INTERNATIONAL STANDARD

ISO 19642-2

Second edition
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Road vehicles — Automotive cables —

Part 2: Test methods

Véhicules routiers — Câbles automobiles —

Partie 2: Méthodes d'essai

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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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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 1817[1)], *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 ≥ 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 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:

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

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, 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 °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 (a) mm^2	Length m
a < 2,5	10
2,5 ≤ a < 10	5
a ≥ 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 (a) mm^2	Maximum permissible current mA
a < 0,35	10
0,35 ≤ a < 6	100
a ≥ 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 ±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.

5.3.2.6 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;

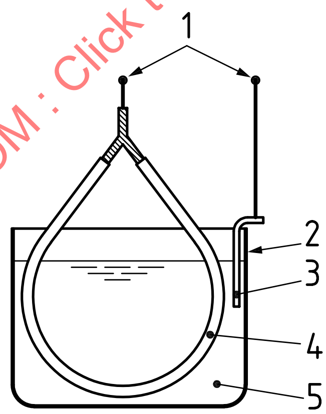
α_ρ is the linear temperature coefficient of material specific resistivity in 1/K.

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 ± 2) °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:

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

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 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 ≤ 6 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

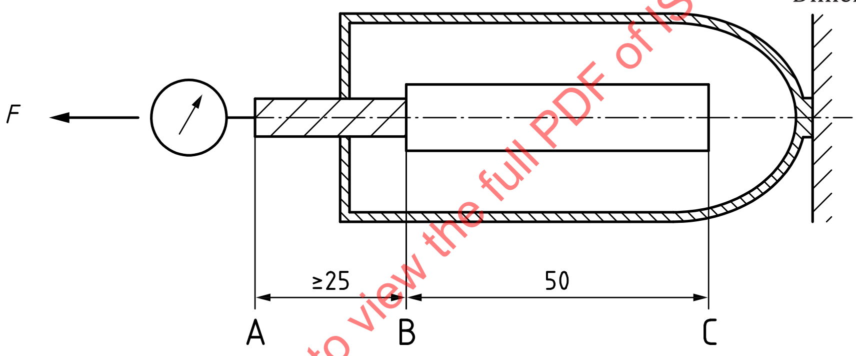
Prepare three test specimens of 100 mm from a cable test specimen 3 m in length. Take the test specimens at 1 m intervals. Cut at least 25 mm of insulation cleanly and strip it carefully from one end of the conductor (see Figure 2, length AB). Then, cut the test specimens leaving a (50 ± 1) mm section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

Dimension in millimetres



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 ≤ 6 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.

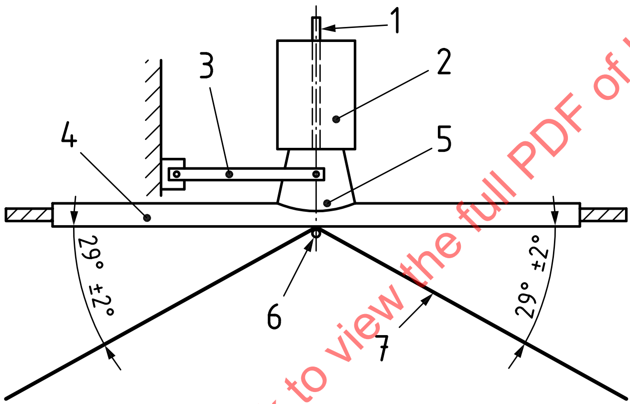
5.4.2.3 Test specimen

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 ± 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

5.4.2.5 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 ± 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;

