
**Road vehicles — 60 V and 600 V
single-core cables — Dimensions, test
methods and requirements**

*Véhicules routiers — Câbles monoconducteurs de 60 V et 600 V —
Dimensions, méthodes d'essai et exigences*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 6722 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 3, *Electrical and electronic equipment*.

This second edition cancels and replaces the first edition (ISO 6722:2002) which has been technically revised.

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Road vehicles — 60 V and 600 V single-core cables — Dimensions, test methods and requirements

1 Scope

This International Standard specifies the dimensions, test methods, and requirements for single-core 60 V cables intended for use in road vehicle applications where the nominal system voltage is $\leq$ (60 V d.c. or 25 V a.c.). It also specifies additional test methods and/or requirements for 600 V cables intended for use in road vehicle applications where the nominal system voltage is $>$ (60 V d.c. or 25 V a.c.) to $\leq$ (600 V d.c. or 600 V a.c.). It also applies to individual cores in multi-core cables.

Eight temperature classes are defined in Table 1.

Table 1 — Temperature class rating

Class	Temperature
A	– 40 °C to 85 °C
B	– 40 °C to 100 °C
C	– 40 °C to 125 °C
D	– 40 °C to 150 °C
E	– 40 °C to 175 °C
F	– 40 °C to 200 °C
G	– 40 °C to 225 °C
H	– 40 °C to 250 °C

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.

ISO 1817, *Rubber, vulcanized — Determination of the effect of liquids*

ISO 6931-1, *Stainless steels for springs — Part 1: Wire*

IEC 60757, *Code for designation of colours*

IEC 60811-2-1, *Common test methods for insulating and sheathing materials of electrical and optical cables — Part 2-1: Methods specific to elastomeric compounds — Ozone resistance, hot set and mineral oil immersion tests*

ASTM B1, *Standard Specification for Hard-Drawn Copper Wire*

ASTM B3, *Standard Specification for Soft or Annealed Copper Wire*

ASTM B33, *Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes*

ASTM B298, *Standard Specification for Silver-Coated Soft or Annealed Copper Wire*

ASTM B355, *Standard Specification for Nickel-Coated Soft or Annealed Copper Wire*

3 Terms and definitions

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

3.1

60 Volt (V) cable

cable intended for use in road vehicle applications where the nominal system voltage is equal to or less than 60 V d.c. or 25 V a.c.

3.2

600 Volt (V) cable

cable intended for use in road vehicle applications where the nominal system voltage is greater than (60 V d.c. or 25 V a.c.) and less than (600 V d.c. or 600 V a.c.)

NOTE a.c. tests are performed at 50 Hz or 60 Hz. Applications at higher frequencies may require additional testing.

3.3

cable family

group with multiple conductor sizes having the same conductor strand coating, insulation formulation and wall-thickness type

3.4

nominal (value)

suitable approximate value used to designate or identify a component

4 General

4.1 Caution

Special care shall be taken with cables used with voltages above (60 V d.c. or 25 V a.c.) to protect them from mechanical stress in order to avoid shock hazard. Regardless of wall thickness, 600 V cables shall meet the "resistance to abrasion" requirements for thick wall cable.

4.2 Conductors

The conductors shall consist of plain or coated copper strands as shown in Table 2. Conductor sizes $\geq 0,5 \text{ mm}^2$ shall consist of soft annealed copper or annealed compressed/compacted wires. Conductor sizes $< 0,5 \text{ mm}^2$ shall consist of soft annealed copper, soft annealed compressed/compacted copper, hard unannealed copper or a copper alloy. The specifications for the conductors shall be completed by material specifications. Elongation requirements shall be established by agreement between customer and supplier. The finished cable shall meet the resistance requirements of 6.1 for all conductors except alloys. When an alloy is used, the resistance requirement shall be established by agreement between customer and supplier.

NOTE Examples of strandings are shown in Table A.1. These strandings highlight examples of conceptual configurations and are not intended to reflect any preferred constructions. Other strandings' configurations may be used provided they meet the requirements shown above and are agreed upon between customer and supplier.

Table 2 — Conductor specifications

ASTM B1	Hard-drawn copper wire
ASTM B3	Soft or annealed copper wire
ASTM B33	Tinned soft or annealed copper wire
ASTM B298	Silver-coated soft or annealed copper wire
ASTM B355	Nickel-coated soft or annealed copper wire
NOTE Silver- and nickel-coated conductors are intended for use with high "temperature class ratings".	

4.3 Tests

The cables shall be submitted to the tests as specified in Table 3.

4.4 General test conditions

Test samples for all tests except those in Clause 5 and in 6.1 and 6.3 shall be preconditioned for at least 16 h at a room temperature of $(23 \pm 5) ^\circ\text{C}$. Unless otherwise specified, all tests other than "in-process" tests shall be conducted at this same temperature. Where no tolerance is specified, all values shall be considered to be approximate.

4.5 Ovens

Unless otherwise specified, when an oven is required, it shall be a hot air oven. The air contained in the oven shall be completely changed at least eight (8) times but not more than twenty (20) times per hour at the specified temperature.

4.6 Representative conductor sizes for testing

When a test is required, all combinations of conductor size, wall thickness and insulation formulation shall meet the appropriate requirements. However, if representative conductor sizes for testing are permitted, compliance for a cable family may be demonstrated by testing examples of large and small conductor sizes only. Permission to show compliance for a cable family by testing "representative conductor sizes" shall be established by agreement between customer and supplier.

4.7 Recommended colours

A list of recommended colours is shown in Table B.1

Table 3 — Tests

Clause	Test description	In-process tests ^a	Certification		If required ^c	
			Initial	Periodic ^b	Initial	Periodic ^b
5	Dimensions					
5.1	Outside cable diameter	—	×	×	—	—
5.2	Insulation thickness	—	×	×	—	—
5.3	Conductor diameter	—	—	—	×	×
6	Electrical characteristics					
6.1	Conductor resistance	—	×	×	—	—
6.2	Withstand voltage	—	d	d	—	—
6.3	Insulation faults	d	—	—	—	—
6.4	Insulation volume resistivity	—	—	—	×	×
7	Mechanical characteristics					
7.1	Pressure test at high temperature	—	×	×	—	—
7.2	Strip force	—	—	—	×	×
8	Low-temperature characteristics					
8.1	Winding	—	×	×	—	—
8.2	Impact	—	—	—	×	×
9	Resistance to abrasion	—	e	e	—	—
9.2	Sandpaper abrasion	—	—	—	—	—
9.3	Scrape abrasion	—	—	—	—	—
10	Heat ageing					
10.1	Long-term ageing, 3 000 h	—	×	—	—	—
10.2	Short-term ageing, 240 h	—	×	×	—	—
10.3	Thermal overload	—	—	—	×	×
10.4	Shrinkage by heat	—	×	×	—	—
11	Resistance to chemicals					
11.2	Fluid compatibility	—	f, g	—	f, g	—
11.3	Durability of cable marking	—	—	—	g	g
11.4	Resistance to ozone	—	—	—	g	—
11.5	Resistance to hot water	—	—	—	g	—
11.6	Temperature and humidity cycling	—	—	—	g	—
12	Resistance to flame propagation	—	×	×	—	—

"X" To be applied.

"—" Not applicable.

^a A test made on all cables during or after manufacture.

^b The frequency of periodic testing shall be established by agreement between customer and supplier.

^c The usage of "if required" tests shall be established by agreement between customer and supplier.

^d Some cables are rated at 60 V and others at 600 V. See 6.2 and 6.3 for details.

^e See Clause 9.

^f Some fluids are for "certification" and others are "if required". See 11.2 for details.

^g Compliance for a cable family may be demonstrated by testing examples of large and small conductor sizes only. See 4.6 for details.

