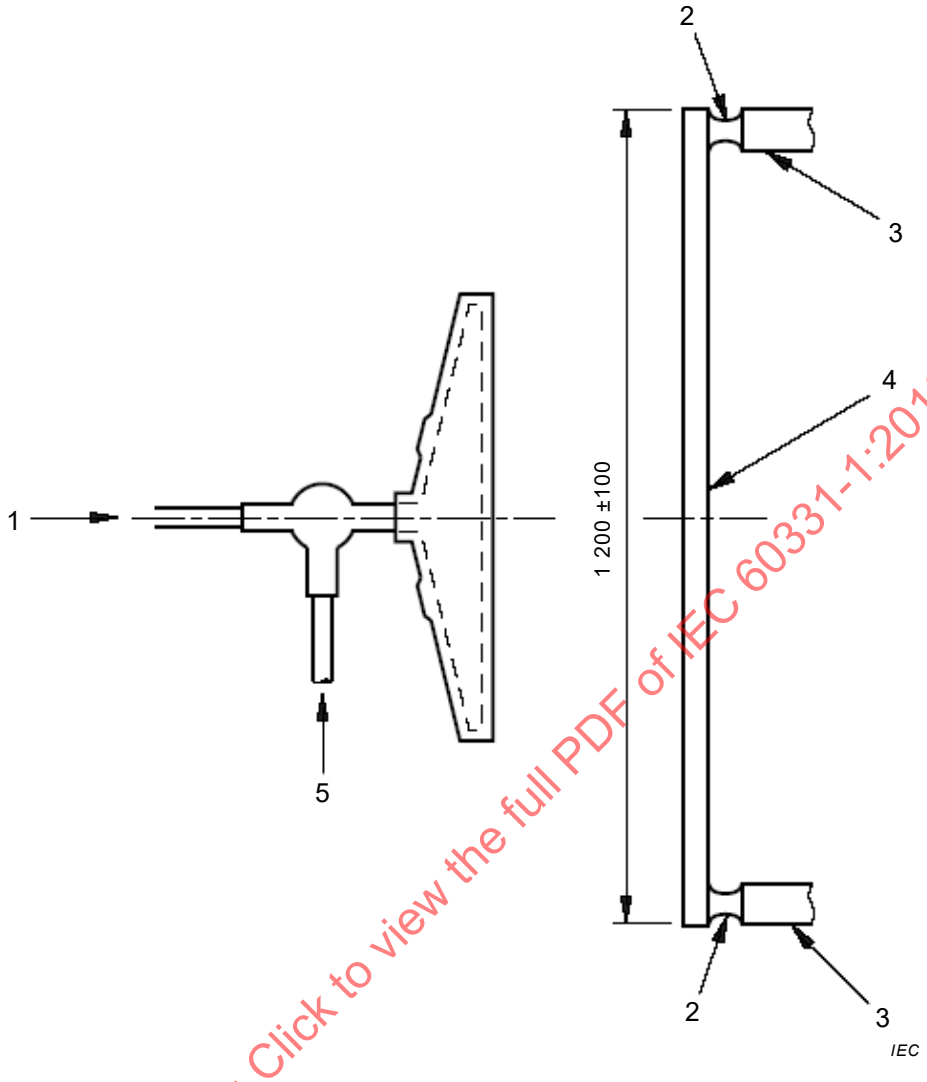


Key

1	shock producing device	5	fixed vertical elements of test ladder
2	steel test ladder	6	adjustable vertical elements of test ladder
3	rubber bush	7	rigid support framework
4	ribbon gas burner	P	plane of adjustment

