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Road vehicles — Automotive cables —

Part 2:
Test methods

Véhicules routiers — Cables automobiles —

Partie 2: Méthodes d'essai

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 32, *Electrical and electronic components and general system aspects*.

A list of all parts in the ISO 19642 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document was prepared following a joint resolution to improve the general structure of the ISO Automotive Electric Cable standards. This new structure adds more clarity and, by defining a new standard family, opens up the standard for future amendments.

Many other standards currently refer to ISO 6722-1, ISO 6722-2 and ISO 14572. So these standards will stay valid at least until the next scheduled systematic review and will be replaced later on by the ISO 19642 series.

For new Automotive Cable Projects customers and suppliers are advised on using the ISO 19642 series.

Road vehicles — Automotive cables —

Part 2:
Test methods

WARNING — The use of this document can involve hazardous materials, operations and equipment. This document 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 document to establish appropriate safety practices and determine the applicability of regulatory limitations prior to use.

1 Scope

This document defines test methods for electrical cables in road vehicles, which are used in other parts of the ISO 19642 series.

2 Normative references

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

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

ISO 4892-2, *Plastics — Methods of exposure to laboratory light sources — Part 2: Xenon-arc lamps*

ISO 4926, *Road vehicles — Hydraulic braking systems — Non-petroleum-base reference fluids*

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

ISO 19642-1, *Road vehicles — Automotive cables — Part 1 — Vocabulary and design guidelines*

IEC 60811-201, *Electric and optical fibre cables — Test methods for non-metallic materials — Part 201: General tests — Measurement of insulation thickness*

IEC 60811-403, *Electric and optical fibre cables — Test methods for non-metallic materials — Part 403: Miscellaneous tests — Ozone resistance test on cross-linked compounds*

IEC 60811-501, *Electric and optical fibre cables — Test methods for non-metallic materials — Part 501: Mechanical tests — Tests for determining the mechanical properties of insulating and sheathing compounds*

IEC 62153-4-3, *Metallic communication cable test methods — Part 4-3: Electromagnetic compatibility (EMC) - Surface transfer impedance — Triaxial method*

IEC 62153-4-4, *Metallic communication cable test methods — Part 4-4: Electromagnetic compatibility (EMC) — Shielded screening attenuation, test method for measuring of the screening attenuation as up to and above 3 GHz*

IEC 62153-4-5, *Metallic communication cables test methods — Part 4-5: Electromagnetic compatibility (EMC) — Coupling or screening attenuation — Absorbing clamp method*

SAE RM-66-06, *Motor Vehicle Brake Fluid — High Boiling Compatibility/Reference Fluid*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 19642-1 apply.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Specifications

4.1 General test conditions

Unless specified otherwise, the device under test (DUT) shall be preconditioned continuously for at least 16 h at a room temperature (RT) of (23 ± 3) °C and a relative humidity (RH) of 45 % to 75 %. Unless specified otherwise, all tests other than “In process” shall be conducted in 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.

Use the temperature tolerances shown in Table 1 unless specified in the individual tests.

Table 1 — Test Temperature Tolerance

Test temperature (t) °C	Temperature tolerance °C
$t \leq 100$	±2
$100 < t \leq 200$	±3
$t > 200$	±4

Unintentional direct contact between different metals shall not occur with any of the test methods, in order to avoid electrochemical effects on the test results.

All tests shall be performed on the same manufactured batch of cable. If, for any reason, a different batch of cable is used for any of the tests, it should be noted accordingly on the test report and test summary.

Unless otherwise specified, each test is to be performed on at least 3 test specimens.

If suppliers and customers agree upon modifications or changes to the methods and requirements, it is required that all the changes and modifications be clearly documented.

4.2 Safety concerns

The precautions as described in the WARNING at the beginning of this document shall be followed.

4.3 Ovens

An oven as described in IEC 60216-4-1 and/or IEC 60216-4-2 Type 1 should be used. The air shall enter the oven in such a way that it flows over the surface of the test specimens and exits 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.

5 Test methods for single core cables

5.1 Dimensional tests

5.1.1 General

Measure with a device accurate to at least 0,01 mm. Other devices may be used. However, in case of dispute, the referee shall be an optical device.

In case of disputed results due to specimen deformation in preparation, a referee method is provided below.

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

5.1.2 Cable outside diameter

5.1.2.1 Purpose

This test is intended to verify that the cable outside diameter is within the required tolerances for intended functional applications.

5.1.2.2 Test specimen

Prepare one test specimen of 3 m in length.

5.1.2.3 Test

The cable outside diameter shall be measured at three separate cross-sections located 1 m apart from each other. A minimum of two readings shall be taken at each cross-section. The specimen should be rotated 90° between readings. The mean of the diameter readings shall determine the cable outside diameter and shall be in accordance with the dimensions tables in the cable documents in the ISO 19642 series for the various cable types. Additionally, no single value, minimum or maximum, may fall outside the range in the dimensions tables in the respective cable documents. For large cables (outside diameter greater than or equal to 18,0 mm), the test method described in IEC 60811-203:2012, 4.2 b, may be used for measuring the outside diameter.

5.1.3 Insulation thickness

5.1.3.1 Purpose

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

5.1.3.2 Test specimens

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

5.1.3.3 Test

Use a measuring device which shall not cause deformation.

Place the test specimen under the measuring equipment with the plane of the cut perpendicular to the optical axis. Determine the minimum insulation thickness in accordance with IEC 60811-201.

5.1.4 Conductor diameter

5.1.4.1 Purpose

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

5.1.4.2 Test specimens

Use the test specimens as specified in 5.1.3.

5.1.4.3 Test

Use a measuring device which shall not cause deformation.

Determine the conductor diameter by measuring the inside diameter of the test specimens and record the maximum inside diameter for each test specimen.

5.1.5 Cross-sectional area (CSA)

5.1.5.1 Purpose

This test is intended to verify that the cable conductor fulfils the specified requirements.

5.1.5.2 Test of cross-sectional area, *A*

In case of dispute, Method 2 (weight method) is the referee method to determine the cross-sectional area, *A*.

— **Method 1:** By using the obtained resistance value, R_{20}, according to 5.2.1, the CSA, *A*, is calculated using the following formula:

$$A = \frac{1\,000 \times (1 + f_b)}{\kappa \times R_{20}}$$

where

A is the cross-sectional area in mm²;

R_{20} is the conductor resistance at 20 °C in mΩ/m;

κ is the conductivity of the used conductor material in Sm/mm²:

for copper use a conductivity of 58,0 Sm/mm²;

for aluminium use a conductivity of 35,5 Sm/mm²;

for aluminium alloy use a conductivity of 33,5 Sm/mm²;

for other alloys with different conductivity, values can be used based on agreement between the customer and supplier;

f_b is bunching loss, depending on strand construction (see ISO 19642-1).

— **Method 2:** Carefully strip the insulation from 1 m ± 5 mm of the cable under test. The conductor is weighed with a scale capable of measurement to 0,5 % accuracy of the measured value. From the result, *A* is calculated using the following formula:

$$A = \frac{W}{\rho}$$

where

A is cross-sectional area in mm^2;

W is the conductor weight in g/m;

ρ is the density of the used conductor material in g/cm^3:
for copper use a density of 8,89 g/cm^3;
for aluminium use a density of 2,70 g/cm^3;
applicable densities shall be used for alloys.

5.1.6 In-process cable outside diameter

5.1.6.1 Purpose

This in-process monitoring is intended to verify that the cable outside diameter is within the required tolerances.

5.1.6.2 Test specimens

The test specimen is 100 % of the cable production; all cable produced is to be monitored.

5.1.6.3 Test

The measurement of diameter shall be performed in the most stable area of the extrusion process.

5.2 Electrical tests

5.2.1 Conductor resistance

5.2.1.1 Purpose

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

5.2.1.2 Test specimens

Prepare one test specimen of 2 m length, including the length necessary for connections.

5.2.1.3 Preparation of conductor ends

For copper and copper alloy conductors, the ends of the test specimen may be soldered.

For aluminium and aluminium alloy conductors, the oxide film on the aluminium surface shall be removed before carrying out the measurement following one of the two methods mentioned below.

In case of dispute, Method 1 is the reference method.

— **Method 1 for removal of oxide film on the aluminium surface by soldering**

Remove the insulation from the wire, apply a soldering fluid on the aluminium surface and dip the aluminium wire into the solder bath.

In case of doubt – for example, if the resistance requirements are not met – it is possible that the soldering fluid is not applicable. The following referee soldering fluid shall be used.

The referee soldering fluid consists of the following components:

— Diethanolamine: 45 % to 65 %;

— Fluoroboric acid: 11 % to 13 %;

— Diethylene triamine: 14 % to 17 %.

The solder bath consists of the following components:

— Tin: 80 % to 90 %;

— Zinc: 10 % to 20 %;

— Other metals: 1 %.

— **Method 2 for removal of oxide film on the aluminium surface by pickling**

Remove the insulation and immerse the aluminium conductor in a solution consisting of 3,5 % hydrochloric acid in water for 1 min. Remove the wire from the hydrochloric acid solution, rinse the immersed part with distilled water and dry. Perform the conductor measurement immediately after drying.

5.2.1.4 Test

The current needs to be supplied to the DUT with extra terminals situated outside of the voltage probes (4-wire measurement method). The thickness of the blades for the voltage measurement shall be smaller than 0,5 mm. The distance between the inner edges of the voltage probes shall be 1 000 mm ± 5 mm.

Use a resistance measuring device with an accuracy of ±0,1 % of the measured value and a thermometer with an accuracy of ±0,5 °C.

Measure the ambient room temperature at the time of test. Take care to ensure that connections are secure. Measure the resistance of the test specimen. Correct the measured value using the following formula:

$$R_{20} = \frac{R_T}{L_\mathrm{v}\left[1+\alpha_\rho\left(T-20\right)\right]}$$

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_v is the distance between the inner edges of the voltage probes, which shall be free from solder and is expressed in m;

T is the ambient room temperature at the time of measurement in °C;

α_ρ in 1/K, is the temperature coefficient for converting the measured resistance to the value at 20 °C.

The temperature coefficient for copper with 100 % conductivity at temperatures at 20 °C is $3{,}93 \times 10^{-3}$ 1/K.

For coated wires or alloys, the correction factor shall be established by agreement between the customer and supplier.

For soft aluminium the temperature coefficient is $4{,}03 \times 10^{-3}$ 1/K.

For other types of aluminium conductor, e.g. alloyed aluminium, CCA, etc, this may be different.

The applied temperature coefficient shall be measured according to 5.2.2 or agreed between customer and supplier and be reported.

5.2.2 Determination of temperature coefficients

5.2.2.1 Purpose

The resistance of a cable under test is determined while its temperature is increased from room temperature up to 50 °C. The resistance is calculated from a measurement of the potential difference across the cable and a measurement of the current passing through the cable. The current is supplied by a constant-current source (a d.c. power supply).

5.2.2.2 Test specimen

Prepare one test specimen according to Table 2, including the length necessary for connections.

Table 2 — Length of cable test specimen

ISO conductor size (a) mm²	Length m
$a < 2{,}5$	10
$2{,}5 \leq a < 10$	5
$a \geq 10$	2

5.2.2.3 Calibration graph

The cable under test is submitted to a temperature range from 20 °C up to 50 °C in a silicone oil bath. At least 80 % of the cable length is submersed in the oil. Alternatively, the test can be performed in a suitable heating chamber.

5.2.2.4 4-point measurement method

Apply a constant current according to Table 3. The current shall not cause warming of the conductor.

