
Road vehicles — 60 V and 600 V single-core cables —

**Part 1:
Dimensions, test methods and
requirements for copper conductor
cables**

Véhicules routiers — Câbles monoconducteurs de 60 V et 600 V —

Partie 1: Dimensions, méthodes d'essai et exigences pour les câbles conducteurs en cuivre



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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 6722-1 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 3, *Electrical and electronic equipment*.

This fourth edition of ISO 6722-1 cancels and replaces ISO 6722:2006, which has been technically revised.

ISO 6722 consists of the following parts, under the general title *Road vehicles — 60 V and 600 V single-core cables*:

- *Part 1: Dimensions, test methods and requirements for copper conductor cables*
- *Part 2: Dimensions, test methods and requirements for aluminium conductor cables*¹⁾

1) To be published.

Road vehicles — 60 V and 600 V single-core cables —

Part 1:

Dimensions, test methods and requirements for copper conductor cables

WARNING — The use of this International Standard may involve hazardous materials, operations, and equipment. This International Standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this International Standard to establish appropriate safety practices and determine the applicability of regulatory limitations prior to use.

1 Scope

This part of ISO 6722 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 greater than $>$ (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.

This part of ISO 6722 specifies requirements for copper conductor cables.

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 or thermoplastic — Determination of the effect of liquids*

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

IEC 60811-2-1, *Common test methods for insulating and sheathing materials of electric 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 Tin Coated 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*

EN 13602, *Copper and copper alloys — Drawn, round copper wire for the manufacture of electrical conductors*

3 Terms and definitions

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

NOTE Whenever a.c. voltage is specified throughout this part of ISO 6722, a.c. rms value shall be used.

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 or equal to (600 V d.c. or 600 V a.c.)

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 Safety concerns

See the “Warning” notice at the beginning of this International Standard.

4.2 Temperature classes

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

4.3 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 Table 5 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 B.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 specified above and are agreed between customer and supplier.

Table 2 — Conductor specifications

ASTM B1	Hard-drawn copper wire
ASTM B3 or EN 13602	Soft or annealed copper wire
ASTM B33 or EN 13602	Tin-coated 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".	

4.4 Tests

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

NOTE A special set of requirements for trucks is intended to be added to the next revision of this International Standard.

Table 3 — Tests

Sub-clause	Test description	Mandatory			If required ^c	
		In progress ^a	Initial	Periodic ^b	Initial	Periodic
5.1	Outside cable diameter	—	X	X	—	—
5.2	Insulation thickness	—	X	X	—	—
5.3	Conductor diameter	—	—	—	X	X
5.4	Conductor resistance	—	X	X	—	—
5.5	Withstand voltage	—	Note 1	Note 1	—	—
5.6	Insulation faults	Note 1	—	—	—	—
5.7	Insulation volume resistivity	—	—	—	X	X
5.8	Pressure test at high temperature	—	X	X	—	—
5.9	Strip force	—	—	—	X	X
5.10	Low temperature winding	—	X	X	—	—
5.11	Cold impact	—	—	—	X	X
5.12	Abrasion test	—	Note 2	Note 2	—	—
5.13	Long term heat ageing, 3 000 h	—	X	—	—	—
5.14	Short term heat ageing, 240 h	—	X	X	—	—
5.15	Thermal overload	—	—	—	X	X
5.16	Shrinkage by heat	—	X	X	—	—
5.17	Fluid compatibility	—	Notes 3 and 4	—	Notes 3 and 4	—
5.18	Durability of cable marking	—	—	—	Note 4	Note 4
5.19	Resistance to ozone	—	—	—	Note 4	—
5.20	Resistance to hot water	—	—	—	Note 4	—
5.21	Temperature and humidity cycling	—	—	—	Note 4	—
5.22	Resistance to flame propagation	—	X	X	—	—
NOTE 1	Some cables are rated at 60 V and others at 600 V. See 5.5.3 and 5.6.3 for details.					
NOTE 2	See 5.12.					
NOTE 3	Some fluids are for "Certification" and others are "If required". See 5.17 for details.					
NOTE 4	Compliance for a cable family may be demonstrated by testing examples of large and small conductor sizes only. See 4.7 for details.					
^a	A test made on an entire cable length during or after the 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.					

4.5 General test conditions

Unless specified otherwise, the device under test (DUT) shall be preconditioned for at least 16 h at a room temperature (RT) of $(23 \pm 5) ^\circ\text{C}$ and a relative humidity (RH) of 45 % to 75 %. Unless specified otherwise, all tests other than “In process” tests shall be conducted at these conditions.

Where no tolerance is specified, all values shall be considered to be approximate.

When a.c. tests are performed, they shall be at 50 Hz or 60 Hz. Applications at higher frequencies may require additional testing.

4.6 Ovens

An oven with air exchange, either natural or by pressure, should be used. The air shall enter the oven in such a way that it flows over the surface of the test pieces and exits near the top of the oven. The oven shall have not less than 8 and not more than 20 complete air changes per hour at the specified ageing temperature.

Forced air circulation, e.g. by a fan inside the oven may be used. However, in case of dispute, an oven without forced air circulation shall be used.

4.7 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 testing of representative conductor sizes is permitted (see Table 3), 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.

4.8 Recommended colours

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

5 Tests and requirements

5.1 Outside cable diameter

5.1.1 Purpose

This test is intended to verify that the cable outside diameter is within the required tolerances to fit seal and harness dimension requirements.

5.1.2 Test Sample

Prepare a test sample of 3 m in length.

5.1.3 Test

Use a measuring device which shall not cause deformation. 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 B.2. The values in Table 4 are normative. Since the values in Table B.2 are informative, they are not required; however, they may be applied by agreement between customer and supplier.

5.2 Insulation thickness

5.2.1 Purpose

This test is intended to verify that the cable insulation thickness is within the required tolerances to withstand electrical, mechanical and chemical abuse.

5.2.2 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.

5.2.3 Test

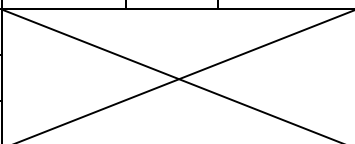
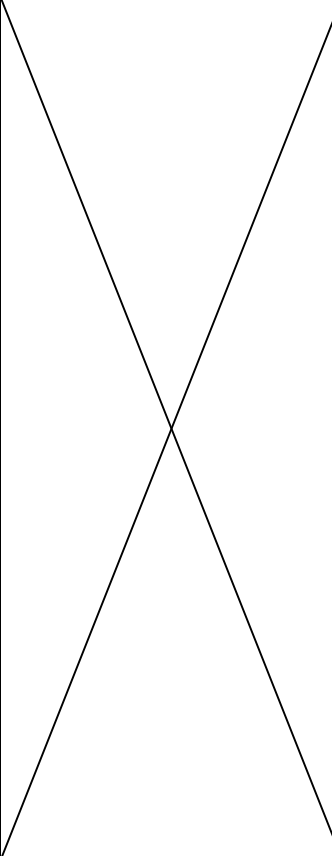
Use a measuring device which shall not cause deformation.