Figure 1 – Schematic diagram of test configuration

Dimensions in millimetres

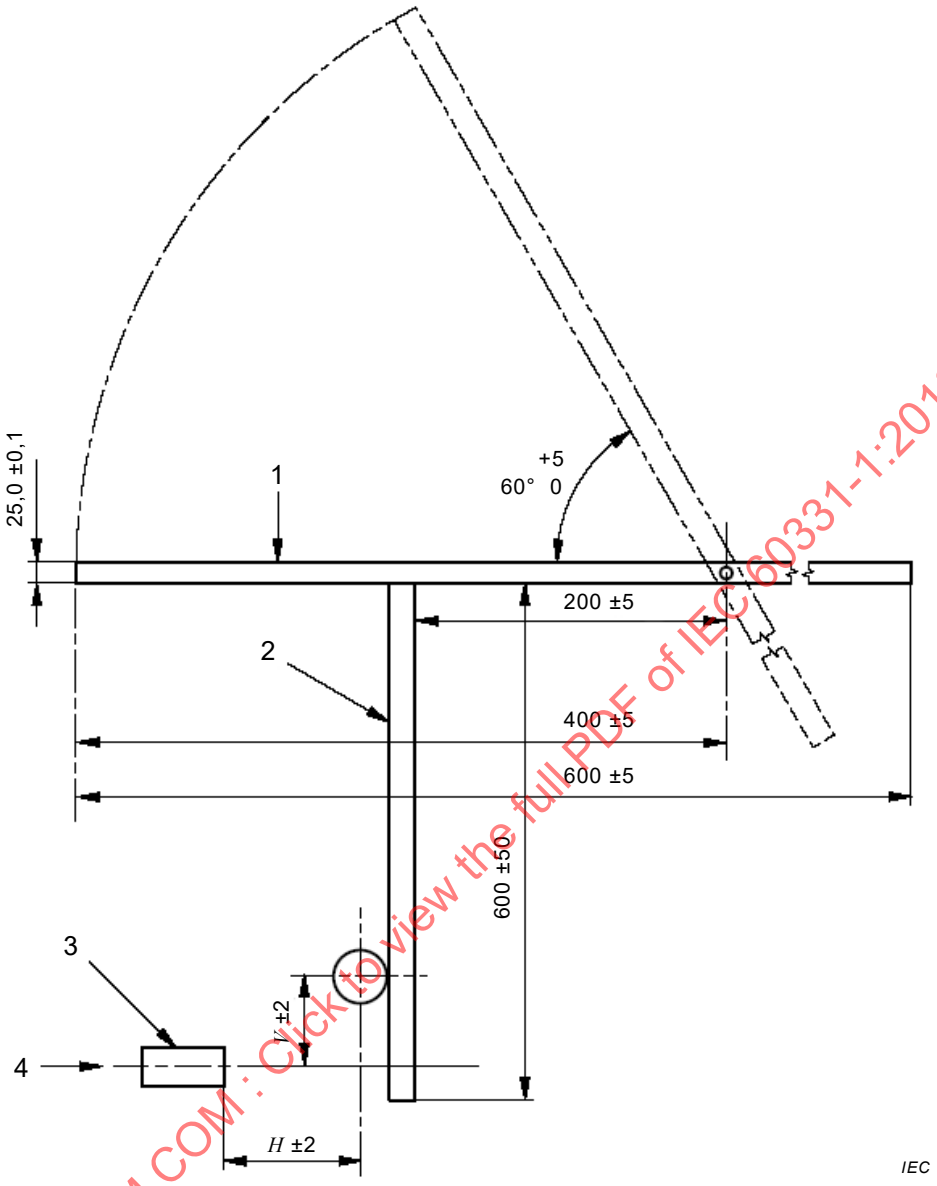


Key

1	entry for air	4	horizontal steel test ladder
2	rubber bush	5	entry for propane gas
3	rigid support framework		

Figure 2 – Plan view of fire test equipment

Dimensions in millimetres



Key

1	shock producing device	*H*	horizontal distance from burner face to the centre of the test specimen
2	steel test ladder	*V*	vertical distance from centre line of burner to the centre of the test specimen
3	gas burner		
4	centre line of burner face		

Figure 3 – End elevation of fire test equipment (not to scale)

5.2 Test ladder and mounting

The test ladder shall consist of a steel framework as shown in Figure 1. The four central vertical elements of the ladder shall be adjustable in order to accommodate different sizes of cable under test. The test ladder shall be (1 200 ± 100) mm long and (600 ± 50) mm high, and the total mass of the test ladder shall be (24 ± 1) kg. Ballast, if required, shall be placed on the steel supports.

NOTE 1 Angle iron approximately 45 mm wide and 6 mm thick, with suitable slots cut to allow for fixing of the bolts or saddles, has been found to be a suitable material for construction of the ladder.

Each horizontal element shall have a mounting hole not more than 200 mm from each end, the exact position and diameter being determined by the particular supporting bush and supporting framework used. The test ladder shall be fastened to a rigid support by four bonded rubber bushes of hardness 50–60 Shore A fitted between the horizontal steel elements of the ladder and the support framework, as shown in Figure 1 and Figure 2 so as to allow movement under impact.

NOTE 2 A typical rubber bush, which has been found to be suitable, is shown in Figure 4.