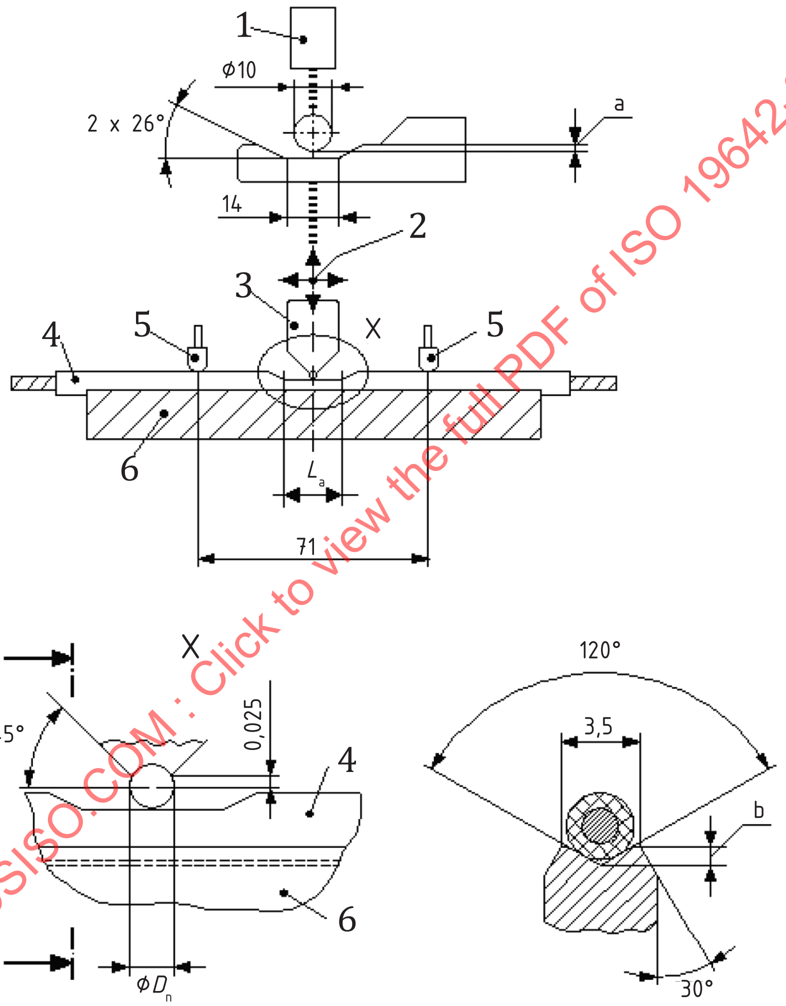
— length of abrasion: (15,5 ± 1) mm;

— 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
2 travel
3 needle holder
4 test specimen
5 clamp
6 test specimen holder

L_a abrasion length: (15,5 ± 1) mm
D_n needle diameter: (0,45 ± 0,01) mm
a Clearance during abrasion.
b Groove depth
0,4 mm, conductor size ≤ 0,35 mm^2
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

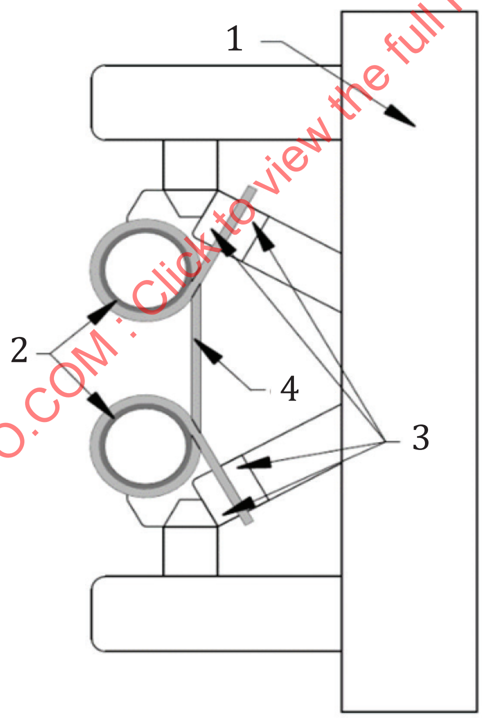
This test is applicable for wires ≤ 6 mm^2.

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 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