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						1,20			1,05
0,35	0,90						1,40 ^a			1,20
0,50	1,10	0,60	0,48	2,30	0,28	0,22	1,60	0,25	0,20	1,40
0,75	1,30			2,50	0,30	0,24	1,90			1,60
1	1,50			2,70			2,10			1,75
1,25	1,70			2,95			2,30			2,00
1,5	1,80			3,00			2,40			2,10
2	2,00	0,70	0,56	3,30	0,35	0,28	2,80	0,25	0,20	2,40
2,5	2,20			3,60			3,00			2,70
3	2,40			0,80	0,64	4,10	0,40	0,32	3,40	
4	2,80	4,40	3,70							
5	3,10	4,90	4,20							
6	3,40	5,00	4,30							
8	4,30	5,90	5,00							
10	4,50	1,00	0,80	6,50	0,60	0,48	6,00			
12	5,40			7,40			6,50			
16	5,80			8,30	0,65	0,52	7,20			
20	6,90	1,10	0,88	9,10			7,80			
25	7,20	1,30	1,04	10,40			8,70			
30	8,30			10,90	0,80	0,64	9,60			
35	8,50			11,60			10,40			
40	9,60	1,40	1,12	12,40	0,90	0,71	11,10			
50	10,50	1,50	1,20	13,50			12,20			
60	11,60			14,60	1,00	0,80	13,30			
70	12,50			15,50			14,40			
95	14,80	1,60	1,28	18,00	1,10	0,90	16,70			
120	16,50			19,70						

NOTE Outside cable diameter minimum values for high volume cable constructions are shown in Table B.2. Since the values in Table B.2 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 max. 1,30 mm.

5.3 Conductor diameter

5.3.1 Purpose

This test is intended to verify that the cable conductor diameter is within the required tolerances to fit terminal crimps and mechanical demands.

5.3.2 Test samples

Use the test samples as specified in 5.2. In case of disputed results, a referee method is provided below.

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

5.3.3 Test

Use a measuring device which shall not cause deformation.

Determine the conductor diameter by measuring the inside diameter of the test samples and record the maximum inside diameter for each test sample.

5.3.4 Requirement

No single value shall exceed the maximum value as specified in Table 4.

5.4 Conductor resistance

5.4.1 Purpose

This test is intended to verify that the cable conductor resistance does not exceed the maximum permitted value.

5.4.2 Test samples

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 shown in 5.4.3. The ends of the test sample may be soldered.

5.4.3 Test

Use a resistance measuring device with an accuracy of $\pm 0,5$ % of the measured value and a thermometer with an accuracy of $\pm 0,5$ °C.

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 Equation (1):

$$R_{20} = \frac{R_t}{L \left[1 + 0,00393(t - 20) \right]} \quad (1)$$

where

R_{20} is the corrected conductor resistance at the reference temperature of 20 °C, expressed in mΩ/m;

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

L is the unsoldered conductor length, expressed in m;

t is the conductor temperature at the time of measuring, expressed in °C.

NOTE The value of 0,00393 is the temperature coefficient for copper with 100 % conductivity at temperatures at 20 °C. For coated wires or alloys, the correction factor shall be established by agreement between customer and supplier.

5.4.4 Requirement

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

Table 5 — Conductor resistance

ISO conductor size mm ²	Maximum conductor resistance per length mΩ/m at 20 °C ^a		
	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
1,25	14,9	15,9	16,0
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
8	2,38	2,52	2,60
10	1,82	1,85	1,90
12	1,52	1,60	1,66
16	1,16	1,18	1,21
20	0,955	0,999	1,03
25	0,743	0,757	0,774
30	0,647	0,684	0,706
35	0,527	0,538	0,549
40	0,473	0,500	0,516
50	0,368	0,375	0,383
60	0,315	0,333	0,344
70	0,259	0,264	0,270
95	0,196	0,200	0,204
120	0,153	0,156	0,159
Conductors produced from silver coated strands shall not exceed the maximum conductor resistance per length for plain copper.			
^a Minimum conductor resistance values for high volume cable constructions are shown in Table B.3. Since the values in Table B.3 are informative, they are not required; however, they may be applied by agreement between customer and supplier.			

5.5 Withstand voltage

5.5.1 Purpose

This test is intended to verify that the cable insulation is capable of withstanding the required rated voltage. It is also used to detect defects caused by mechanical, chemical and/or other environmental stress.

5.5.2 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.

5.5.3 Test

5.5.3.1 General

Partially fill an electrically non-conductive vessel with salt water with 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 50 Hz or 60 Hz a.c. voltage source.

5.5.3.2 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 (a.c.) 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:

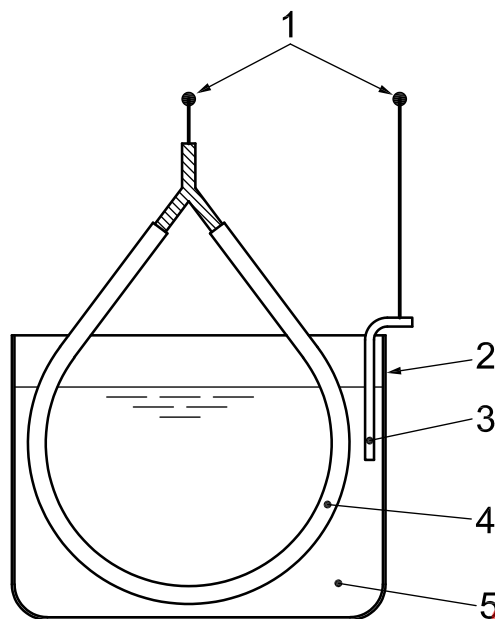
- 3 kV (a.c.) for cables $< 0,5 \text{ mm}^2$
- 5 kV (a.c.) for cables $\geq 0,5 \text{ mm}^2$

5.5.3.3 600 V cable

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

5.5.4 Requirement

Breakdown shall not occur.

**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**5.6 Insulation faults****5.6.1 Purpose**

This test is intended to verify that the cable insulation has no defects which can cause electrical failures.

5.6.2 Test sample

All cables produced are used.

5.6.3 Test

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 (a.c.) kV	
	60 V cables	600 V cables
< 0,5	3	6
≥ 0,5	5	8

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.

5.6.4 Requirement

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

5.7 Insulation volume resistivity

5.7.1 Purpose

This test is intended to ensure limitation of leakage current by verifying that the volume resistivity meets the requirements as specified.

5.7.2 Test sample

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

5.7.3 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.

