55/1069/FDIS

FINAL DRAFT INTERNATIONAL STANDARD
PROJET FINAL DE NORME INTERNATIONALE

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Functions concerned
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☒ Safety Sécurité	☐ EMC CEM	☐ Environment Environnement	☒ Quality assurance Assurance de la qualité

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Titre

CEI 60851-5 Ed. 4.0: Fils de bobinage - Méthodes d'essai - Partie 5: Propriétés électriques

Title

IEC 60851-5 Ed. 4.0: Winding wires - Test methods - Part 5: Electrical properties

ATTENTION **VOTE PARALLÈLE** **CEI – CENELEC** L'attention des Comités nationaux de la CEI, membres du CENELEC, est attirée sur le fait que ce projet finale de Norme internationale est soumis au vote parallèle. Les membres du CENELEC sont invités à voter via le système de vote en ligne du CENELEC.	**ATTENTION** **IEC – CENELEC** **PARALLEL VOTING** The attention of IEC National Committees, members of CENELEC, is drawn to the fact that this final draft International Standard (DIS) is submitted for parallel voting. The CENELEC members are invited to vote through the CENELEC online voting system.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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WINDING WIRES –
TEST METHODS –

Part 5: Electrical properties

FOREWORD

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International Standard IEC 60851-5 has been prepared by IEC technical committee 55: Winding wires.

This fourth edition cancels and replaces the third edition (1996) and its amendments 1 (1997) and 2 (2004). It constitutes a technical revision.

Significant revisions to the previous edition include the following points:

- in Subclause 5.3, the addition of the use of carbon brush electrodes for the counting discontinuities during the high voltage continuity test, as an alternative to the V-groove pulley electrode;
- clarifications in the breakdown voltage test for round wires larger than 2,500 mm and for fibrous covered wires.

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

FDIS	Report on voting
55/XX/FDIS	55/XX/RVD

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

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

A list of all the parts in the IEC 60851 series, under the general title *Winding wires – Test methods*, can be found on the website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date[1] 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.

1 The National Committees are requested to note that for this publication the maintenance result date is 2011.

INTRODUCTION

This part of IEC 60851 forms an element of a series of standards which deals with insulated wires used for windings in electrical equipment. The series has three groups describing

a) winding wires – Test methods (IEC 60851);

b) specifications for particular types of winding wires (IEC 60317);

c) packaging of winding wires (IEC 60264).

WINDING WIRES –
TEST METHODS –

Part 5: Electrical properties

1 Scope

This part of IEC 60851 specifies the following tests:

– Test 5: Electrical resistance;
– Test 13: Breakdown voltage;
– Test 14: Continuity of insulation;
– Test 19: Dielectric dissipation factor;
– Test 23: Pin hole.

For definitions, general notes on methods of test and the complete series of methods of test for winding wires, see IEC 60851-1.

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 60851-1, *Winding wires – Test methods – Part 1: General*

3 Test 5: Electrical resistance

Electrical resistance is the d.c. resistance at 20 °C of 1 m of wire.

The method used shall provide a precision of 0,5 %.

For bunched wires a length of up to 10 m shall be used and the ends shall be soldered before the measurement. When measuring the resistance to check for an excessive number of broken wires, a length of 10 m of bunched wire shall be used.

If the resistance R_t is measured at a temperature t other than 20 °C, the resistance R_{20} at 20 °C shall be calculated by means of the following formula:

$$R_{20} = \frac{R_t}{1+\alpha\,(t-20)}$$

where

t is the actual temperature in degrees Celsius during the measurement;

α is the temperature coefficient in K^{-1}.

In the temperature range from 15 °C to 25 °C, the temperature coefficient to be used shall be:

– for copper: $\alpha_{20} = 3{,}96 \times 10^{-3}\ K^{-1}$;

– for aluminium: $\alpha_{20} = 4{,}07 \times 10^{-3}\ K^{-1}$.

One test shall be made. The electrical resistance shall be reported.

4 Test 13: Breakdown voltage

4.1 Principle

The test voltage shall be an a.c. voltage of 50 Hz or 60 Hz nominal frequency. The test voltage shall be applied at zero and increased at a uniform rate according to Table 1.

Table 1 – Rates of test voltage increase

Breakdown voltage V		Rate of increase V/s
Over	**Up to and including**	
–	500	20
500	2 500	100
2 500	–	500

4.2 Equipment

The following equipment shall be used:

– test transformer with a rated power of at least 500 VA providing an a.c. voltage of an undistorted sine waveform under test conditions, with a peak factor being within the limits of $\sqrt{2} \pm 5$ % (1,34 to 1,48) and with a capacity to supply a current of 5 mA with a maximum voltage drop of 2 %;

– fault detection circuit, which operates at a current of 5 mA or more;

– arrangement to provide a uniform rise of the test voltage at the specified rate;

– oven with forced air circulation;

– polished metal cylinder, 25 mm ± 1 mm in diameter, mounted with its axis horizontal (see Figure 1) and electrically connected to one terminal of the test voltage supply;

– twisting device according to Figure 2, that allows to twist two pieces of wire for a length of 125 mm;

– strips of metal foil, 6 mm in width and pressure sensitive tape, 12 mm in width;

– container with metal shot of stainless steel or nickel-plated iron. The diameter of the shot shall not exceed 2 mm. The shot shall be cleaned periodically by suitable means;

– metal mandrel, 50 mm ± 2 mm in diameter;

– metal mandrel, 25 mm ± 1 mm in diameter.

4.3 Enamelled round wire with a nominal conductor diameter up to and including 0,100 mm

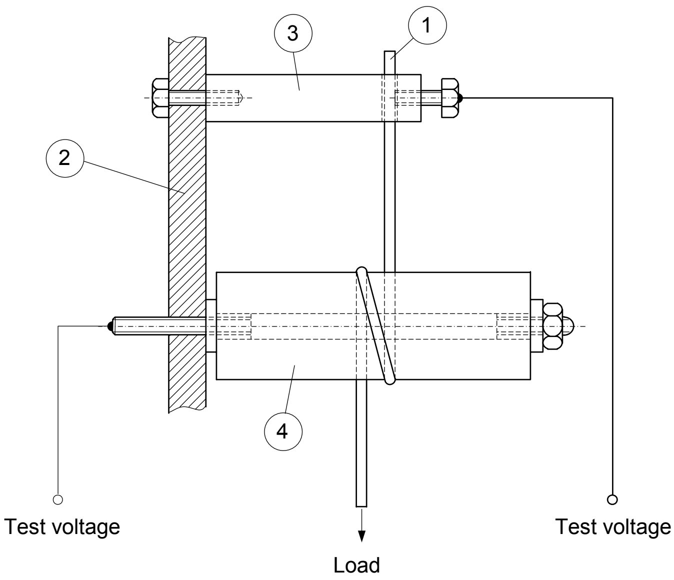
A straight piece of wire with the insulation removed at one end shall be connected to the upper terminal as shown in Figure 1 and wound once around the cylinder. A load as specified in Table 2 shall be applied to the lower end of the wire to keep the specimen in close contact with the cylinder.