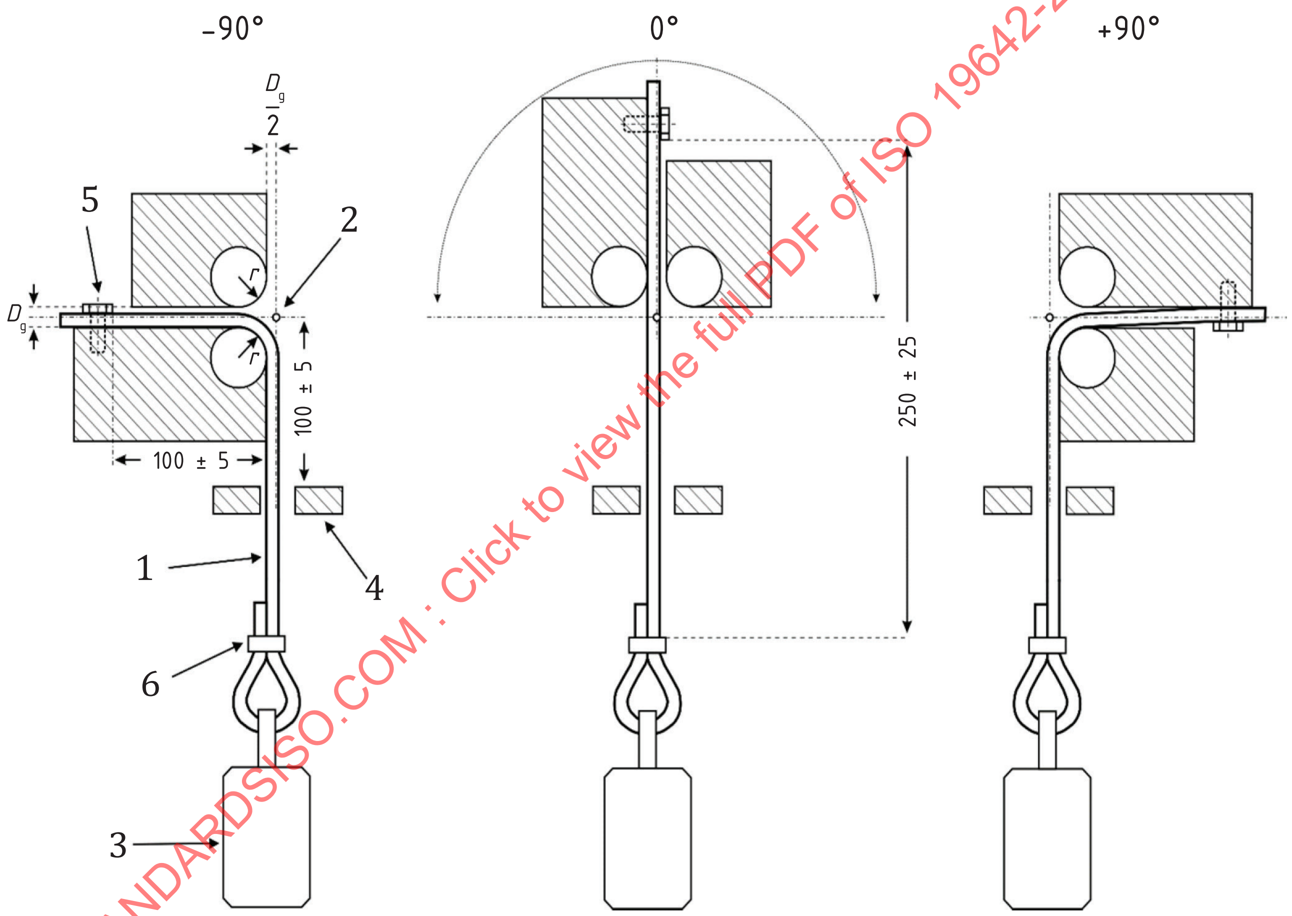
Cyclic bending test is performed to determine the number of bending cycles until the conductor breaks (fatigue resistance) in this defined dynamic condition.

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

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°

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: $D_g = (1{,}5 \times D) \pm 0{,}5$ 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 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.

5.4.5 Flexibility

5.4.5.1 General

Build information for this apparatus is found in Annex B.

5.4.5.2 Purpose

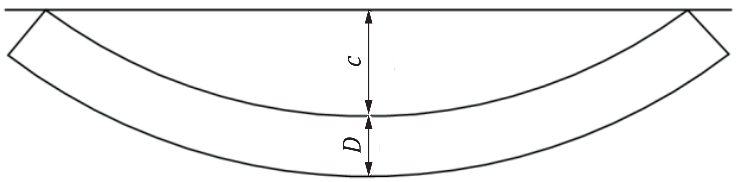
This test is intended to measure and quantify cable flexibility.

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

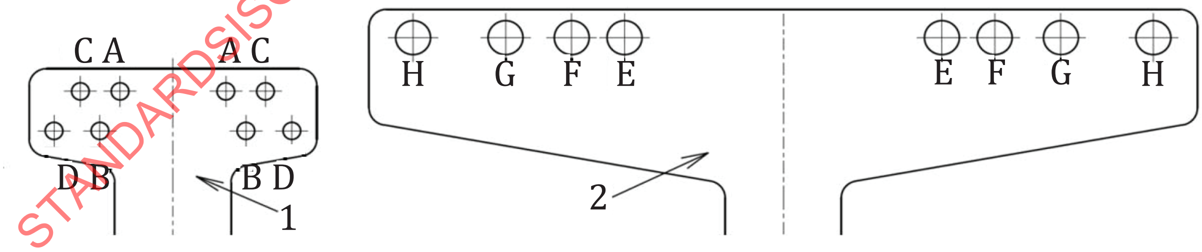
For multi-core cable, measure the maximum cable outside diameter as specified in 5.2.1. For single core cable, select pin position according to specified maximum cable outside diameter for the thick wall cable ISO conductor size under test. Refer to Table 4 and Figure 8 for the pin testing positions.

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



Key

1 small holder

2 big holder

A - H pin testing positions

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.