5.7.4 Test

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 Equation (2):

(2)

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

where

ρ_0 is the insulation volume resistivity, expressed in Ωmm ;

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

R is the measured insulation resistance in Ω ;

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

d is the conductor diameter in mm according to 5.3;

$\lg$ is logarithm to the base 10.

5.7.5 Requirement

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

5.8 Pressure test at high temperature

5.8.1 Purpose

This test is intended to verify that the electrical integrity of the cable is maintained after thermal and mechanical stress.

5.8.2 Test samples

Prepare three test samples, each of 600 mm in length.

5.8.3 Test

The test temperature is specified in Table 7 and the test 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 Equation (3):

$$F = 0,8\sqrt{i(2 \times D - i)} \quad (3)$$

where

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

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

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

0,8 is a coefficient in (N/mm).

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).	

Place a test sample in the apparatus as shown in Figure 2. Attach the test sample to the support so as not to bend under the pressure of the blade. The load and the blade of the apparatus shall be perpendicular to the test sample axis 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 5.5.

- 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 (a.c.) voltage for 1 min.
- Do not “ramp up” the voltage after the application of the 1 kV (a.c.) voltage.

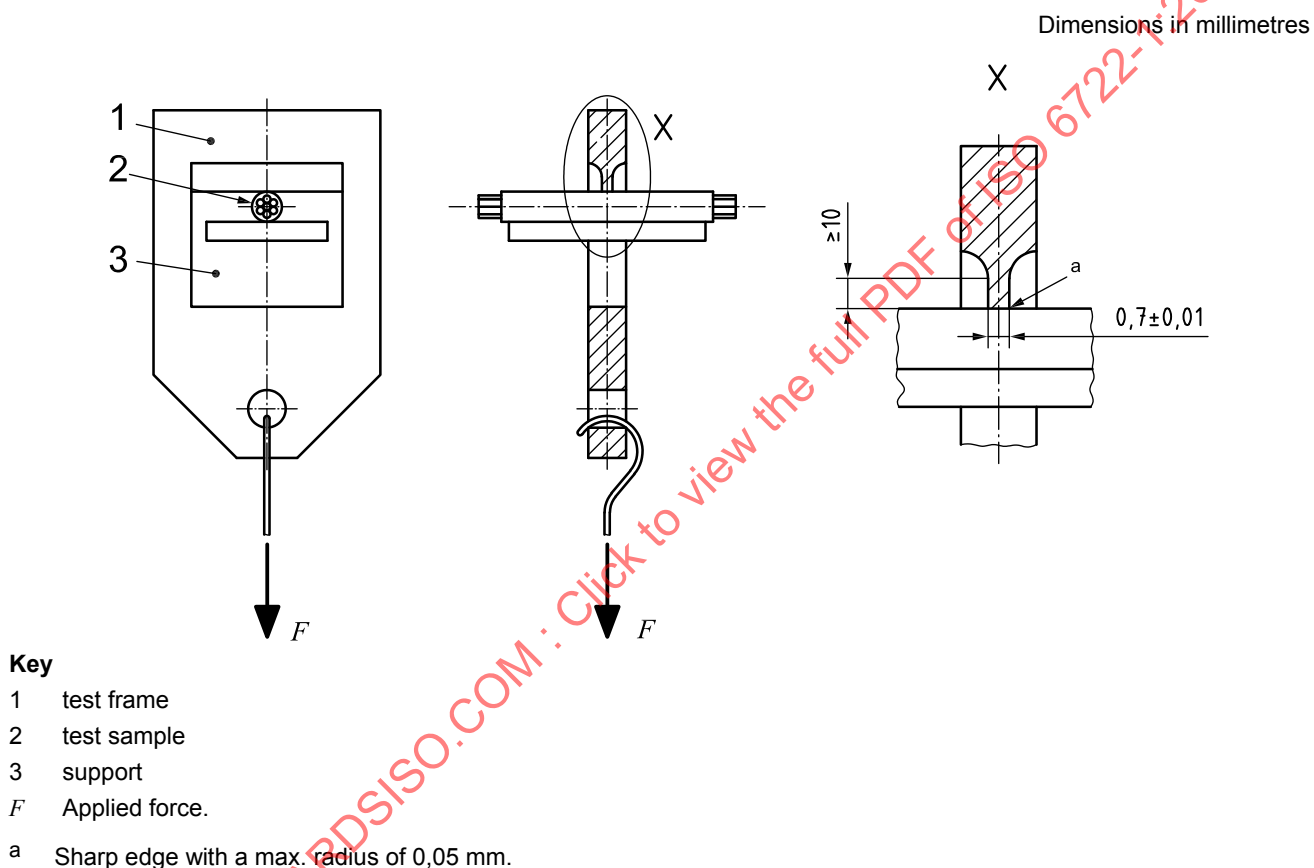


Figure 2 — Apparatus for pressure test at high temperature

5.8.4 Requirement

Breakdown shall not occur during the withstand voltage test.

5.9 Strip force

5.9.1 General

This test is applicable to cables with a conductor size of $\leq 6 \text{ mm}^2$.

5.9.2 Purpose

This test is intended to verify that the force required to remove the insulation from the conductor meets customer requirements.

5.9.3 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 BC undisturbed. A different length for the section BC may be agreed between customer and supplier.

5.9.4 Test

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.

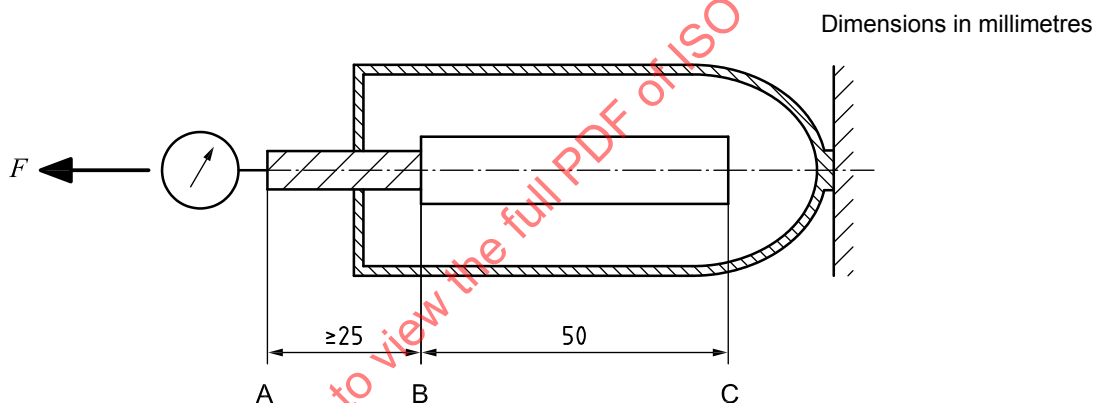


Figure 3 — Apparatus for strip force

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) in Newtons. Repeat the procedure for the other test samples. If the 50 mm section of insulation BC buckles when sliding, prepare new test samples with the length BC equal to 25 mm and repeat this procedure.