The test voltage shall be applied according to 4.1 between the conductor of the wire and the cylinder. The test shall be carried out at room temperature.

Five specimens shall be tested. The five single values shall be reported.

Table 2 – Loads applied to the wire

Nominal conductor diameter mm		**Load** N
Over	**Up to and including**	
–	0,018	0,013
0,018	0,020	0,015
0,020	0,022	0,020
0,022	0,025	0,025
0,025	0,028	0,030
0,028	0,032	0,040
0,032	0,036	0,050
0,036	0,040	0,060
0,040	0,045	0,080
0,045	0,050	0,100
0,050	0,056	0,120
0,056	0,063	0,150
0,063	0,071	0,200
0,071	0,080	0,250
0,080	0,090	0,300
0,090	0,100	0,400



1 specimen

2 insulating material

3 upper terminal

4 cylinder

Figure 1 – Arrangement of cylinder and specimen for the breakdown voltage test

4.4 Enamelled round wire with a nominal conductor diameter over 0,100 mm up to and including 2,500 mm

4.4.1 Test at room temperature

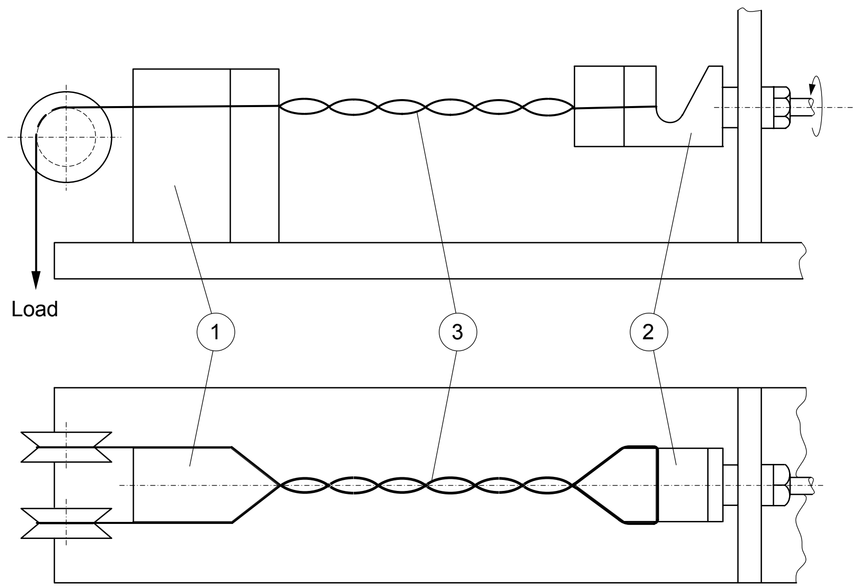
A straight piece of wire, approximately 400 mm in length, with the insulation removed at both ends, shall be twisted back on itself for a distance of (125 ± 5) mm on the twisting device as shown in Figure 2. The ends of the wire shall be joined, and the load applied with the number of twists, as given in Table 3. The loop at the end of the twisted section shall be cut at two places to provide a maximum spacing between the cut ends. Any bending to ensure adequate separation between the two wire ends shall avoid sharp bends or damage to the coating.

The test voltage shall be applied according to 4.1 between the conductors of the wires.

Five specimens shall be tested. The five single values shall be reported.

Table 3 – Loads applied to the wire and number of twists

Nominal conductor diameter mm		Load N	Number of twists
Over	**Up to and including**		
0,100	0,250	0,85	33
0,250	0,355	1,70	23
0,355	0,500	3,40	16
0,500	0,710	7,00	12
0,710	1,060	13,50	8
1,060	1,400	27,00	6
1,400	2,000	54,00	4
2,000	2,500	108,00	3



1 spacer

2 rotary hook

3 specimen

Figure 2 – Device for twisting the specimen for breakdown voltage test

4.4.2 Test at elevated temperature

A specimen prepared according to 4.4.1 shall be placed in the oven preheated to the specified test temperature ±3 °C. The test voltage shall be applied according to 4.1 between the conductors of the wires in not less than 15 min after placing the specimen in the oven. The test shall be completed within 30 min.

Five specimens shall be tested. The five single values shall be reported.

4.5 Round wire with a nominal conductor diameter over 2,500 mm

4.5.1 Test at room temperature

A straight piece of wire of sufficient length, with the insulation removed at one end, shall be bent around a mandrel as shown in Figure 3.

The diameter of the mandrel shall be 50 mm ± 2 mm.

The specimen shall be placed in the container and shall be surrounded by shot at least 5 mm between the specimen and the inner walls of the container. The ends of the specimen shall be sufficiently long to avoid flashover.

The shot shall be poured gently into a container until the specimen is covered by shot at a depth of 90 mm. The metal shot shall be not more than 2 mm in diameter; balls of stainless steel, nickel or nickel-plated iron have been found suitable. The shot shall be cleaned periodically with a suitable solvent (for example, 1,1,1-trichloroethane).

The test voltage shall be applied according to 4.1, between the conductor and the shot.

NOTE By agreement between the purchaser and the supplier, the test may be carried out with the specimen under oil. Oil should be in accordance with IEC 60296 or as agreed upon between customer and supplier.

Five specimens shall be tested. The five single values shall be reported.

