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ISO 6722

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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

Reference number
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Contents

Page

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 3.

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 International Standard 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*.

ISO 6722 cancels and replaces ISO 6722-1:1996, ISO 6722-2:1996, ISO 6722-3:1993 and ISO 6722-4:1993, which have been technically revised.

Annexes A and B of this International Standard are for information only.

This corrected version of ISO 6722:2002 now includes reference to the fact that this International Standard incorporates parts 1 to 4 as previously published.

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

1 Scope

This International Standard specifies dimensions, test methods and requirements for the following single-core cables:

— 60 V cables intended for use in road vehicle applications where the nominal system voltage is ⩽ 60 V d.c.;

— 600 V cables intended for use in road vehicle applications where the nominal system voltage is in the range of from 60 V d.c. to 600 V d.c. inclusive.

It also covers individual cores of multi-core cables falling within these parameters.

It is applicable to eight temperature classes, each with its own temperature range, as follows:

Class A – 40 °C to 85 °C;

Class B – 40 °C to 100 °C;

Class C – 40 °C to 125 °C;

Class D – 40 °C to 150 °C;

Class E – 40 °C to 175 °C;

Class F – 40 °C to 200 °C;

Class G – 40 °C to 225 °C;

Class H – 40 °C to 250 °C.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

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

ISO 8458-2, *Steel wire for mechanical springs — Part 2: Patented cold-drawn non-alloy steel wire*

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 Term and definition

For the purposes of this International Standard, the following term and definition apply.

3.1
nominal value
suitable approximate value used to designate or identify a component

4 General

CAUTION — Special care shall be taken for cables used with voltages above 60 V d.c. to protect them from mechanical stress in order to avoid shock hazard.

4.1 Conductors

The conductors shall consist of plain or coated copper strands as given in Table 1.

Table 1 — Conductor specifications

Conductor	Description
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[a]
ASTM B355	Nickel-coated soft or annealed copper wire[a]
[a] Silver and nickel-coated wires are intended for use with high temperature class ratings.	

Conductors with conductor sizes $\geqslant 0{,}5\ mm^2$ shall consist of soft annealed copper or annealed compressed/compacted wires. Wires in conductors $< 0{,}5\ mm^2$ shall consist of soft annealed copper, soft annealed compressed/compacted copper, hard unannealed copper, or a copper alloy. The specifications for the conductors are to be completed by material specifications. Elongation requirements are to be established by agreement between the customer and the supplier. The finished cable shall meet the resistance requirements of clause 6.1 for all conductors except alloys. When an alloy is used, the resistance requirement is to be established by agreement between the customer and the supplier.

See annex A for strandings that highlight examples of conceptual configurations and which are not intended to reflect any preferred constructions. Other strandings' configurations may be used provided they meet the requirements shown above and are agreed between customer and supplier.

4.2 Tests

The cables shall be submitted to the tests given in Table 2.

Table 2 — Tests

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

[a] These are tests of all cable during or after manufacture carried out in order to check that the cables comply with the requirements of the standard concerned or the criteria specified.

[b] The frequency of periodic testing is to be established by agreement between the customer and the supplier.

[c] The usage of “If required” tests is to 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 “If required”. See 11.1 for details.

4.3 General test conditions

Test samples for all tests except those given in clause 5 and in 6.1 and 6.3 shall be preconditioned for at least 16 h at a room temperature of (23 ± 5) °C. Unless otherwise specified, all tests other than "in-process" tests shall be conducted at this temperature. Where no tolerance is specified, all values are to be considered to be approximate.

4.4 Ovens

When an oven is required, unless otherwise specified it shall be a hot air oven. The air contained in the oven shall be completely changed a minimum of eight times and a maximum of twenty times per hour at the specified temperature.

5 Dimensions

5.1 Outside cable diameter

5.1.1 Test sample

Prepare a test sample of 3 m length.

5.1.2 Apparatus

Use a measuring device that does not cause deformation.

5.1.3 Procedure

Determine the maximum outside cable diameter by taking three sets of measurements at 1 m intervals, and recording the greatest outside diameter at each point to within an accuracy of ± 0,01 mm.

5.1.4 Requirement

The outside cable diameter shall be in accordance with Table 3.

5.2 Insulation thickness

5.2.1 Test samples

Prepare three test samples, each consisting of a thin cross-section of insulation, taken at 1 m intervals from a cable sample 3 m in length. Strip the insulation from the cable. Take care not to deform the test samples 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 that does 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. The measurement accuracy shall be ± 0,01 mm.

5.2.4 Requirement

The insulation thickness shall be in accordance with Table 3.

Table 3 — Dimensions

ISO conductor size	Conductor maximum diameter	Thick wall			Thin wall			Ultra thin wall		
		Insulation thickness		Outside cable diameter	Insulation thickness		Outside cable diameter	Insulation thickness		Outside cable diameter
		nom.	min.	max.	nom.	min.	max.	nom.	min.	max.
mm^2	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
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	0,20	0,16	1,20
0,50	1,10	0,60	0,48	2,30	0,28	0,22	1,70	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	3,80	—	—	—
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	—	—	—	—	—	—

5.3 Conductor diameter

5.3.1 General

The usage of this test is to be established by agreement between customer and supplier. For cases where results are disputed, a referee method is provided in 5.3.2.2, 5.3.3.2 and 5.3.4.2.

