



BSI Standards Publication

Road vehicles — Automotive cables

Part 2: Test methods

National foreword

This British Standard is the UK implementation of ISO 19642-2:2023. It supersedes BS ISO 19642-2:2019, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee AUE/32, Electrical and electronic components and general system aspects (Road vehicles).

A list of organizations represented on this committee can be obtained on request to its committee manager.

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Part 2:
Test methods

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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 document 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).

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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*.

This second edition cancels and replaces the first edition (ISO 19642-2:2019), which has been technically revised.

The main changes are as follows:

- new parts have been added to the ISO 19642 series (ISO 19642-11 and ISO 19642-12);
- both new International Standards refer to this document for definition of test procedures. Some new test procedures are needed for the new standards of the ISO 19642 series and have been added accordingly;
- some new test procedures for screened RF cables have been added for a new standard of the ISO 19642 series.

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. 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 1817¹⁾, *Rubber, vulcanized or thermoplastic — Determination of the effect of liquids*

ISO 4141-1, *Road vehicles — Multi-core connecting cables — Part 1: Test methods and requirements for basic performance sheathed cables*

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-based reference fluid*

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

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

ISO 19642-3, *Road vehicles — Automotive cables — Part 3: Dimensions and requirements for 30 V a.c. or 60 V d.c. single core copper conductor cables*

ISO 19642-4, *Road vehicles — Automotive cables — Part 4: Dimensions and requirements for 30 V a.c. and 60 V d.c. single core aluminium conductor cables*

ISO 19642-5, *Road vehicles — Automotive cables — Part 5: Dimensions and requirements for 600 V a.c. or 900 V d.c. and 1 000 V a.c. or 1 500 V d.c. single core copper conductor cables*

ISO 19642-6, *Road vehicles — Automotive cables — Part 6: Dimensions and requirements for 600 V a.c. or 900 V d.c. and 1 000 V a.c. or 1 500 V d.c. single core aluminium conductor cables*

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

IEC 60216-4-1, *Electrical insulating materials — Thermal endurance properties — Part 4-1: Ageing ovens — Single-chamber ovens*

IEC 60216-4-2, *Electrical insulating materials — Thermal endurance properties — Part 4-2: Ageing ovens — Precision ovens for use up to 300 °C*

1) Eight edition under preparation. Stage at the time of publication: ISO/DIS 1817:2023.

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

IEC 60811-202, *Electric and optical fibre cables — Test methods for non-metallic materials — Part 202: General tests — Measurement of thickness of non-metallic sheath*

IEC 60811-401, *Electric and optical fibre cables — Test methods for non-metallic materials — Part 401: Miscellaneous tests - Thermal ageing methods - Ageing in an air oven*

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 60811-508:2012, *Electric and optical fibre cables — Test methods for non-metallic materials — Part 508: Mechanical tests — Mechanical tests - Pressure test at high temperature for insulation and sheaths*

IEC 61156-1, *Multicore and symmetrical pair/quad cables for digital communications - Part 1 — Generic specification*

IEC TR 61156-1-2:2009+AMD1:2014, *CSV Consolidated version, Multicore and symmetrical pair/quad cables for digital communications — Part 1-2: Electrical transmission characteristics and test methods of — Symmetrical pair/quad cables*

IEC 61196-1, *Coaxial communication cables — Part 1: Generic specification — General, definitions and requirements*

IEC 61196-1-100, *Coaxial communication cables — Part 1-100: Electrical test methods — General requirements*

IEC 61196-1-103, *Coaxial communication cables — Part 1-103: Electrical test methods — Test for capacitance of cable*

IEC 61196-1-108, *Coaxial communication cables — Part 1-108: Electrical test methods — Test for characteristic impedance, phase and group delay, electrical length and propagation velocity*

IEC 61196-1-112, *Coaxial communication cables — Part 1-112: Electrical test methods — Test for return loss (uniformity of impedance)*

IEC 61196-1-113, *Coaxial communication cables — Part 1-113: Electrical test methods — Test for attenuation constant*

IEC 61196-1-114, *Coaxial communication cables — Part 1-114: Electrical test methods — Test for inductance*

IEC 61196-1-116, *Coaxial communication cables — Part 1-116: Electrical test methods — Test for impedance with time domain reflectometry (TDR)*