5 Dimensions

5.1 Outside cable diameter

5.1.1 Test Sample

Prepare a test sample 3 m in length.

5.1.2 Apparatus

Use a measuring device with an accuracy of $\pm 0,01$ mm. The device shall not cause deformation.

5.1.3 Procedure

Take three sets of measurements at positions separated by 1 m and record the highest and lowest outside cable diameter at each position.

5.1.4 Requirement

All measurements shall be within the limits of the appropriate maximum and minimum “outside cable diameter” specified in Table 4 and Table C.1. The values in Table 4 are normative. Since the values in Table C.1 are informative, they are not required; however, they may be applied by agreement between customer and supplier.

5.2 Insulation thickness

5.2.1 Test samples

Prepare three test samples from a cable sample 3 m in length. Take the test samples at 1 m intervals. Strip the insulation from the cable. A test sample consists of a thin cross section of insulation. Take care not to deform the test sample during the preparation process. If cable marking causes indentation of the insulation, take the first test sample through this indentation.

5.2.2 Apparatus

Use a measuring device with an accuracy of $\pm 0,01$ mm. The device shall not cause deformation.

5.2.3 Procedure

Place the test sample under the measuring equipment with the plane of the cut perpendicular to the optical axis. Determine the minimum “insulation thickness”.

5.2.4 Requirement

No single value shall be less than the appropriate minimum insulation thickness specified in Table 4.

Table 4 — Dimensions

ISO conductor		Thick wall			Thin wall			Ultra-thin wall		
Size	Diameter	Insulation thickness		Outside cable diameter	Insulation thickness		Outside cable diameter	Insulation thickness		Outside cable diameter
mm ²	mm	mm		mm	mm		mm	mm		mm
	max.	nominal	min.	max.	nominal	min.	max.	nominal	min.	max.
0,13	0,55	—	—	—	0,25	0,20	1,05	0,20	0,16	0,95
0,22	0,70	—	—	—	0,25	0,20	1,20	0,20	0,16	1,05
0,35	0,90	—	—	—	0,25	0,20	1,40 ^a	0,20	0,16	1,20
0,50	1,10	0,60	0,48	2,30	0,28	0,22	1,60	0,20	0,16	1,40
0,75	1,30	0,60	0,48	2,50	0,30	0,24	1,90	0,20	0,16	1,60
1	1,50	0,60	0,48	2,70	0,30	0,24	2,10	0,20	0,16	1,75
1,5	1,80	0,60	0,48	3,00	0,30	0,24	2,40	0,20	0,16	2,10
2	2,00	0,60	0,48	3,30	0,35	0,28	2,80	0,25	0,20	2,40
2,5	2,20	0,70	0,56	3,60	0,35	0,28	3,00	0,25	0,20	2,70
3	2,40	0,70	0,56	4,10	0,40	0,32	3,40	—	—	—
4	2,80	0,80	0,64	4,40	0,40	0,32	3,70	—	—	—
5	3,10	0,80	0,64	4,90	0,40	0,32	4,20	—	—	—
6	3,40	0,80	0,64	5,00	0,40	0,32	4,30	—	—	—
10	4,50	1,00	0,80	6,50	0,60	0,48	6,00	—	—	—
16	6,30	1,00	0,80	8,30	0,65	0,52	7,90	—	—	—
25	7,80	1,30	1,04	10,40	0,65	0,52	9,40	—	—	—
35	9,00	1,30	1,04	11,60	—	—	—	—	—	—
50	10,50	1,50	1,20	13,50	—	—	—	—	—	—
70	12,50	1,50	1,20	15,50	—	—	—	—	—	—
95	14,80	1,60	1,28	18,00	—	—	—	—	—	—
120	16,50	1,60	1,28	19,70	—	—	—	—	—	—

NOTE Outside cable diameter minimum values for high-volume cable constructions are shown in Table C.1. Since the values in Table C.1 are informative, they are not required; however, they may be applied by agreement between customer and supplier.

^a The outside cable diameter for conductor size 0,35 mm² with 7 strands shall be a maximum of 1,30 mm.

5.3 Conductor diameter

5.3.1 Test samples

The usage of this test shall be established by agreement between customer and supplier. In case of disputed results, a refereeing method is provided.

Referee test samples: in case of a dispute, prepare three test samples from a cable sample 3 m in length. Take the test samples at 1 m intervals. A test sample consists of a 20 mm length of cable. Take care not to deform the test sample. Immerse the test samples in a casting resin. After hardening, take a section perpendicular to the axis of the test sample.

5.3.2 Apparatus

Carry out this test on the same apparatus used for the measurement of the insulation thickness (see 5.2).

Referee apparatus: in case of a dispute, the measuring device shall be capable of at least $10 \times$ linear magnification.

5.3.3 Procedure

Check the conductor diameter by measuring the inside diameter of the samples used in 5.2 and recording the maximum inside diameter for each test sample.

Referee procedure: in case of a dispute, measure the conductor diameter using the “referee test samples” and the “referee apparatus”. Record the maximum conductor diameter for each test sample.

5.3.4 Requirement

The measured value shall not exceed the maximum value, specified in Table 4. This measured value is also required in 6.4.

6 Electrical characteristics

6.1 Conductor resistance

6.1.1 Test samples

Prepare a test sample 1 m in length plus the length necessary for connections. Other lengths may be used providing that the resistance reading is adjusted using the method shown in 6.1.3. The ends of the test sample may be soldered.

6.1.2 Apparatus

Use a resistance-measuring device with an accuracy of $\pm 0,5 \%$ of the measured value and a thermometer with an accuracy of $\pm 0,5 \text{ }^{\circ}\text{C}$.

6.1.3 Procedure

Measure the temperature of the test sample and the unsoldered length. Take care to ensure that connections are secure. Measure the resistance of the test sample. Correct the measured value using the following equation:

$$R_{20} = \frac{R_t}{L[1 + 0,003\,93(t - 20)]}$$

where

R_{20} is the corrected conductor resistance at the reference temperature of $20 \text{ }^{\circ}\text{C}$, expressed in milliohms per metre;

R_t is the conductor resistance measured at the conductor temperature, expressed in milliohms;

L is the unsoldered conductor length, expressed in metres;

t is the conductor temperature at the time of measuring, expressed in degrees centigrade.

NOTE The value of 0,003 93 is the temperature coefficient for copper with 100 % conductivity at a temperature of 20 °C. For coated wires or alloys, the correction factor shall be established by agreement between customer and supplier.

6.1.4 Requirement

The corrected value shall not exceed the appropriate maximum resistance specified in Table 5.

Conductors produced from silver-coated strands shall not exceed the maximum conductor resistance per length for plain copper.

6.2 Withstand voltage

6.2.1 Test sample

Prepare a test sample of a minimum length of 350 mm, strip 25 mm of insulation from each end and twist the ends together to form a loop.

6.2.2 Apparatus

Partially fill an electrically non-conductive vessel with salt water (aqueous solution of 3 % by mass of NaCl) with the ends of the test sample emerging above the bath as shown in Figure 1. Use a 50 Hz or 60 Hz a.c. voltage source.

6.2.3 Procedure

6.2.3.1 60 V cable

Immerse the test sample in the bath, as shown in Figure 1, for 4 h and then apply a test voltage of 1 kV (r.m.s.) for 30 min between the conductor and the bath. Then increase the voltage at a rate of 500 V/s until the following value is reached:

— 3 kV (r.m.s.) for cables $< 0,5 \text{ mm}^2$;

— 5 kV (r.m.s.) for cables $\geq 0,5 \text{ mm}^2$.

6.2.3.2 600 V cable

After completing the procedure for a 60 V cable, hold the 3 kV or 5 kV for a further 5 min.