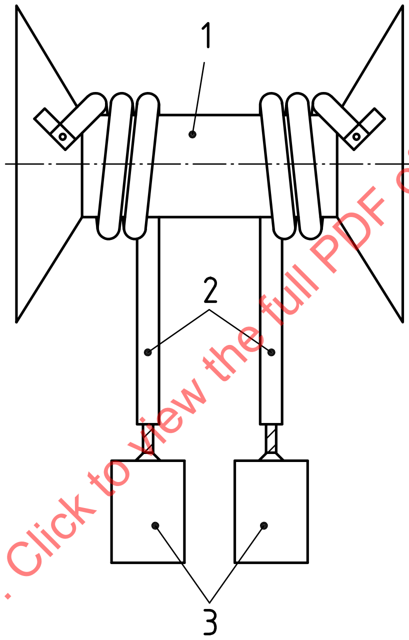
Wind the test specimen for at least the minimum number of turns around the mandrel within the freezing chamber and at winding speed as specified in Table 5. Ensure that there is continuous contact between the test specimens and the mandrel.

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) mm²	Mandrel diameter mm A	Mandrel diameter mm B	Mass kg	Winding speed s^{-1}	Minimum number of turns
a ≤ 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 ≤ 1,5			2,5		
1,5 < a ≤ 6			5		2
6 < a ≤ 10			8	0,5	0,5
10 < a ≤ 25			10		
25 < a ≤ 35			20		
35 < a			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 aging.

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.

5.5.3.2 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.

5.5.3.3 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.

5.5.3.4 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 5.5.1 using a mandrel size of Column A according to Table 5 at (−25 ± 2) °C.

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

5.5.4.1 Purpose

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

5.5.4.2 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.

5.5.4.3 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.

5.5.4.4 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 5.5.1 using a mandrel size of Column B according to Table 5 at RT.

5.5.5 Pressure test at high temperature

5.5.5.1 Purpose

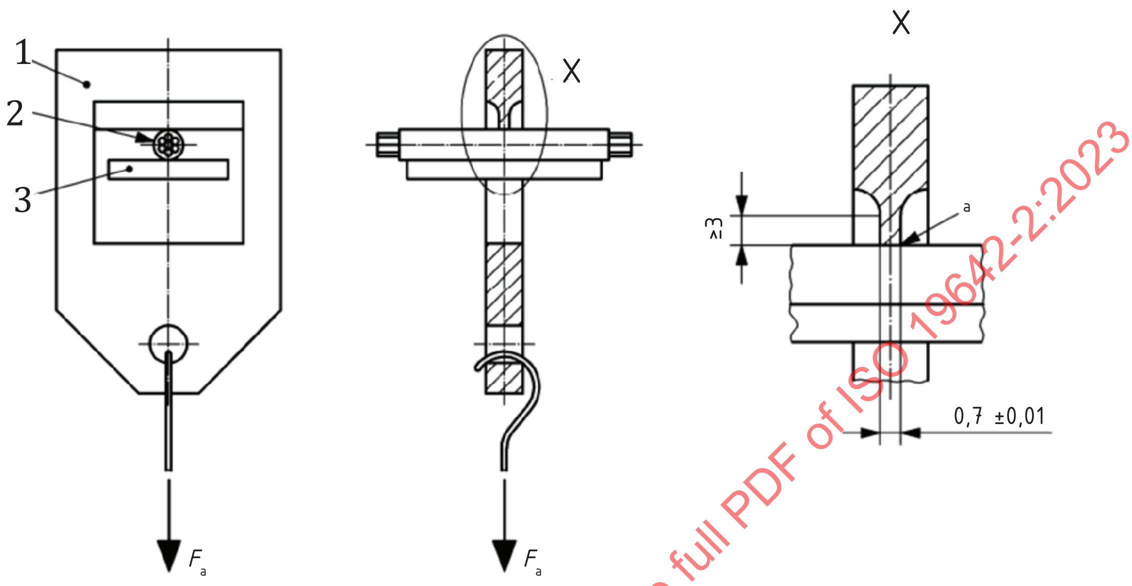
This test is intended to verify that the electrical integrity of the cable is maintained after thermal and mechanical stress.

5.5.5.2 Test specimens

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

5.5.5.3 Test

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

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 5.3.4.

5.5.6 Shrinkage by heat

5.5.6.1 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.

5.5.6.2 Test specimens

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

5.5.6.3 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.

5.5.7 Low temperature winding

5.5.7.1 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.

5.5.7.2 Test specimens

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

5.5.7.3 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.