Table 3 — Maximum permissible current for resistance measurement

ISO conductor size (a) mm²	Maximum permissible current mA
$a < 0{,}35$	10
$0{,}35 \leq a < 6$	100
$a \geq 6$	1 000

The contact points for voltage measurement shall be below the oil surface in the oil bath to ensure that the part of cable between the voltage measurement points has a uniform temperature.

For the voltage measurement, a gauge with an input impedance greater than 1 MΩ shall be used.

The resistance of the cable is determined at each predefined temperature point by measurement of the current and voltage drop.

5.2.2.5 Procedure

The temperature of the oil bath shall be measured and controlled. The oil bath temperature measurement shall be more accurate than ±0,2 °C. The temperature of the oil bath shall be constant throughout the duration of the bath.

Starting at room temperature less than or equal to 25 °C, the oil is heated up to 30 °C and subsequently in steps of 10 °C up to 60 °C.

After each temperature step, wait until the change in oil temperature is less than ±0,2 °C and the change in the measured resistance value is lower than 0,04 % for 60 s.

Calculate the resistance at each temperature from the measured current, voltage and length between the voltage measurement terminals.

5.2.2.6 Analysis of test results, linear approximation

The determined resistance values, R' in Ω/m, compared to the temperature increase, ΔT (Oil bath temperature T_0 – 20 °C), represents the calibration graph, $R'(\Delta T)$.

The data pairs $R'(\Delta T)$ and ΔT from 30 °C up to and including 60 °C are fitted by linear interpolation to determine the parameters a and b in the following formula:

$$R'\left(\Delta T\right) = a \times \Delta T + b$$

where

$R'(\Delta T)$ is the determined resistance at the increased temperature ΔT;

ΔT is the increased temperature.

For calculation of the resistance temperature coefficient, α_ρ, this formula can be expressed as:

$$R'\left(\Delta T\right) = \alpha_\rho \times R'_{20} \times \Delta T + R'_{20}$$

where

R'_{20} is the electrical resistance per unit length at 20 °C in Ω/m;

α_ρ is the linear temperature coefficient of material specific resistivity in 1/K.

The constants R'_{20} and α_ρ are calculated using the following formulae:

$$R'_{20} = b$$

$$\alpha_\rho = \frac{a}{b}$$

5.2.3 Withstand voltage

5.2.3.1 Purpose

This test is intended to verify that the cable insulation is capable of withstanding the required rated voltage.

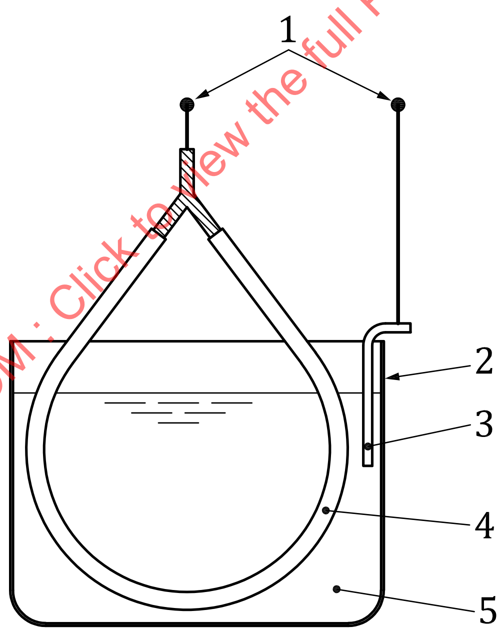
5.2.3.2 Test specimen

Prepare one test specimen of a minimum length of 350 mm. Strip 25 mm of insulation from each end and twist the ends together to form a loop.

5.2.3.3 Test

Partially fill an electrically non-conductive vessel with water salted with 3 % by weight of NaCl with the ends of the test specimen emerging above the bath as shown in Figure 1. Use a 50 Hz or 60 Hz a.c. voltage source.

Immerse the test specimen 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 the conductor and the bath. Increase the voltage at a rate of 500 V/s until the specified value in the relevant part of the ISO 19642 series is reached, then hold this value for the time specified in the relevant part of the ISO 19642 series. Breakthrough shall not occur. Document “pass” or “fail” in the test report.



Key

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

Figure 1 — Test apparatus for withstand voltage

5.2.4 Withstand voltage after environmental testing

5.2.4.1 Purpose

This test is intended to detect defects caused by mechanical, chemical and/or other environmental stress.

5.2.4.2 Test

The withstand voltage test described in 5.2.3 applies with the following changes to the procedure:

— Immerse the test specimens in the salt water bath for a minimum of 10 min prior to the application of the voltage.

— Apply the specified voltage in the relevant part of the ISO 19642 series.

5.2.5 Insulation faults

5.2.5.1 Purpose

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

5.2.5.2 Test specimen

The test specimen is 100 % of the cable production; all cable produced is to be monitored.

5.2.5.3 Test

Use a sinusoidal voltage source set at the specified value in the relevant part of the ISO 19642 series. The test electrode can 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 9 voltage cycles.

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.

5.2.6 Insulation volume resistivity

5.2.6.1 Purpose

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

5.2.6.2 Test specimen

Prepare one test specimen of 5 m length and remove 25 mm of insulation from each end.

In case of dispute, the test specimen preparation of aluminium conductor cables shall be carried out according to the method specified in 5.2.1.

5.2.6.3 Test

Partially fill an electrically non-conductive vessel with tap water at 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; however, if a dispute arises, the referee apparatus shall be a resistance measuring device with a d.c. voltage of 500 V.

Immerse the test specimen for 2 h with each end emerging from the bath by 250 mm. Apply the d.c. voltage between the conductor and the bath. Measure the insulation resistance 1 min after application of the voltage.

Calculate the insulation volume resistivity using the following formula:

$$\rho_0 = 2{,}725 \times \frac{L_\mathrm{i} \times R}{\lg\left(\frac{D}{d}\right)}$$

where

ρ_0 is the insulation volume resistivity, expressed in Ω·mm;

L_i is the immersed length of the test specimen in mm;

R is the measured insulation resistance in Ω;

D is the mean of the maximum cable outside diameter measurements in mm according to 5.1.2;

d is the average conductor diameter in mm according to 5.1.4.

5.3 Mechanical tests

5.3.1 Strip force

5.3.1.1 General

This test is applicable to cables with a conductor size smaller than or equal to 6 mm^2.

5.3.1.2 Purpose

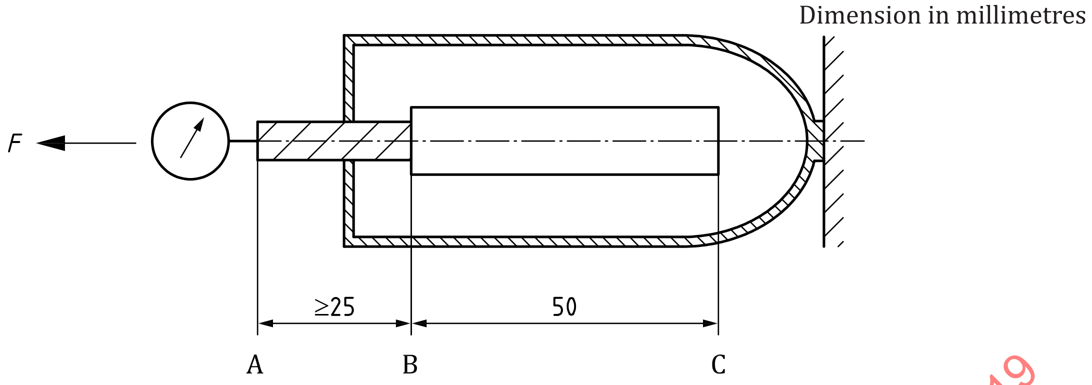
This test is intended to verify that the force required to remove the insulation from the conductor meets customer requirements.

5.3.1.3 Test specimens

Prepare three test specimens of 100 mm from a cable test specimen 3 m in length. Take the test specimens at 1 m intervals. Cut at least 25 mm of insulation cleanly and strip it carefully from one end of the conductor (see Figure 2, length AB). Then, cut the test specimens leaving a (50 ± 1) mm section BC undisturbed. A different length for the section BC may be agreed between customer and supplier.

5.3.1.4 Test

Use a test fixture similar to the one shown in Figure 2. A metal plate is provided with a round hole suitable for the conductor diameter. Use a tensile machine with a speed of 250 mm/min. Ensure that the apparatus is capable of pulling the test specimens without friction between the conductor and the apparatus.



Key

F force

AB insulation removed

BC insulation undisturbed

Figure 2 — Test apparatus for strip force

Place a test specimen in the test fixture. Pull the test specimen without friction between the conductor and the apparatus at a speed of 250 mm/min and record the force, *F*, in newtons (N). Repeat the procedure for the other test specimens. If the 50 mm section of insulation BC buckles when sliding, prepare new test specimens with the length BC equal to 25 mm and repeat this procedure.

5.3.2 Abrasion

5.3.2.1 General

This test is applicable to cables with a conductor size smaller than or equal to 6 mm^2. The tests described in 5.3.2.4 or 5.3.2.5 shall be used. The customer and supplier shall define which test shall be used.

5.3.2.2 Purpose

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

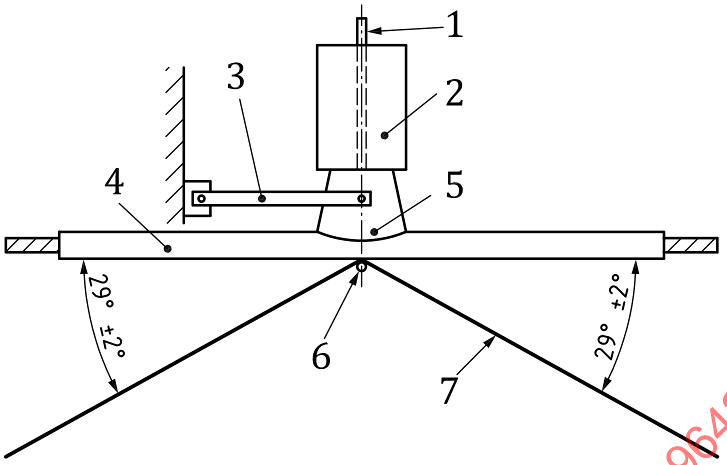
5.3.2.3 Test specimen

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

5.3.2.4 Sandpaper abrasion test

Measure the resistance to sandpaper abrasion using 180J Al_2O_3 (Aluminium oxide) 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 3) to maintain the test specimen position over an unused portion of the sandpaper abrasion tape. Exert a force of (0,63 ± 0,05) N on the test specimen by the combination of the bracket, support rod and pivoting arm. The total vertical force exerted on the test specimen 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 the definition in the relevant part of the ISO 19642 series.

Mount the test specimen, without stretching, in a horizontal position using an area of the sandpaper abrasion tape not previously used, immediately after a conductive stripe. Place the additional mass and bracket on top of the test specimen. Draw the sandpaper abrasion tape under the test specimen at a rate of (1 500 ± 75) mm/min and record the length of sandpaper abrasion tape necessary to expose the conductor. Move the test specimen 50 mm and rotate the test specimen 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 specimen
5 bracket
6 tape supporting pin, diameter = 6,9 mm
7 180J Al_2O_3 sandpaper abrasion tape

Figure 3 — Test apparatus for sandpaper abrasion

5.3.2.5 Scrape abrasion test

Use a resistance to scrape abrasion apparatus according to Figure 4. It consists of a device designed to abrade the surface of the insulation in both directions along the longitudinal axis of the test specimen 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 stops operating.

The characteristics of a suitable apparatus shall be as follows:

— Diameter of needle: (0,45 ± 0,01) mm.

— Type of needle: spring wire (polished) material according to ISO 6931-1.