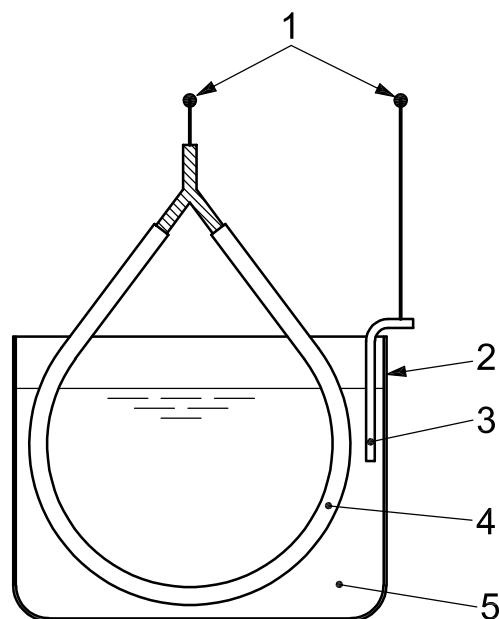
6.2.4 Requirement

Breakdown shall not occur.

Table 5 — Conductor resistance

ISO conductor Size mm ²	Maximum conductor resistance per length mΩ/m at 20 °C		
	Plain copper	Sn-plated copper	Ni-plated copper
0,13	136	140	142
0,22	84,8	86,5	87,9
0,35	54,4	55,5	56,8
0,50	37,1	38,2	38,6
0,75	24,7	25,4	25,7
1	18,5	19,1	19,3
1,5	12,7	13,0	13,2
2	9,42	9,69	9,82
2,5	7,60	7,82	7,92
3	6,15	6,36	6,41
4	4,71	4,85	4,91
5	3,94	4,02	4,11
6	3,14	3,23	3,27
10	1,82	1,85	1,90
16	1,16	1,18	1,21
25	0,743	0,757	0,774
35	0,527	0,538	0,549
50	0,368	0,375	0,383
70	0,259	0,264	0,270
95	0,196	0,200	0,204
120	0,153	0,156	0,159

NOTE Conductor resistance, minimum values for high-volume cable constructions are shown in Table C.2. Since the values in Table C.2 are informative, they are not required; however, they may be applied by agreement between customer and supplier.

**Key**

- 1 test voltage (terminals)
- 2 non-conductive vessel
- 3 electrode
- 4 test sample
- 5 salt-water bath

Figure 1 — Apparatus for withstand voltage test**6.3 Insulation faults****6.3.1 Test sample**

All cable-produced.

6.3.2 Apparatus

Use a sinusoidal voltage source set at the value shown in Table 6. The test electrode may consist of metal ball chains, metal brushes or any other type of suitable electrodes. Choose the electrode length and frequency considering the speed of the cable running through the field of the electrode so that each point of the cable is loaded by at least nine voltage cycles.

Table 6 — Insulation faults

ISO conductor size mm ²	Voltage rating kV (r.m.s.)	
	60 V cables	600 V cables
< 0,5	3	6
≥ 0,5	5	8

6.3.3 Procedure

This test shall be carried out under production conditions. Subject all cables to this test. Other methods of test may be used provided that insulation faults are detected with the same certainty.

6.3.4 Requirement

No breakdown shall occur when the earthed cable is drawn through the test electrode.

6.4 Insulation volume resistivity

6.4.1 Usage of test

The usage of this test shall be agreed between customer and supplier.

6.4.2 Test sample

Prepare a test sample of 5 m length and remove 25 mm of insulation from each end.

6.4.3 Apparatus

Partially fill an electrically non-conductive vessel with tap water at a temperature of $(70 \pm 2) ^\circ\text{C}$. Use a resistance-measuring device with a d.c. voltage of 500 V. Voltages between 100 V and 500 V are allowed; however, if a dispute arises, the referee apparatus shall be a resistance-measuring device with a d.c. voltage of 500 V.

6.4.4 Procedure

Immerse the test sample for 2 h with each end emerging from the bath by 250 mm. Apply the d.c. voltage between the conductor and the bath. Measure the insulation resistance 1 min after application of the voltage. Calculate the insulation volume resistivity using the following formula:

$$\rho_0 = 2,725 \times \frac{L \times R}{\lg \frac{D}{d}}$$

where

ρ_0 is the insulation volume resistivity, expressed in ohm millimetres;

L is the immersed length of the test sample in millimetres;

R is the measured insulation resistance in ohms;

D is the outside cable diameter in millimetres according to 5.1;

d is the conductor diameter in millimetres according to 5.3;

$\lg$ is logarithm to the base 10.

6.4.5 Requirement

The insulation volume resistivity shall not be less than $10^9 \Omega \cdot \text{mm}$.

7 Mechanical characteristics

7.1 Pressure test at high temperature

7.1.1 Test samples

Prepare three test samples, each of 600 mm length.

7.1.2 Apparatus

The test temperature for the oven is given in Table 7 and the apparatus is shown in Figure 2. Ensure that the apparatus is free from vibrations. Apply the force, F , by the blade to the test sample as given by the formula:

$$F = 0,8\sqrt{i(2D-i)}$$

where

F is the total vertical force exerted on the test sample in newtons;

0,8 is a coefficient which carries the dimension in newtons per millimetre;

D is the appropriate “outside cable diameter maximum” in millimetres according to Table 4;

i is the appropriate nominal value of the “insulation thickness” in millimetres according to Table 4.

The calculated force may be rounded off at the lower digit, but not beyond 3 %.

Table 7 — Pressure test at high temperature

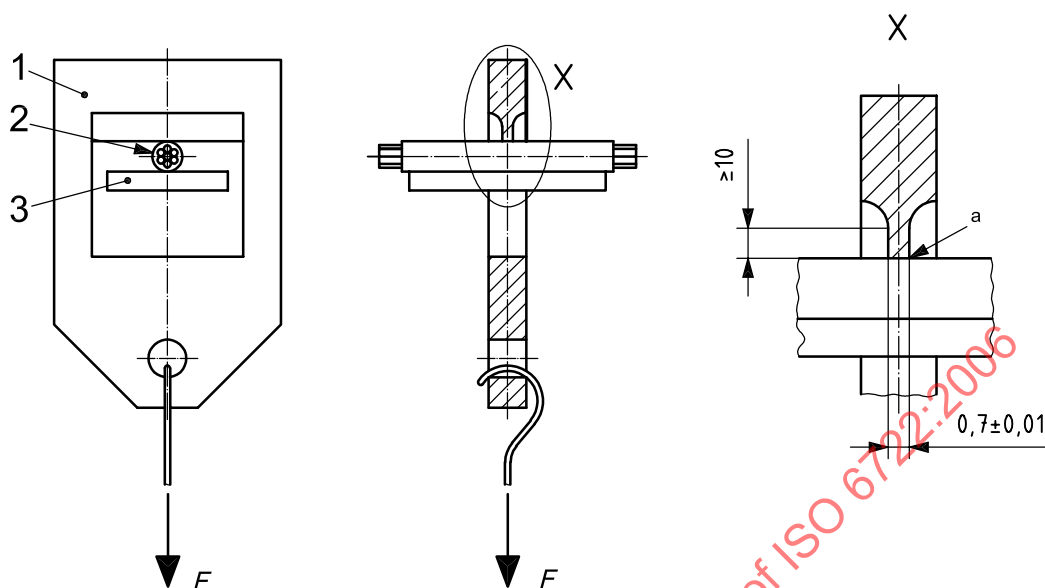
Class	Test temperature ^a °C
A	85 ± 2
B	100 ± 2
C	125 ± 3
D	150 ± 3
E	175 ± 3
F	200 ± 3
G	225 ± 4
H	250 ± 4
^a Upper value of temperature class rating (see Table 1).	