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) — Test method for measuring of the screening attenuation as up to and above 3 GHz, triaxial method*

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

IEC 62153-4-9, *Metallic communication cables test methods — Part 4-9: Electromagnetic compatibility (EMC) — Coupling attenuation of screened balanced cables, triaxial method*

EN 50289-1-1, *Communication cables— Specifications for test methods— Electrical test methods — General requirements*

EN 50289-1-5, *Communication cables— Specifications for test methods— Electrical test methods — Capacitance*

EN 50289-1-12, *Communication cables— Specifications for test methods— Electrical test methods — Inductance*

3 Terms and definitions

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

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://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) (see ISO 19642-1). 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 AC 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 three 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.

4.1.1 General information on dimensional tests

Measure with a device accurate to at least 0,01 mm.

It is preferred to cut a small slice from the sample (perpendicular to the cable length) and use an optical measurement device to magnify the specimen.

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.

In case of dispute specimen under test may be encapsulated in synthetic resin before performing the measurement. In this case the following measurement is to be performed using a microscope with a resolution better than 10 µm.

This remark is applicable to tests [5.2.1](#), [5.2.2](#) and [5.2.3](#).

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 with or without forced air circulation as described in IEC 60216-4-1 and/or IEC 60216-4-2 or equivalent shall 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. Measure the rate of complete air changes per hour according to IEC 60811-401:2012, Annex A, Method 1. 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 General

This paragraph is needed to ensure the alignment of paragraph numbers with the other parts of the ISO 19642 series.

5.2 Dimensional tests

5.2.1 Cable outside diameter

5.2.1.1 Purpose

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

5.2.1.2 Test specimen

Prepare one test specimen of 3 m in length.

5.2.1.3 Test

The cable outside diameter shall be measured at three separate cross-sections located 1 m apart from each other. Two perpendicular readings shall be taken at each cross-section.

Document the initial readings for each cross section for determination of ovality.

For each specimen calculate the mean value from each point of measurement. From the mean values of all three specimens determine the minimum and maximum value.

The minimum and maximum values shall be in accordance with the cable dimension tables in the ISO 19642 series for the various cable types.

For large cables (outside diameter $\geq 18,0$ mm), the test method described in IEC 60811-203:2012, 4.2 b, may be used for measuring the outside diameter.

5.2.2 Insulation thickness

5.2.2.1 Purpose

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

5.2.2.2 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 and measure at this indentation.

5.2.2.3 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. For sheath use IEC 60811-202.

5.2.3 Conductor diameter

5.2.3.1 Purpose

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

5.2.3.2 Test specimens

Use the test specimens as specified in [5.2.2](#).

5.2.3.3 Test

Use a measuring device which does 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.

5.2.4 Cross-sectional area (CSA)

5.2.4.1 Purpose

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

5.2.4.2 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 [5.3.1](#), the CSA, A , is calculated using the following formula:

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

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;

$F_{x,b}$ 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:

$$A = \frac{m_{co}}{\rho}$$

where

- A is cross-sectional area in mm²;
- m_{co} is the conductor weight in g/m;
- ρ is the density of the used conductor material in g/cm³:
for copper use a density of 8,89 g/cm³;
for aluminium use a density of 2,70 g/cm³;
applicable densities shall be used for alloys.

5.2.5 In-process cable outside diameter

5.2.5.1 Purpose

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

5.2.5.2 Test specimens

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

5.2.5.3 Test

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

5.3 Electrical tests

5.3.1 Conductor resistance

5.3.1.1 Purpose

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

5.3.1.2 Test specimens

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

5.3.1.3 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.

5.3.1.4 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 $1\,000\text{ mm} \pm 5\text{ mm}$.

Use a resistance measuring device with an accuracy of $\pm 0,1\%$ of the measured value and a thermometer with an accuracy of $\pm 0,5\text{ }^{\circ}\text{C}$.

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:

$$R_{20} = \frac{R_T}{L_v \times [1 + \alpha_p \times (T - 20)]}$$

where

R_{20} is the corrected conductor resistance at the reference temperature of $20\text{ }^{\circ}\text{C}$, expressed in $\text{m}\Omega/\text{m}$;

R_T is the conductor resistance measured at the conductor temperature in $\text{m}\Omega$;

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 $^{\circ}\text{C}$;

α_p in $1/\text{K}$, is the temperature coefficient for converting the measured resistance to the value at $20\text{ }^{\circ}\text{C}$.