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

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

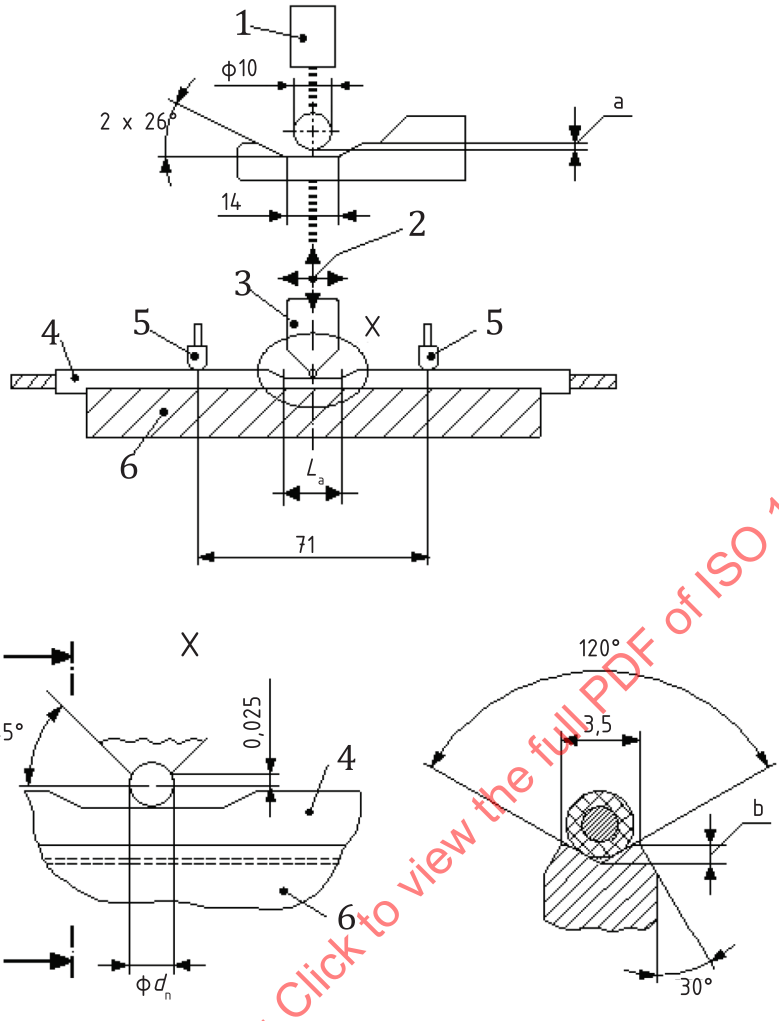
— Length of abrasion: (15,5 ± 1) mm.

— Mass: the vertical force on the test specimen shall be constant under dynamic conditions.

— The test specimen shall not move during test.

Apply the total vertical force as specified in the relevant part of the ISO 19642 series to the test specimen. Determine the number of cycles by taking four measurements at a temperature of (23 ± 1) °C. After each reading, move the test specimen 100 mm and rotate it 90° clockwise. Change the needle after each reading. The minimum value shall be noted.

Dimensions in millimetres



Key

1	mass	L_a	abrasion length: (15,5 ± 1) mm
2	travel	d_n	needle diameter: (0,45 ± 0,01) mm
3	needle holder	a	Clearance during abrasion.
4	test specimen	b	Groove depth
5	clamp		0,4 mm, Conductor size ≤ 0,35 mm^2
6	test specimen holder		0,8 mm, Conductor size > 0,35 mm^2.

Figure 4 — Test apparatus for scrape abrasion

5.3.3 Breaking force of the finished cable

5.3.3.1 Purpose

This test is intended to verify that the tensile force required to break the cable meets customer requirements.

5.3.3.2 Test specimens

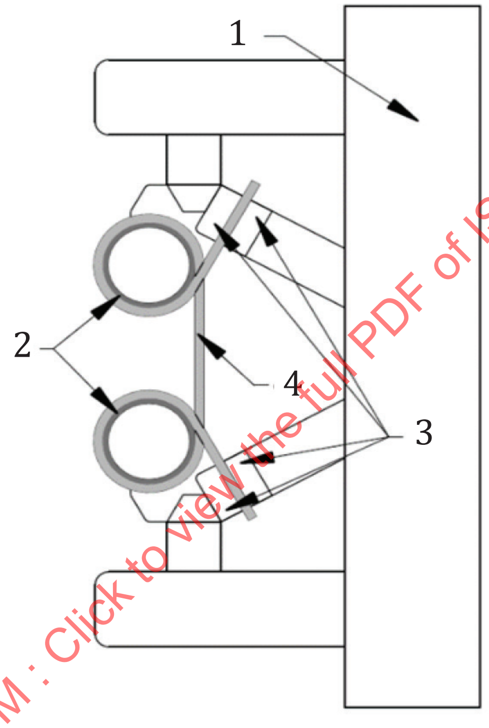
This test is applicable for wires smaller than or equal to 6 mm^2.

Prepare three test specimens of adequate length to extend from the clamping jaws, create two loops around the two, load reduction stationary pulleys and allow for minimum 50 mm of cable in the centre test section.

5.3.3.3 Test

Use a test fixture similar to the one shown in Figure 5. Use a tensile machine with a speed of 50 mm/min. Ensure that the apparatus is capable of pulling the test specimens.

Place a test specimen in the test fixture. Pull the test specimen at a speed of minimum 50 mm/min and record the maximum force, F_{max}, in newtons, upon cable separation. Repeat the procedure for the other test specimens.



Key

1 tensile test rig

2 load reduction stationary pulleys (fixed cylindrical mandrels)

3 cable clamps

4 specimen under test

Figure 5 — Test apparatus for breaking force

5.3.4 Cyclic bending

5.3.4.1 Purpose

Cyclic bending test is performed to determine the number of bending cycles until the conductor breaks (fatigue resistance) in this defined dynamic condition.

5.3.4.2 Test specimens

Take two test specimens of 600 mm in length from points separated by at least 1 m.

5.3.4.3 Test

The apparatus shall be similar to the one shown in Figure 6. Any apparatus is acceptable as long as it meets the following conditions:

— A fixture that bends the test specimen (1) by ±90° at a rate of 15 cycles/min around a pivot (2).

— Two mandrels shall be placed symmetrically to the centre line which passes through the pivot. The radius of the mandrels shall be r = 2,5 D (0 %/−20 %), where D is the maximum cable outside diameter.

— The gap, D_g, between both mandrels shall be adjusted to: D_g = (1,5 × D) ± 0,5 mm, where D is the maximum cable outside diameter.

— One end of the test specimen is attached to the flexing fixture at position (5). Its other end is looped and fixed at position (6) by suitable means (e.g. cable strap). The distance between (5) and (6) on the cable shall be (250 ± 25) mm.

— A mass (3), m, which depends on the total cross-section of the conductors and the screen (if any) is attached to the cable loop (not to the conductors) as shown. It is given by m = 1,0 kg/mm^2 × total cross-section in mm^2. Though, it shall not be less than 0,25 kg and not exceed 12 kg.

— A guide (4) of appropriate size is placed at the indicated position, (100 ± 5) mm below the pivot, to prevent the mass from swinging.

— Interruption of electrical conduction shall be detected by an appropriated method.

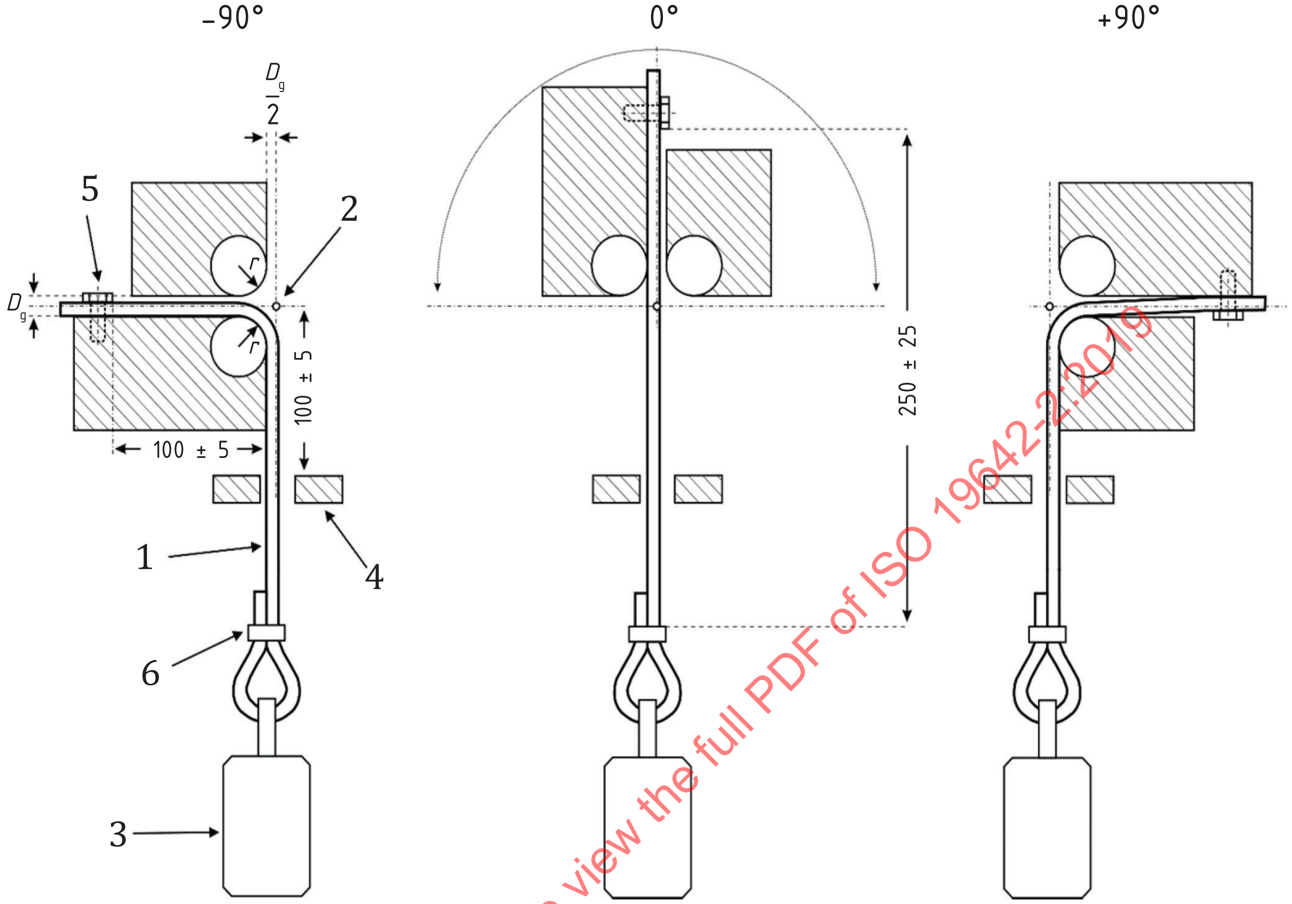
Test is performed at room temperature.

Only for cables with cross-sectional area (conductor) smaller than 25 mm^2.

The number of cycles at which the interruption of the electrical conduction occurs is recorded.

Repeat the procedure for the other test specimen.

Dimensions in millimetres



Key

1	cable	5	fixture at flex member
2	pivot	6	fixture to form the cable loop
3	mass *m*	*r*	radius of the mandrels
4	guide	D_g	gap between both mandrels

Figure 6 — Test apparatus for cyclic bending shown at flex positions −90°, 0° and +90°

5.3.5 Flexibility

5.3.5.1 General

Build information for this apparatus is found in Annex B.