7.1.3 Procedure

Place a test sample as shown in Figure 2. Attach the test sample to the support so as not to bend it under the pressure of the blade. The load and the blade of the apparatus shall be perpendicular to the test-sample axis and applied in the middle of the test sample. Place the test sample under load, not preheated, for 4 h in the oven. Then cool the test sample within 10 s by immersion in cold water. Repeat the procedure for the other test samples. After immersion, subject the test samples to the withstand voltage test and make the following changes to the procedure in 6.2.

- Immerse the test samples in the salt-water bath for a minimum of 10 min prior to the application of the voltage.
- Apply the 1 kV (r.m.s.) voltage for 1 min.
- Do not “ramp up” the voltage after the application of the 1 kV (r.m.s.) voltage.

Dimensions in millimetres

**Key**

- 1 test frame
- 2 test sample
- 3 support

F Applied force.

a Sharp edge with a max. radius of 0,005 mm.

Figure 2 — Apparatus for pressure test at high temperature

7.1.4 Requirement

Breakdown shall not occur during the withstand voltage test.

7.2 Strip force

7.2.1 Usage of test

The usage of this test shall be agreed between customer and supplier. This test is applicable to cables with a conductor size $\leq 6 \text{ mm}^2$.

7.2.2 Test samples

Prepare three test samples of 100 mm from a cable sample 3 m in length. Take the test samples at 1 m intervals. Cut at least 25 mm of insulation cleanly and strip it carefully from one end of the conductor (see Figure 3, length AB). Then cut the test samples leaving a 50 mm section (B-C) undisturbed.

7.2.3 Apparatus

Use a test fixture similar to the one shown in Figure 3. A metal plate is provided with a round hole equal to the appropriate conductor diameter. Use a tensile machine with a speed of 250 mm/min. Ensure that the apparatus is capable of pulling the test samples without friction between the conductor and the apparatus.

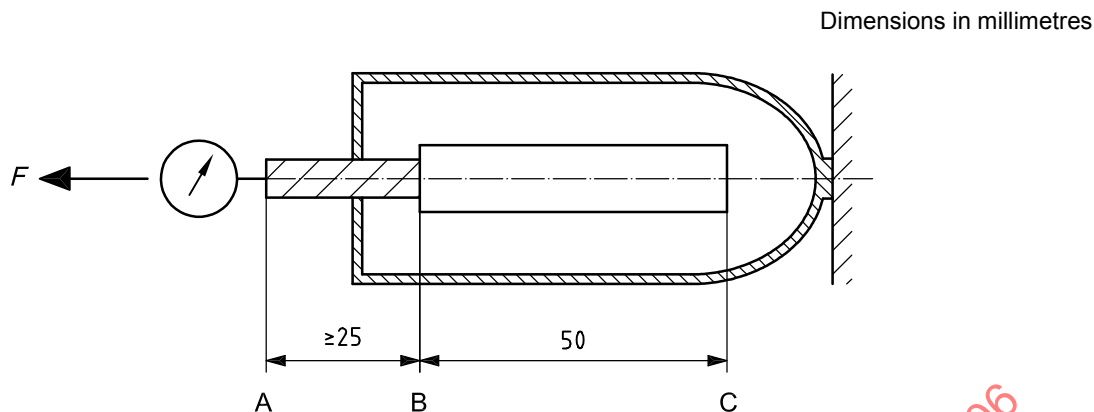


Figure 3 — Apparatus for strip force

7.2.4 Procedure

Place a test sample in the test fixture. Pull the test sample without friction between the conductor and the apparatus at a speed of 250 mm/min and record the force, F . Repeat the procedure for the other test samples. If the 50 mm section of insulation B-C buckles when sliding, prepare new test samples with the length B-C equal to 25 mm and repeat this procedure.

7.2.5 Requirement

The measured force shall be within the values agreed between customer and supplier.

8 Low-temperature characteristics

8.1 Winding

8.1.1 Test samples

Prepare two test samples of 600 mm and remove 25 mm of insulation from each end.

8.1.2 Apparatus

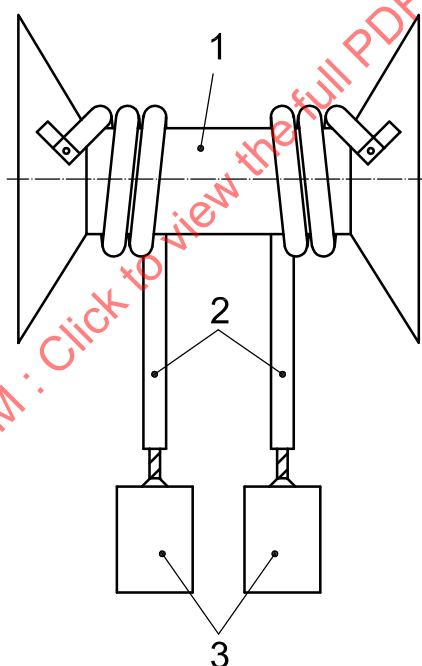
Use a freezing chamber at $(-40 \pm 2)^\circ\text{C}$ [$(-25 \pm 2)^\circ\text{C}$ may be used for thick wall cables when agreed to between customer and supplier]. Either a rotatable or a stationary mandrel may be used. See Table 8 for mandrel diameter.

Rotatable mandrel: when a rotatable mandrel is used, it shall be in accordance with Figure 4. See Table 8 for mass.

Stationary mandrel: when a stationary mandrel is used, no mass is used.

Table 8 — Winding

ISO conductor size a mm ²	Mandrel diameter mm		Mass kg	Winding speed s ⁻¹	Number of turns min.
	Reference: 8.1, 10.2, 11.2, 11.4, 11.5	Reference: 10.1, 10.3, 11.6			
$a \leq 0,75$	$\leq 5 \times$ outside cable diameter maximum	$\leq 1,5 \times$ outside cable diameter maximum	0,5	1	3
$0,75 < a \leq 1,5$			2,5	1	3
$1,5 < a \leq 6$			5	1	2
$6 < a \leq 10$			8	0,5	0,5
$10 < a \leq 25$			10	0,5	0,5
$25 < a \leq 35$			20	0,5	0,5
$35 < a \leq 120$			30	0,2	0,5

**Key**

- 1 mandrel
- 2 test sample(s)
- 3 mass(es)

Figure 4 — Apparatus for winding

8.1.3 Procedure

The test samples and mandrel shall be conditioned for a minimum of 4 h in the freezing chamber.

Rotatable mandrel: when a rotatable mandrel is used, the test samples shall be fixed on the mandrel as shown in Figure 4. The free ends are loaded with the mass. Position the mandrel with the test samples hanging vertically.

Stationary mandrel: when a stationary mandrel is used, a test sample shall be wrapped around the mandrel by hand. Repeat the procedure for the other test sample.

Wind the test sample for at least the “minimum number of turns” around the mandrel within the freezing chamber and at winding speed as specified in Table 8. Ensure that there is continuous contact between the test samples and the mandrel.

After the cold winding, allow the test samples to return to room temperature, and make a visual examination of the insulation. If no exposed conductor is visible, perform the withstand voltage test; however, make the following changes to the procedure in 6.2:

- immerse the test sample in the salt-water bath for a minimum of 10 min prior to the application of the voltage;
- apply the 1 kV (r.m.s.) voltage for 1 min;
- do not “ramp up” the voltage after the application of the 1 kV (r.m.s.) voltage.

8.1.4 Requirement

After winding, no conductor shall be visible. During the withstand voltage test, breakdown shall not occur.

8.2 Impact

8.2.1 Usage of test

The usage of this test shall be agreed between customer and supplier.

8.2.2 Test samples

Prepare three test samples, each of 1,2 m length and remove 25 mm of insulation from each end.