Dimensions in millimetres

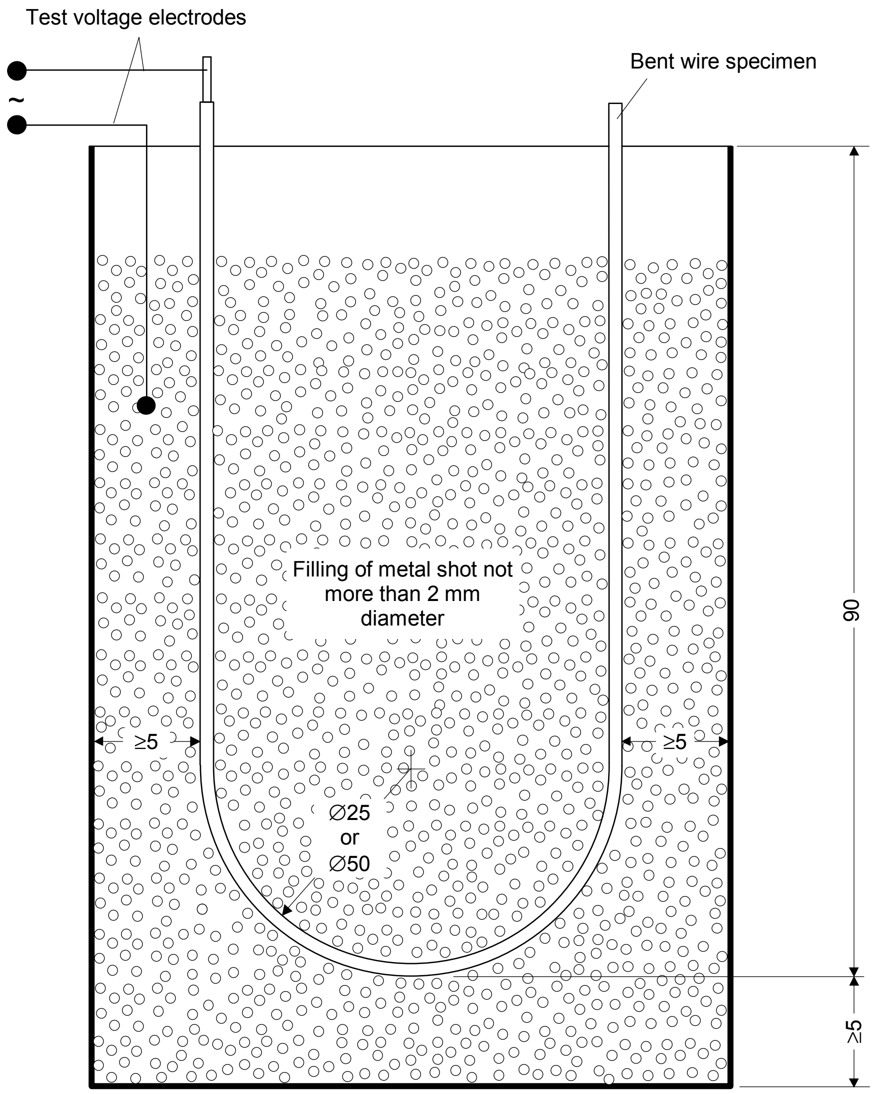


Figure 3 – U-bend specimen for the breakdown voltage test
(specimen placed in shot bath)

4.5.2 Test at elevated temperature

A specimen prepared according to 4.5.1 shall be placed in the oven preheated to the specified test temperature ±3 °C. The shot and container shall be preheated within the oven at the test temperature and kept there during the loading of the test specimen. The loading operation of the test specimen shall be performed very gently in order to avoid damage to the specimen.

The test voltage shall be applied according to 4.1 between the conductor and the shot in not less than 15 min after placing the specimen in the oven. The test shall be completed within 30 min.

The temperature shall be kept within ±3 °C.

Five specimens shall be tested. The five single values shall be reported.

4.6 Fibre wound round wire

4.6.1 Test at room temperature

A straight piece of wire of sufficient length with the insulation removed at one end shall be bent 10 turns around a mandrel as shown in Figure 4. The diameter of the mandrel shall be

– 25 mm ± 1 mm for nominal diameter up to and including 2,500 mm;

– 50 mm ± 2 mm for nominal diameter over 2,500 mm.

The specimen shall be placed in the container as shown in Figure 4 and shall be surrounded by shot at least 5 mm between the specimen and the inner walls of the container. There shall be a minimum distance of 2,5 mm between adjacent turns. The ends of the specimen shall be sufficiently long to avoid flashover.

The shot shall be poured gently into the container until the specimen is covered by shot at a depth of 90 mm. The metal shot shall not be more than 2 mm in diameter; balls of stainless steel, nickel or nickel-plated iron have been found suitable. The shot shall be cleaned once per year.

The test voltage shall be applied according to 4.1 between the conductor of the wire and the shot.

NOTE By agreement between the purchaser and the supplier, the test may be carried out with the specimen under oil. Oil should be in accordance with IEC 60296 or as agreed upon between customer and supplier.

Five specimens shall be tested. The five single values shall be reported.