5.9.5 Requirement

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

5.10 Low temperature winding

5.10.1 Purpose

This test is intended to verify that the cable can withstand bending at low temperature without cracking and still maintain insulation properties. This test is also intended to verify the low temperature class rating according to Table 1. A modification of this test is used to detect defects caused by environmental stresses.

5.10.2 Test samples

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

5.10.3 Test

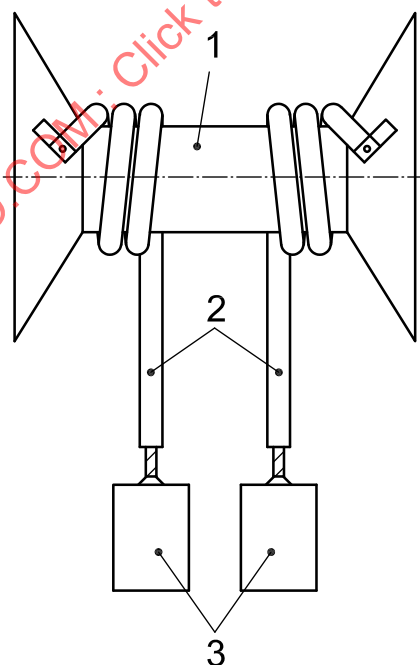
Use a freezing chamber at $(-40 \pm 2) ^\circ\text{C}$. Either a rotatable or a stationary mandrel may be used. See Table 8 for the mandrel diameter, winding speed and the number of turns.

When a rotatable mandrel is used, it shall be in accordance to Figure 4. See Table 8 for the mass.

When a stationary mandrel is used, no mass is applied.

Table 8 — Winding

ISO conductor size a mm ²	Mandrel diameter mm		Mass Kg	Winding speed s ⁻¹	Number of turns min.
	A ^a	B ^a			
a ≤ 0,75	Mandrel diameter ≤ 5 × required maximum outside cable diameter	Mandrel diameter ≤ 1,5 × required maximum outside cable diameter	0,5	1	3
0,75 < a ≤ 1,5			2,5		
1,5 < a ≤ 6			5		2
6 < a ≤ 10			8	0,5	0,5
10 < a ≤ 25			10		
25 < a ≤ 35			20		
35 < a ≤ 120			30	0,2	
a References to Column A are made in 5.17.4.2, 5.17.5.4 and 5.20.3. References to Column B are made in 5.21.3.					



Key

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

Figure 4 — Apparatus for winding

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

5.10.3.1 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.

5.10.3.2 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 RT, 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 5.5.

- 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 (a.c.) voltage for 1 min.
- Do not ramp up the voltage after the application of the 1 kV (a.c.) voltage.

5.10.4 Requirement

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

5.11 Cold impact

5.11.1 Purpose

This test is intended to verify that the cable can withstand impact at low temperature without cracking and still maintain insulation properties.

5.11.2 Test samples

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

5.11.3 Test

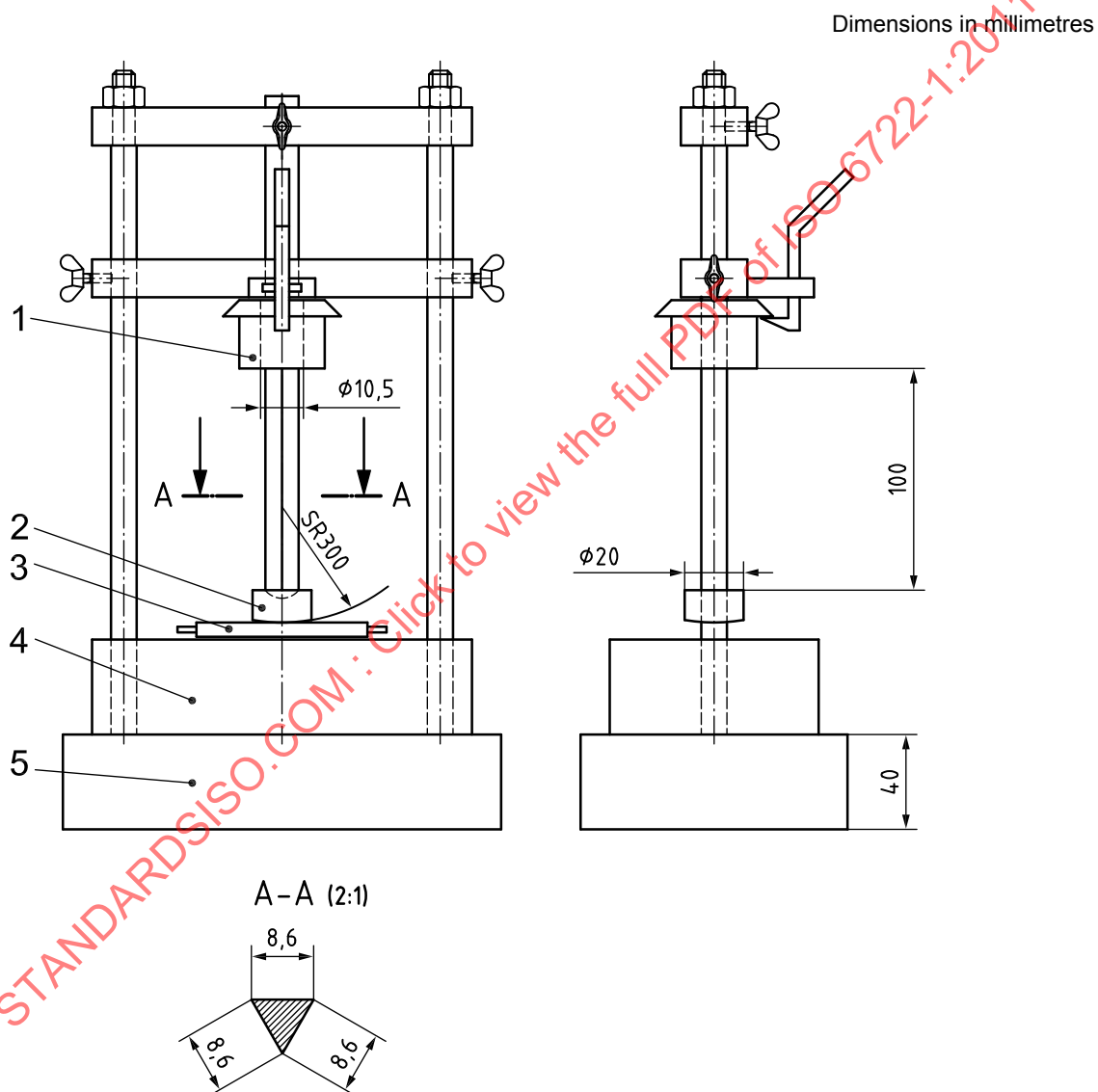
The apparatus shown in Figure 5 is positioned on a foam rubber pad of 40 mm thickness. The mass of the hammer is specified in Table 9. Set the freezing chamber temperature to $(-15 \pm 2) ^\circ\text{C}$.