Dimensions in millimetres

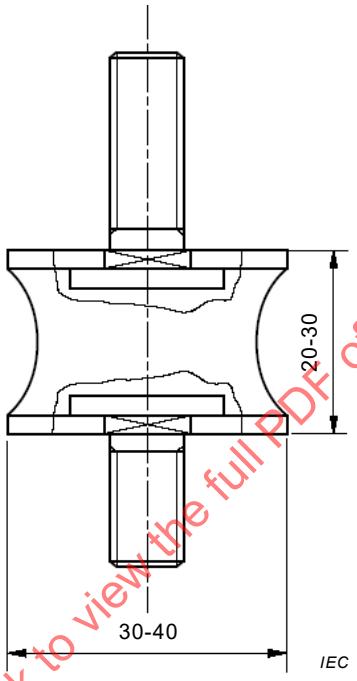


Figure 4 – Typical rubber bush for supporting the test ladder

5.3 Source of heat

5.3.1 Burner

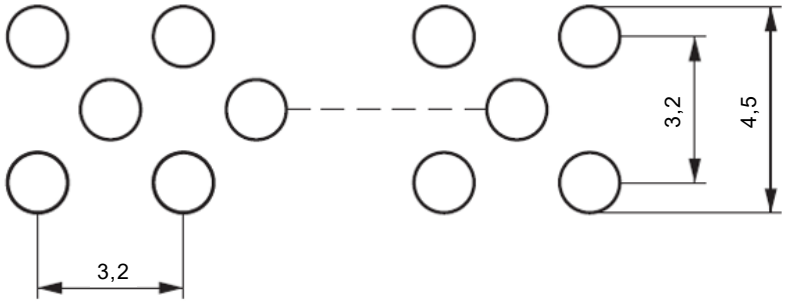
The source of heat shall be a ribbon type propane gas burner with a nominal burner face length of 500 mm (outer distance between outer holes) with a venturi mixer. The nominal burner face width shall be 10 mm. The face of the burner shall have three staggered rows of drilled holes, nominally 1,32 mm in diameter and drilled at centres 3,2 mm from one another, as shown in Figure 5.

A centre-feed burner is recommended.

A row of small holes milled on each side of the burner plate, to serve as pilot holes for keeping the flame burning, is permitted.

Guidance on the choice of a recommended burner system is given in Annex B.

Dimensions in millimetres
(Dimensions are approximate)



NOTE Round holes, 1,32 mm in diameter, on centres 3,2 mm from one another, staggered in three rows and centred on the face of the burner. Nominal burner face length 500 mm.

Figure 5 – Burner face

5.3.2 Flow meters and flow rates

Mass flow meters/controllers shall be used as the means of controlling accurately the input flow rates of fuel and air to the burner.

For the purposes of this test, the air shall have a dew point not higher than 0 °C.

The mass flow rates used for the test shall be as follows:

Propane: (320 ± 13) mg/s

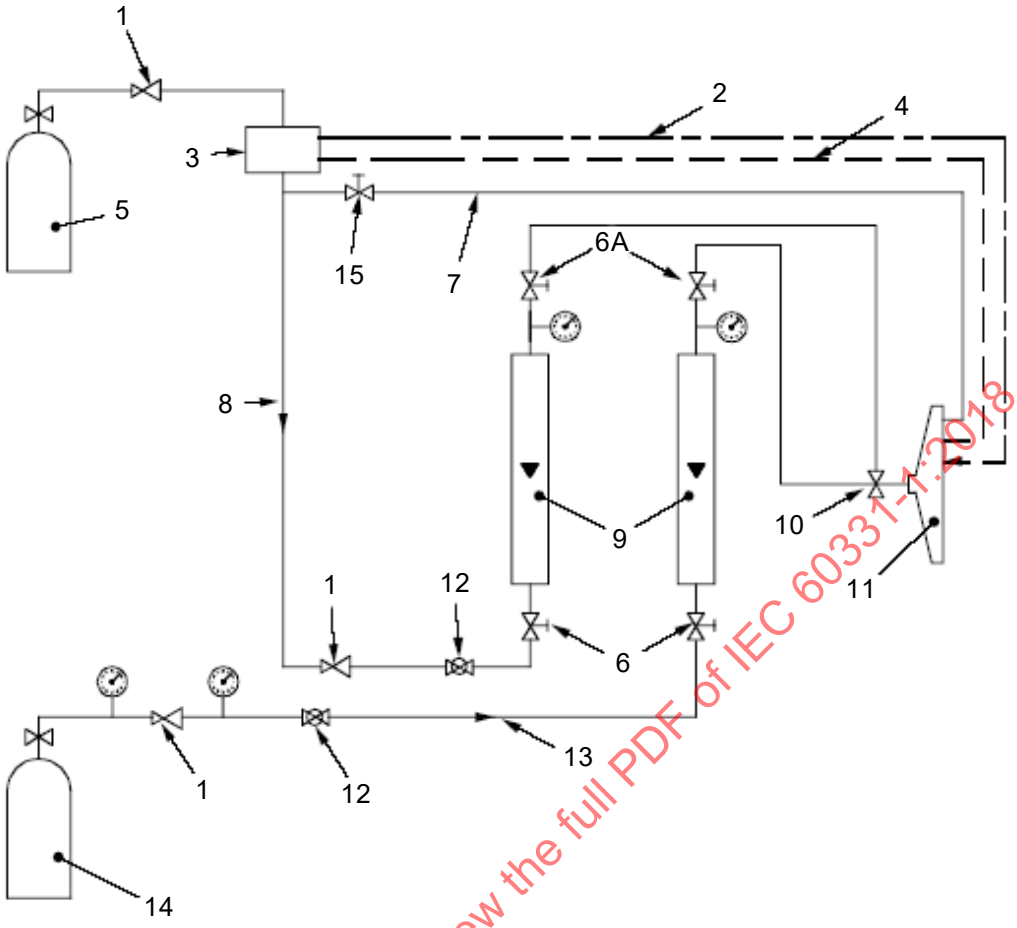
NOTE 1 This is approximately equivalent to a volume flow rate of (10,0 ± 0,4) litres/min at reference conditions (1 bar and 20 °C).