Dimensions in millimetres

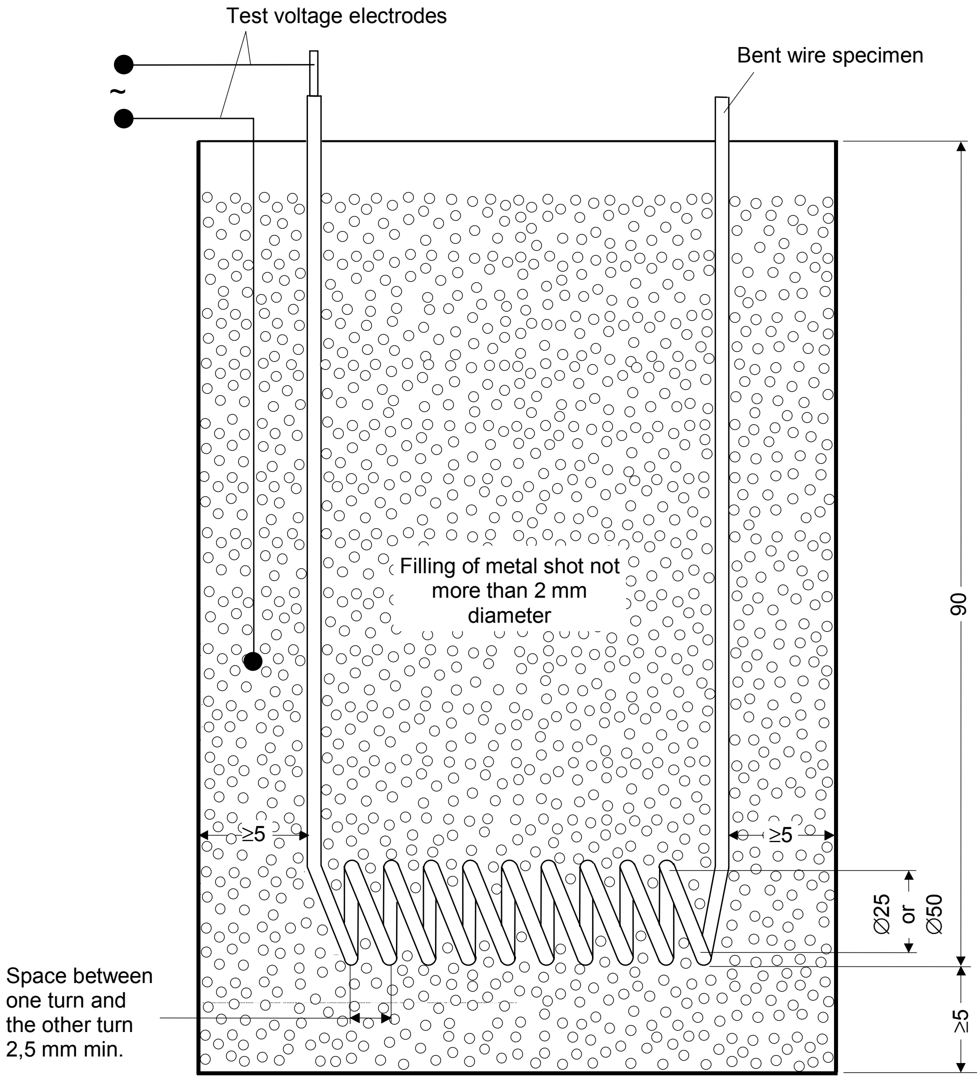


Figure 4 – Coil-wound specimen for the breakdown voltage test

4.6.2 Test at elevated temperature

A specimen prepared according to 4.6.1 shall be placed in the oven preheated to the specified test temperature ±3 °C. The shot and container shall be preheated within the oven at the test temperature and kept there during the loading of the test specimen. The loading operation of the test specimen shall be performed very gently in order to avoid damage to the specimen. The test voltage shall be applied according to 4.1 between the conductor and the shot in not less than 15 min after placing the specimen in the oven. The test shall be completed within 30 min.

The temperature shall be kept within ±3 °C.

Five specimens shall be tested. The five single values shall be reported.

4.7 Rectangular wire

4.7.1 Test at room temperature

A straight piece of wire approximately 350 mm in length with the insulation removed at one end shall be bent on the flat around a mandrel as shown in Figure 3. The diameter of the mandrel shall be

– 25 mm ± 1 mm for nominal thicknesses up to and including 2,500 mm;
– 50 mm ± 2 mm for nominal thicknesses over 2,500 mm.

The specimen shall be placed in the container and shall be surrounded by shot at least 5 mm between the specimen and the inner walls of the container. The ends of the specimen shall be sufficiently long to avoid flashover.

The shot shall be poured gently into the container until the specimen is covered by shot at a depth of 90 mm. The metal shot shall not be more than 2 mm in diameter; balls of stainless steel, nickel or nickel-plated iron have been found suitable. The shot shall be cleaned periodically.

The test voltage shall be applied according to 4.1 between the conductor of the wire and the shot.

NOTE By agreement between purchaser and supplier, the test may be carried out with the specimen under oil. Oil should be in accordance with IEC 60296 or as agreed upon between customer and supplier.

Five specimens shall be tested. The five single values shall be reported.

4.7.2 Test at elevated temperature

A specimen prepared according to 4.7.1 shall be placed in the oven preheated to the specified test temperature ±3 °C. The shot and container shall be preheated within the oven at the test temperature and kept there during the loading of the test specimen. The loading operation of the test specimen shall be performed very gently in order to avoid damage to the specimen. The test voltage shall be applied according to 4.1 between the conductor and the shot in not less than 15 min after placing the specimen in the oven. The test shall be completed within 30 min.

The temperature shall be kept within ±3 °C.

Five specimens shall be tested. The five single values shall be reported.

5 Test 14: Continuity of insulation (applicable to enamelled round and tape wrapped round wire)

5.1 General

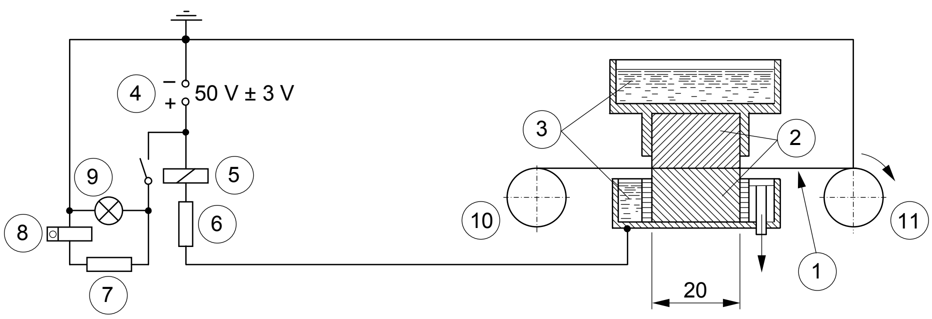
Continuity of insulation is expressed by the number of faults per length of wire detected by means of an electrical test circuit.

5.2 Low-voltage continuity (nominal conductor diameter up to and including 0,050 mm)

A wire specimen of (30 ± 1) m shall be pulled with a speed of (275 ± 25) mm/s between two felt pads, which shall be immersed in an electrolytic solution of sodium sulphate in water (30 g/l) with the conductor of the wire and the solution connected to an electrical circuit with an open-circuit d.c. test voltage of (50 ± 3) V (see Figure 5). The force applied to the wire shall not exceed 0,03 N. Faults shall be detected by means of a suitable relay along with a counter. The counter shall operate when the wire coating has a resistance of less than 10 kΩ for a period of at least 0,04 s. The counter shall not operate when the resistance is 15 kΩ or more. The fault detection circuit shall operate with a speed response of (5 ± 1) m/s and with a fault counter repeating at a rate of (500 ± 25) counts per minute when a bare wire is tested.

One test shall be made. The number of faults per 30 m of wire length shall be reported.

Dimensions in millimetres



1 wire

2 felt pads

3 electrolytic solution bath (30 g Na_2SO_4/l water)

4 d.c. supply

5 relay

6 resistor 50 kΩ

7 resistor 50 kΩ

8 counter

9 pilot lamp

10 delivery spool with winding wire

11 take-up spool

Figure 5 – Apparatus for testing the low-voltage continuity of covering

5.3 High-voltage continuity (nominal conductor diameter over 0,050 mm up to and including 1,600 mm)

5.3.1 Principle

A wire specimen with the conductor earthed is pulled over a "V" grooved electrode (pulley) or through a graphite brush electrode at a constant speed. A d.c. test voltage is applied between the electrode and earth. Any faults in the insulation of the wire are detected and recorded on a counter. The result is listed in faults per 30 m.