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 RT, and make a visual examination of the insulation. If no exposed conductor is visible, perform the withstand voltage, however, make the following changes to the procedure in 5.5.

- 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 (a.c.) voltage for 1 min.
- Do not ramp up the voltage after the application of the 1 kV (a.c.) voltage.

5.11.4 Requirement

After impact, no conductor shall be visible. During the withstand voltage test according to 5.5, breakdown shall not occur.



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 a	Mass of the hammer g		
mm ²	Thick wall cable	Thin wall cable	Ultra thin wall cable
a ≤ 0,35		100	100
0,35 < a ≤ 2,5	100		
2,5 < a ≤ 4			
4 < a ≤ 10	200	200	
10 < a ≤ 25	300	300	
25 < a ≤ 50			
50 < a ≤ 95	400	400	
95 < a ≤ 120			
NOTE	“X” = cable type does not exist.		

5.12 Abrasion test

5.12.1 General

This test is only applicable to cables with a conductor size $\leq 6 \text{ mm}^2$, for which either 5.12.4.1 (Sandpaper abrasion) or 5.12.4.2 (Scrape abrasion) shall be used. The customer and supplier shall define which test shall be used. No abrasion test is required for conductor sizes $> 6 \text{ mm}^2$.

5.12.2 Purpose

This test is intended to verify that the resistance of the cable insulation to abrasion meets customer requirements.

5.12.3 Test sample

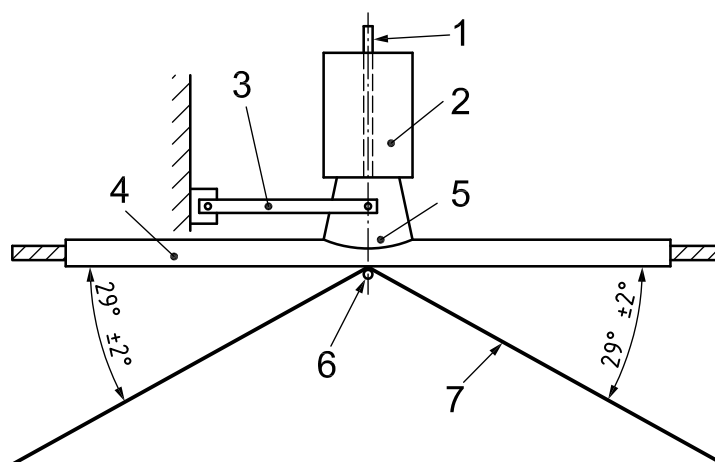
Prepare a test sample of 1 m in length and remove 25 mm of insulation from each end.

5.12.4 Test

5.12.4.1 Sandpaper abrasion

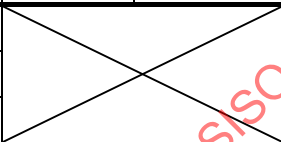
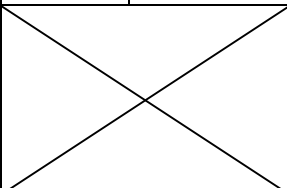
Measure the "resistance to sandpaper abrasion" using 150J garnet sandpaper tape with 5 mm to 10 mm conductive strips perpendicular to the edge of the sandpaper spaced a maximum of every 75 mm. Mount a suitable bracket to the pivoting arm (see Figure 6) to maintain the test sample position over an unused 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.

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 $(1\,500 \pm 75) \text{ mm/min}$ 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
- 2 additional mass
- 3 pivoting arm
- 4 test sample
- 5 bracket
- 6 tape supporting pin, diameter = 6,9 mm
- 7 150J, garnet sandpaper abrasion tape

Figure 6 — Apparatus for sandpaper abrasion test**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
1,25		425		425		240			425
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	

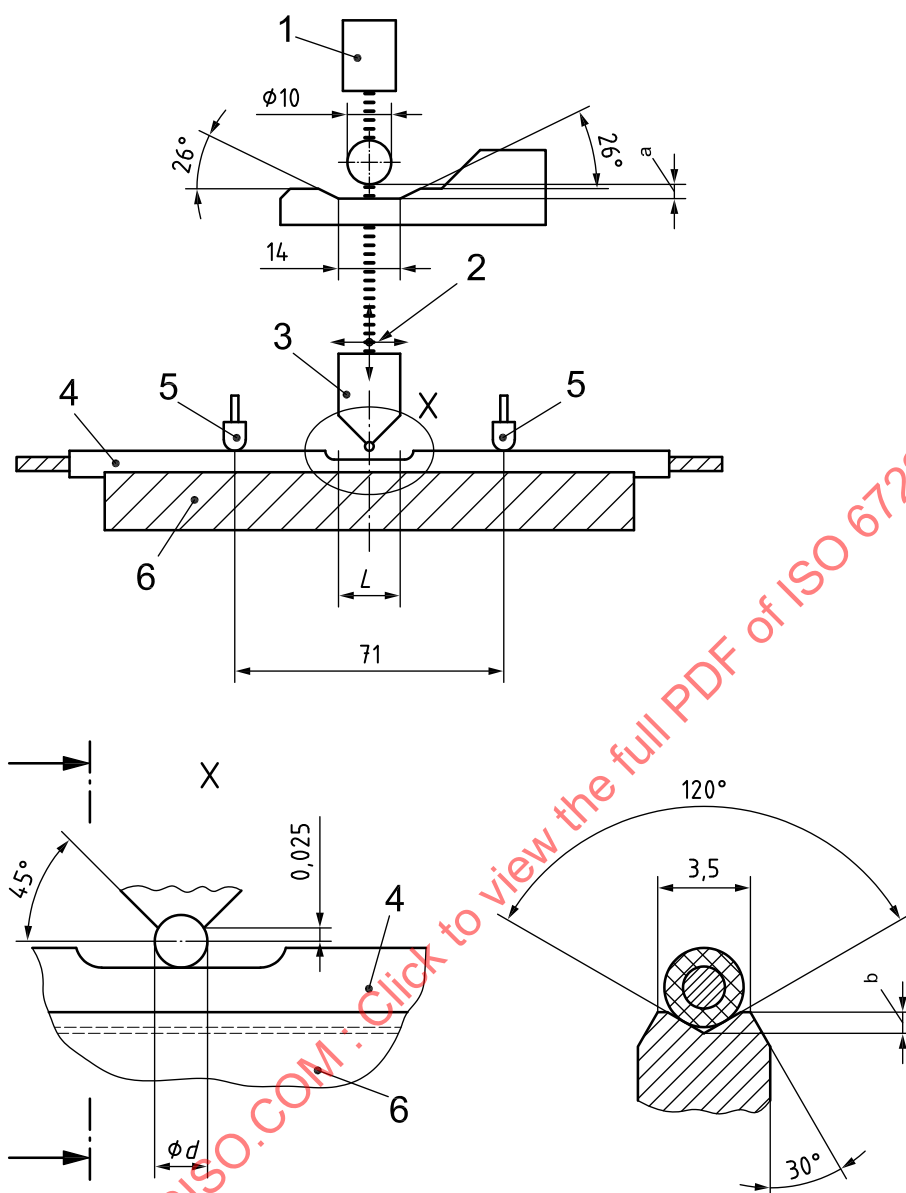
NOTE The total vertical force exerted on the test sample shall be the combination of the force exerted by the bracket, pivoting arm, support rod and additional mass.