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

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 $4,03 \times 10^{-3}\text{ }1/\text{K}$.

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

The applied temperature coefficient shall be measured according to [5.3.2](#) or as agreed between customer and supplier and be reported.

5.3.2 Determination of temperature coefficients

5.3.2.1 Purpose

The resistance of a cable under test is determined while its temperature is increased from room temperature up to $50\text{ }^{\circ}\text{C}$. 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 DC power supply).

5.3.2.2 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 (<i>a</i>) mm ²	Length m
$a < 2,5$	10
$2,5 \leq a < 10$	5
$a \geq 10$	2

5.3.2.3 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.

5.3.2.4 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 (<i>a</i>) mm ²	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.

5.3.2.5 Procedure

The temperature of the oil bath shall be measured and controlled. The oil bath temperature measurement shall be more accurate than $\pm 0,2$ °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 $\pm 0,2$ °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.

5.3.2.6 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:

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

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:

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

where

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

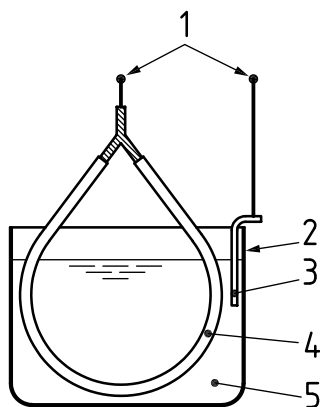
α_ρ is the linear temperature coefficient of material specific resistivity in 1/K.

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

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

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

5.3.3 Withstand voltage



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

5.3.3.1 Purpose

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

5.3.3.2 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.

5.3.3.3 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.

5.3.4 Withstand voltage after environmental testing

5.3.4.1 Purpose

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

5.3.4.2 Test

The withstand voltage test described in [5.3.3](#) 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.

5.3.5 Insulation faults

5.3.5.1 Purpose

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

5.3.5.2 Test specimen

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

5.3.5.3 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 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 insulation faults are detected with the same certainty.

5.3.6 Insulation volume resistivity

5.3.6.1 Purpose

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

5.3.6.2 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 [5.3.1](#).

5.3.6.3 Test

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 DC 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 DC voltage of 500 V.

Immerse the test specimen for 2 h with each end emerging from the bath by 250 mm. Apply the DC 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:

$$\rho_0 = 2,725 \times \frac{L_i \times R}{\lg\left(\frac{D}{D_{\text{ave}}}\right)}$$

where

ρ_0 is the insulation volume resistivity, expressed in $\Omega \cdot \text{mm}$;

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

R is the measured insulation resistance in Ω ;

D is the maximum cable outside diameter in mm according to [5.2.1](#);

D_{ave} is the average conductor diameter in mm according to [5.2.3](#).

5.4 Mechanical tests

5.4.1 Strip force

5.4.1.1 General

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

5.4.1.2 Purpose

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

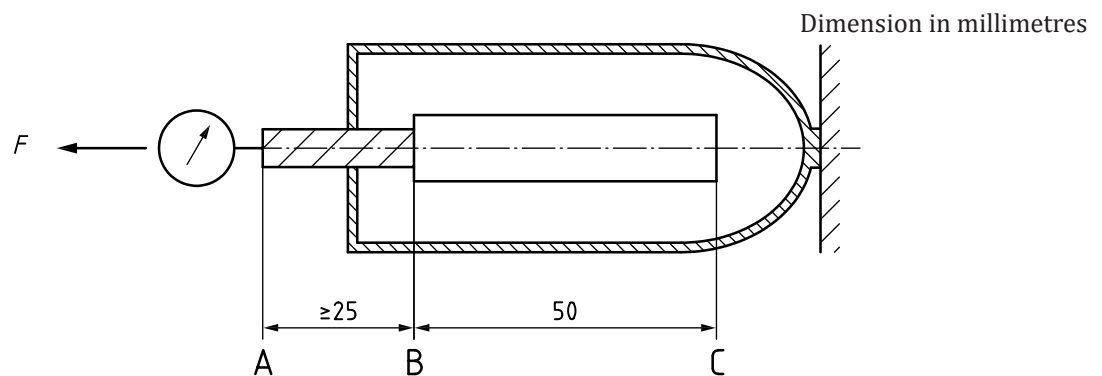
5.4.1.3 Test specimens

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.