5.3.5.2 Purpose

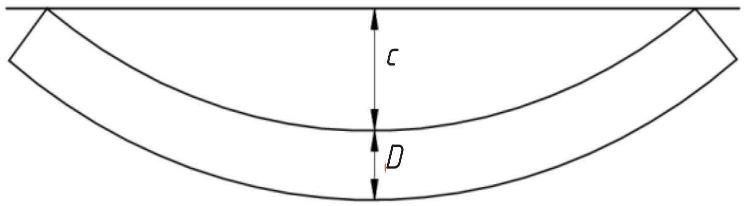
This test is intended to measure and quantify cable flexibility.

5.3.5.3 Test specimen

Cut five test specimens to a length as specified in Table 4.

Avoid additional mechanical stress as far as possible.

If any curvature is noticed, record the curvature *c* shown in Figure 7, then place the specimen in the fixture with the direction of the ends of the cable upwards.



Key

c curvature

D maximum cable outside diameter

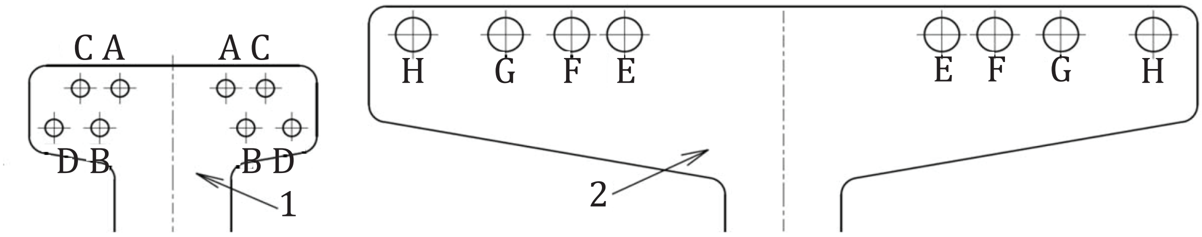
Figure 7 — Measurement of curvature

5.3.5.4 Test

For multi-core cable, measure the maximum cable outside diameter as specified in 5.1.2. For single core cable, select pin position according to specified maximum cable outside diameter for the thick wall cable ISO conductor size under test. Refer to Table 4 and Figure 8 for the pin testing positions. Align the two lower pulleys according to Table 4 and lower the top third pulley to rest on top of the cable. If any curvature is noticed, place the specimen in the fixture with the direction of the ends of the cable upwards. Use a test fixture similar to the one shown in Annex B. Use a tensile machine with a speed of 100 mm/min and run the test until maximum force is achieved. Record the highest value of force, F_{max}, in newtons and report the average of all five test specimens.

Table 4 — Test parameters for flexibility test apparatus

Parameter	Dimensions in millimetres							
Maximum cable outside diameter (*D*)	$D \leq 4{,}0$	$4{,}0 < D \leq 5{,}5$	$5{,}5 < D \leq 7{,}0$	$7{,}0 < D \leq 9{,}0$	$9{,}0 < D \leq 12$	$12 < D \leq 16$	$16 < D \leq 21$	$21 < D \leq 28$
Pin spread	36,4	50,2	63,7	81,9	109,2	145,6	191,1	254,8
Inner pulley diameter	10,2	13,5	16,9	21,9	29,6	38,8	51,7	68,6
Outside pulley diameter	14,0	19,3	24,5	31,5	42,0	56,0	73,5	98,0
Pulley groove radius	2,0	3,0	4,0	5,0	6,5	9,0	11,5	15,5
Pulley groove depth	1,9	2,9	3,8	4,8	6,2	8,6	10,9	14,7
Length of specimen	55	75	95	125	165	220	285	380
Position (see Figure 8)	A	B	C	D	E	F	G	H



Key

1 small holder

2 big holder

A - H pin testing positions

Figure 8 — Test apparatus for flexibility — Pin testing positions

5.4 Environmental tests

5.4.1 Test specimen preparation and winding tests

5.4.1.1 Purpose

This subclause describes the mandrel sizes used for preparation of test specimens in different subsequent environmental tests.

It also describes the winding tests used to detect defects caused by environmental stresses.

5.4.1.2 Test specimens

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

5.4.1.3 Test

Winding tests after environmental stresses are performed with different mandrel diameters and at different test temperatures.

For winding tests at low temperatures, the test specimens and the mandrel shall be conditioned for a minimum of 4 h in the precooled freezing chamber at the designated temperature in Table 6, before the winding test is performed.

If, according to Table 6, a test at RT needs to be performed, keep the test specimens at RT for at least 4 h before the winding test is performed. Use of a freezing chamber is not mandatory in these cases.

Either a rotatable or a stationary mandrel may be used. See Table 5 for the mandrel diameter, winding speed and the number of turns. When a rotatable mandrel is used, it shall be in accordance to Figure 9. See Table 5 for the applied mass.

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

5.4.1.4 Rotatable mandrel

When a rotatable mandrel is used, the test specimens shall be fixed on the mandrel as shown in Figure 9. The free ends are loaded with the mass. Position the mandrel with the test specimens hanging vertically.

5.4.1.5 Stationary mandrel

When a stationary mandrel is used, a test specimen shall be wrapped around the mandrel by hand. Repeat the procedure for the other test specimen.

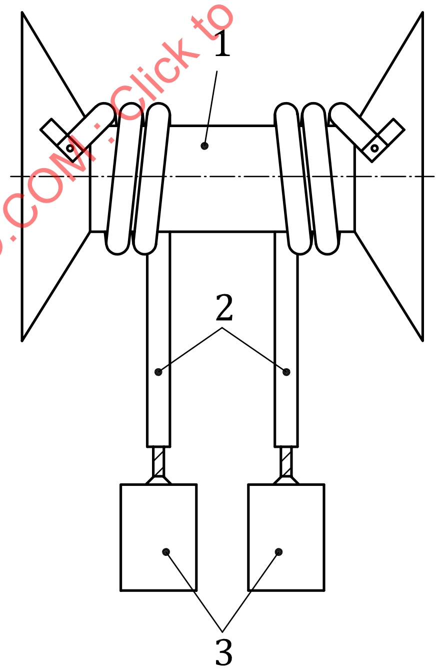
Wind the test specimen for at least the minimum number of turns around the mandrel within the freezing chamber and at winding speed as specified in Table 5. Ensure that there is continuous contact between the test specimens and the mandrel.

After the cold winding, allow the test specimens to return to RT, and make a visual examination of the insulation.

If no exposed conductor is visible, perform the withstand voltage after environmental testing according to 5.2.4.

Table 5 — Winding single core cables

ISO conductor size (a) mm²	**Mandrel diameter** mm		**Mass** kg	**Winding speed** s^{-1}	**Minimum number of turns**
	A	B			
$a \le 0,75$	≤5 × D where D = maximum cable outside diameter	≤1,5 × D where D = maximum cable outside diameter	0,5	1	3
$0,75 < a \le 1,5$			2,5		
$1,5 < a \le 6$			5		2
$6 < a \le 10$			8	0,5	0,5
$10 < a \le 25$			10		
$25 < a \le 35$			20		
$35 < a$			30	0,2	



Key

1 mandrel

2 test specimen(s)

3 mass(es)

Figure 9 — Test apparatus for winding

Table 6 — Mandrel sizes and test temperatures after environmental tests

Test number	Title	Winding temperature	Column in Table 5
5.4.2	Long term heat ageing, 3 000 h at temperature class rating	RT	B
5.4.3	Short term heat ageing, 240 h at temperature class rating +25 °C	(−25 ± 2) °C	A
5.4.4	Thermal overload, 6 h at temperature class rating +50 °C	RT	B
5.4.7	Low-temperature winding	(−40 ± 2) °C	A
5.4.9	Temperature and humidity cycling	Test preparation[a]	B
5.4.10	Resistance to hot water	Test preparation[a]	A
5.4.11	Resistance to liquid chemicals	RT	A
5.4.13	Stress cracking resistance	RT	B
5.4.14	Resistance to ozone	Test preparation[a]	A

[a] No winding test performed, mandrel is only used for test specimen preparation before test.

5.4.2 Long term heat ageing, 3 000 h at temperature class rating

5.4.2.1 Purpose

This test is intended to verify the upper value of the temperature class rating as specified in the relevant part of the ISO 19642 series.

5.4.2.2 Test specimens

Prepare two test specimens, each of a minimum length of 350 mm, and remove 25 mm of insulation from each end, a specimen of at least 600 mm may be needed for the winding tests after heat aging.

5.4.2.3 Apparatus

Use an oven at the upper value of the temperature class rating T, specified in the relevant part of the ISO 19642 series.

5.4.2.4 Test

Place the test specimens in the oven for 3 000 h. Fix the test specimens by the conductor to avoid any contact between the insulation and the supports. The test specimens 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 specimens from the oven and maintain them at RT continuously for at least 16 h.

Perform the winding test according to 5.4.1 using a mandrel size of Column B according to Table 5 at RT.

5.4.3 Short term heat ageing, 240 h at temperature class rating +25 °C

5.4.3.1 Purpose

This test is intended to simulate thermal excursions.

5.4.3.2 Test specimens

Prepare two test specimens, each of a minimum length of 350 mm, and remove 25 mm of insulation from each end, a specimen of at least 600 mm may be needed for the winding tests after heat aging.

5.4.3.3 Apparatus

Use an oven at the upper value of the temperature class rating T, specified in the relevant part of the ISO 19642 series, +25 °C.

5.4.3.4 Test

Place the test specimens in the oven for 240 h. Fix the test specimens by the conductor to avoid any contact between the insulation and the supports. The test specimens 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 specimens from the oven and maintain them at RT continuously for at least 16 h.

Perform the winding test according to 5.4.1 using a mandrel size of Column A according to Table 5 at (−25 ± 2) °C.

5.4.4 Thermal overload, 6 h at temperature class rating +50 °C

5.4.4.1 Purpose

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

5.4.4.2 Test specimens

Prepare two test specimens, each of a minimum length of 350 mm, and remove 25 mm of insulation from each end, a specimen of at least 600 mm may be needed for the winding tests after heat aging.

5.4.4.3 Apparatus

Use an oven at the upper value of the temperature class rating T, specified in the relevant part of the ISO 19642 series, +50 °C.

5.4.4.4 Test

Place the test specimens in the oven for 6 h. Fix the test specimens by the conductor to avoid any contact between the insulation and the supports. The test specimens 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 specimens from the oven and maintain them at RT continuously for at least 16 h.

Perform the winding test according to 5.4.1 using a mandrel size of Column B according to Table 5 at RT.