5.5.8 Cold impact

5.5.8.1 Purpose

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

5.5.8.2 Test specimens

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

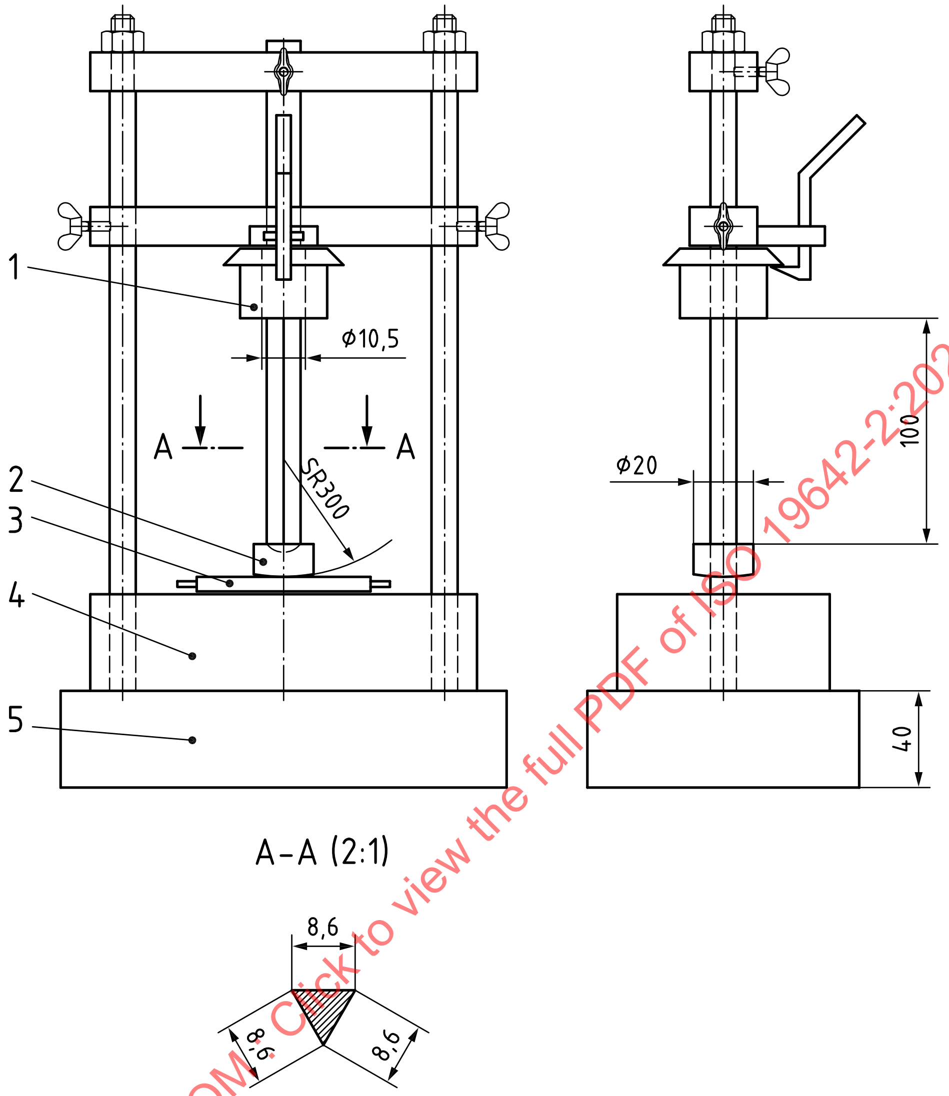
5.5.8.3 Test

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 5.3.4.

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

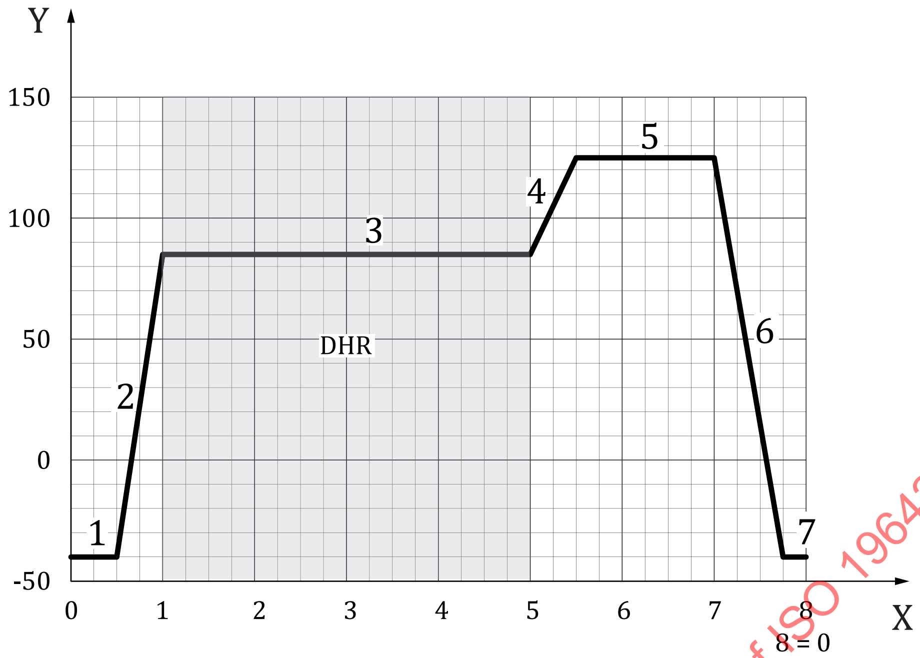
5.5.9 Temperature and humidity cycling

5.5.9.1 Purpose

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

5.5.9.2 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.