5.3.2 Test samples

5.3.2.1 Under normal circumstances

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

5.3.2.2 Referee test samples

In case of dispute, prepare three test samples, each 20 mm in length, taken at intervals of 1 m from a cable sample 3 m in length. Take care not to deform the test samples.

Immerse the test samples in a casting resin. After hardening, take a section perpendicular to the axis of the test sample.

5.3.3 Apparatus

5.3.3.1 Under normal circumstances

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

5.3.3.2 Referee apparatus

In case of dispute, the measuring device shall be capable of at least 10 times linear magnification.

5.3.4 Procedure

5.3.4.1 Under normal circumstances

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.

5.3.4.2 Referee procedure

In case of dispute, measure the conductor diameter using the referee test samples and the referee apparatus. Record the maximum conductor diameter for each test sample.

5.3.5 Requirement

The conductor diameter shall be in accordance with Table 3.

NOTE This measured value is also a requirement of 6.4.

6 Electrical characteristics

6.1 Conductor resistance

6.1.1 Test sample

Prepare a test sample of 1 m length plus the length necessary for connections. Other lengths may be used providing that the resistance reading is adjusted using the method given 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 to within ± 0,5 % of the measured value and a thermometer with an accuracy of ± 0,5 °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:

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

where

R_{20} is the corrected conductor resistance at the reference temperature of 20 °C, expressed in milliohms per metre;

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

L is the unsoldered conductor length, expressed in metres;

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

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

6.1.4 Requirement

The corrected value of the conductor resistance shall be in accordance with Table 4.

Table 4 — Conductor resistance test specifications

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	84,4	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

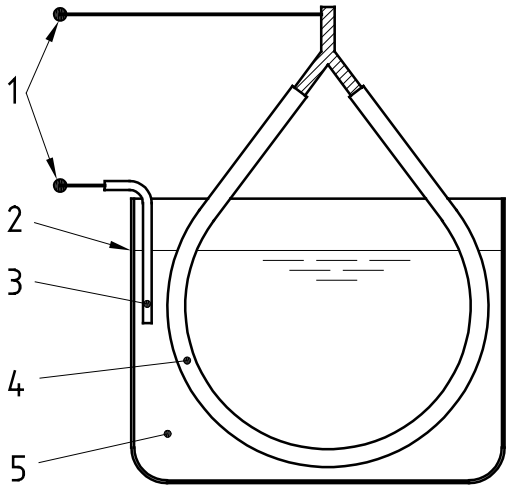
6.2 Withstand voltage

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 conductor ends together to form a loop.

6.2.2 Apparatus

Partially fill a non-conductive vessel with saltwater (3 % by weight of NaCl in water) with the ends of the test sample emerging above the bath as shown in Figure 1. Use a voltage source of a frequency of 50 Hz or 60 Hz.



Key

1 Test voltage
2 Non-conductive vessel
3 Electrode
4 Test sample
5 Saltwater bath

Figure 1 — Apparatus for withstand voltage test

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 apply a test voltage of 1 kV (rms) for 30 min between conductor and the bath. Then increase the voltage at a rate of 500 V/s until the following value is reached:

— 3 kV (rms) for cables $< 0{,}5\ mm^2$;

— 5 kV (rms) for cables $\geqslant 0{,}5\ mm^2$.

6.2.3.2 600 V cable

After completing a procedure identical to that of 6.2.3.1, hold the value 3 kV or 5 kV for 5 min.

6.2.4 Requirement

Breakdown shall not occur.

6.3 Insulation faults

6.3.1 General

This test is to be carried out under production conditions.

6.3.2 Apparatus

Use a sinusoidal voltage source set at the value shown in Table 5.

Table 5 — Insulation faults

ISO conductor size mm²	Voltage rating kV (rms)	
	60 V cables	600 V cables
< 0,5	3	6
⩾ 0,5	5	8

The test electrode may consist of metal ball chains, metal brushes, or any other type of suitable electrode. 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.

6.3.3 Procedure

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 General

The usage of this test is to be established by agreement 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

6.4.3.1 Under normal circumstances

Partially fill a non-conductive vessel with tap water of a temperature of (70 ± 2) °C. Use a resistance-measuring device with a d.c. voltage of 500 V. Voltages between 100 V and 500 V are allowed.

6.4.3.2 Referee apparatus

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:

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

where

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

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

R is the measured insulation resistance, expressed in ohms;

D is the outside cable diameter, in accordance with 5.1, expressed in millimetres;

d is the conductor diameter, in accordance with 5.3, expressed in millimetres;

lg is log to the base 10.