5.4.5 Pressure test at high temperature

5.4.5.1 Purpose

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

5.4.5.2 Test specimens

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

5.4.5.3 Test

Test the specimen at the upper value of the temperature class rating T specified in the relevant part of the ISO 19642 series. The test apparatus is shown in Figure 10. Ensure that the apparatus is free from vibrations. Apply the force, *F*, by the blade to the test specimen as given by the following formula:

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

where

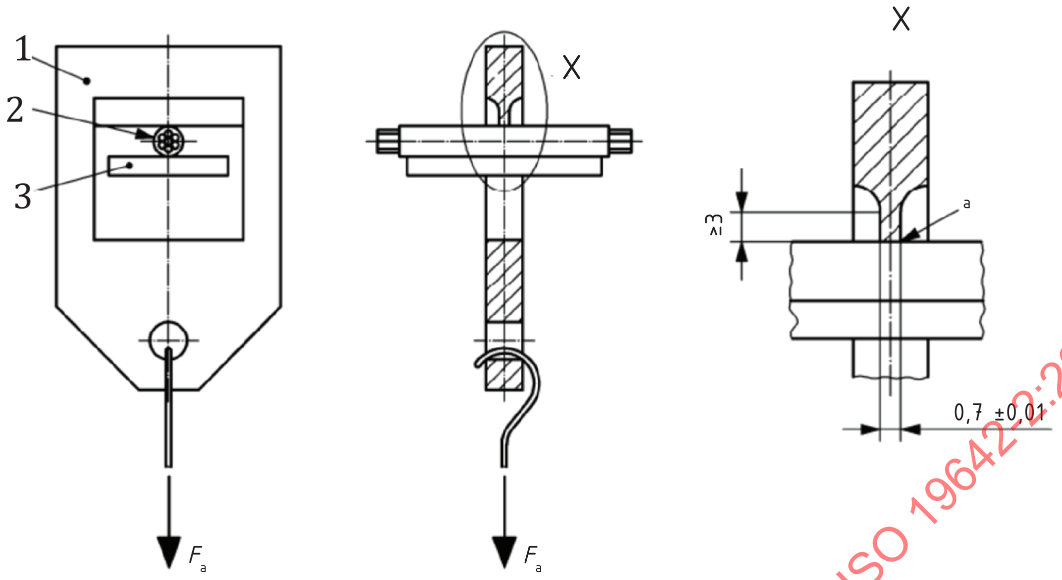
- F is the total force exerted on the test specimen in N;
- D is the appropriate maximum cable outside diameter in mm as specified in the relevant part of the ISO 19642 series;
- i is the appropriate nominal value of the insulation thickness in mm as specified in the relevant part of the ISO 19642 series;
- 0,8 is a coefficient in N/mm.

The applied force shall be within a tolerance of ±3 % to the calculated value *F*.

Place a test specimen in the apparatus as shown in Figure 10. Attach the test specimen 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 specimen axis applied in the middle of the test specimen. Place the test specimen under load, not preheated, for 4 h in the oven. Then cool the test specimen within 10 s by immersion in cold water. Repeat the procedure for the other test specimens.

After immersion, perform the withstand voltage after environmental testing according to 5.2.4.

Dimensions in millimetres



Key

1 test frame
2 test specimen
3 support
F_a applied force
a Sharp edge with a maximum radius of 0,05 mm.

Figure 10 — Test apparatus for pressure test at high temperature

5.4.6 Shrinkage by heat

5.4.6.1 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.

5.4.6.2 Test specimens

Prepare three test specimens, each of 100 mm in length.

5.4.6.3 Test

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

Measure the exact length of the insulation of the test specimens at RT prior to the test. Put the test specimens 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.

5.4.7 Low temperature winding

5.4.7.1 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 as specified in the relevant part of the ISO 19642 series.

5.4.7.2 Test specimens

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

5.4.7.3 Test

Perform the winding test according to 5.4.1 using a mandrel size of Column A according to Table 5 at (−40 ± 2) °C.

5.4.8 Cold impact

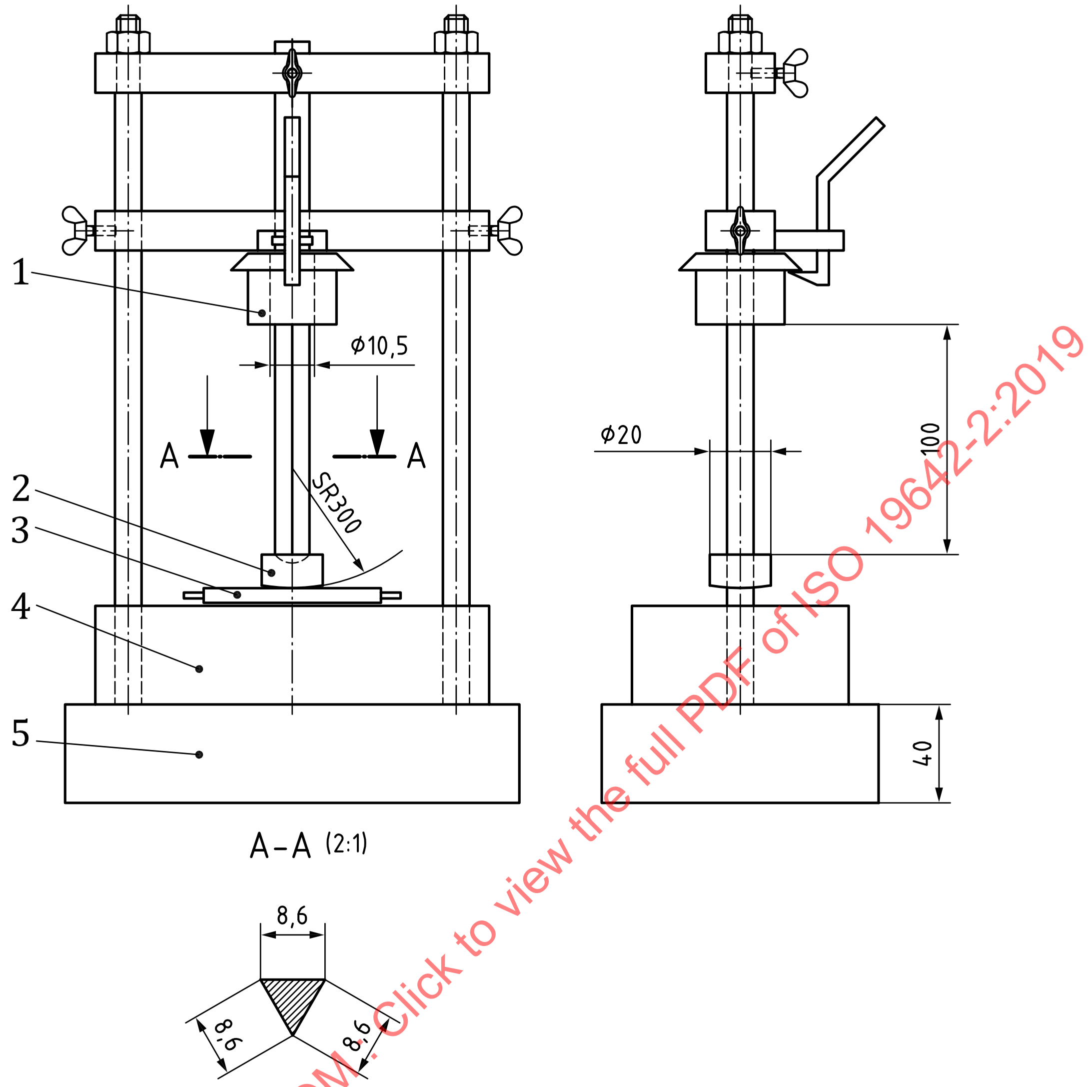
5.4.8.1 Purpose

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

5.4.8.2 Test specimens

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

Dimensions in millimetres



Key

1 hammer

2 steel intermediate piece, 100 g

3 test specimen

4 steel base, mass 10 kg

5 foam rubber pad

Figure 11 — Test apparatus for cold impact

5.4.8.3 Test

The apparatus shown in Figure 11 is positioned on a foam rubber pad of 40 mm thickness. The mass of the hammer is specified in the relevant part of the ISO 19642 series. Set the freezing chamber temperature to (−15 ± 2) °C. Shown in Figure 11 is an example of a single specimen test apparatus.

Perform the impact test in the middle of the test specimen. Place the apparatus, positioned on the foam rubber pad, together with the test specimens 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 specimens have reached the specified temperature. At the end of this period, place a test specimen parallel to the steel base.

The hammer is then allowed to fall from a height of 100 mm. After the impact, allow the test specimens to return to RT and make a visual examination of the insulation. If no exposed conductor is visible, perform the withstand voltage after environmental testing according to 5.2.4.

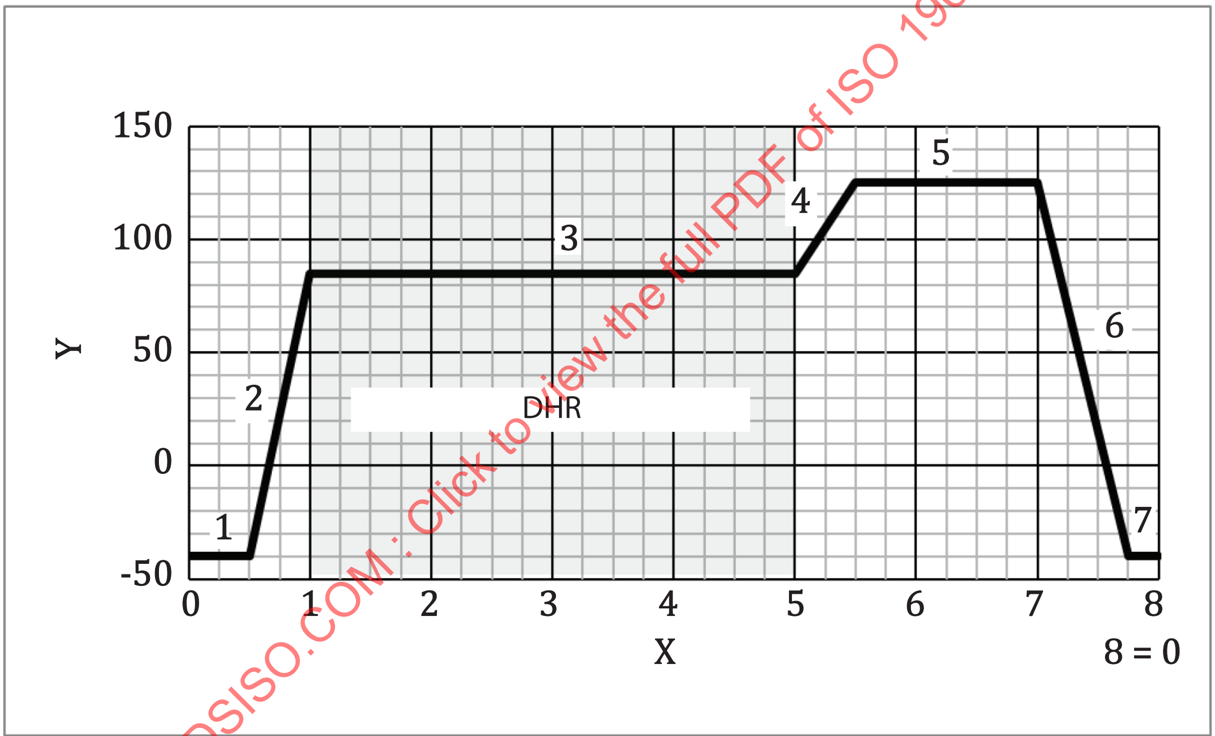
5.4.9 Temperature and humidity cycling

5.4.9.1 Purpose

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

5.4.9.2 Test specimens

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



Key

X time (h)

Y temperature (°C)

DHR defined humidity region

NOTE 1 Explanations for regions 1 to 7 are given in Table 7.

NOTE 2 Regions 4, 5 and 6 are variables based on temperature class rating.

Figure 12 — Procedure for temperature and humidity cycling

Table 7 — Explanations for regions 1 to 7 in Figure 12

Region	Stable/transition to	Value °C	Duration h		Humidity % RH
1	stable	−40	minimum	0,5	uncontrolled
2	transition to	85	maximum	0,5	uncontrolled
3	stable	85	minimum	4,0	90 ± 10
4	transition to	T[a]	maximum	0,5	uncontrolled
5	stable	T[a]	minimum	1,5	uncontrolled
6	transition to	−40	maximum	0,75	uncontrolled
7	stable	−40	minimum	0,25	uncontrolled

[a] T = Upper Value of Temperature Class Rating. For a test temperature higher than 175 °C, the test temperature is limited to 175 °C due to test equipment limitations.