The purity of the propane is not defined. Industrial grades that contain impurities are allowed provided that the calibration requirements are achieved.

Air: (3 270 ± 163) mg/s

NOTE 2 This is approximately equivalent to a volume flow rate of (160 ± 8) litres/min at reference conditions (1 bar and 20 °C).

A schematic diagram of an example of a burner control system is given in Figure 6.



Key

1	regulator	9	mass flow meters
2	piezoelectric igniter	10	venturi mixer
3	flame failure device	11	burner
4	control thermocouples	12	ball valve
5	propane cylinder	13	air flow
6	screw valve (6A = alternative position)	14	compressed air cylinder
7	pilot feed	15	screw valve on pilot feed
8	gas flow		

Figure 6 – Schematic diagram of an example of a burner control system

5.3.3 Verification

The burner and control system shall be subject to verification following the procedure given in Annex A.

5.4 Shock producing device

The shock-producing device shall consist of a mild steel round bar (25,0 ± 0,1) mm in diameter and (600 ± 5) mm long. The bar shall be freely pivoted about an axis parallel to the test ladder, which shall be in the same horizontal plane as, and (200 ± 5) mm away from, the upper edge of the ladder. The axis shall divide the bar into two unequal lengths, the longer length being (400 ± 5) mm which shall impact the ladder. The bar shall drop under its own weight from an angle of $(60^{+5}_{0})°$ to the horizontal to strike the upper edge of the ladder at its midpoint as shown in Figure 1 and Figure 3.

5.5 Positioning of source of heat

The burner face shall be positioned in the test chamber so that it is at least 200 mm above the floor of the chamber, or any solid mounting block, and at least 500 mm from any chamber wall.

By reference to the centre point of the test specimen (cable) to be tested, the burner shall be positioned centrally at a horizontal distance of $(H \pm 2)$ mm from the burner face to the centre of the test specimen and at a vertical distance of $(V \pm 2)$ mm from the burner horizontal central plane to the centre of the test specimen, as shown in Figure 3.

The exact burner location to be used during cable testing shall be determined using the verification procedure given in Annex A, where the values of H and V to be used shall be determined.

The burner should be rigidly fixed to the framework during testing so as to prevent movement relative to the test specimen.

5.6 Continuity checking arrangements for electric power and control cables with rated voltage up to and including 600 V/1 000 V

During the test, a current for continuity checking shall be passed through all conductors of the test specimen. This shall be provided by a three-phase star connected or single-phase transformer(s) of sufficient capacity to maintain the test voltage up to the maximum leakage current allowable.

NOTE 1 Note the fuse characteristics when determining the power rating of the transformer.

This current shall be achieved by connecting, at the other end of the test specimen, a suitable load and an indicating device (e.g. lamp) to each conductor, or group of conductors.

NOTE 2 A current of 0,25 A at the test voltage, through each conductor or group of conductors, has been found to be suitable.

5.7 Fuses

Fuses used in the test procedure in Clause 7 shall comply with IEC 60269-3 Fuse System A-D Type DII, 2A. Alternatively, a circuit-breaker with equivalent characteristics may be used.

Where a circuit-breaker is used, its equivalent characteristics shall be demonstrated by reference to the characteristic curve shown in IEC 60269-3.

The test method using fuses shall be the reference method in the case of dispute.

6 Test specimen (electric power and control cables with rated voltage up to and including 600 V/1 000 V)

6.1 Test specimen preparation

A cable sample at least 4,5 m long shall be available from the cable length for test. Each individual test specimen to be tested shall consist of a piece of cable, taken from the cable sample, not less than 1 500 mm long with approximately 100 mm of sheath or outer covering removed at each end.

At each end of the test specimen each conductor shall be suitably prepared for electrical connections, and, if there is more than one conductor, the exposed conductors shall be spread apart to avoid contact with each other.