8.2.3 Apparatus

The apparatus shown in Figure 5 is positioned on a foam rubber pad of 40 mm thickness. The mass of the hammer is specified in Table 9. Set the freezing chamber temperature to $(-15 \pm 2) ^\circ\text{C}$.

8.2.4 Procedure

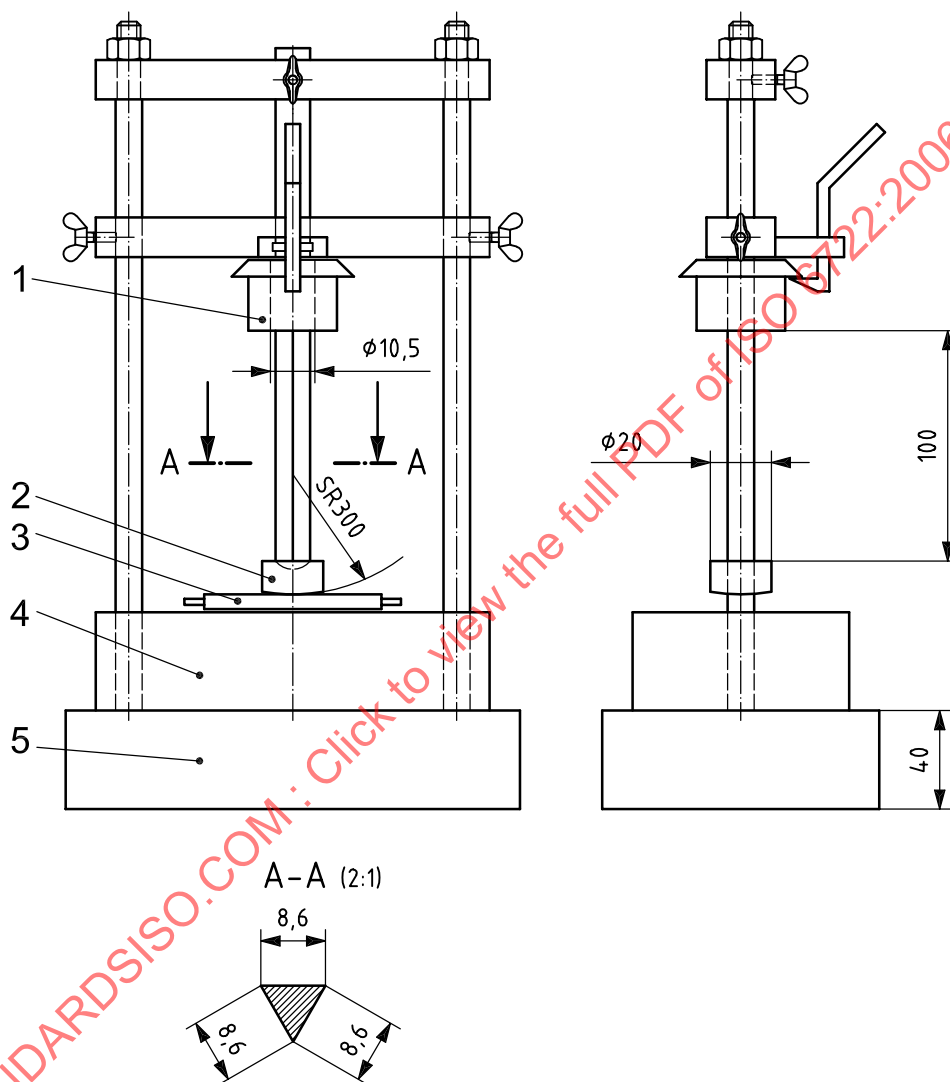
Perform the “impact test” in the middle of the test sample. Place the apparatus, positioned on the foam rubber pad, together with the test samples, in the freezing chamber for at least 16 h. If the apparatus is pre-cooled, a freezing time of 4 h is sufficient, providing that the test samples have reached the specified temperature. At the end of this period, place a test sample parallel to the steel base. The hammer is then allowed to fall from a height of 100 mm. Repeat the procedure for the remaining test samples. After the impact, allow the test samples to return to room temperature, and make a visual examination of the insulation. If no exposed conductor is visible, perform the withstand voltage test; however, make the following changes to the procedure in 6.2:

- immerse the test samples in the salt-water bath for a minimum of 10 min prior to the application of the voltage;
- apply the 1 kV (r.m.s.) voltage for 1 min;
- do not “ramp up” the voltage after the application of the 1 kV (r.m.s.) voltage.

8.2.5 Requirement

After impact, no conductor shall be visible. During the withstand voltage test according to 6.2, breakdown shall not occur.

Dimensions in millimetres



Key

- 1 hammer
- 2 steel intermediate piece, 100 g
- 3 test sample
- 4 steel base, mass 10 kg
- 5 foam rubber pad

Figure 5 — Apparatus for impact test

Table 9 — Impact

ISO conductor size <i>a</i> mm ²	Mass of the hammer		
	g		
	Thick wall cable	Thin wall cable	Ultra-thin wall cable
<i>a</i> ≤ 0,5	—	N/A	N/A
0,5 < <i>a</i> ≤ 2,5	100	100	
2,5 < <i>a</i> ≤ 4			
4 < <i>a</i> ≤ 10	200	200	—
10 < <i>a</i> ≤ 25	300	300	
25 < <i>a</i> ≤ 50		—	
50 < <i>a</i> ≤ 120	400		
“N/A”	Not applicable.		
“—”	Cable type does not exist.		

9 Resistance to abrasion

9.1 Usage of test

This test is only applicable to cables with a conductor size $\leq 6 \text{ mm}^2$, for which either 9.2 (sandpaper abrasion) or 9.3 (scrape abrasion) shall be used. The customer and supplier shall define which test shall be used. No abrasion test is required for conductor sizes $> 6 \text{ mm}^2$.

9.2 Sandpaper abrasion

9.2.1 Test sample

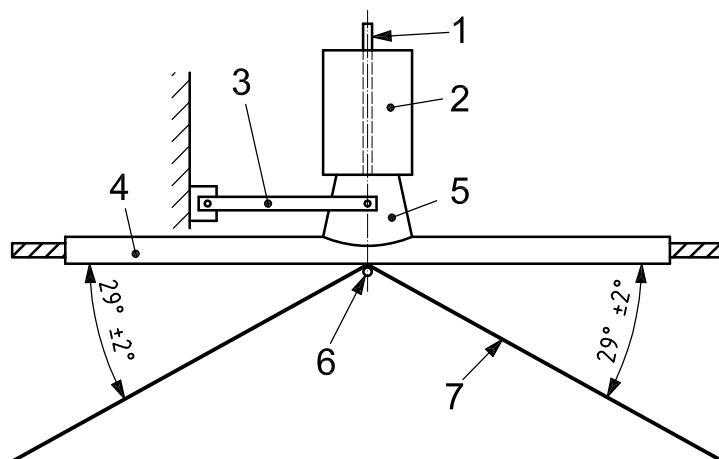
Prepare a test sample of 1 m length and remove 25 mm of insulation from each end.

9.2.2 Apparatus

Measure the “resistance to sandpaper abrasion” using 150 J garnet sandpaper tape with 10 mm conductive strips perpendicular to the edge of the sandpaper spaced a maximum of every 75 mm. Mount a suitable bracket to the pivoting arm (see Figure 6) to maintain the test-sample position over an unused portion of the sandpaper abrasion tape. Exert a force of $(0,63 \pm 0,05) \text{ N}$ on the test sample by the combination of the bracket, support rod and pivoting arm. The total vertical force exerted on the test sample shall be the combination of the force exerted by the bracket, pivoting arm, support rod and additional mass. The additional mass shall be according to Table 10.