5.4.9.3 Test

Perform the test in a temperature chamber which is capable of cycling between −40 °C and the test temperature as specified in Figure 12. The chamber shall also be capable of controlling the relative humidity between 80 % and 100 %. See Table 5, Column B, for the mandrel diameter.

Wind at least the minimum number of turns as specified in Table 5 around the mandrel and secure the ends.

Condition the test specimens according to the temperature and relative humidity as shown in Figure 12. The cycle begins and ends with the chamber at −40 °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 specimen 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 specimen. 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 after environmental testing according to 5.2.4.

5.4.10 Resistance to hot water

5.4.10.1 Purpose

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

5.4.10.2 Test specimens

Prepare two test specimens, each of (2,5 ± 0,1) m in length and remove 25 mm of insulation from each end.

In case of dispute, the test specimen preparation for aluminium conductor cables shall be carried out according to the method specified in 5.2.1.

5.4.10.3 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 ± 5) °C for each test, a 48 V d.c. power source, a copper electrode with a submerged electrode surface of (10 000 ± 1 000) mm^2 and a resistance measuring device as specified in 5.2.6. See Table 5, Column A, for mandrel diameter. The test vessel with the cable test specimens shall be heated evenly by means of an external temperature bath. Take care that the test specimen does not touch the electrode in the test vessel. The volume of the water in the vessel shall be between 2 l and 5 l (1 l = 10^6 mm^3) and shall be reported in the test report. For larger CSAs (≥10 mm^2), larger water volumes may be used but need to be reported in the test report.

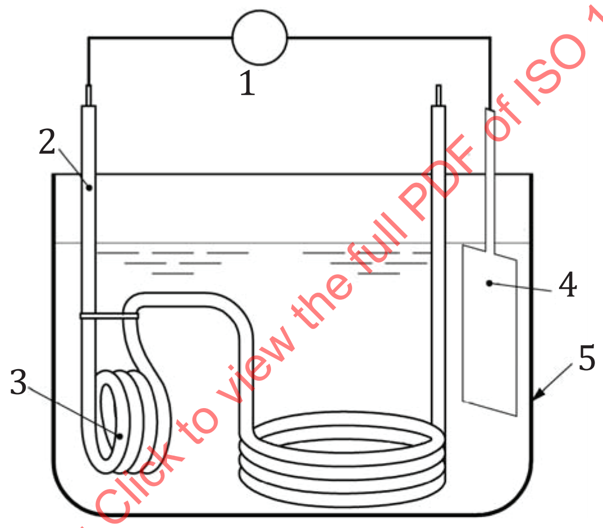
Closely wind at least three complete turns of a test specimen on the mandrel and secure the wraps as shown in Figure 13. After removing the mandrel, immerse the test specimen in the bath with both ends projecting 250 mm above the bath. To avoid interaction between materials, do not test specimens with different insulating materials in the same bath. Connect one end of the test specimen to the positive electrode of the power source. After 7 days, disconnect the power supply and measure the insulation volume resistivity according to 5.2.6. Make the following changes to the procedure in 5.2.6:

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

This completes one cycle. Repeat this procedure for a total of 5 cycles, i.e. 35 days.

Remove the test specimen from the bath, allow the specimen to cool in air at RT for 16 h, 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 after environmental testing according to 5.2.4.

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



Key

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

Figure 13 — Test apparatus for resistance to hot water

5.4.11 Resistance to liquid chemicals

5.4.11.1 General

When any resistance to chemicals is specified, compliance for a cable family may be demonstrated by testing representative conductor sizes as specified in the relevant part of the ISO 19642 series.

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 the customer and supplier.

The terms “chemicals” and “fluids” may be used interchangeably throughout 5.4.11.

5.4.11.2 Purpose

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

5.4.11.3 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 8 shall be tested:

— Media Group 1 with a heat ageing period of 1 000 h at the upper value of the temperature class rating; and

— Media Group 2 with a heat ageing period of 240 h at the upper value of the temperature class rating.

Table 8 — Resistance to liquid chemicals

Media		Specification	Test specimen pieces	Storage time in oven at
Group	**Fluid**			
1	Engine coolant	50 % ethylene glycol + 50 % distilled water	8	240 h + 240 h + 240 h + 280 h
	Engine oil	Oil No. 2 ,as defined in ISO 1817:2015, A.2,	8	
	Salt water	5 % NaCl, 95 % water (mass %)	8	
	Windscreen washer fluid	50 % Iso-propanol, 50 % water	8	
2	Gasoline	Liquid C, as defined in ISO 1817	2	240 h
	Diesel	90 % Oil No. 3, as defined in ISO 1817 + 10 % p-xylene	2	
	Ethanol	85 % Ethanol + 15 % liquid C, as defined in ISO 1817	2	
	Power steering fluid	Oil No. 3, as defined in ISO 1817,	2	
	Auto. Transmission fluid	Dexron VI	2	
	Brake fluid	As defined in ISO 4926 or SAE RM-66-06	2	
	Battery acid	25 % H_2SO_4 with a specific gravity of (1,260 ± 0,005) at 20 °C and 75 % H_2O	2	

NOTE 1 Solutions are determined as % by volume if not otherwise specified.

NOTE 2 Examples of sources for reference materials are shown in Annex A, Table A.1.

5.4.11.4 Test specimens

Prepare individual test specimens, 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 specimens to be hung on to the grids in the oven. The number of test specimens to be prepared for each chemical shall be according to Table 8.

5.4.11.5 Apparatus

Use an oven at the upper value of the temperature class rating T specified in the relevant part of the ISO 19642 series.

The oven shall be equipped with grids, making it possible to hang the test specimens on them. A collecting tray shall be placed in the bottom of the oven to gather chemical spills.

5.4.11.6 Test performance

For each fluid to be tested, immerse 400 mm of the length of the test specimens for 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 specimens from one and the same type of tested cable, but exposed to the different test fluids, can be stored in the same oven. Test specimens from different types of cables are not allowed to be stored in the same oven.

For Media Group 1 test specimens, 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 eight test specimens for each fluid and store in the oven. At 240 h, take out two test specimens and pass them on to final test as follows. The remaining six test specimens should be re-immersed and stored in the oven for another 240 h exposure. At 480 h, take out another two test specimens for final test and re-immerse the remaining four test specimens. At 720 h, again take out two test specimens for final testing and re-immerse the remaining two test specimens for storing up to 1 000 h.

Media Group 2 test specimens should only be immersed once before the exposure at the upper value of the temperature class rating.

After fulfilled exposure, remove the test specimens from the oven and maintain them at RT for 30 min. Afterwards, perform the winding test according to 5.4.1 at RT. See Table 5, Column A for the mandrel diameter. Make sure that the winding test is performed in the middle of the test specimens. After winding, make a visual examination of the insulation.

If no exposed conductor is visible, perform the withstand voltage after environmental testing according to 5.2.4.

5.4.12 Durability of cable marking

5.4.12.1 Purpose

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

5.4.12.2 Test specimens

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

5.4.12.3 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 Oil No. 2 as defined in ISO 1817, at (50 ± 3) °C.

5.4.12.4 Test

Immerse a test specimen for 20 h with the test specimen ends emerging 50 mm above the surface of the liquid.

Remove the test specimen from the oil and allow it to drain at RT for 30 min. Position the test specimen 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 specimen from between the felt. Repeat the procedure for the other test specimens. Visually examine the test specimens after the test.

5.4.13 Stress cracking resistance

5.4.13.1 General

This test shall be performed for cables with insulation materials that are prone to environmental stress cracking problems.

5.4.13.2 Purpose

This test is intended to verify if the cable insulation is resistant to stress cracking resulting from the combined effect of mechanical and thermal stress.

5.4.13.3 Test specimen preparation

Two test specimens with a length of about 2 m each are cut from the test specimen. The location of the two test specimens should be separated at least by 1 m. An appropriate length of insulation is stripped off on both sides of the two test specimens.

5.4.13.4 First temperature exposure

The test specimens are formed into a circular bunch with a diameter of approximately 200 mm and put into an oven at the upper value of the temperature class rating +25 °C for 3 h.

5.4.13.5 Cooling down and wrapping

Afterwards the test specimens are removed from the oven and cooled down to RT for a time period of at least 16 h. Then, the test specimens are wrapped on a mandrel with a diameter according to Column B of Table 5 in a closed helix of at least 6 turns and are fixed by the stripped of ends according to Figure 14. The lengths shall be L_1 > 60 mm and L_2 > 10 mm.

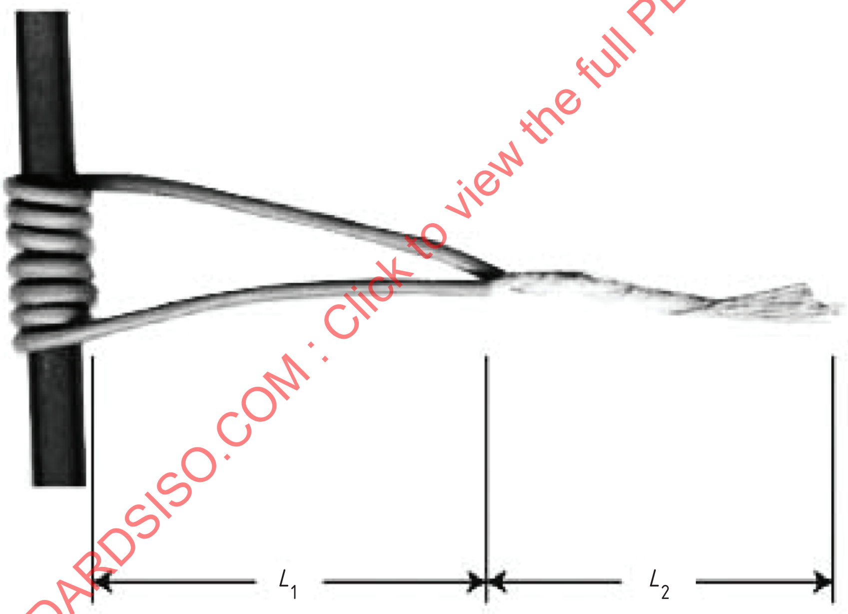


Figure 14 — Test specimen preparation for stress cracking

5.4.13.6 Second temperature exposure

The coiled test specimens together with the mandrel are put into the oven again at the above specified temperature for 3 h.

5.4.13.7 Cooling down and removing of mandrel

Then, the test specimens are removed from the oven and cooled down to RT for a time period of at least 16 h. The mandrel is removed without uncoiling.

If no exposed conductor is visible, perform the withstand voltage after environmental testing according to 5.2.4.

5.4.14 Resistance to ozone

5.4.14.1 Purpose

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

5.4.14.2 Test specimens

Prepare 3 test specimens, each of 300 mm in length.

5.4.14.3 Apparatus

Use an ozone chamber in accordance with IEC 60811-403, applying an atmosphere containing a mass fraction of $(1 \pm 0{,}05) \times 10^{-6}$ of ozone at (65 ± 3) °C. Attention is drawn to the highly toxic nature of ozone. Efforts should be made to minimize the exposure of workers at all times. See Column A of Table 5 for the mandrel diameter. Aluminium mandrels are preferred since other materials can affect the ozone concentration.

5.4.14.4 Test

Wind at least the minimum number of turns according to Table 5 and secure the ends. Condition the test specimens for 192 h in the ozone chamber. While still on the mandrel, remove the test specimens 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.

5.4.15 Resistance to flame propagation

5.4.15.1 General

The apparatus build information for this test shall be found in Annex C.