6.2 Test specimen mounting

6.2.1 Single core cables with concentric metal layer and multicore cables

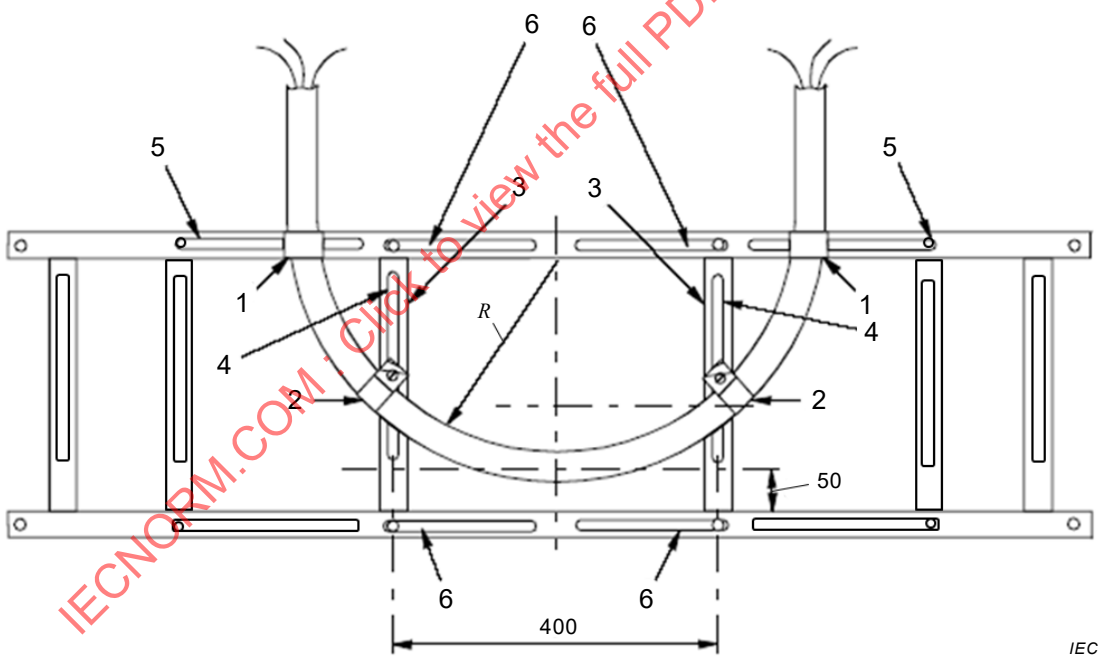
The test specimen shall be bent to form an approximate arc of a circle. The internal radius of the bend shall be the manufacturer's declared minimum bending radius in normal use.

The test specimen shall be mounted centrally on the test ladder, as shown in Figure 7, using metal clips which shall be earthed. Two U-bolts on the upper horizontal element of the ladder are recommended, but P-clips made of metal strip (20 ± 2) mm wide for cables from 20 mm up to 50 mm in diameter, and (30 ± 3) mm wide for larger cables shall be used on the two central vertical elements. The P-clips shall be formed so as to have approximately the same diameter as the test specimen under test.

If the test specimen is too small to be mounted on the central vertical elements when in the position shown in Figure 7, the two central vertical elements shall be equally moved towards the centre so that the specimen may be mounted as shown in Figure 8.

If the bending radius in normal use is too large to mount the cable as shown in Figure 7 on the slots for the U-bolt (key 5 in Figure 7), the test specimen shall be mounted as shown in Figure 9, using P-clips, which shall be earthed, on the four central vertical elements.

Dimensions in millimetres
(dimensions are approximate)

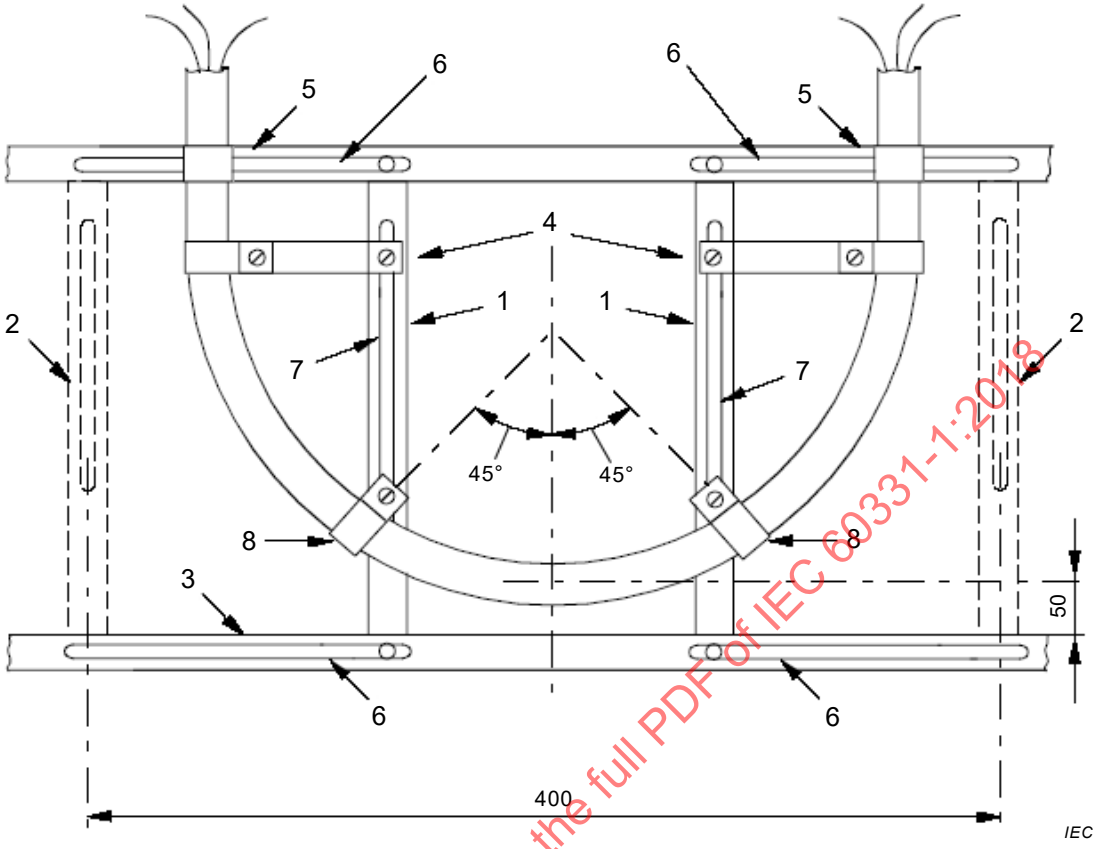


Key

1	U-bolt	5	slot for U-bolt
2	P-clip	6	slot for movement of adjustable vertical elements
3	adjustable vertical elements	*R*	minimum bending radius of cable in normal use
4	slot for P-clip fixing		