6.4.5 Requirement

The insulation volume resistivity shall not be less than $10^9\ \Omega$ 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

Perform this test with the test apparatus shown in Figure 2, ensuring that the apparatus is free of vibration. Apply a force, F, by the blade, to the test sample as given by the formula:

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

where

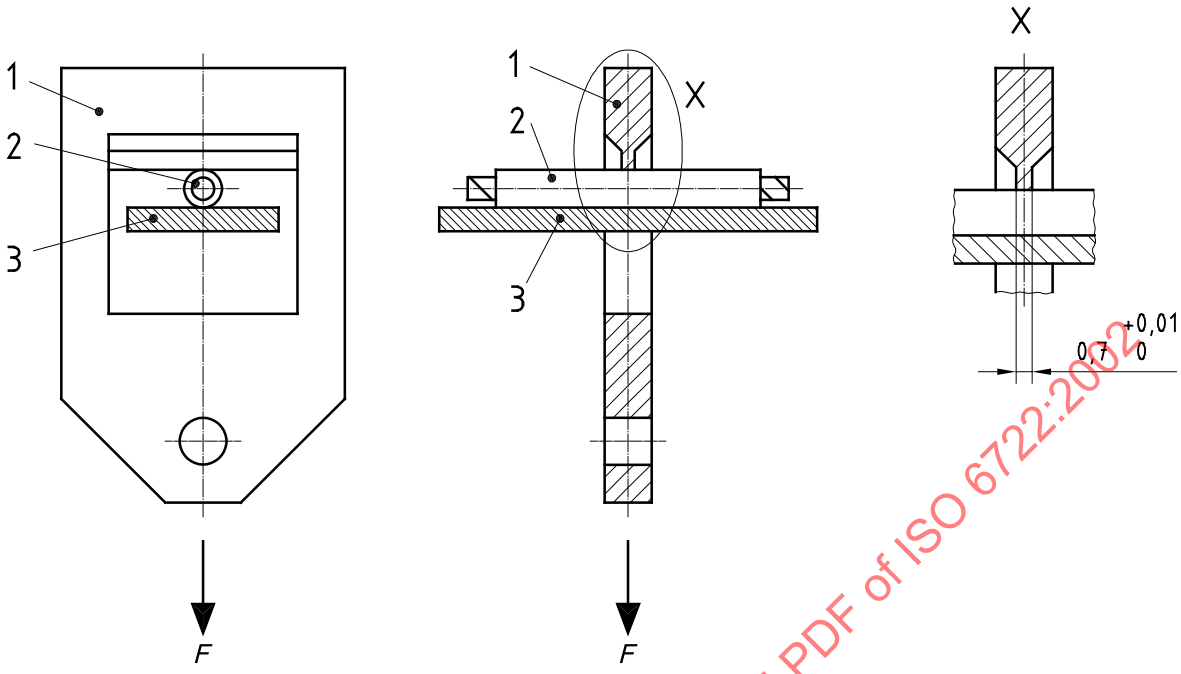
F is the total vertical force exerted on the test sample, expressed in newtons, and the coefficient 0,8 carries the dimension newtons per millimetre;

D is the appropriate outside cable diameter maximum given in Table 4, expressed in millimetres;

i is the appropriate nominal value of the insulation thickness given in Table 4, expressed in millimetres.

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

Dimensions in millimetres



Key

1 Test frame
2 Test sample
3 Support

Figure 2 — Apparatus for pressure test at high temperature

7.1.3 Procedure

Place the test samples as shown in Figure 2. Attach the test samples to the support so that they do not bend under the pressure of the blade. The load and the blade of the apparatus shall be perpendicular to the test-sample axis.

Place the test samples under load, not preheated, for 4 h in an oven at the temperature specified in Table 6.

Cool the test samples within 10 s by immersion in cold water. After immersion, subject the test samples, at the point where the pressure was applied, to the withstand voltage test; however, make the following changes to the procedure given in 6.2.

a) Immerse the test samples in the saltwater bath for a minimum of 10 min prior to the application of the voltage.

b) Apply the 1 kV (rms) voltage for 1 min.

c) Do not "ramp up" the voltage after the application of the 1 kV (rms) voltage.

Table 6 — 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 clause 1).

7.1.4 Requirement

Breakdown shall not occur during the withstand voltage test.

7.2 Strip force

7.2.1 General

The usage of this test is to be established by agreement between customer and supplier. This test is applicable to cables with a conductor size of ⩽ 6 mm^2.

7.2.2 Test samples

Prepare three test samples, each of 100 mm length, at 1 m intervals from a cable sample 3 m in length. See Figure 3. Cut a 25 mm length of insulation (A·B in Figure 3) cleanly and strip it carefully from one end of the conductor. Then cut the test samples to a length of 75 mm (at C), leaving a 50 mm section (B·C) undisturbed.

Dimensions in millimetres

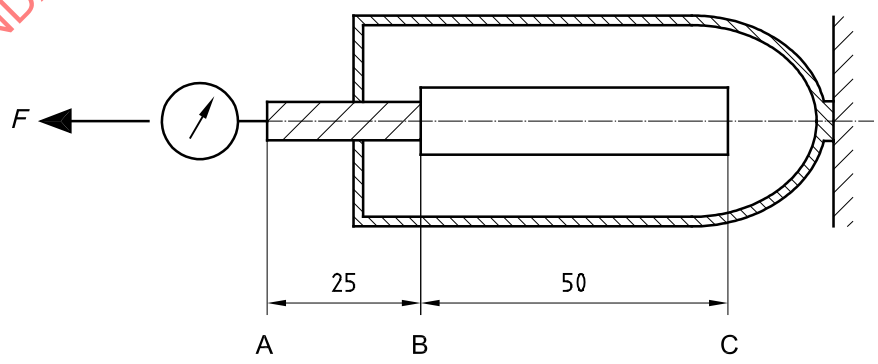


Figure 3 — Apparatus for strip force test

7.2.3 Apparatus

Use a test fixture similar to the one shown in Figure 3. A metal plate is to be 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 itself.