5.4.15.2 Purpose

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

5.4.15.3 Test specimen

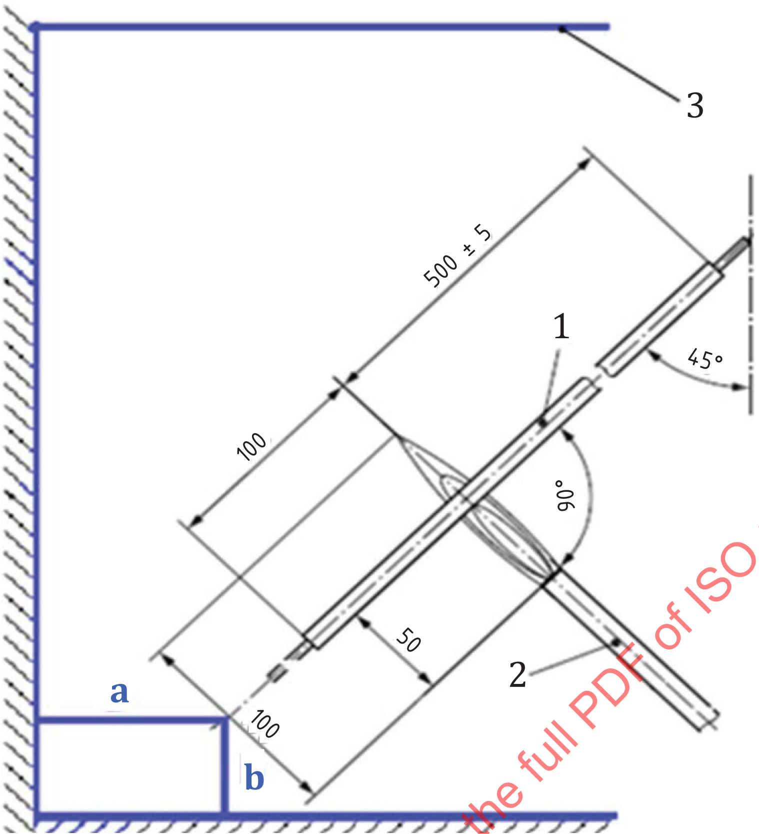
Prepare 5 test specimens with at least 600 mm of insulation.

5.4.15.4 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 ± 50) °C.

If the conductor breaks during the test, repeat the test, reducing the flame exposure time in steps of 1 s until the conductor does not break.

Dimensions in millimetres



Key

1	test specimen	a	cable lower end distance to metallic enclosure (130 mm ± 10 mm)
2	bunsen burner	b	cable lower end hight (150 mm ± 10 mm)
3	metallic enclosure		

Figure 15 — Test apparatus for resistance to flame propagation

Suspend the test specimen inside the metallic enclosure in a draught-free chamber and expose the test specimen to the tip of the inner cone of the flame, as shown in Figure 15. The specimen shall be subject to a stress, e.g. by means of a weight over a pulley, in order to keep it straight at all times. The angle of the cable shall be 45° ± 1° relative to the vertical line. In any case, the shortest distance of any part of the specimen shall be 100 mm minimum from any wall of the metallic enclosure. Apply the flame with the tip of the inner blue cone touching the insulation (500 ± 5) mm from the upper end of the insulation. Finish the exposure to the test flame after 15 s (0/+2) s for cables with conductor sizes smaller than or equal to 2,5 mm^2 and 30 s (0/+2) s for cables with conductor sizes larger than 2,5 mm^2. Remove the flame sideways from the cable after exposure.

6 Test methods for sheathed cables

6.1 Dimensional tests

6.1.1 Cable outside diameter

6.1.1.1 Purpose

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

Due to the variety of constructions, the requirements for dimensions shall be established by agreement between the customer and the supplier.

6.1.1.2 Test

Perform the test according to 5.1.2.

6.1.2 Ovality of sheath

6.1.2.1 Purpose

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

6.1.2.2 Test

Measure the maximum cable outside diameter, D, and the minimum cable outside diameter, D_{min}, according to 5.1.2. Then, calculate the ovality, O, using the formula:

$$O = \frac{\left(D - D_{min}\right)}{0{,}5\left(D + D_{min}\right)} \times 100$$

where

O is the amount the sheath is “out of round” in %;

D is the maximum cable outside diameter in mm;

D_{min} is the minimum cable outside diameter in mm.

6.1.3 Thickness of sheath

6.1.3.1 Purpose

This test is intended to verify that the cable sheath thickness is within the required tolerances.

6.1.3.2 Test

Perform the test according to 5.1.3.

6.1.4 In-process cable outside diameter

6.1.4.1 Purpose

This in-process monitoring is intended to verify that the cable outside diameter is within the required tolerances.

6.1.4.2 Test specimens

The test specimen is 100 % of the cable production; all cable produced is to be monitored.

6.1.4.3 Test

The measurement of diameter shall be performed in the most stable area of the extrusion process.

6.2 Electrical tests

6.2.1 Electrical continuity

6.2.1.1 Purpose

This test is intended to verify the electrical continuity of the core(s).

6.2.1.2 Test specimen

Remove 100 mm of sheath from each end of the cable and 25 mm of insulation from each end of the cores.

6.2.1.3 Test

Use an appropriate source connected in series with an indicator such as an ohmmeter, light or buzzer. Connect the apparatus to one of the cores. Repeat the procedure until all cores have been tested. If a screen is present, test the continuity using the same procedure as for a core. Alternatively, all of the cores may be tested at once by connecting them in series. Take care to select a current which does not damage the individual conductors.

6.2.2 Withstand voltage at final inspection

6.2.2.1 Purpose

This test is intended to find electrical defects in the cable.

6.2.2.2 Test specimen

This test specimen is 100 % of the cable length after cable production. This test is intended to be carried out directly after production on the total cable length as well as on the test specimens subjected to environmental tests.

Remove 100 mm of sheath from one end of the cable and remove 25 mm of insulation from each core. For the test, connect the conductors of all the cores together at one end, except for the core being tested. If a screen is present, it shall be connected in the same manner as a core.

An unscreened sheathed single-core cable is tested according to the insulation fault test in Clause 4. Therefore, withstand voltage at final inspection is not required.

6.2.2.3 Test

Use a 50 Hz or 60 Hz a.c. or a d.c. voltage source capable of applying the required voltage for the required time. Apply the required voltage between a core and the remaining core(s) for the required time. Repeat the procedure until all cores have been tested. If a screen is present, it shall be tested as one of the cores.

6.2.3 Screening effectiveness

6.2.3.1 Purpose

The test is intended to determine the effectiveness of a screened cable to electromagnetic interference (EMI).

NOTE The test is not applicable to un-screened cables.

The customer and supplier shall define which test(s) shall be used.

6.2.3.2 d.c. resistance of the screen

6.2.3.2.1 Purpose

This test is intended to verify that the d.c. resistance of the screen does not exceed the maximum permitted value.

6.2.3.2.2 Test specimen

Prepare a test specimen of 1 m length plus the length necessary for connections. Gather together the strands of the screen at both ends and form a connection. The ends of the specimen shall be soldered.

6.2.3.2.3 Test

Use a resistance measuring device with an accuracy of ±0,5 % of the measured value at reference temperature of 20 °C. A four-wire measurement method shall be used. See Figure 16.

The d.c. resistance of the screen is calculated with the following formula:

$$R_L = \frac{U}{I}$$

where

R_L is the resistance of the screen in mΩ;

U is the measured voltage in mV;

I is the current supply in A.

The measured value shall be adjusted according to the following formula:

$$R_{20} = \frac{R_L}{L_\text{v} \times \left[1 + \alpha_\rho \times \left(T_\text{c} - 20\right)\right]}$$

where

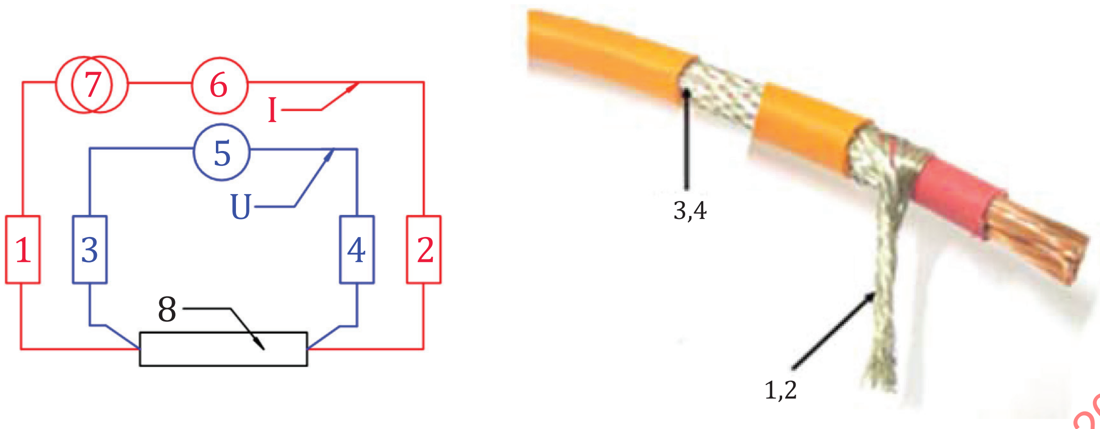
R_L is the resistance of the screen in mΩ;

R_{20} is the resistance of the screen at 20 °C in mΩ/m;

α_ρ is the temperature coefficient in 10^{-3} 1/K;

T_c is the measured conductor temperature in °C;

L_v is the length between voltage test points in m.



Key

I current path
U voltage path
1 current connection point left side
2 current connection point right side
3 voltage connection point left side
4 voltage connection point right side
5 volt-meter
6 ampere-meter
7 current source
8 specimen under test

NOTE Picture on the right is depicted with the needed adaptions for one of the two ends of the specimen under test. Also, the test specimen of 1 m length is measured from point 3,4 between the two ends.

Figure 16 — Four-wire measurement method (aka. Kelvin measurement method)

6.2.3.3 Surface transfer impedance — Tri-axial method

6.2.3.3.1 Purpose

The test determines the screening effectiveness of a shielded cable by applying a well-defined current and voltage to the screen of the cable and measuring the induced voltage in a secondary circuit in order to determine the surface transfer impedance.

6.2.3.3.2 General

Allowable frequency ranges should be according to IEC 62153-4-3.

6.2.3.3.3 Test specimen

Prepare the test specimen according to IEC 62153-4-3.

6.2.3.3.4 Test

Perform the test according to IEC 62153-4-3.

6.2.3.4 Screening attenuation — Absorbing clamp method

6.2.3.4.1 Purpose

The test determines the coupling or screening attenuation of metallic communication cables in the frequency range of 30 MHz to 1 GHz.

6.2.3.4.2 General

Allowable frequency ranges should be according to IEC 62153-4-5.

6.2.3.4.3 Test specimen

Prepare the test specimen according to IEC 62153-4-5.

6.2.3.4.4 Test

Perform the test according to IEC 62153-4-5.

6.2.3.5 Screening attenuation — Tri-axial method

6.2.3.5.1 Purpose

The test determines the screening attenuation a_S of metallic communication cable screens. Due to concentric outer tube, measurements are independent of irregularities on the circumference and outer electromagnetic field.

6.2.3.5.2 General

Allowable frequency ranges should be according to a_S, as specified in IEC 62153-4-4.

6.2.3.5.3 Test specimen

Prepare the test specimen according to a_S, as specified in IEC 62153-4-4.

6.2.3.5.4 Test

Perform the test according to IEC 62153-4-4.

6.2.4 Sheath fault on screened cables

6.2.4.1 Purpose

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

6.2.4.2 Test specimen

The test specimen is 100 % of the cable production; all cable produced is to be monitored.