5.4.1.4 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.

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.



Key

F force

AB insulation removed

BC insulation undisturbed

Figure 2 — Test apparatus for strip force

5.4.2 Abrasion

5.4.2.1 General

This test is applicable to cables with a conductor size $\leq 6 \text{ mm}^2$. The tests described in [5.4.2.4](#) or [5.4.2.5](#) shall be used. The customer and supplier shall define which test shall be used.

5.4.2.2 Purpose

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

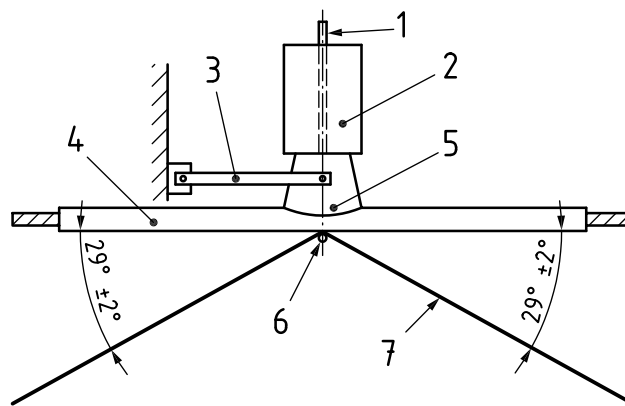
5.4.2.3 Test specimen

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

5.4.2.4 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 $(0,63 \pm 0,05)$ 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 $(1\,500 \pm 75)$ 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 | 5 bracket |
| 2 additional mass | 6 tape supporting pin, diameter = 6,9 mm |
| 3 pivoting arm | 7 180J Al_2O_3 sandpaper abrasion tape |
| 4 test specimen | |

Figure 3 — Test apparatus for sandpaper abrasion

5.4.2.5 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.

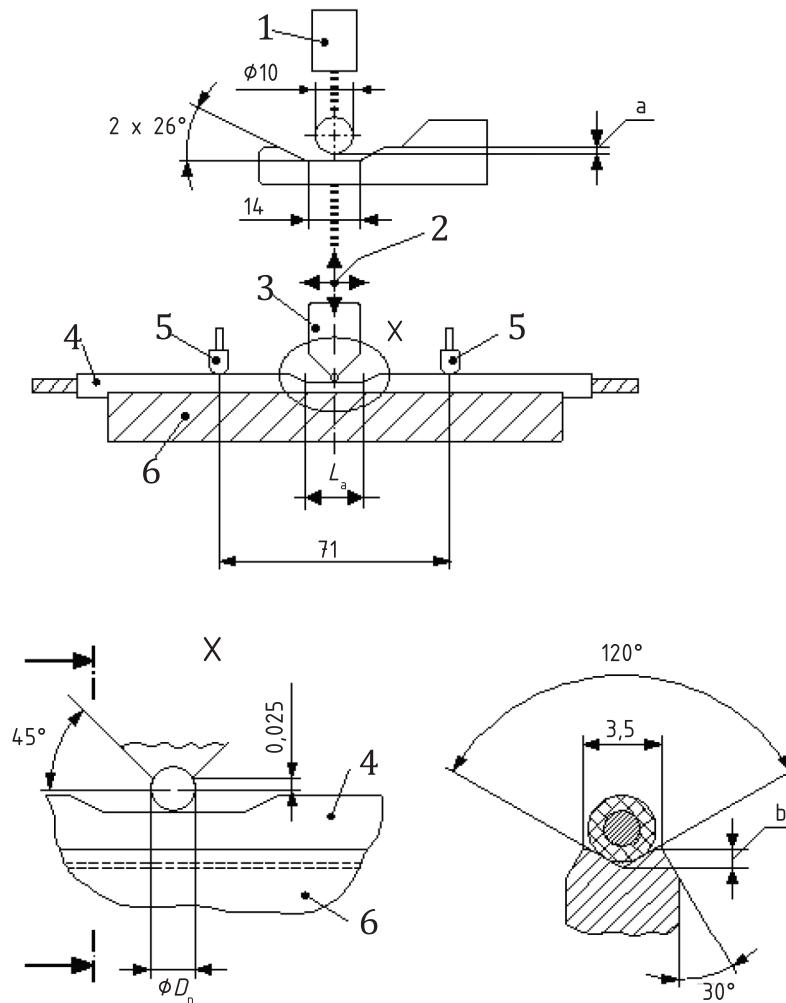
The characteristics of a suitable apparatus shall be as follows:

- diameter of needle: $(0,45 \pm 0,01)$ 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: $(15,5 \pm 1)$ 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 $(23 \pm 1) ^\circ\text{C}$. 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: $(15,5 \pm 1)$ mm |
| 2 | travel | D_n | needle diameter: $(0,45 \pm 0,01)$ mm |
| 3 | needle holder | ^a | Clearance during abrasion. |
| 4 | test specimen | ^b | Groove depth |
| 5 | clamp | | 0,4 mm, conductor size $\leq 0,35$ mm ² |
| 6 | test specimen holder | | 0,8 mm, conductor size $> 0,35$ mm ² . |

Figure 4 — Test apparatus for scrape abrasion

5.4.3 Breaking force of the finished cable

5.4.3.1 Purpose

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

5.4.3.2 Test specimens

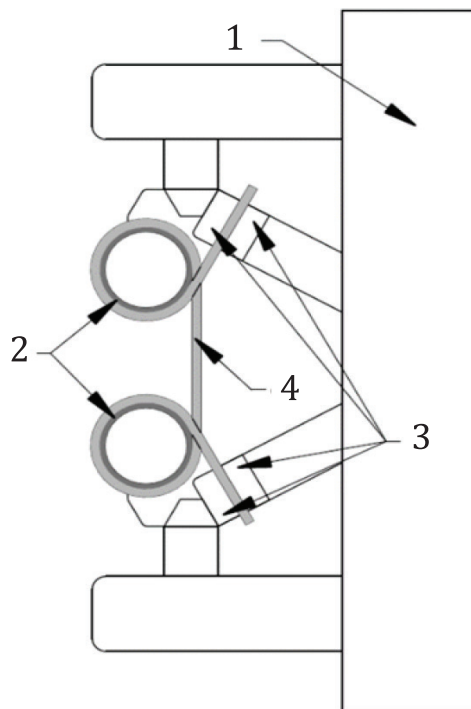
This test is applicable for wires $\leq 6 \text{ mm}^2$.

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 a minimum of 50 mm of cable in the centre test section.

5.4.3.3 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 [N], 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