7.2.4 Procedure

Place the test samples in the test fixture as shown in Figure 3. Pull the test samples without friction between the conductor and the apparatus at a speed of 250 mm/min. Record the force (F). If the 50 mm section of insulation, (BC) buckles when sliding, prepare new test samples with this length equal to 25 mm and repeat this procedure.

7.2.5 Requirement

The measured force shall be within the values established by agreement between the 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

A freezing chamber at (−40 ± 2) °C shall be used [(−25 ± 2) °C may be used for thick wall cables when agreed to between the customer and supplier]. Either a rotatable or a stationary mandrel may be used, with the following provisions:

— the rotatable mandrel shall conform to Figure 4, and whenever a rotatable mandrel is used, the mass and mandrel shall be according to Table 7.

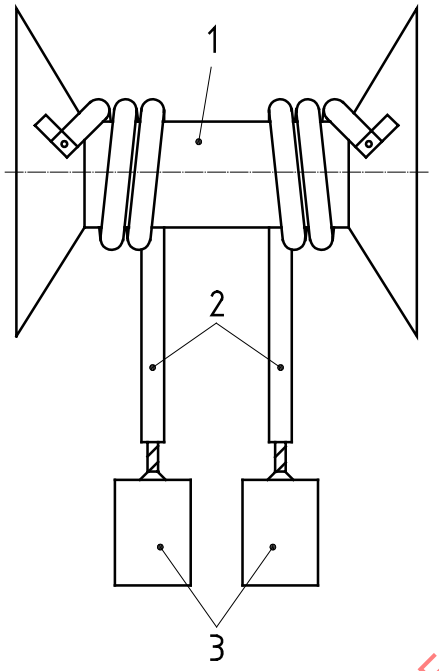
— when a stationary mandrel is used, no mass shall be used.

8.1.3 Procedure

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

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

— When a stationary mandrel is used, the test samples shall be wrapped around the mandrel by hand.



Key

1 Mandrel
2 Test sample(s)
3 Mass

Figure 4 — Apparatus for winding test

Wind at least the minimum number of turns specified in Table 7 around the mandrel within the freezing chamber at the appropriate winding speed specified in Table 7. Take care to ensure that there is continuous contact between the test samples and the mandrel.

Table 7 — Winding test specifications

ISO conductor size a	Mandrel diameter mm			Mass	Winding speed	Minimum number of turns
mm^2	(See 8.1 and 10.1)	(See 10.2, 10.3 and 11.5)	(See 11.1)	kg	turns/s	
$a \leqslant 0{,}75$	6	2	25	0,5	1	3
$0{,}75 < a \leqslant 1{,}5$	10	3	25	2,5	1	3
$1{,}5 < a \leqslant 2{,}5$	15	4	75	5	1	2
$2{,}5 < a \leqslant 6$	20	5	75	5	1	3 2
$6 < a \leqslant 10$	40	8	100	8	0,5	0,5
$10 < a \leqslant 25$	50	10	150	10	0,5	0,5
$25 < a \leqslant 35$	75	15	250	20	0,5	0,5
$35 < a \leqslant 95$	100	20	450	30	0,2	0,5
$95 < a \leqslant 120$	125	30	450	30	0,2	0,5

After the cold winding, allow the test sample to return to room temperature, and perform 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 given in 6.2.

a) Immerse the test sample in the saltwater bath for a minimum of 10 min prior to the application of the voltage.

b) Apply the 1 kV (rms) voltage for 1 min.

c) Do not "ramp up" the voltage after the application of the 1 kV (rms) voltage.

8.1.4 Requirements

After winding, no conductor shall be visible.

During the withstand voltage test, breakdown shall not occur.

8.2 Impact

8.2.1 General

The usage of this test will be established by agreement 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 of each sample.

8.2.3 Apparatus

Perform the impact test using the apparatus shown in Figure 5, positioned on a sponge rubber pad of 40 mm thickness. The mass of the hammer shall be as specified in Table 8. Set the freezing chamber temperature to (−15 ± 2) °C.

8.2.4 Procedure

Perform the impact test in the middle of the test samples. Place the apparatus, positioned on the sponge 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 shall be sufficient, providing that the test samples have reached the specified temperature. At the end of this period, place the test sample parallel to the steel base. The hammer then shall be allowed to fall from a height of 100 mm. After the impact, allow the test samples to return to room temperature, and perform 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 given in clause 6.2.

a) Immerse the test samples in the saltwater bath for a minimum of 10 min prior to the application of the voltage.