6.2.4.3 Test

Use a sinusoidal voltage source set at the specified value in the in the relevant part of the ISO 19642 series. 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.

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

6.3 Mechanical tests

6.3.1 Strip force of sheath

6.3.1.1 Purpose

This test is intended to verify that the force required to remove the sheath from the core stranding meets customer requirements.

6.3.1.2 Test specimen

Prepare the test specimen according to 5.3.1 Prepare three test specimens of 150 mm from a cable test specimen 3 m in length. Take the test specimens at 1 m intervals. The undisturbed length of sheath shall be 100 mm.

6.3.1.3 Test

Perform the test according to 5.3.1. A metal plate is provided with a round hole equal to the approximate inside diameter of the sheath. If the 100 mm section of sheath buckles when sliding, prepare new test specimens with the undisturbed length of sheath equal to 50 mm and repeat the procedure.

6.3.2 Cyclic bending

6.3.2.1 Purpose

Cyclic bending test is performed to determine the number of bending cycles until the conductor breaks (fatigue resistance) in this defined dynamic condition.

6.3.2.2 Test specimens

Take two test specimens of 600 mm in length from points separated by at least 1 m.

6.3.2.3 Test

Perform the test according to 5.3.4. Connect the individual conductors and the screen, if present, in series for the detection of interruption of electrical continuity.

6.3.3 Flexibility

6.3.3.1 General

This test is applicable to all multi-core cables with a cable outside diameter less than 28 mm. Build information for this apparatus is found in Annex B.

6.3.3.2 Purpose

This test is intended to measure and quantify cable flexibility.

6.3.3.3 Test specimen

Cut five test specimens to a length as specified in Table 4.

6.3.3.4 Test

Perform the test according to 5.3.5.

6.4 Environmental tests

6.4.1 Test specimen preparation and winding tests

6.4.1.1 Purpose

This subclause describes the mandrel sizes used for preparation of test specimens in different subsequent environmental tests.

It also describes the winding tests used to detect defects caused by environmental stresses.

6.4.1.2 Test specimens

Prepare two test specimens of 600 mm in length. Remove 100 mm of sheath from one end of the cable and remove 25 mm of insulation from each core.

6.4.1.3 Test

Winding tests after environmental stresses are performed at different test temperatures.

For winding tests at low temperatures, the test specimens and the mandrel shall be conditioned for a minimum of 4 h in the precooled freezing chamber at the designated temperature in Table 9 before the winding test is performed.

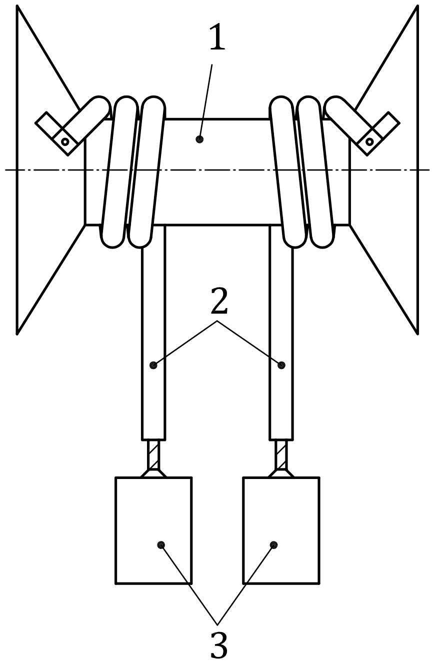
If a test at RT needs to be performed according to Table 9, keep the test specimens at RT for at least 4 h before the winding test is performed. Use of a freezing chamber is not mandatory in these cases.

Either a rotatable or a stationary mandrel may be used. See Table 10 for the mandrel diameter, winding speed and the number of turns. When used, rotatable mandrels shall be used in accordance to Figure 17. See Table 10 for the applied mass.

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

6.4.1.4 Rotatable mandrel

When a rotatable mandrel is used, the test specimens shall be fixed on the mandrel as shown in Figure 17. The free ends are loaded with the mass. Position the mandrel with the test specimens hanging vertically.



Key

1 mandrel

2 test specimen(s)

3 mass(es)

Figure 17 — Test apparatus for winding

6.4.1.5 Stationary mandrel

When a stationary mandrel is used, a test specimen shall be wrapped around the mandrel by hand. Repeat the procedure for the other test specimen.

Wind the test specimen for at least the minimum number of turns around the mandrel within the freezing chamber and at winding speed as specified in Table 10 Ensure that there is continuous contact between the test specimens and the mandrel.

After the cold winding, allow the test specimens to return to RT and make a visual examination of the sheath.

After winding, the outer sheath shall be visually examined. If there is no sign of cracks in the sheath, perform withstand voltage at final inspection according to 6.2.2 on the test specimen. If required by the customer, strip the sheath without damage to the inner cores, visually examine them, and if there is no sign of cracks, perform a 1 kV a.c. withstand voltage test with the separate cores as in 5.2.4.

Table 9 — Test temperatures after environmental tests

Test number	Title	Test temperature °C
6.4.2	Long-term heat ageing, 3 000 h at temperature class rating	RT
6.4.3	Short term heat ageing, 240 h at temperature class rating +25 °C	−25
6.4.4	Thermal overload, 6 h at temperature class rating +50 °C	RT
6.4.7	Low temperature winding	−40
6.4.10	Resistance to liquid chemicals	RT

Table 10 — Winding multi core cables

Cable outside diameter (D) mm	Mandrel diameter mm	Mass kg	Winding speed S^{-1}	Minimum number of turns
$D \leq 2{,}5$	≤5 × D D = maximum cable outside diameter	0,5	0,2	3
$2{,}5 < D \leq 5$		2,5		3
$5 < D \leq 10$		5		2
$10 < D \leq 15$		10		0,5
$15 < D \leq 25$		20		0,5
$25 < D$		30		0,5

6.4.2 Long-term heat ageing, 3 000 h at temperature class rating

6.4.2.1 Purpose

This test is intended to confirm the temperature class rating.

6.4.2.2 Test specimens

Prepare the test specimens according to 5.4.2. Remove 25 mm of sheath from each end of the cable.

6.4.2.3 Test

Perform the test according to 5.4.2.

Perform the winding test at RT according to 6.4.1. See Table 10 for mandrel diameter and mass.

6.4.3 Short term heat ageing, 240 h at temperature class rating +25 °C

6.4.3.1 Purpose

This test is intended to simulate thermal excursions.

6.4.3.2 Test specimens

Prepare the test specimens according to 5.4.3. Remove 25 mm of sheath from each end of the cable.

6.4.3.3 Test

Perform the test according to 5.4.3.

Perform the winding test at −25 ± 2 °C according to 6.4.1. See Table 10 for mandrel diameter and mass.

6.4.4 Thermal overload, 6 h at temperature class rating +50 °C

6.4.4.1 Purpose

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

6.4.4.2 Test specimens

Prepare the test specimens according to 5.4.4. Remove 25 mm of sheath from each end of the cable.

6.4.4.3 Test

Perform the test according to 5.4.4.

Perform the winding test at RT according to 6.4.1. See Table 10 for mandrel diameter and mass.

6.4.5 Pressure test at high temperature

6.4.5.1 Purpose

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

6.4.5.2 Test specimens

Prepare three test specimens, each of 100 mm in length.

6.4.5.3 Test

Perform the test in accordance with 5.4.5 and the following.

Measure the thickness of the sheath immediately after cooling, at the point of indentation and at points 10 mm to both sides of the impression, by means of a measuring device that does not cause deformation. Omit the withstand voltage test.

6.4.6 Shrinkage by heat of sheath

6.4.6.1 Purpose

This test is intended to verify the longitudinal dimensional stability of the sheath, at the end of cable, after elevated temperature to avoid exposure of the core stranding.

6.4.6.2 Test specimen

Prepare three test specimens of 200 mm in length.

6.4.6.3 Test

Perform the test according to 5.4.6.

Measure the shrinkage of the sheath.

6.4.7 Low temperature winding

6.4.7.1 Purpose

This test is intended to verify that the cable can withstand bending at low temperature without cracking and still maintain sheath properties. This test is also intended to verify the low temperature class rating as specified in the relevant part of the ISO 19642 series.

6.4.7.2 Test

Perform the test in accordance with 5.4.7 at −40 °C. See Table 10 for mandrel diameter, winding speed and mass, if rotating mandrel is used.

Other test temperature may be used when agreed between the customer and supplier.

6.4.8 Cold impact

6.4.8.1 Purpose

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

6.4.8.2 Test specimens

Prepare three test specimens of a minimum length of 600 mm. Unless otherwise specified, a test specimen shall contain the complete sheath including any existing multiple layers.

6.4.8.3 Test

Perform the test according to 5.4.8. The mass of the hammer is specified in the relevant part of the ISO 19642 series.

After impact, allow the test specimens to return to RT and make a visual examination of the sheath.

If a screen is present, bend the test specimen at RT to form a U-shape with a mandrel according to Table 10 and perform the withstand voltage after environmental testing between the screen and salt water bath according to 5.2.4.

6.4.9 Temperature and humidity cycling

6.4.9.1 Purpose

This test is intended to verify the cable's sheath integrity after temperature and humidity cycling.

6.4.9.2 General

This test shall be as agreed between the customer and supplier.

6.4.9.3 Test specimens

Prepare two test specimens, each of approximately 600 mm in length.

6.4.9.4 Test

Use the test chamber according to 5.4.9. See Table 10 for mandrel diameter.

Wind test specimens equal to or less than 10 mm in diameter 3 turns, and test specimens greater than 10 mm half a turn around the mandrel and secure the ends. Condition the test specimens according to 5.4.9. Make a visual examination of the sheath. Ignore any damage caused by the clamps which secure the ends.

6.4.10 Resistance to liquid chemicals

6.4.10.1 Purpose

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

6.4.10.2 General

The applicability of this test should be according to 5.4.11.

6.4.10.3 Test specimens

Prepare the test specimens according to 5.4.11.

6.4.10.4 Test

Perform the test according to 5.4.11. During immersion, the bend diameter of the cable shall be a minimum of ten times its outside diameter. See Table 10 for mandrel diameter and mass. Omit the withstand voltage test.

6.4.11 Durability of sheath marking

6.4.11.1 Purpose

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

6.4.11.2 Test specimens

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

6.4.11.3 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/cm^3 (dimensions 50 mm × 50 mm × 3 mm) and a vessel containing ISO 1817, Oil No. 2 at (50 ± 3) °C.

6.4.11.4 Test

Immerse a test specimen for 20 h with the test specimen ends emerging 50 mm above the surface of the liquid.

Remove the test specimen from the oil and allow it to drain at RT for 30 min. Position the test specimen 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 specimen from between the felt. Repeat the procedure for the other test specimens. Visually examine the test specimens after the test.

6.4.12 Resistance to ozone

6.4.12.1 Purpose

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

6.4.12.2 Test specimens

Prepare three test specimens, each a minimum of 300 mm in length.

6.4.12.3 Apparatus

Use an ozone chamber in accordance with IEC 60811-403, applying an atmosphere containing a mass fraction of (1 ± 0,05) × 10^{-6} of ozone at (65 ± 3) °C. Attention is drawn to the highly toxic nature of ozone. Efforts should be made to minimize the exposure of workers at all times. See Table 10 for the mandrel diameter. Aluminium mandrels are preferred since other materials can affect the ozone concentration.

6.4.12.4 Test

Wind at least the minimum number of turns according to Table 10 and secure the ends. Condition the test specimens for 192 h in the ozone chamber. While still on the mandrel, remove the test specimens