Figure 7 – Example of method of mounting a larger diameter test specimen for test (with a bending radius between approximately 200 and 400 mm)

Dimensions in millimetres
(dimensions are approximate)

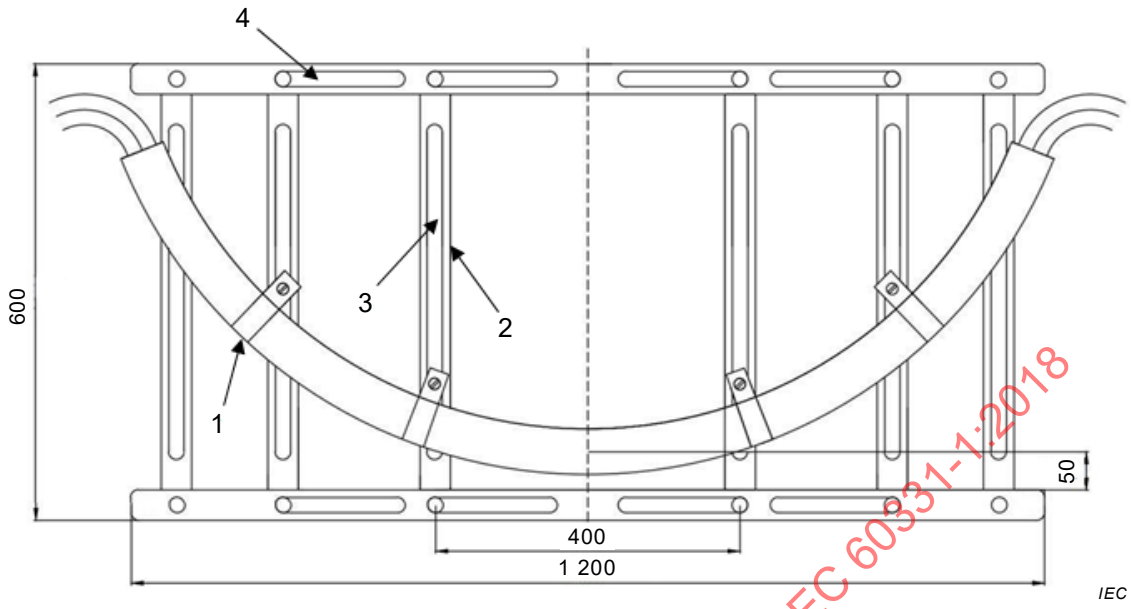


Key

1	adjustable position of vertical elements	5	U-bolt
2	normal position of vertical elements	6	slot for movement of adjustable vertical elements
3	lower horizontal element of test ladder	7	slot for P-clip fixing
4	additional clip to maintain cable arc (if required)	8	P-clip

Figure 8 – Detailed section of adjustable position of vertical ladder elements for mounting a smaller diameter test specimen for test (with a maximum bending radius of approximately 200 mm)

Dimensions in millimetres
(dimensions are approximate)



Key

1	P-clip	3	slot for P-clip fixing
2	adjustable vertical elements	4	slot for movement of adjustable vertical elements

Figure 9 – Example of method of mounting test specimen with a bending radius in normal use larger than approximately 400 mm