9.2.3 Procedure

Mount the test sample taut, without stretching, in a horizontal position using an area of the sandpaper abrasion tape not previously used. Place the additional mass and bracket on top of the test sample. Draw the sandpaper abrasion tape under the test sample at a rate of $(100 \pm 75) \text{ mm/min}$ and record the length of sandpaper abrasion tape necessary to expose the conductor. Move the test sample 50 mm and rotate the test sample clockwise 90° . Repeat the procedure for a total of four readings. The mean of the readings shall determine the resistance to sandpaper abrasion.

**Key**

- | | | | |
|---|-----------------|---|--|
| 1 | support rod | 5 | bracket |
| 2 | additional mass | 6 | tape supporting pin, diameter = 6,9 mm |
| 3 | pivoting arm | 7 | 150 J, garnet sandpaper abrasion tape |
| 4 | test sample | | |

Figure 6 — Apparatus for sandpaper abrasion test**9.2.4 Requirement**

The resistance to sandpaper abrasion shall meet or exceed the minimum length of sandpaper requirements according to Table 10.

Table 10 — Sandpaper abrasion

ISO conductor size	60 V thick wall		60 V thin wall		60 V ultra-thin wall		600 V			
	Additional mass	Minimum length of sandpaper	Additional mass	Minimum length of sandpaper	Additional mass	Minimum length of sandpaper	Additional mass	Minimum length of sandpaper		
mm ²	kg	mm	kg	mm	kg	mm	kg	mm		
0,13	—	—	0,1	200	0,05	150	0,5	400		
0,22				225		175				
0,35				250		200				
0,5	0,5	400	0,2	300	0,1	175			410	
0,75		410		350		200				
1		420		400		225				420
1,5		430		450		250				430
2		450		500		275				450
2,5	1,5	280	0,5	250	0,2	125	1,5	280		
3		330		300	—	—		330		
4		400		350				400		
5		450		430				450		
6		500		500				500		

NOTE The total vertical force exerted on the test sample is the combination of the force exerted by the bracket, pivoting arm, support rod and additional mass.

9.3 Scrape abrasion

9.3.1 Test sample

Prepare a test sample of 1 m length and remove 25 mm of insulation from one end.

9.3.2 Apparatus

Use a "resistance to scrape abrasion" apparatus according to Figure 7. It consists of a device designed to abrade the surface of the insulation in both directions along the longitudinal axis of the test sample and a counter for recording the numbers of cycles to failure. It shall be controlled in such a way that when the needle abrades through the insulation and makes contact with the conductor, the machine shall stop operating. The characteristics of a suitable apparatus shall be as follows:

- diameter of needle: $(0,25 \pm 0,01)$ mm or $(0,45 \pm 0,01)$ mm as agreed between customer and supplier;
- type of needle: spring wire (polished) material in accordance with ISO 6931-1;
- frequency: (55 ± 5) cycles/min (one cycle consists of one reciprocating movement);
- displacement of the needle: (20 ± 1) mm;
- length of abrasion: $(15,5 \pm 1)$ mm;
- type of movement: design details shall not influence the test result;
- mass (position, value, design details): the vertical force on the test sample shall be constant under dynamic conditions;
- test sample mounting force: the test sample shall not move during the test; if fixing is necessary, the tension applied on the conductor shall not exceed 100 MPa (N/mm^2);
- stability of equipment: the apparatus shall be so stable that the results shall not be affected.

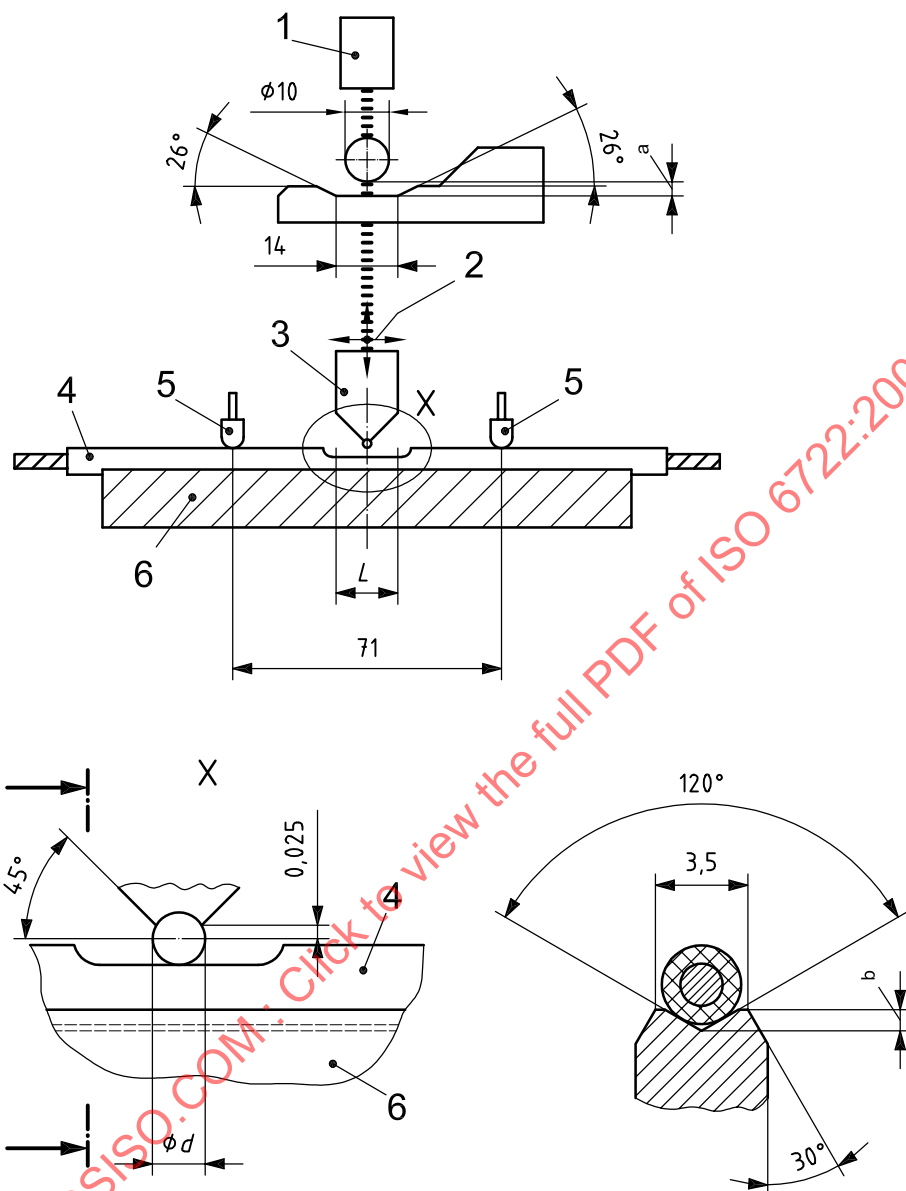
9.3.3 Procedure

Apply a total vertical force of $(7 \pm 0,05)$ N to the test sample. Determine the number of cycles by taking four measurements at a temperature of (23 ± 1) °C. After each reading, move the test sample 100 mm and rotate it clockwise 90°. Change the needle after each reading.

9.3.4 Requirement

The number of cycles shall be agreed between customer and supplier.

Dimensions in millimetres

**Key**

1	mass	L	Abrasion length = $(15,5 \pm 1)$ mm.	a	Clearance during abrasion.
2	travel	d	Needle diameter:	b	Groove depth:
3	needle holder		$(0,25 \pm 0,01)$ mm or		0,4 mm, conductor size $\leq 0,35$ mm ²
4	test sample		$(0,45 \pm 0,01)$ mm		0,8 mm, conductor size $> 0,35$ mm ²
5	clamp				
6	test-sample holder				

Figure 7 — Apparatus for scrape abrasion

10 Heat ageing

10.1 Long-term ageing, 3 000 h

10.1.1 Purpose

This test is intended to confirm the “temperature class rating” according to Table 1.