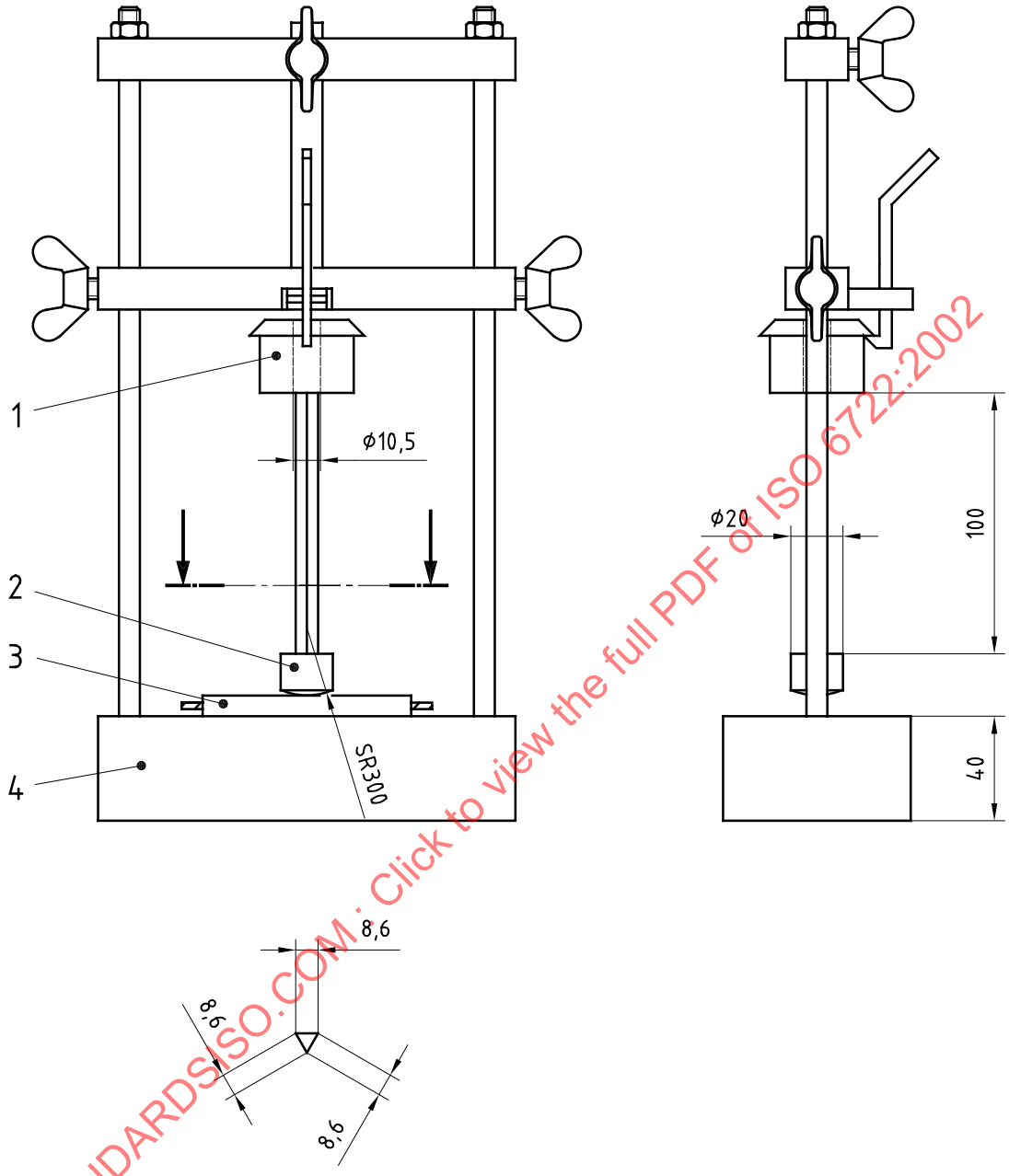
b) Apply the 1 kV (rms) voltage for 1 min.

c) Do not "ramp up" the voltage after the application of the 1 kV (rms) voltage.

8.2.5 Requirements

After impact, no conductor shall be visible. During the withstand voltage test, 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

Figure 5 — Apparatus for impact test

Table 8 — Impact test specifications

ISO conductor size a mm²	Mass of the hammer g		
	Thick-walled cable	Thin-walled cable	Ultra-thin-walled cable
$a \leqslant 0{,}5$	—[a]	[b]	[b]
$0{,}5 < a \leqslant 2{,}5$	100	100	[b]
$2{,}5 < a \leqslant 4$	100	100	—[a]
$4 < a \leqslant 10$	200	200	—[a]
$10 < a \leqslant 25$	300	300	—[a]
$25 < a \leqslant 50$	300	—[a]	—[a]
$50 < a \leqslant 120$	400	—[a]	—[a]

[a] Non-existent cable type.

[b] Not applicable.

9 Resistance to abrasion

9.1 General

This test is only applicable to cables with a conductor size $\leqslant 6$ mm², for which either 9.2 (sandpaper abrasion) or 9.3 (scrape abrasion) shall be used; the decision as to which test is used shall be determined by the customer and supplier. No abrasion test is required for conductor sizes > 6 mm².