5.12.4.2 Scrape abrasion

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: $(0,45 \pm 0,01)$ mm;
- Type of needle: spring wire (polished) material according to 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;
- Mass: the vertical force on the test sample shall be constant under dynamic conditions;
- Test sample mounting force: the test sample shall not move during test. If fixing is necessary, the tension applied on the conductor shall not exceed 100 MPa (N/mm^2).

Apply a total vertical force as specified in Table 11 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. The minimum value shall be noted.



Key

- 1 mass
- 2 travel
- 3 needle holder
- 4 test sample
- 5 clamp
- 6 test sample holder
- L abrasion length, $(15,5 \pm 1)$ mm
- d needle diameter, $(0,45 \pm 0,01)$ mm
- a Clearance during abrasion.
- b Groove depth
 - 0,4 mm, Conductor size $\leq 0,35$ mm²
 - 0,8 mm, Conductor size $> 0,35$ mm².

Figure 7 — Apparatus for scrape abrasion

Table 11 — Scrape abrasion

ISO conductor size	mm ²	0,13	0,22	0,35	0,5	0,75	1	1,25	1,5	2	2,5	3	4 ... 6
Vertical force	N	4,00	7,00										
Tolerance	N	± 0,05											
Cycles	min	100	125	150	300	350	400	450	500	550	600	700	

5.12.5 Requirement

5.12.5.1 Sandpaper abrasion

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

5.12.5.2 Scrape abrasion

The resistance to scrape abrasion shall meet or exceed the minimum number of cycle requirements according to Table 11.

5.13 Long term heat ageing, 3 000 h

5.13.1 Purpose

This test is intended to verify the upper value of the “temperature class rating” according to Table 1.

5.13.2 Test samples

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

5.13.3 Apparatus

Use an oven at the temperature specified in Table 12. See 5.10, Table 8, Column B, for the mandrel diameter.

Table 12 — Long term ageing and environmental cycling

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

5.13.4 Test

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 RT for at least 16 h. After conditioning, perform the “winding test” at RT according to 5.10 using a mandrel diameter according to Table 8, Column B. 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 5.5:

- 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 (a.c.) voltage for 1 min;
- Do not ramp up the voltage after the application of the 1 kV (a.c.) voltage.

5.13.5 Requirement

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

5.14 Short term heat ageing, 240 h

5.14.1 Purpose

This test is intended to simulate thermal excursions.

5.14.2 Test samples

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

5.14.3 Apparatus

Perform the short term ageing test using an oven at the temperature as specified in Table 13 and a freezing chamber at $(-25 \pm 2) ^\circ\text{C}$. See 5.10, Table 8, Column A, for mandrel diameter.

Table 13 — Short term heat ageing

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

5.14.4 Test

Follow the same procedure as 5.13.4; however, make the following changes:

- Use an ageing time of 240 h;
- Perform the winding test according to 5.10 using the freezing chamber at $(-25 \pm 2) ^\circ\text{C}$;
- Allow the test samples to return to RT before making the visual examination.

5.14.5 Requirement

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

5.15 Thermal overload

5.15.1 Purpose

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

5.15.2 Test samples

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

5.15.3 Apparatus

Perform the thermal overload test using an oven at the temperature as specified in Table 14. See 5.10, Table 8, column B, for mandrel diameter.

Table 14 — Thermal overload

Class	Test temperature °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
NOTE Upper value of temperature class rating (see Table 1) + 50 °C.	

5.15.4 Test

Follow the same procedure as specified in 5.13.4; however, use an ageing time of 6 h.

5.15.5 Requirement

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

5.16 Shrinkage by heat

5.16.1 Purpose

This test is intended to verify the longitudinal dimensional stability of the insulation, at the end of cable, at elevated temperature to avoid exposure of the conductor.

5.16.2 Test samples

Prepare three test samples, each of 100 mm length.

5.16.3 Test

Perform the test using an oven at $(150 \pm 3) ^\circ\text{C}$.

Measure the exact length of the insulation of the test samples at RT 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 RT measure the length of the insulation again.

5.16.4 Requirement

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

5.17 Fluid compatibility

5.17.1 General

When any resistance to chemicals is specified, compliance for a cable family may be demonstrated by testing representative conductor sizes according to 4.7.

This test is required for gasoline, diesel fuel, ethanol, engine oil, windscreen washer fluid and salt water. All other fluids shall be tested by agreement between customer and supplier.

The terms “chemicals” and “fluids” may be used interchangeably throughout 5.17.

Test Method 1 (5.17.3) shall be used for cables insulated with new materials or existing materials where the formulation has been changed and introduced to the industry after the publication date of this International Standard.

Test Method 2 (5.17.4) may be used for cables insulated with materials existing prior to the publication date of this International Standard.

Either test method may be used on any of the materials if agreed between customer and supplier.

5.17.2 Purpose

This test is intended to verify resistance of the insulation to chemical loads in automotive environments where exposure is limited.

5.17.3 Test Method 1 — Resistance to liquid chemicals

5.17.3.1 Test setup

The test shall consist of one or several exposures to chemicals with intermediate exposure to heat ageing conditions. Two different test media groups in accordance with Table 15 shall be tested, Media Group 1 with a heat ageing period of 1 000 h at the actual cable class temperature and Media Group 2 with a heat ageing period of 240 h at the actual cable class temperature (see 5.17.3.4).

Table 15 — Resistance to liquid chemicals — Test method 1

Group	Media Fluid	Specification	Samples (pcs)	Storage time in oven at class temp.
1	Engine coolant	50 % ethylene glycol + 50 % distilled water	8	240 h + 240 h + 240 h + 280 h
	Engine oil	ISO 1817, Oil No 2	8	
	Salt water (road)	5 % NaCl , 95 % water (mass %)	8	
	Windscreen washer fluid	50 % Iso-propanol, 50 % water	8	
2	Gasoline	ISO 1817, liquid C	2	240 h
	Diesel	90 % ISO 1817, Oil No 3 + 10 % p-xylene	2	
	Ethanol	85 % Ethanol + 15 % ISO 1817 liquid C	2	
	Power steering fluid	ISO 1817, Oil No 3	2	
	Auto. transmission fluid	Dexron VI	2	
	Brake fluid	SAE RM-66-06	2	
	Battery acid	25 % H ₂ SO ₄ and 75 % H ₂ O, density 1,28	2	
NOTE 1 Solutions are determined as % by volume if not otherwise specified.				
NOTE 2 Changes in the specified fluids may be considered in future revisions 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.				