5.4.4 Cyclic bending

5.4.4.1 Purpose

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

5.4.4.2 Test specimens

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

5.4.4.3 Test

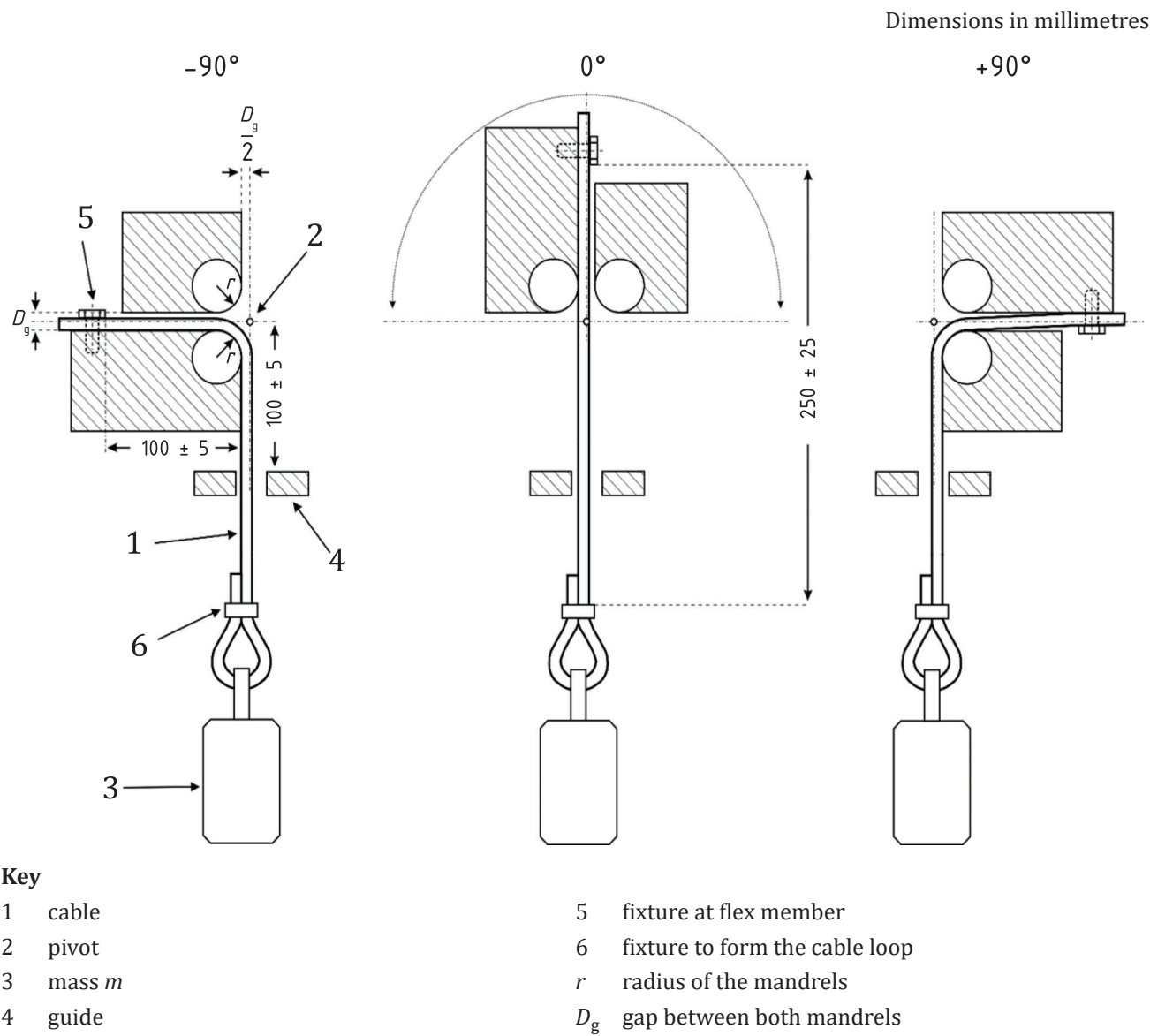


Figure 6 — Test apparatus for cyclic bending shown at flex positions -90° , 0° and $+90^\circ$

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 $\pm 90^\circ$ 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: $D_g = (1,5 \times D) \pm 0,5$ 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 $m = 1,0 \text{ kg/mm}^2 \times \text{total cross-section in mm}^2$. 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.

5.4.5 Flexibility

5.4.5.1 General

Build information for this apparatus is found in [Annex B](#).

5.4.5.2 Purpose

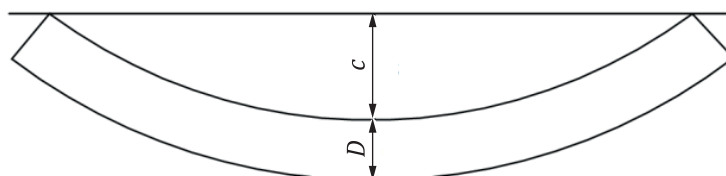
This test is intended to measure and quantify cable flexibility.

5.4.5.3 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

5.4.5.4 Test

For multi-core cable, measure the maximum cable outside diameter as specified in 5.2.1. 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 [N] (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