5.3.2 Equipment

The following equipment shall be used:

– high-voltage power supply providing a smooth filtered d.c. voltage with a ripple content less than 5 %, with an open-circuit test voltage adjustable from 350 V to 2 000 V with a short-circuit current limited by internal series resistance to (25 ± 5) µA at any test voltage and with not more than 75 % drop in voltage in case of a 50 MΩ fault resistance;
– fault detection circuit, which operates at a fault current as shown in Table 4 with a speed of response of (5 ± 1) ms and with a fault counter repeating at a rate of (500 ± 25) counts per minute when a bare wire is tested;
– dual high-voltage electrode pulleys according to Figure 6 made of stainless steel and providing a wire contact length of approximately 25 mm on each pulley;
– high-voltage electrode pulley according to Figure 7 made of stainless steel and providing a wire contact length of 25 mm to 30 mm;
– graphite fibre brush electrode assembly according to Figure 8, constructed so that the conductive brushes completely surround and contact the wire surface for a length of (25 ± 2,5) mm (see Figure 6). The graphite fibre brush electrode shall be inspected, cleaned, or replaced if excessive wear or accumulation of foreign material is present. The graphite brush electrode assembly shall be electrically isolated for the duration of the test to prevent false readings at the specified voltages;
– earthed guide pulleys having an outside diameter of (50 ± 0,25) mm and root diameter of (40 ± 0,25) mm and spaced (140 ± 2) mm apart;
– surge damping resistor of 4,7 MΩ ± 10 % installed in the high-voltage line.

NOTE The earth insulation for the high-voltage electrode should be a high-resistivity material, non-hygroscopic, non-tracking and easily cleaned, having a clearance for maintaining a continuous voltage of 3 000 V. No shielding should be used on the high-voltage lead since a minimum capacitance to ground is required during switching and counting events. The drive motor should be the brushless type and should have sufficient power to maintain the required speed to pull 1,600 mm wire.

Table 4 – Fault currents

Test voltage (d.c.) V	**Fault current** µA
2 000	12
1 500	10
1 000	8
750	7
500	6
350	5

Dimensions in millimetres

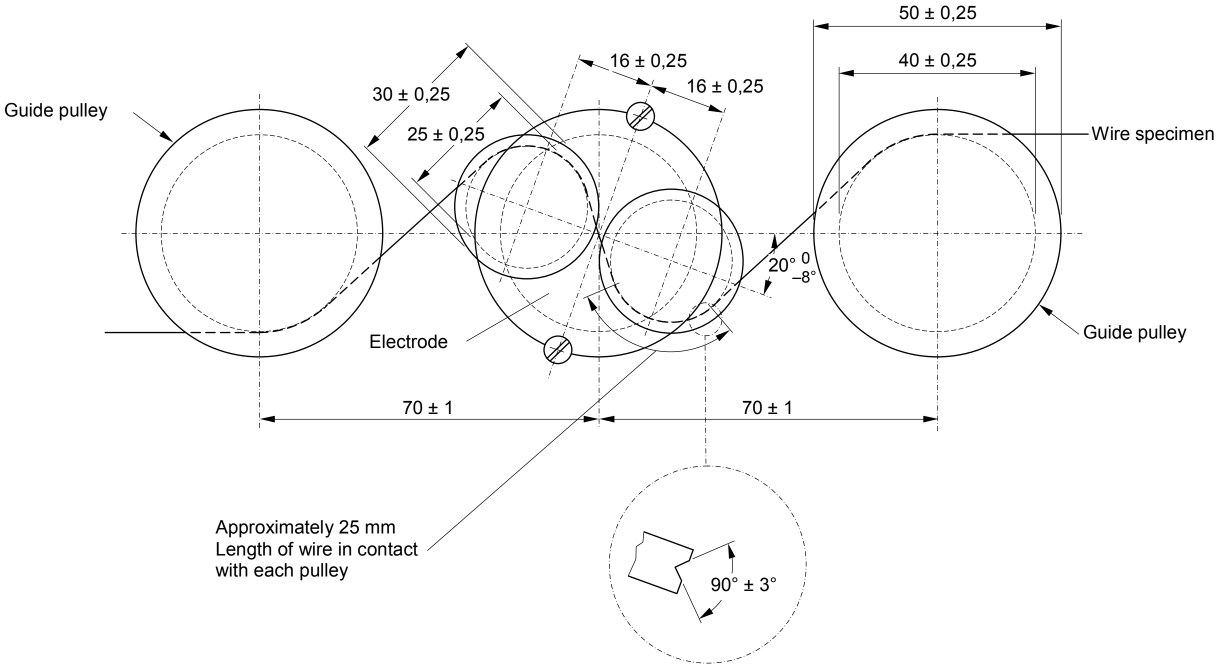


Figure 6 – High-voltage d.c. continuity – Pulleys for wire size 0,050 mm to 0,250 mm