6.2.2 Single core cables without concentric metal layer

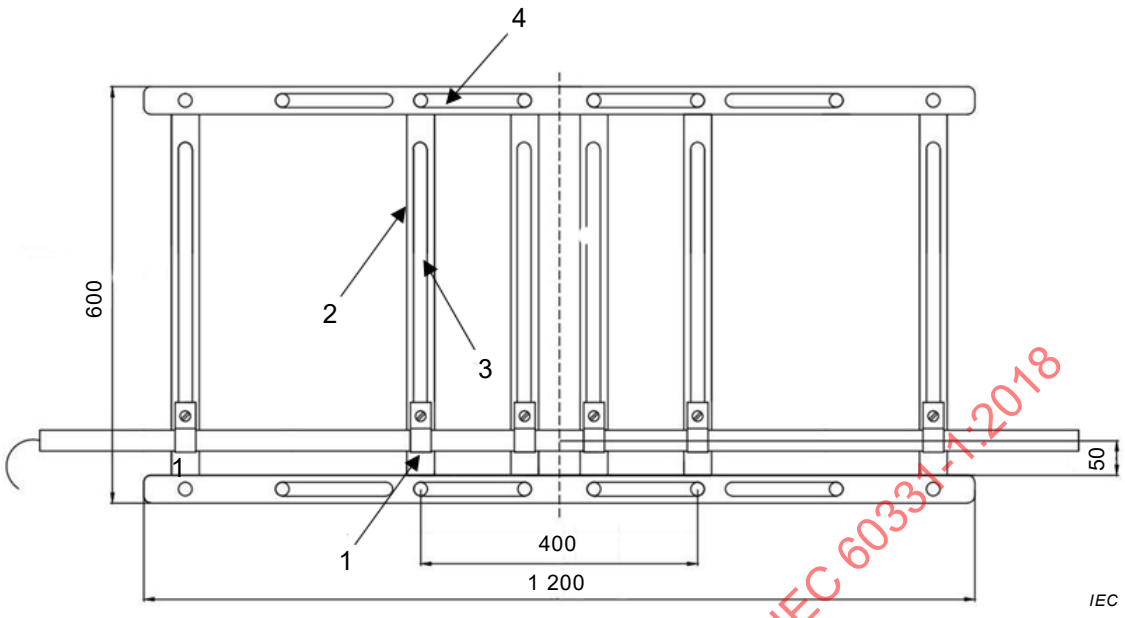
The test specimen shall be mounted straight centrally on the test ladder using four vertical elements, as shown in Figure 10, using metal clips which shall be earthed to fix the cable to these vertical elements.

The width of the metal clips shall be in accordance with 6.2.1.

NOTE Testing of a straight test specimen is appropriate for single core cables without concentric metal layer, as bending will not affect the performance for this type of cable, as internal forces such as in multicore cables will not occur.

The P-clips shall be formed so as to have approximately the same diameter as the test specimen under test.

Dimensions in millimetres
(dimensions are approximate)



Key

1	P-clip	3	slot for P-clip fixing
2	adjustable vertical elements	4	slot for movement of adjustable vertical elements

Figure 10 – Method of mounting test specimen of a single core cable without concentric metal layer

7 Test procedure (electric power and control cables with rated voltage up to and including 600 V/1 000 V)

7.1 Test equipment and arrangement

The test procedure defined in this clause shall be carried out using the apparatus detailed in Clause 5.

Mount the test specimen on the test ladder and adjust the burner to the correct position relative to the test specimen in accordance with 5.5.

7.2 Electrical connections

At the transformer end of the test specimen, earth the neutral conductor, if present, and any protective conductors. Any metal screens, drain wire or metal layer shall be interconnected and earthed. Connect the transformer(s) to the conductors, excluding any conductor which is specifically identified as intended for use as a neutral or a protective conductor, as shown in the circuit diagram in Figure 11. Where a metal sheath, armour or screen acts as a neutral or protective conductor, it shall be connected, as shown in the circuit diagram in Figure 11, as for a neutral or protective conductor.

For single-, twin- or three-phase conductor cables, connect each phase conductor to a separate phase of the transformer(s) output with a 2 A fuse or circuit-breaker with equivalent characteristics in each phase.

For multicore cables that have four or more conductors (excluding any neutral or protective conductors), the conductors shall be divided into three roughly equal groups, ensuring that adjacent conductors are, as far as possible, in different groups.

For multipair cables, the conductors shall be divided into two equal groups, ensuring that the a-core of each pair is connected to one phase and the b-core of each pair is connected to another phase (L1 and L2 in Figure 11). Quads shall be treated as two pairs.

For multi-triple cables, the conductors shall be divided into three equal groups, ensuring that the a-core of each triple is connected to one phase, the b-core of each triple to another phase and the c-core of each triple to the third phase of the transformer (L1, L2 and L3 in Figure 11).

Connect the conductors of each group in series and connect each group to a separate phase of the transformer output with a 2 A fuse or circuit-breaker with equivalent characteristics in each phase.

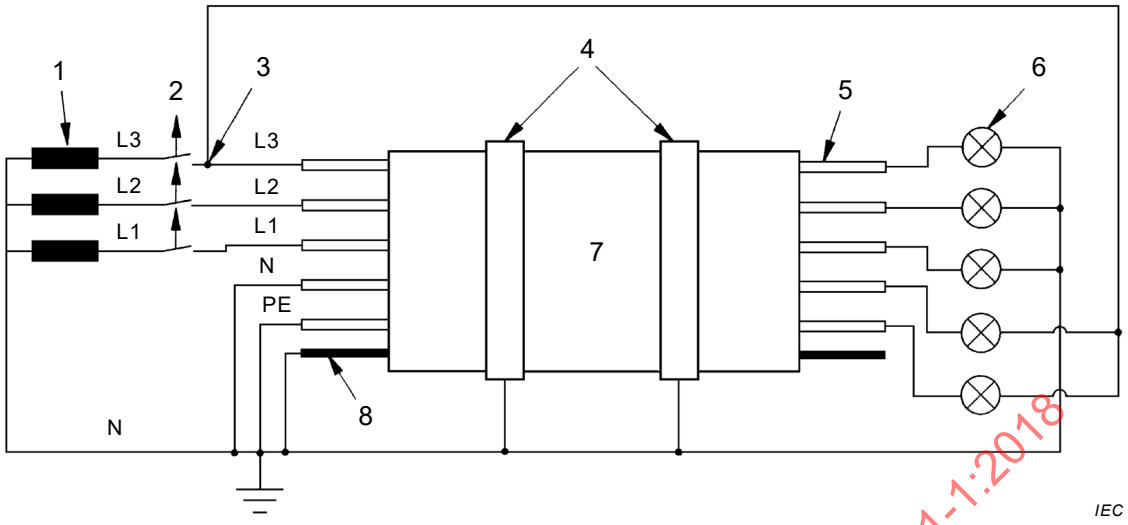
The above test procedure connects the neutral conductor to earth. This may not be appropriate if the cable is designed for use on a system where neutral is not earthed. If required by the cable standard, it is permissible for the neutral conductor to be tested as if it were a phase conductor. Where a metal sheath, armour or screen acts as a neutral conductor, it shall always be connected to earth. Any such variations in methodology should be included in the test report.