5.17.3.2 Test samples

Prepare individual test samples, each 600 mm long with 25 mm of insulation removed from each end, bent around a 50 mm diameter mandrel to a U-shape. The stripped ends should be formed as hooks, allowing the test objects to be hung on to the grids in the oven. The number of test objects to be prepared for each chemical shall be according to Table 15.

5.17.3.3 Apparatus

Use an oven in accordance with 4.6 at the specified maximum temperature class rating according to Table 1. The oven shall be equipped with grids, making it possible to hang the test objects on them. A collecting tray shall be placed in the bottom of the oven to gather chemical spills. See 5.10, Table 8, Column A, for the mandrel diameter.

5.17.3.4 Test performance

For each fluid to be tested, immerse 2/3 of the test objects 10 s in the fluid, then remove from the fluid and allow to drain off for 3 min before storage in the oven. Care should be taken that the stripped ends are not exposed to the fluid. Test objects from one and the same type of tested cable, but exposed to the different test fluids, can be stored in the same oven. Test objects from different types of cables are not allowed to be stored in the same oven.

For Media Group 1 objects, the immersing in the respective fluid shall be repeated at 240 h, 480 h and 720 h of the 1 000 h test in the following way: initially immerse 8 objects for each fluid and store in the oven. At 240 h, take out two objects and pass them on to final test according to below. The remaining 6 objects should be re-immersed and stored in the oven for another 240 h exposure. At 480 h, take out another two objects for final test, and re-immerses the remaining 4 objects. At 720 h, again take out two objects for final testing and re-immerses the remaining 2 objects for storing up to 1 000 h.

Media Group 2 objects should only be immersed once before the exposure in the actual cable class temperature.

After fulfilled exposure, remove the test samples from the oven and maintain them at RT (23 ± 5 °C) for 30 min. Thereafter, perform the "winding test" according to 5.10 at RT. Make sure that the winding test is performed in the middle of the test objects. 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 5.5:

- 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 (a.c.) for 1 min.
- Do not ramp up the voltage after the application of the 1 kV (a.c.).

5.17.3.5 Requirement

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

5.17.4 Test Method 2 — Resistance to liquid chemicals

5.17.4.1 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.

5.17.4.2 Test

The fluid compatibility is determined via a measurement of the outside cable diameter with the apparatus specified in 5.1. Fill the vessels with the fluids at the temperatures according to Table 16. See 5.10, Table 8, Column A, for mandrel diameter.

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 shall be needed for the winding test for 20 h in a fluid specified in Table 16 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 RT for 30 min. Within 5 min after 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 5.10.

- Perform the winding test at RT.
- Calculate the percentage of change in outside cable diameter.

Table 16 — Chemical load — Test Method 2

Fluid	Specification (see ISO 16750-5)	Test temperature °C	Test Duration h	Maximum outside cable diameter change %
Gasoline	ISO 1817, liquid C	RT	20	15
Diesel fuel	90 % ISO 1817, Oil No. 3 + 10 % p-xylene	RT	20	15
Engine oil	ISO 1817, Oil No. 2	50 ± 3	20	15
Ethanol	85 % Ethanol + 15 % ISO 1817 liquid C	RT	20	15
Power steering fluid	ISO 1817, Oil No. 3	50 ± 3	20	30
Automatic transmission fluid	Dexron VI	50 ± 3	20	25
Engine coolant	50 % ethylene glycol + 50 % distilled water	50 ± 3	20	15
NOTE 1 Solutions are determined as % by volume. NOTE 2 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.				

5.17.4.3 Requirement

The maximum outside cable diameter change shall meet the requirements shown in Table 16. After winding, no conductor shall be visible. During the withstand voltage test, breakdown shall not occur.

5.17.5 Battery acid

5.17.5.1 General

If the chemical resistance Test Method 1 is performed, this test is not applicable.

5.17.5.2 Purpose

See 5.17.2.

5.17.5.3 Test sample

Prepare one test sample according to 5.17.4.2.

5.17.5.4 Apparatus

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 5.10, Table 8, Column A, for the mandrel diameter.

5.17.5.5 Test

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 RT for 30 min. After conditioning at RT, perform the “winding test” according to 5.10 at RT. 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 5.5:

- 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 (a.c.) for 1 min.
- Do not ramp up the voltage after the application of the 1 kV (a.c.).

5.17.5.6 Requirements

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

5.18 Durability of cable marking

5.18.1 Purpose

This test is intended to verify that marking is still legible after combined chemical and mechanical loads.

5.18.2 Test samples

Prepare three test samples, each of 600 mm in length.

5.18.3 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.

5.18.4 Test

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 RT 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.

5.18.5 Requirement

All cable markings shall remain legible.

5.19 Resistance to ozone

5.19.1 Purpose

This test is intended to verify the resistance of the cable insulation to ozone exposure.

5.19.2 Test samples

Prepare three test samples, each of 300 mm in length.

5.19.3 Apparatus

Use an ozone chamber in accordance with IEC 60811-2-1 applying an atmosphere containing a mass fraction of $(1 \pm 0,05) \times 10^{-6}$ of ozone at $(65 \pm 3) ^\circ\text{C}$. Attention is drawn to the highly toxic nature of ozone. Efforts should be made to minimize the exposure of workers at all times. See 5.10, Table 8, Column B, for the mandrel diameter. Aluminium mandrels are preferred since other materials may affect the ozone concentration.

5.19.4 Test

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 RT, and make a visual examination of the insulation. Ignore any damage caused by the clamps which secure the ends.

5.19.5 Requirement

The visual examination of the insulation shall show no cracks.