Dimensions in millimetres

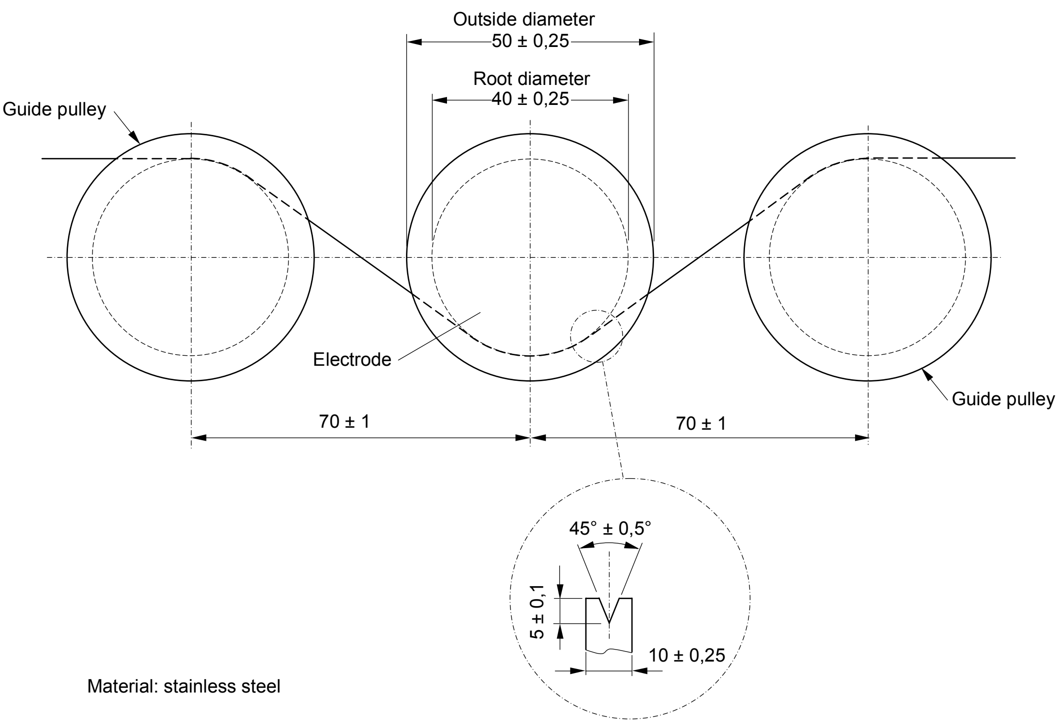
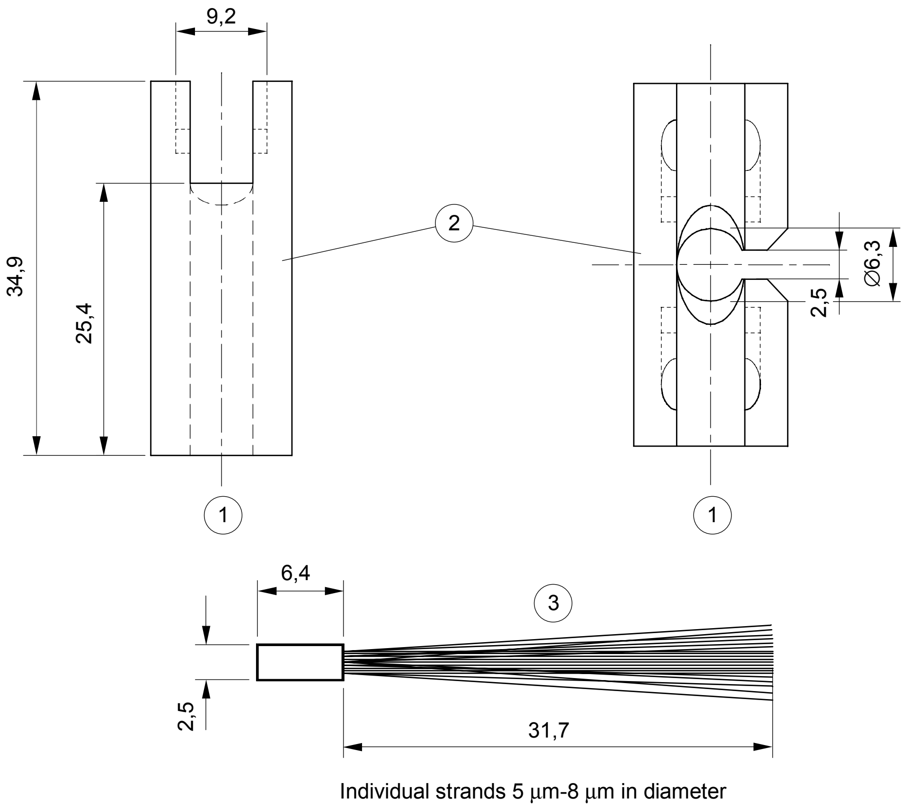


Figure 7 – Pulley dimensions and spacing for wire size 0,250 mm to 1,600 mm

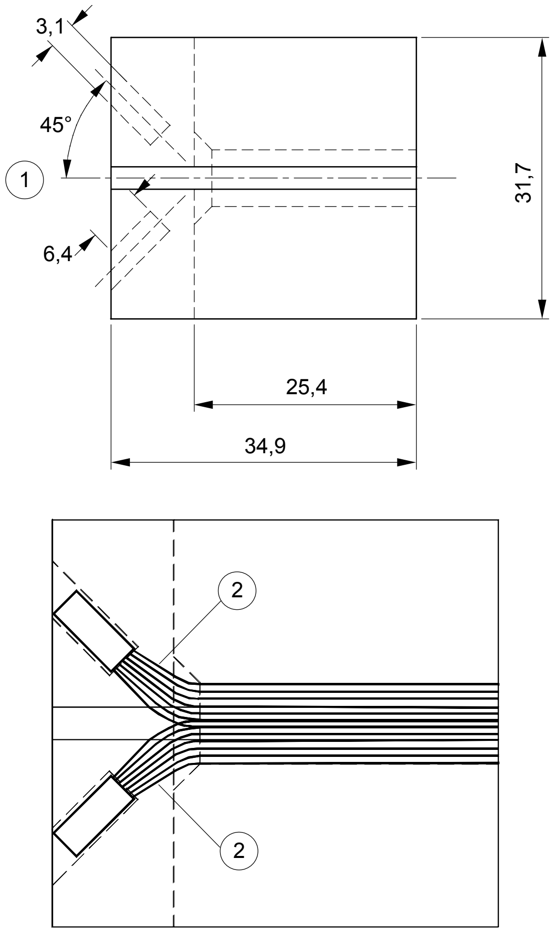
Dimensions in millimetres, tolerance of ±1%



1 wire path
2 brush mounting block
3 single graphite brush

Figure 8a – Graphite fibre single brush electrode assembly

Dimensions in millimetres, tolerance of ±1%



Individual strands 5 µm-8 µm in diameter

1 wire path
2 dual graphite brushes

Figure 8b – Graphite fibre dual brush electrode assembly

Figure 8 – Graphite fibre single or dual brush electrode asssembly

5.3.3 Procedure

A wire specimen of 30 m ± 1 m shall be pulled with a speed of (275 ± 25) mm/s over the high-voltage electrode pulley or through the graphite brush electrode mounted between the earthed guide pulleys with the conductor of the wire and the electrode connected to the electrical circuit, with the open-circuit d.c. test voltage adjusted according to Table 5 with a tolerance of ±5 % and with a positive polarity with respect to the earthed conductor of the wire.