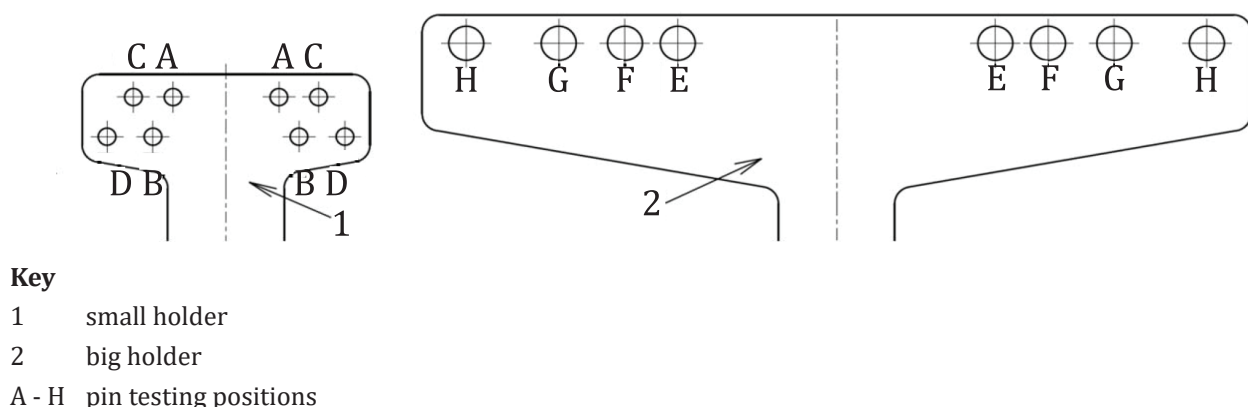


Figure 8 — Test apparatus for flexibility — Pin testing positions

5.5 Environmental tests

5.5.1 Test specimen preparation and winding tests

5.5.1.1 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.

5.5.1.2 Test specimens

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

5.5.1.3 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.

5.5.1.4 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.

5.5.1.5 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.

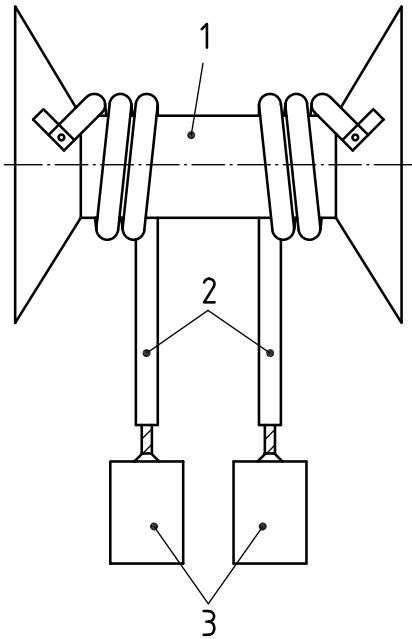
Wind the test specimen for at least the minimum number of turns around the mandrel within the freezing chamber and at winding speed as specified in [Table 5](#). Ensure that there is continuous contact between the test specimens and the mandrel.

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 [5.3.4](#).

Table 5 — Winding parameters single core cables

ISO conductor size (a) mm ²	Mandrel diameter mm		Mass kg	Winding speed s ⁻¹	Minimum number of turns
	A	B			
$a \leq 0,75$	$\leq 5 \times D$ where D = maximum cable outside diameter	$\leq 1,5 \times D$ where D = maximum cable outside diameter	0,5	1	3
$0,75 < a \leq 1,5$			2,5		2
$1,5 < a \leq 6$			5		
$6 < a \leq 10$			8	0,5	0,5
$10 < a \leq 25$			10		
$25 < a \leq 35$			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
5.5.2	Long term heat ageing, 3 000 h at temperature class rating	RT	B
5.5.3	Short term heat ageing, 240 h at temperature class rating +25 °C	(−25 ± 2) °C	A
5.5.4	Thermal overload, 6 h at temperature class rating +50 °C	RT	B
5.5.7	Low-temperature winding	(−40 ± 2) °C	A
5.5.9	Temperature and humidity cycling	Test preparation ^a	B
5.5.10	Resistance to hot water	Test preparation ^a	A
5.5.11	Resistance to liquid chemicals	RT	A
5.5.13	Stress cracking resistance	RT	B
5.5.14	Resistance to ozone	Test preparation ^a	A
^a No winding test performed, mandrel is only used for test specimen preparation before test.			

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

5.5.2.1 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.

5.5.2.2 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 ageing.

5.5.2.3 Apparatus

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

5.5.2.4 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 [5.5.1](#) using a mandrel size of Column B according to [Table 5](#) at RT.

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

5.5.3.1 Purpose

This test is intended to simulate thermal excursions.