NOTE 3 Temperature class C used for example.

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.

5.5.9.3 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 and Table 7. 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 5.3.4.

5.5.10 Resistance to hot water

5.5.10.1 Purpose

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

5.5.10.2 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 5.3.1.

5.5.10.3 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 5.3.6. 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.

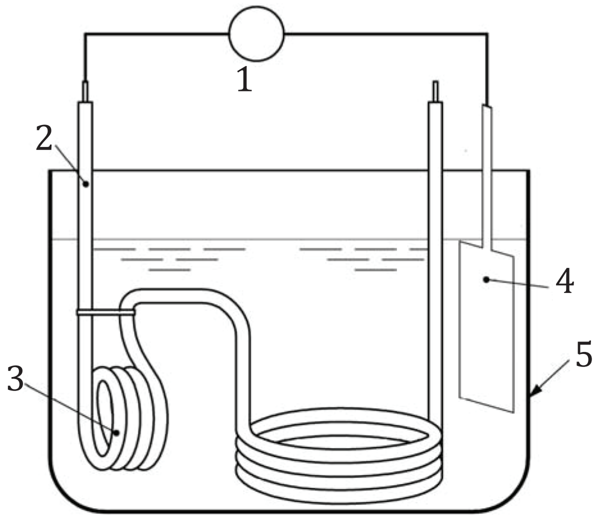
Closely wind at least three complete turns of a test specimen on the mandrel and secure the wraps as shown in Figure 13. After removing the mandrel, immerse the test specimen in the bath with both ends projecting 250 mm above the bath. To avoid interaction between materials, do not test specimens with 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 5.3.6. Make the following changes to the procedure in 5.3.6:

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 5.3.4.

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

5.5.11 Resistance to liquid chemicals

5.5.11.1 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 5.5.11.

5.5.11.2 Purpose

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

5.5.11.3 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 class temp.
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:—, A.2[a]	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 + 75 % H_2O with a combined gravity of (1,260 ± 0,005) g/cm^3 at 20 °C	2	

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

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

NOTE 3 For brake fluid, is it possible to use DOT 4 as agreed between customer and supplier.

[a] Eigth edition under preparation. Stage at the time of publication: ISO/DIS 1817:2023.

5.5.11.4 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.

5.5.11.5 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.

5.5.11.6 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 5.5.1 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 5.3.4.

5.5.12 Durability of cable marking

5.5.12.1 Purpose

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

5.5.12.2 Test specimens

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

5.5.12.3 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/cm^3 (dimensions 50 mm × 50 mm × 3 mm) and a vessel containing oil No. 2 as defined in ISO 1817, at (50 ± 3) °C.

5.5.12.4 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.

5.5.13 Stress cracking resistance

5.5.13.1 General

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

5.5.13.2 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.

5.5.13.3 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.

5.5.13.4 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.

5.5.13.5 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 six 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.

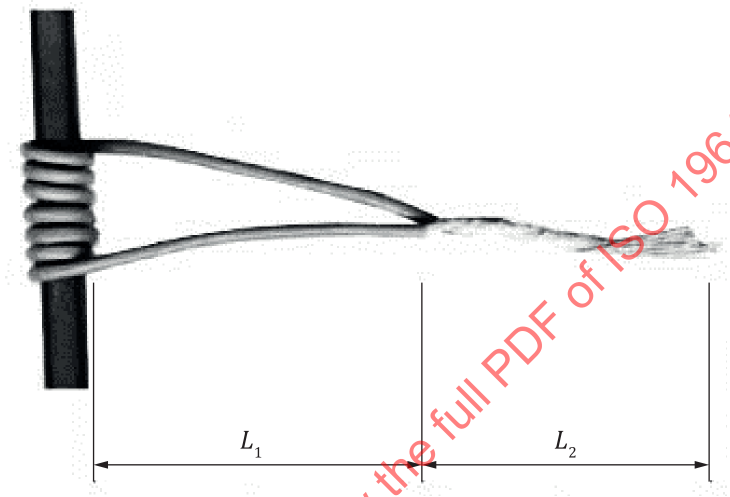


Figure 14 — Test specimen preparation for stress cracking

5.5.13.6 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.

5.5.13.7 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 5.3.4.

5.5.14 Resistance to ozone

5.5.14.1 Purpose

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

5.5.14.2 Test specimens

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

5.5.14.3 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 column A of Table 5 for the mandrel diameter. Aluminium mandrels are preferred since other materials can affect the ozone concentration.