9.2 Sandpaper abrasion test

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

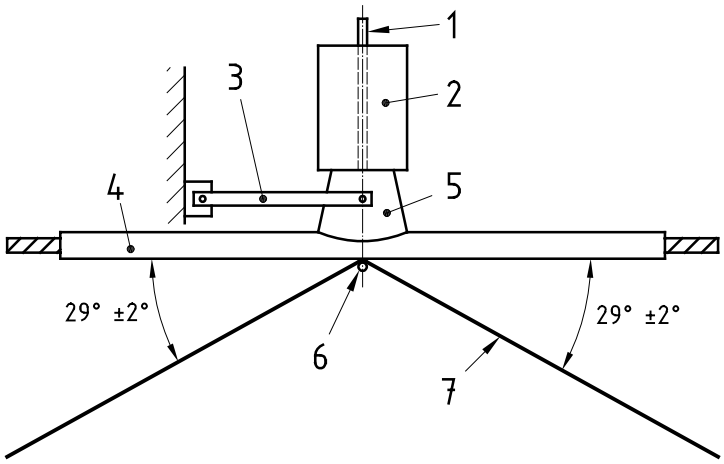
Measure the resistance to sandpaper abrasion using 150J garnet sandpaper tape with 10 mm conductive strips perpendicular to the edge of the sandpaper spaced a maximum of every 75 mm. Mount a suitable bracket to the pivoting arm (see Figure 6) to maintain the test sample position over an unused portion of the sandpaper abrasion tape (see Footnote 1). Exert a force of $(0{,}63 \pm 0{,}05)$ 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 will be the combination of the force exerted by the bracket, pivoting arm, support rod and additional mass. See Table 9 for additional mass.

9.2.3 Procedure

Mount the test sample so that it is taut, but without stretching it, 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 $(1\,500 \pm 75)$ mm/min and record the length of sandpaper abrasion tape necessary to expose the core. 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 will determine the resistance to sandpaper abrasion.

9.2.4 Requirements

The resistance to sandpaper abrasion shall be in accordance with Table 9.



Key

1 Support rod
2 Additional mass
3 Pivoting arm
4 Test sample
5 Bracket
6 Tape supporting pin, diameter = 6,9 mm
7 150 J garnet sandpaper abrasion tape[1)]

Figure 6 — Apparatus for sandpaper abrasion test

Table 9 — Sandpaper abrasion test requirements

ISO conductor size	Thick-walled cable		Thin-walled cable		Ultra-thin-walled cable	
	Additional mass	Min. length of sandpaper	Additional mass	Min. length of sandpaper	Additional mass	Min. length of sandpaper
mm^2	kg	mm	kg	mm	kg	mm
0,13	—	—	0,1	200	0,05	150
0,22	—	—	0,1	225	0,05	175
0,35	—	—	0,1	250	0,05	200
0,5	0,5	400	0,2	300	0,1	175
0,75	0,5	410	0,2	350	0,1	200
1	0,5	420	0,2	400	0,1	225
1,5	0,5	430	0,2	450	0,1	250
2	0,5	450	0,2	500	0,1	275
2,5	1,5	280	0,5	250	0,2	125
3	1,5	330	0,5	300	—	—
4	1,5	400	0,5	350	—	—
5	1,5	450	0,5	430	—	—
6	1,5	500	0,5	500	—	—

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

1) 150 J garnet sandpaper abrasion tape is an example of a suitable product available commercially (Glowe-Smith Industrial, Inc. 812 Youngstown Kingsville Rd. Vienna, Ohio 44473, USA; contact: Terry Dillman, tel.: +1 (330) 539-5085; fax. +1 (330) 539-7750). This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of this product.

9.3 Scrape abrasion test

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 as shown in Figure 7. This 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 so that when the needle abrades through the insulation and makes contact with the conductor, the machine will stop operating. The characteristics of a suitable apparatus shall be as follows.

— Diameter of needle: (0,25 ± 0,01) mm or (0,45 ± 0,01) mm as agreed between customer and supplier.

— Type of needle: spring wire (polished) material according to ISO 8458-2.

— Frequency: (55 ± 5) cycles/min (one cycle consists of one reciprocating movement).

— Displacement of needle: (20 ± 1) mm.

— Length of abrasion: (15,5 ± 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 N/mm^2.

— Stability of equipment: the apparatus shall be stable enough so that the results are not affected.

9.3.3 Procedure

Apply a total vertical force of (7 ± 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.