For cable constructions not specifically identified above, the test voltage should be applied, as far as is practicable, to ensure that adjacent conductors are connected to different phases.

In certain cases, for example when testing a control cable using a three-phase transformer, it may not be possible to apply a test voltage between conductors and from conductor to earth equal to the rated voltage simultaneously. In such cases, either the test voltage between conductors, or the test voltage from conductor to earth shall be equal to the rated voltage, such that both the test voltage between conductors and the test voltage from conductor to earth is equal to or higher than the rated voltage.

At the end of the test specimen remote from the transformer:

– connect each phase conductor, or group of conductors, to one terminal of the load and indicating device (as described in 5.6), the other terminal being earthed;
– connect the neutral conductor and any protective conductor to one terminal of the load and indicating device (as described in 5.6), the other terminal being connected to L1 (or L2 or L3) at the transformer end (see Figure 11).



Key

L1, L2, L3	phase conductor (L2, L3 if present)
N	neutral conductor (if present)
PE	protective conductor (if present)

1	transformer	5	test conductor or group
2	fuse, 2 A	6	load and indicating device
3	L1 or L2 or L3	7	test specimen
4	metal clips	8	metal screen (if present)

Figure 11 – Basic circuit diagram – Electric power and control cables with rated voltage up to and including 600 V/1 000 V

7.3 Flame and shock application

Ignite the burner and adjust the propane and air flow rates to those obtained during the verification procedure (see Annex A).

Immediately after igniting the burner, activate the shock-producing device and start the test duration timer. The shock-producing device shall impact the ladder after 5 min ± 10 s from activation and subsequently at 5 min ± 10 s intervals. After each impact, the impacting bar shall be raised from the test ladder no more than 20 s after the impact.

7.4 Electrification

Immediately after starting the test duration timer, switch on the electricity supply and adjust the voltage to the rated voltage of the cable (subject to a minimum voltage of 100 V AC), i.e. the test voltage between conductors shall equal the rated voltage between conductors, and the test voltage from conductor to earth shall equal the rated voltage from conductor to earth.

The test shall continue for the flame application time given in 8.1, after which the flame shall be extinguished.

8 Performance requirements (electric power and control cables with rated voltage up to and including 600/1 000 V)

8.1 Flame application time

The flame application time shall be as specified in the relevant cable standard. In the absence of such a standard, a flame and impact application time of 30 min, 60 min, 90 min or 120 min shall be chosen.

8.2 Acceptance criteria

With reference to the test procedure given in Clause 7, the cable possesses the characteristics for providing circuit integrity so long as during the course of the test

– the voltage is maintained, i.e. no fuse fails or circuit-breaker is interrupted,

– a conductor does not rupture, i.e. the lamp is not extinguished.

Failure by either one of the criteria listed shall be sufficient to show a failure for that cable.

9 Retest procedure

In the event of a failure, as judged by the requirements of the relevant standard, two further test specimens, taken from the same cable sample, shall be tested. If both comply, the test shall be deemed successful.

10 Test report (electric power and control cables with rated voltage up to and including 600 V/1 000 V)

The test report shall include the following information:

a) the number of this document;

b) a full description of the cable tested;

c) the manufacturer of the cable tested;

d) the test voltage and actual applied electrical connections, in accordance with Paragraphs 7 to 9 of 7.2;

e) any option used in the test procedure (i.e. failure detection method);

f) the type and disposition of clips supporting cable sample;

g) the actual cable bending radius used for the test;

h) the method used for temperature monitoring during the verification procedure;

i) the point of failure mechanism (i.e. voltage not maintained or conductor rupture);

j) the actual performance requirement applied (by reference to Clause 8);

k) the flame application time;

l) the chamber volume and temperature at the start of the test.

11 Cable marking

If a cable is required to be marked to signify compliance with this document, it shall be marked with the number of this document and the duration of flame application, as follows: “IEC 60331-1 (XX)” where XX shall be the duration in minutes. The marking shall be in addition to any requirement of the cable standard.