10.1.2 Test samples

Prepare two test samples, each of a minimum length of 350 mm, and remove 25 mm of insulation from each end.

10.1.3 Apparatus

Use an oven at the temperature specified in Table 11. The masses and mandrels for winding are specified in Table 8.

Table 11 — Long-term ageing and environmental cycling

Class	Test temperature ^a °C
A	85 ± 2
B	100 ± 2
C	125 ± 3
D	150 ± 3
E	175 ± 3
F	200 ± 3
G	225 ± 4
H	250 ± 4
^a Upper value of temperature class rating, see Table 1.	

10.1.4 Procedure

Place the test samples in the oven for 3 000 h. Fix the test samples by the conductor to avoid any contact between the insulation and the supports. The test samples shall be separated by at least 20 mm from each other and from the inner surface of the oven. Cable insulations made of different materials shall not be tested at the same time. After ageing, withdraw the test samples from the oven and maintain them at room temperature (23 ± 5) °C for at least 16 h. After conditioning, perform the winding test according to 8.1, but at room temperature. After winding, make a visual examination of the insulation. If no exposed conductor is visible, perform the withstand voltage test; however, make the following changes to the procedure in 6.2:

- immerse the test samples in the salt-water bath for a minimum of 10 min prior to the application of the voltage;
- apply the 1 kV (r.m.s.) voltage for 1 min;
- do not “ramp up” the voltage after the application of the 1 kV (r.m.s.) voltage.

10.1.5 Requirement

After winding, no conductor shall be visible. During the withstand voltage test, breakdown shall not occur.

10.2 Short-term ageing, 240 h

10.2.1 Purpose

This test is intended to simulate thermal excursions.

10.2.2 Test samples

Prepare two test samples, each of a minimum length of 350 mm, and remove 25 mm of insulation from each end.

10.2.3 Apparatus

Perform the short-term ageing test using an oven at the temperature as specified in Table 12 and a freezing chamber at $(-25 \pm 2) ^\circ\text{C}$. The masses and mandrels are specified in Table 8.

Table 12 — Short-term ageing

Class	Test temperature ^a °C
A	110 ± 2
B	125 ± 3
C	150 ± 3
D	175 ± 3
E	200 ± 3
F	225 ± 4
G	250 ± 4
H	275 ± 4
^a Upper value of temperature class rating (see Table 1) + 25 °C.	

10.2.4 Procedure

Follow the same procedure as 10.1.4; however, make the following changes:

- use an ageing time of 240 h;
- perform the winding test according to 8.1 using the freezing chamber at $(-25 \pm 2) ^\circ\text{C}$;
- allow the test samples to return to room temperature before making the visual examination.

10.2.5 Requirement

After winding no conductor shall be visible. During the withstand voltage test, breakdown shall not occur.

10.3 Thermal overload

10.3.1 Purpose

This test is intended to simulate thermal overload conditions of the cable.

10.3.2 Test samples

Prepare two test samples, each of 350 mm minimum length, and remove 25 mm of insulation from each end.

10.3.3 Apparatus

Perform the thermal overload test using an oven at the temperature as specified in Table 13. The masses and mandrels are specified in Table 8.

Table 13 — Thermal overload

Class	Test temperature ^a
	°C
A	135 ± 3
B	150 ± 3
C	175 ± 3
D	200 ± 3
E	225 ± 4
F	250 ± 4
G	275 ± 4
H	300 ± 4
^a Upper value of temperature class rating (see Table 1) + 50 °C.	

10.3.4 Procedure

Follow the same procedure as 10.1.4; however, use an ageing time of 6 h.

10.3.5 Requirement

After winding, no conductor shall be visible. During the withstand voltage test, breakdown shall not occur.

10.4 Shrinkage by heat

10.4.1 Test samples

Prepare three test samples, each of 100 mm length.

10.4.2 Apparatus

Perform the test using an oven at (150 ± 3) °C.

10.4.3 Procedure

Measure the exact length of the insulation of the test samples at room temperature (23 ± 5) °C prior to the test. Put the test samples in the oven, in a horizontal position, so that air may circulate freely from all sides, for 15 min. After cooling to room temperature, measure the length of the insulation again.

10.4.4 Requirement

The maximum shrinkage shall not exceed 2 mm from either end.

11 Resistance to chemicals

11.1 Compliance

When any resistance-to-chemicals test is specified, compliance for a cable family may be demonstrated by testing representative conductor sizes according to 4.6.

11.2 Fluid compatibility

11.2.1 General

This test is required for gasoline, diesel fuel and engine oil. All other fluids shall be tested upon agreement between customer and supplier. The tests are intended to qualify cables for limited exposure to fluids. Additional tests are necessary to qualify cables for continuous immersion.

11.2.2 Immersion

11.2.2.1 Test samples

Prepare individual test samples, each 600 mm long with 25 mm of insulation removed from each end, for each fluid to be tested.

11.2.2.2 Apparatus

Fluid compatibility is determined via a measurement of the outside cable diameter with the apparatus shown in 5.1. Fill the vessels with the fluids at temperatures according to Table 14. See Table 8 for masses and mandrels. Either a rotatable or a stationary mandrel may be used.

Table 14 — Fluid compatibility

Fluid	Specification	Test temperature °C	Test duration h	Maximum outside cable diameter change %	Requirement
Gasoline	ISO 1817, liquid C	23 ± 5	20	15	Certification
Diesel fuel	90 % ISO 1817, Oil No. 3 + 10 % <i>p</i> -xylene	23 ± 5	20	15	Certification
Engine oil	ISO 1817, Oil No. 2	50 ± 3	20	15	Certification
Ethanol	85 % Ethanol + 15 % ISO 1817 liquid C	23 ± 5	20	15	If required
Power steering fluid	ISO 1817, Oil No. 3	50 ± 3	20	30	If required
Automatic transmission fluid	Dexron III	50 ± 3	20	25	If required
Engine coolant	50 % ethylene glycol + 50 % distilled water	50 ± 3	20	15	If required

NOTE 1 Solutions are determined as % by volume.

NOTE 2 Changes in the specified fluids are being considered in a future revision of this International Standard.

NOTE 3 Sources for reference materials are shown in Table D.1. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of the source. Equivalent products may be used if they can be shown to lead to the same results.

11.2.2.3 Procedure

Determine the outside cable diameter of each test sample by taking three measurements distributed at intervals of 120° around the circumference of the cable in the middle of the test sample. Calculate an average of the three measurements. Immerse the area of each test sample which shall be needed for the winding test for 20 h in a fluid specified in Table 14 with the test sample ends emerging above the surface of the fluid. Remove the test sample from the fluid and wipe the surface to remove any remaining liquid. Allow it to dry at room temperature for 30 min. Within 5 min of the end of the drying period, measure the outside cable diameter at the same place as before the immersion and perform the winding test; however, make the following changes to the procedure in 8.1.3:

- perform the winding test at room temperature;
- calculate the percentage of change in outside cable diameter.

11.2.2.4 Requirement

The maximum outside cable diameter change shall meet the requirements shown in Table 14. After winding, no conductor shall be visible. During the withstand voltage test, breakdown shall not occur.

11.2.3 Battery acid

11.2.3.1 Usage of test

The usage of this test shall be agreed between customer and supplier.

11.2.3.2 Test sample

Prepare one test sample according to 11.2.2.1.

11.2.3.3 Apparatus

Use battery acid (H_2SO_4 with a specific gravity of $1,260 \pm 0,005$) and an oven at $(90 \pm 2)^\circ\text{C}$. See Table 8 for masses and mandrels. Either a rotatable or a stationary mandrel may be used.