10 Heat ageing

10.1 Short-term ageing (240 h)

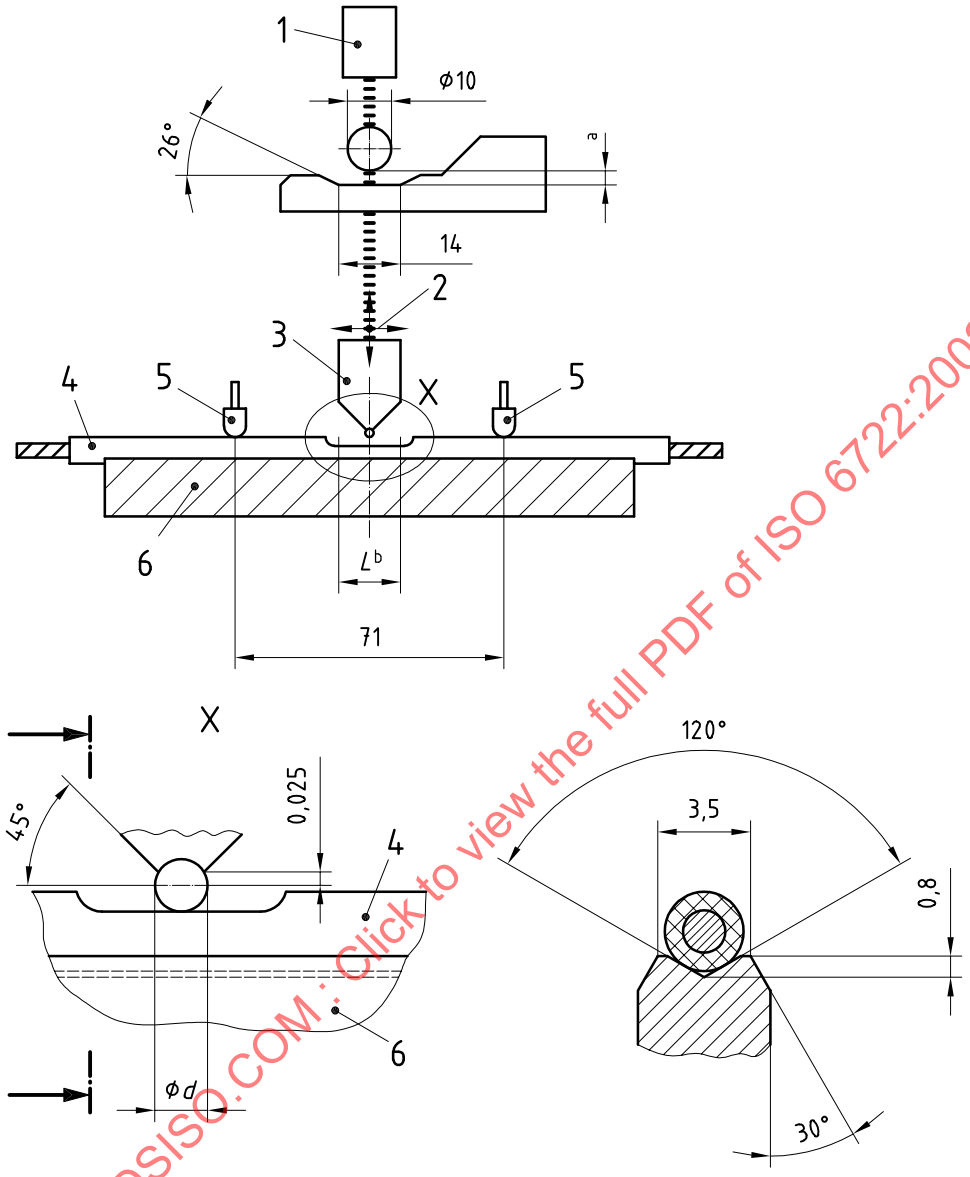
10.1.1 Test samples

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

10.1.2 Apparatus

Perform the short-term ageing test using an oven at the appropriate temperature as specified in Table 10, and a freezing chamber at (–25 ± 2) °C. The masses and mandrels shall be as specified in Table 7.

Dimensions in millimetres



Key

1 Mass
2 Travel
3 Needle holder
4 Test sample
5 Clamp
6 Test sample holder
d = (0,25 ± 0,01) mm or (0,45 ± 0,01) mm

a Clearance during abrasion.
b Abrasion length from start is L = (15,5 ± 1) mm.

Figure 7 — Apparatus for scrape test

Table 10 — 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 clause 1) + 25 °C.

10.1.3 Procedure

Place the test samples in an oven for 240 h. Fix the test samples by the conductor to avoid any contact between the insulation and the supports. The test samples shall be separated from each other by at least 20 mm 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 (23 ± 5) °C for at least 16 h. After conditioning at room temperature, perform the winding test (see 8.1) using the freezing chamber and the mandrels specified in Table 7.

After winding, allow the test samples to return to room temperature and perform 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 given in clause 6.2.

— Immerse the test samples in the saltwater bath for a minimum of 10 min prior to the application of the voltage.

— Apply the 1 kV (rms) voltage for 1 min.

— Do not “ramp up” the voltage after the application of the 1 kV (rms) voltage.

10.1.4 Requirements

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

10.2 Long-term ageing (3 000 h)

10.2.1 Test samples

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

10.2.2 Apparatus

Perform the long-term ageing test using an oven at the temperature specified in Table 11. The masses and mandrels shall be as specified in Table 7.

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 clause 1).	

10.2.3 Procedure

Follow the same procedure as is specified in 10.1.3; however, make the following changes to that procedure.

— Use an ageing time of 3 000 h.

— Perform the winding test at room temperature.

10.2.4 Requirement

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

10.3 Thermal overload

10.3.1 Test samples

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

10.3.2 Apparatus

Perform the thermal overload test using an oven at the temperature specified in Table 12. The masses and mandrels are specified in Table 7.

10.3.3 Procedure

Follow the same procedure as is specified in 10.1.3; however, make the following changes to that procedure.

— Use an ageing time of 6 h.