5.5.14.4 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.

5.5.15 Resistance to flame propagation

5.5.15.1 General

The apparatus build information for this test shall follow Annex C.

5.5.15.2 Purpose

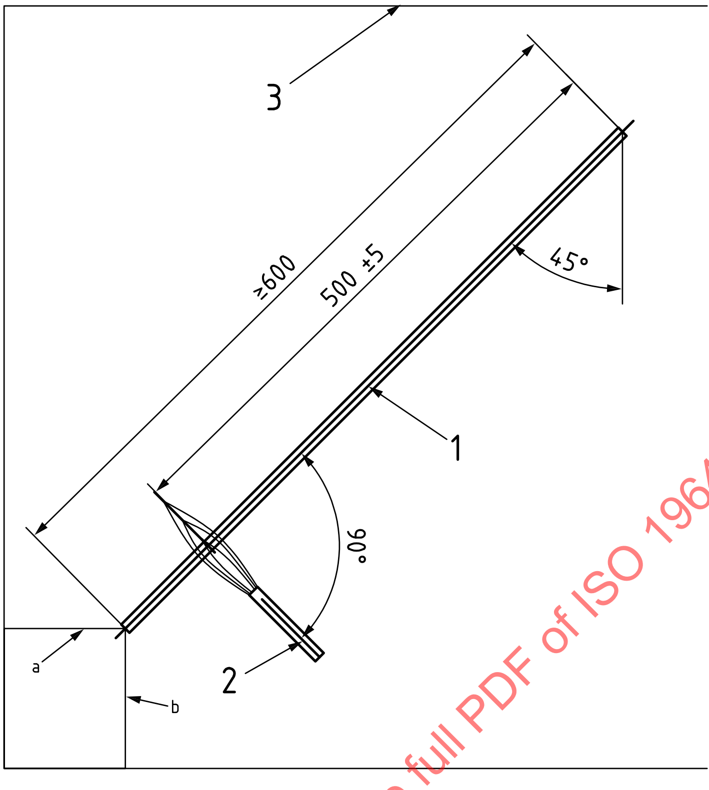
This test is intended to verify that a cable should not sustain combustion.

5.5.15.3 Test specimen

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

5.5.15.4 Test

Dimensions in millimetres



Key

1 test specimen
2 gas burner
3 metallic enclosure

a Cable lower end distance to metallic enclosure (130 mm ± 10 mm).
b Cable lower end hight (150 mm ± 10 mm).

Figure 15 — Test apparatus for resistance to flame propagation

Determine the resistance to flame propagation using a gas burner (e.g. Bunsen-or Teclu burner type) fed with appropriate gas, having a combustion tube of (8 – 9) mm internal diameter, where the flame temperature at the tip of the inner blue cone shall be (950 ± 50) °C. The preferred method for the verification of flame temperature shall use a type K thermocouple, 150 mm length and 1,5 mm diameter. The tip of the thermocouple shall be positioned on the tip of the inner blue cone.

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.

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 ≤ 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 and/or multi-conductor cables

6.1 General

This clause describes all tests required for sheathed and/or multi-conductor cables.

6.2 Dimensional tests

6.2.1 Cable outside diameter

6.2.1.1 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.

6.2.1.2 Test

Perform the test according to 5.2.1.

6.2.2 Ovality of sheath

6.2.2.1 Purpose

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

6.2.2.2 Test

Measure the maximum cable outside diameter, D, and the minimum cable outside diameter, D_{min}, according to 5.2.1. Then, calculate the ovality, O, using the formula:

$$O = \frac{(D_{max} - D_{min})}{0,5\,x\,(D_{max} + D_{min})} \times 100$$

where

O is the amount the sheath is "out of round" in %;

D_{max} is the maximum cable outside diameter in mm;

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

6.2.3 Thickness of sheath

6.2.3.1 Purpose

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

6.2.3.2 Test

Perform the test according to 5.2.2 in accordance with IEC 60811-202.

6.2.4 In-process cable outside diameter

6.2.4.1 Purpose

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

6.2.4.2 Test specimens

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

6.2.4.3 Test

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

6.2.5 Lay length

6.2.5.1 Cable element types

The lay length property applies to several cable element types. See the list below:

- unshielded twisted pair (UTP) or unshielded twisted quad (UTQ) cable;
- twisted core cable with other elements;
- carriers in a braid or carriers in a unidirectional helical screen;
- wrapped foil or foil screen;
- twisted cable core element in a sheathed cable.

6.2.5.2 Purpose

This test is intended to verify that lay length of the defined cable or cable element is within the required tolerances.

6.2.5.3 Test specimens

Minimum sample length: 10 m.

Take at least three test specimens with a minimum length of 1 200 mm from the whole length.