5.20 Resistance to hot water

5.20.1 Purpose

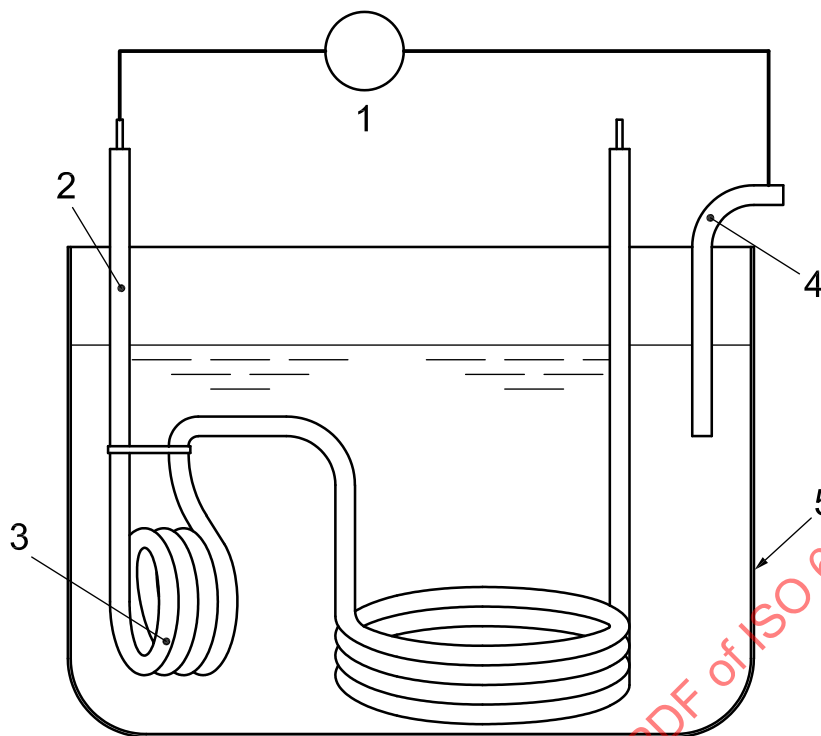
This test is intended to verify that the cable maintains electrical integrity after exposure to hot water.

5.20.2 Test samples

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

5.20.3 Test

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 5.7. See 5.10, Table 8, Column A, 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

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 days, disconnect the power supply, and measure the insulation volume resistivity according to 5.7. Make the following changes to the procedure in 5.7:

- Measure the insulation volume resistivity in the salt water bath and at the temperature as described above.

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 RT, 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 5.5.

- 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 (a.c.) for 1 min.
- Do not ramp up the voltage after the application of the 1 kV (a.c.).

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

5.20.4 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.

5.21 Temperature and humidity cycling

5.21.1 Purpose

This test is intended to verify that the cable maintains mechanical and electrical integrity after temperature and humidity cycling.

5.21.2 Test samples

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

5.21.3 Test

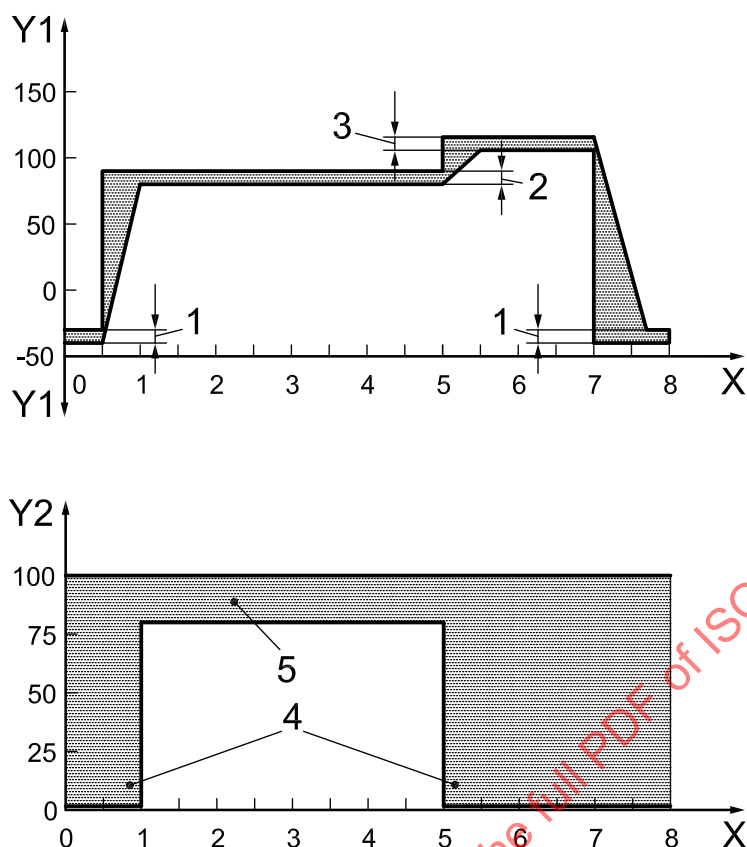
Perform the test in a temperature chamber which is capable of cycling between $(-40 \pm 2)^\circ\text{C}$ and the test temperature as specified in Table 12. The chamber shall also be capable of controlling the relative humidity between 80 % and 100 %. See 5.10, Table 8, Column B, for the mandrel diameter.

Wind at least the minimum number of turns as specified in Table 8 around the mandrel and secure the ends. Condition the test samples according to the temperature and relative humidity as shown in Figure 9. The cycle begins and ends with the chamber at $(-40 \pm 2)^\circ\text{C}$ and uncontrolled relative humidity. Extended transition times may be used as long as the dwell times at temperature are maintained. This shall constitute one cycle. Repeat the cycle for a total of 40 cycles. While still on the mandrel, remove the test sample from the chamber, allow it to condition at relative humidity for approximately 30 min, and unwind it from the mandrel. Repeat the procedure for the other test sample. Make a visual examination of the insulation. Ignore any damage caused by the clamps which secure the ends. If no exposed conductor is visible, perform the withstand voltage test; however, make the following changes to the procedure in 5.5:

- Immerse the test samples in the salt water bath for a minimum of 10 min without the 4h of conditioning prior to the application of the voltage.
- Apply the 1 kV (a.c.) for 1 min.
- Do not ramp up the voltage after the application of the 1 kV (a.c.).

5.21.4 Requirement

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



Key

- | | | | |
|---|--|----|--------------------------------------|
| 1 | $(-40 \pm 2) ^\circ\text{C}$ | X | time in h |
| 2 | $80 ^\circ\text{C}$ to $90 ^\circ\text{C}$ | Y1 | test temperature in $^\circ\text{C}$ |
| 3 | test temperature (see Table 12) | Y2 | relative humidity in % |
| 4 | relative humidity, uncontrolled | | |
| 5 | 80 % to 100% relative humidity | | |

NOTE 1 This figure is for temperature class C.

NOTE 2 For higher than $175 ^\circ\text{C}$ temperature class materials, the test temperature will be limited to $175 ^\circ\text{C}$ due to the test equipment limitations.

Figure 9 — Procedure for temperature and humidity cycling test

5.22 Resistance to flame propagation

5.22.1 Purpose

This test is intended to verify that a cable should not sustain combustion.

5.22.2 Test sample

Prepare five test samples with at least 600 mm of insulation.

5.22.3 Test

Determine the resistance to flame propagation using a Bunsen burner fed with appropriate gas, having a combustion tube of 9 mm internal diameter, where the flame temperature at the tip of the inner blue cone shall be $(950 \pm 50) ^\circ\text{C}$.