— Perform the winding test at room temperature.

10.3.4 Requirements

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

Table 12 — Thermal overload

Class	Test temperature[a] °C
A	135 ± 2
B	150 ± 2
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 clause 1) + 50 °C.	

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. Place the test samples in the oven in a horizontal position, so that air may circulate freely on all sides, for 15 min. After cooling to (23 ± 5) °C, measure the length of the insulation again.

10.4.4 Requirement

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

11 Chemical resistance

11.1 Fluid compatibility

11.1.1 General

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

11.1.2 Test samples

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

11.1.3 Apparatus

The fluid compatibility shall be determined through a measurement of the outside cable diameter using the apparatus specified in 5.1.

Fill the vessels with the fluids at the temperatures indicated in Table 13.

See Table 7 for masses and mandrels. Either a rotatable or a stationary mandrel may be used.

Table 13 — 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 % p-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[2)]	50 ± 3	20	25	If required
Engine coolant	50 % ethylene glycol + 50 % distilled water	50 ± 3	20	15	If required
Battery acid	H_2SO_4 (specific gravity = 1,260 ± 0,005)	23 ± 5	20	5	If required
NOTE Solutions are determined as percentage by volume.					

11.1.4 Procedure

Determine the outside cable diameter of each test sample by taking three measurements distributed 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 will be needed for the winding test) for 20 h in one of the fluids specified in Table 13, 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 after the end of the drying period, measure the outside cable diameter at the same point as before the immersion and perform the winding test; however, make the following changes to the procedure given in 8.1.3.

— Perform the winding test at room temperature.

— Calculate the percentage of change in the outside cable diameter.

11.1.5 Requirements

The maximum outside cable diameter change shall meet the requirements shown in Table 13. After winding, no conductor shall be visible. During the withstand voltage test, breakdown shall not occur.

2) Dexron III (Citgo part no. 33123) is an example of a suitable product available commercially [Citgo Petroleum, 555 East Butterfield Rd., Lombard, IL, 60148, USA; contact: Technical Infoline, tel.: +1 (800)-331-4068]. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of this product.

11.2 Durability of cable marking

The usage of this test is to be established by agreement between customer and supplier.

11.2.1 Test samples

Prepare three test samples, each of 600 mm length.

11.2.2 Apparatus

Use an apparatus consisting of two pieces of felt without dressing, having a minimum wool content of 75 % and a packing density of (0,171 to 0,191) g/cm^3 (dimensions 50 mm × 50 mm × 3 mm), and a vessel containing ISO 1817, oil no. 2 at (50 ± 3) °C.

11.2.3 Procedure

Immerse the test samples for 20 h with the test sample ends emerging 50 mm above the surface of the liquid. Remove the test samples from the oil and allow them 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. Visually examine the test samples after the test.

11.2.4 Requirement

All cable markings shall remain legible.

11.3 Resistance to ozone

DANGER — Attention is drawn to the highly toxic nature of ozone. Efforts should be made to minimize the exposure of workers at all times.

11.3.1 General

The usage of this test is to be established by agreement between customer and supplier. When resistance to ozone is specified, cables with all conductor sizes shall be in accordance with the following; however, compliance may be demonstrated by testing examples of large and small conductor areas. Testing of sizes 0,75 mm^2 and 16 mm^2 is preferred. Test conditions for cables with other conductor sizes have been included for information.

11.3.2 Test samples

Prepare three test samples, each of 300 mm length.

11.3.3 Apparatus

Use an ozone chamber in accordance with IEC 811-2-1 and having an atmosphere containing a mass fraction of (1 ± 0,05) × 10^{-6} of ozone at (65 ± 3) °C.

See Table 14 for the mandrel diameter. Aluminium mandrels are preferred since other materials may affect the ozone concentration.

11.3.4 Procedure

Wind at least the minimum number of turns specified in Table 14 and secure the ends. Condition the test samples for 192 hours 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 perform a visual examination of the insulation. Ignore any damage caused by the clamps which secure the ends.

11.3.5 Requirement

The visual examination of the insulation shall not reveal any cracks.

Table 14 — Resistance to ozone

ISO conductor size mm²	Mandrel diameter mm			Minimum number of turns
	Thick wall cables	Thin wall cables	Ultra thin wall cables	
0,13	—	6	6	3
0,22	—	6	6	3
0,35	—	6	6	3
0,5	6	6	6	3
0,75	6	6	6	3
1	10	6	6	3
1,5	10	10	6	3
2	10	10	6	3
2,5	15	10	6	3
3	15	15	—	3
4	20	15	—	3
5	20	20	—	3
6	20	20	—	3
10	40	30	—	0,5
16	50	50	—	0,5
25	75	50	—	0,5
35	75	—	—	0,5
50	75	—	—	0,5
70	100	—	—	0,5
95	100	—	—	0,5
120	125	—	—	0,5

11.4 Resistance to hot water

11.4.1 General

The usage of this test is to be established by agreement between customer and supplier. When resistance to hot water is specified, cables with all conductor sizes shall meet the requirements; however, compliance may be demonstrated by testing examples of large and small conductor sizes only. Testing of cables with conductor sizes of 0,35 mm² and 2,5 mm² is preferred.