Table 5 – Test voltages

Type of conductor	Nominal conductor diameter mm		Voltage (d.c.) V		
	Over	Up to and including	Grade 1	Grade 2	Grade 3
Copper	0,050 0,125 0,250 0,500	0,125 0,250 0,500 1,600	350 500 750 1 000	500 750 1 000 1 500	750 1 000 1 500 2 000
Aluminium	0,400	1,600	500	1 500	–

5.3.4 Result

One test shall be made. The number of faults per 30 m of wire length shall be reported.

6 Test 19: Dielectric dissipation factor (applicable to enamelled wire and bunched wire)

6.1 Principle

A piece of wire is treated as a capacitor whose coating forms the dielectric and whose conductor acts as one and a conducting medium as the second electrode. This capacitor is connected into a circuit, which operates at the required frequency and which is suitable for measurement of the capacitive and resistive components from which the dielectric dissipation factor is obtained.

6.2 Equipment

The following equipment shall be used:

– impedance meter, which shall operate at the frequency specified in the relevant standard and which shall provide a precision of ±1 % based on capacitance through the capacitance range required by the specimen at this frequency;

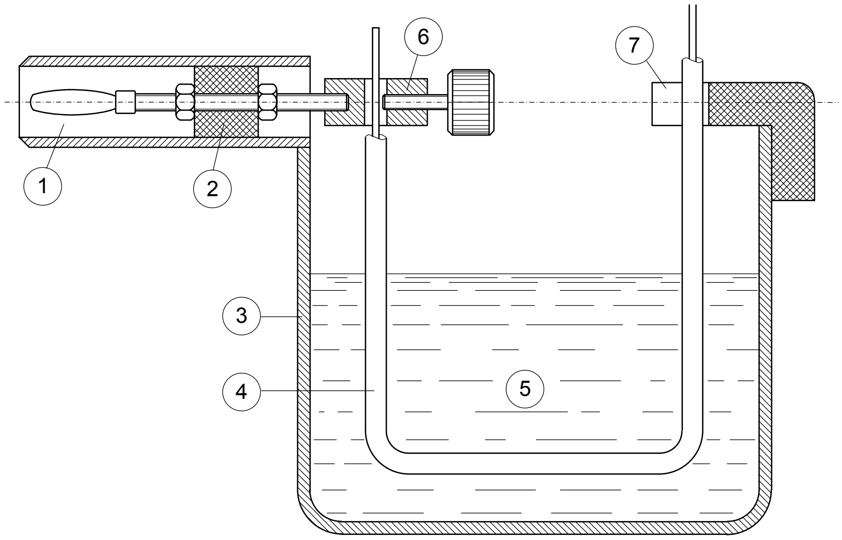
– frequency generator, which shall have a sinusoidal voltage output with a frequency specified in the relevant standard;

– test method A:

  metal bath according to Figure 9, which shall contain any suitable liquid metal (alloy) and which shall have a heating system that controls the temperature to ±1 °C;

– test method B:

  - two metal blocks with a heating system that controls the temperature to ±1 °C;
  - conducting suspension.



1 plug
2 insulating material
3 metallic container
4 specimen
5 electrode
6 terminal
7 insulated clamp

Figure 9 – Suitable electrode arrangement for testing the dielectric dissipation factor

6.3 Specimen

6.3.1 Specimen for a metal bath electrode

A straight piece of wire shall be bent into a U-shape to be lowered into the metal bath according to Figure 9.

6.3.2 Specimen for a conductive suspension electrode

6.3.2.1 Enamelled round wire with a nominal conductor diameter up to and including 0,100 mm

A straight piece of wire (100 ± 5) mm in length shall be wound around a straight piece of bare copper wire of 1 mm to 2 mm diameter and subsequently coated with a conductive suspension, for example by brushing a layer of an aqueous graphite dispersion on the specimen, which shall then be dried, for example, for 30 min at 100 °C in an oven with forced air circulation.

6.3.2.2 Enamelled round wire with a nominal conductor diameter over 0,100 mm and enamelled rectangular wire

A straight piece of wire about 150 mm in length shall be coated with a conductive suspension, for example, by brushing a layer of an aqueous graphite dispersion on the wire. The length of this layer shall be (100 ± 5) mm. The specimen shall be dried, for example, for 30 min at 100 °C in an oven with forced air circulation.

6.4 Procedure

Test method A: The specimen according to 6.3.1 shall be lowered into the metal bath according to Figure 9.

Test method B: The specimen according to 6.3.2 shall be placed between the two metal blocks. The specimen shall be connected to the impedance meter and shall be allowed to reach the specified test temperature. Thereafter, the dielectric dissipation factor shall be read directly from the impedance meter.

6.5 Result

One specimen shall be tested. The dielectric dissipation factor, the test frequency and the test temperature shall be reported.

7 Test 23: Pin hole test

The intent of this test is to find insulation defects after treatment with a salt water solution. The objective of this test is similar to that of the high-voltage continuity test in 5.3.

A wire specimen approximately 1,5 m in length is taken for conductors of nominal diameter less than 0,07 mm, and approximately 6 m in length for conductors of nominal diameter equal to 0,07 mm or more.

For a nominal diameter less than 0,07 mm, 1 m ± 0,05 m of wire shall be wound in a round shape with a diameter of 100 mm ± 50 mm.

For a nominal diameter of 0,07 mm or more, 5 m ± 0,2 m of wire shall be wound in a round shape with a diameter of 300 mm ± 100 mm.

The specimen is placed in an air circulation oven at 125 °C ± 3 °C for 10 min (see note 1 below) (if not otherwise specified in the relevant specification).

After this heat treatment, without any bending or stretching (see note 2 below), the specimen after cooling to room temperature shall be immersed in an electrolytic solution of sodium chloride (2 g/l) added with a proper quantity of phenolphthalein alcohol solution (30 g/l) for the easy evidence of any pin holes (typically pink streams in the solution), with the conductor of the wire and the solution connected to an electrical circuit with an open-circuit d.c. test voltage of (12 ± 2) V.

The voltage shall be applied for 1 min with the specimen as negative electrode relative to the solution and, in order to avoid excessive heating, the short-circuit current shall be limited to 500 mA.

The number of observed pin holes, without magnification (normal vision), shall be reported.

NOTE 1 Without heat treatment the results cannot be significant.

NOTE 2 Elongation of the wire may lead to the creation of pin holes in the electrolytic solution.

NOTE 3 Because this test is done in an aqueous solution, misleading results may be found for specific enamel types, which show crazing behaviour in water.