11.2.3.4 Procedure

Place drops of battery acid on the cable such that the drops of acid do not touch each other. Condition the test sample in the oven for 8 h. Cable insulations made of different materials shall not be tested at the same time. Remove the test sample from the oven and re-apply drops of acid. Condition the test sample for 16 h (24 h total). Remove the test sample from the oven. This completes one cycle. Repeat the procedure for a total of two cycles. Maintain the test sample at room temperature $(23 \pm 5)^\circ\text{C}$ for 30 min. After conditioning at room temperature, perform the winding test according to 8.1 at room temperature. After winding, make a visual examination of the insulation. If no exposed conductor is visible, perform the withstand voltage test; however, make the following changes to the procedure in 6.2:

- immerse the test samples in the salt-water bath for a minimum of 10 min prior to the application of the voltage;
- apply the 1 kV (r.m.s.) for 1 min;
- do not “ramp up” the voltage after the application of the 1 kV (r.m.s.).

11.2.3.5 Requirement

After winding, no conductor shall be visible. During the withstand voltage test, breakdown shall not occur.

11.3 Durability of cable marking

11.3.1 Test samples

Prepare three test samples, each of 600 mm length.

11.3.2 Apparatus

Use an apparatus consisting of two pieces of felt, having a minimum wool content of 75 % and with a packing density of (0,171 to 0,191) g/cm³ (dimensions 50 mm × 50 mm × 3 mm) and a vessel containing ISO 1817, Oil No. 2 at (50 ± 3) °C.

11.3.3 Procedure

Immerse a test sample for 20 h with the test sample ends emerging 50 mm above the surface of the liquid. Remove the test sample from the oil and allow it to drain at room temperature for 30 min. Position the test sample between two pieces of felt using an area of the felt not previously used. Apply a force of (10 ± 1) N while pulling the test sample from between the felt. Repeat the procedure for the other test samples. Visually examine the test samples after the test.

11.3.4 Requirement

All cable markings shall remain legible.

11.4 Resistance to ozone

11.4.1 Usage of test

The usage of this test shall be agreed between customer and supplier.

11.4.2 Test samples

Prepare three test samples, each of 300 mm length.

11.4.3 Apparatus

Use an ozone chamber in accordance with IEC 60811-2-1 with an atmosphere containing a mass fraction of $(1 \pm 0,05) \times 10^{-6}$ of ozone at (65 ± 3) °C. Attention is drawn to the highly toxic nature of ozone. Efforts should be made to minimize the exposure of workers at all times. See Table 8 for mandrel diameter. Aluminium mandrels are preferred since other materials may affect the ozone concentration.

11.4.4 Procedure

Wind at least the minimum number of turns according to Table 8 and secure the ends. Condition the test samples for 192 h in the ozone chamber. While still on the mandrel, remove the test samples from the ozone chamber, allow them to cool to room temperature, and make a visual examination of the insulation. Ignore any damage caused by the clamps that secure the ends.

11.4.5 Requirement

The visual examination of the insulation shall show no cracks.

11.5 Resistance to hot water

11.5.1 Usage of test

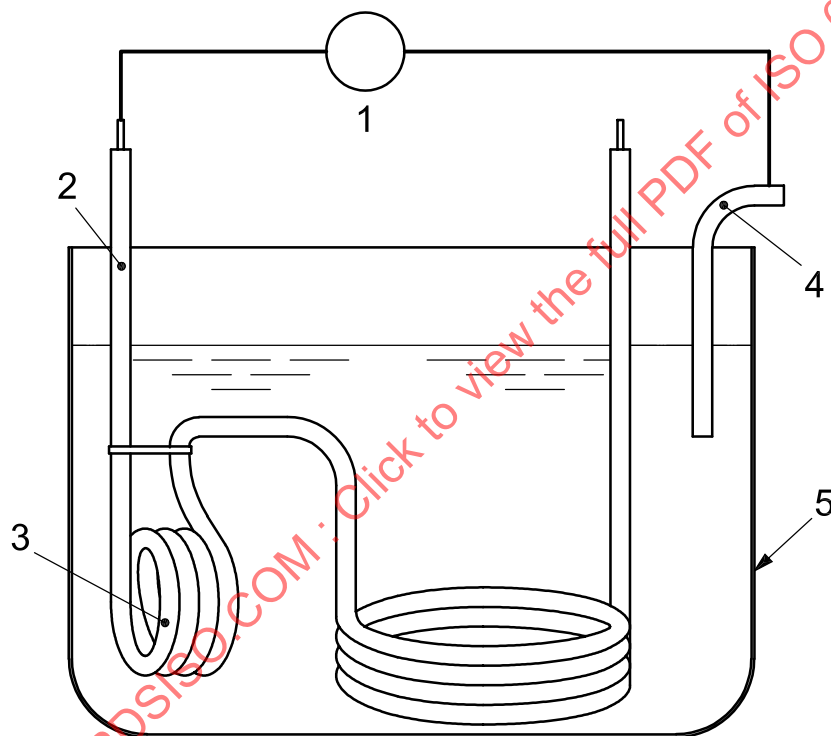
The usage of this test shall be agreed between customer and supplier.

11.5.2 Test samples

Prepare two test samples, each of $(2,5 \pm 0,1)$ m length, and remove 25 mm of insulation from each end.

11.5.3 Apparatus

The apparatus consists of an electrically non-conductive vessel containing an unused salt-water bath with 10 g/l of NaCl in water at $(85 \pm 5) ^\circ\text{C}$ for each test, a 48 V d.c. power source, a copper electrode and a resistance-measuring device as specified in 6.4.3. See Table 8 for "mandrel diameter".



Key

- 1 48 V d.c. power source
- 2 test sample
- 3 closely wound turns of test sample
- 4 copper electrode
- 5 non-conductive vessel

Figure 8 — Apparatus for resistance to hot water

11.5.4 Procedure

Closely wind at least three complete turns of a test sample on the mandrel and secure the wraps as shown in Figure 8. After removing the mandrel, immerse the test sample in the bath with both ends projecting 250 mm above the bath. To avoid interaction between materials, do not test samples with different insulating materials in the same bath. Connect one end of the test sample to the positive electrode of the power source. After 7 d, disconnect the power supply and measure the insulation volume resistivity according to 6.4. Make the following changes to the procedure in 6.4:

- measure the insulation volume resistivity in the salt-water bath and at the temperature described in 11.4.3.

This completes one cycle. Repeat this procedure for a total of 5 cycles, i.e. 35 days. After conditioning, remove the test sample from the bath, allow it to cool to room temperature, and make a visual examination of the insulation. Ignore any damage caused by the ties which secure the coils. If no exposed conductor is visible, perform the withstand voltage test; however, make the following changes to the procedure in 6.2.

- immerse the test sample in the salt solution for a minimum of 10 min prior to the application of the voltage;
- apply the 1 kV (r.m.s) for 1 min;
- do not "ramp up" the voltage after the application of the 1 kV (r.m.s).

Repeat the entire test procedure using the second test sample but with the polarity of the 48 V d.c. power supply reversed.

11.5.5 Requirement

The insulation volume resistivity shall not be less than $10^9 \Omega \cdot \text{mm}$. A visual examination of the insulation shall show no cracks. During the withstand voltage test, breakdown shall not occur.

11.6 Temperature and humidity cycling

11.6.1 Usage of test

The usage of this test shall be agreed between customer and supplier.

11.6.2 Test samples

Prepare two samples, each of approximately 600 mm length and remove 25 mm of insulation from each end.

11.6.3 Apparatus

Perform the test in a temperature chamber which is capable of cycling at $(-40 \pm 2) ^\circ\text{C}$ and the test temperature specified in Table 11. The chamber shall also be capable of controlling the relative humidity between 80 % and 100 %. See Table 8 for "mandrel diameter".