Annex A
(informative)

Dissipation factor methods

A.1 Tangent delta – Intersection point

A number of methods are available in order to check the repeatability of curing. These are included as examples.

The principle is as follows: A specimen of enamelled wire is treated as a capacitor, using the conductor as one electrode and as the other electrode either a coating of dried film of graphite, or a bath of molten metal. The temperature of the specimen is raised at a controlled and uniform rate and the dissipation factor (*d*) is determined and plotted to produce a graph of dissipation factor (tangent delta) vs. temperature. Interpretation of the curve allows a value of temperature to be obtained which relates directly to the degree of cure of the enamel film. Alternative methods are in use, in which the specimen is cooled from a higher to a lower temperature.

A.2 Test methods

A.2.1 Method A

A.2.1.1 Using molten metal alloy with increasing temperature

An electronic bridge allowing the value of *d* to be determined directly shall be used.

Enamelled wire specimen shall be wiped clean with soft cloth and assembled onto the fixture. The wire specimen with fixture shall be immersed in a molten liquid metal bath pre-adjusted at the lowest temperature. The specimen shall be connected to the bridge with the conductor as the one electrode and the molten liquid metal as the other. The temperature of the assembly shall be increased at a steady rate from ambient temperature to a temperature to give a clearly defined curve. Readings of tangent delta and temperature are taken regularly and the results are plotted in a graph with linear axis for temperature and logarithmic or linear axis for tangent delta. Because the readings can vary quickly, it is preferable to take the readings automatically onto a chart recorder or computer system. The use of automatic recording allows the test to be performed with a more rapid temperature rise although great care should be taken to ensure that there is no significant lag between the reading and the actual temperature. The actual equipment, temperature rise and interpretation should be agreed between customer and supplier.

A.2.1.2 Using molten metal alloy with decreasing temperature

An electronic bridge allowing the value of *d* to be determined directly shall be used.

An enamelled wire specimen shall be wiped clean with a soft cloth and assembled onto the fixture. The wire specimen with fixture shall be immersed for 30 s in a molten liquid metal bath pre-adjusted at the highest temperature. The specimen shall then be removed and shaken to remove excess molten alloy, cooled for approximately 10 s at room temperature, then immersed again. The specimen shall be connected to the bridge with the conductor as the one electrode and the molten liquid metal as the other. The temperature of the assembly shall be steadily decreased to give a clearly defined curve of dielectric dissipation factor vs. temperature. One test shall be conducted.

Readings of tangent delta and temperature shall be taken regularly and the results plotted in a graph with temperature on the X-axis (linear) and dielectric dissipation factor (tangent delta) on the Y-axis (logarithmic or linear). Because the readings can vary quickly, it is preferable to take the readings automatically onto a chart recorder or computer system. The use of automatic recording allows the test to be performed with a more rapid temperature rise although great care should be taken to ensure that there is no significant lag between the reading and the actual temperature. The actual equipment, temperature rise and interpretation should be agreed upon between customer and supplier.

NOTE The highest temperature of molten alloy bath at which the wire specimen is inserted and tan-delta plotted on the cooling curve depends on the type of insulation and the glass-transition temperature (tg) of the enamel. This can be determined by pre-testing of unknown wire enamel.

A.2.2 Method B – Wire coated with a conductive film

An electronic bridge allowing the value of *d* to be determined directly shall be used.

The specimen shall be connected to the bridge with the conductor as the one electrode and the graphite coating as the other.

The temperature of the assembly shall be increased at a steady rate from ambient temperature to a temperature to give a clearly defined curve. The temperature shall be taken through a detector in contact with the specimen. The position of the temperature detector and the type of contact can influence the reading and different devices can give different results. Readings of tangent delta and temperature are taken regularly and the results are plotted in a graph with linear axis for temperature and logarithmic or linear axis for tangent delta. Because the readings can vary quickly it is preferable to take the readings automatically onto a chart recorder or computer system. The use of automatic recording allows the test to be performed with a more rapid temperature rise although great care should be taken to ensure that there is no significant lag between the reading and the actual temperature. The actual equipment, temperature rise and interpretation should be agreed between customer and supplier.

A.3 Interpretation of results

A.3.1 General

The tangent delta curve can be presented in two ways in the resulting graphs shown in Figures A.1 and A.2.

The *d* value can be presented on either a linear or a logarithmic Y-axis. The calculation of the tgδ value is made in different ways for the two methods. Distinction shall be made when presenting the results as to which method has been used. The following graphs are only to be used to understand the methods and do not represent any specific requirements for materials.

A.3.2 Linear method

A tangent is drawn to the steepest part of the first ascent with rising temperature of the tangent delta versus temperature curve. A horizontal line is drawn through a point on the curve corresponding to a temperature to be agreed between customer and supplier. The temperature corresponding to the point where this line crosses the aforesaid tangent is determined. The value is presented as tgδ = xxx °C (lin).

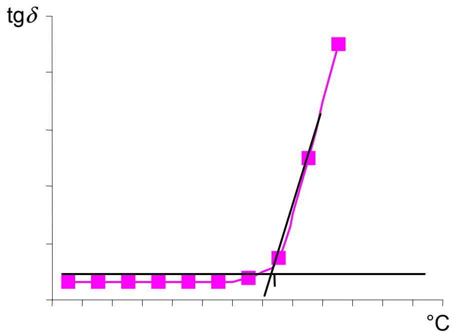


Figure A.1 – Example of linear method for sole coating

A.3.3 Logarithmic method

In the case of increasing temperature, two horizontal lines are drawn from the Y- axis at values agreed between customer and supplier. A line is drawn through the intersections of these points and the curve, and extended to cross a horizontal line through the minimum value on the curve.

The temperature corresponding to the latter crossing point is determined. The value is presented as tgδ = xxx °C (log).

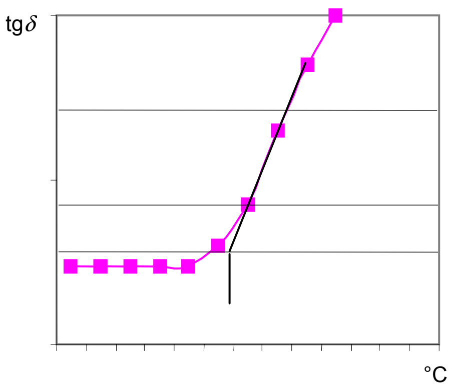


Figure A.2 – Example of logarithmic method for sole coating