6.2.5.4 Test specimen preparation

Depending on the cable element to be assessed, carefully remove a minimum of five times the lay length of the sheath and any other cable element from the centre of the test specimen. The test specimen shall be subjected to a small longitudinal force to straighten the test specimen under test.

6.2.5.5 Test

Count the number of total lay lengths n_{LL} in each subsample. Measure the end to end length L_{EE} of all counted lay lengths.

$$L_L = \frac{L_{EE}}{n_{LL}}$$

where

L_L is the lay length of the cable or cable element, in mm;

L_{EE} is the end to end distance of all counted lay lengths, in mm;

n_{LL} is the number of counted lay lengths in the sample.

6.3 Electrical tests

6.3.1 Electrical continuity

6.3.1.1 Purpose

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

6.3.1.2 Test specimen

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

6.3.1.3 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.

6.3.2 Withstand voltage at final inspection

6.3.2.1 Purpose

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

6.3.2.2 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.

6.3.2.3 Test

Use a 50 Hz or 60 Hz AC or a DC 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.

6.3.3 Screening effectiveness

6.3.3.1 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.

6.3.3.2 DC resistance of the screen

6.3.3.2.1 Purpose

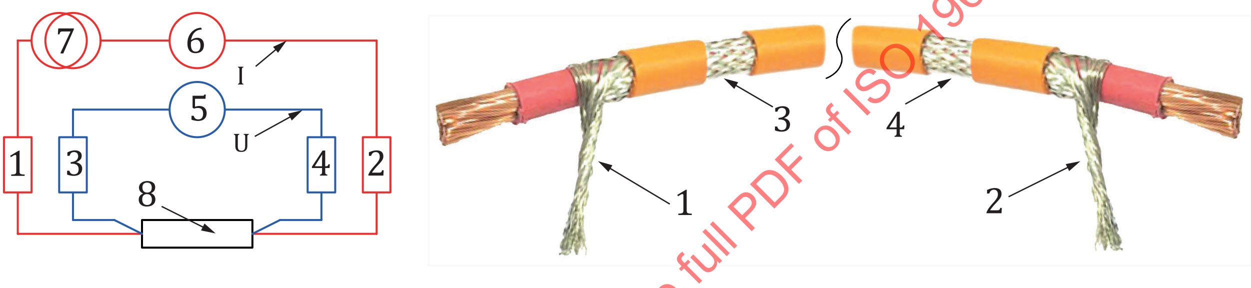
This test is intended to verify that the DC resistance of the screen does not exceed the maximum permitted value.

6.3.3.2.2 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.

6.3.3.2.3 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 and 5.3.2.4.



Key

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

NOTE The 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 (i.e. Kelvin measurement method)

The DC resistance of the screen is calculated with the following formula:

$$R_{\mathrm{L}} = \frac{U}{I}$$

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:

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

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.

6.3.3.3 Surface transfer impedance — Tri-axial method

6.3.3.3.1 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.

6.3.3.3.2 General

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

6.3.3.3.3 Test specimen

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

6.3.3.3.4 Test

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

6.3.3.4 Screening attenuation — Absorbing clamp method

6.3.3.4.1 Purpose

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

6.3.3.4.2 General

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

6.3.3.4.3 Test specimen

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

6.3.3.4.4 Test

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

6.3.3.5 Screening attenuation — Tri-axial method

6.3.3.5.1 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.

6.3.3.5.2 General

Allowable frequency ranges should be according to a_s, as specified in IEC 62153-4-4 or a measurement frequency range agreed between customer and supplier if required.

6.3.3.5.3 Test specimen

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

6.3.3.5.4 Test

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

6.3.3.6 Coupling attenuation — Tri-axial method

6.3.3.6.1 Purpose

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

6.3.3.6.2 General

Allowable frequency ranges should be according to a_c, as specified in IEC 62153-4-9.

6.3.3.6.3 Test specimen

Prepare the test specimen according to a_c, as specified in IEC 62153-4-9.

6.3.3.6.4 Test

Perform the test according to IEC 62153-4-9.

The use of a 4-port VNA instead of a 2-port VNA with baluns (transformers) is recommended.

6.3.4 Sheath fault on screened cables

6.3.4.1 Purpose

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

6.3.4.2 Test specimen

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

6.3.4.3 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.

6.3.5 General information on electrical test setups of unscreened balanced cables

Avoid influences of exogenous frequency sources on the cables under test have when testing low or high (RF) frequency cable parameters. This holds especially true for unscreened cables. In cables measured on a spool, the single turns influence each other electromagnetically too.

6.3.5.1 Test set ups for unscreened balanced cables

Use one of the four enumerated test setups below following the requirements of the test specification.

6.3.5.1.1 Test set up 1, on spool

Measure the cable under test on a spool.

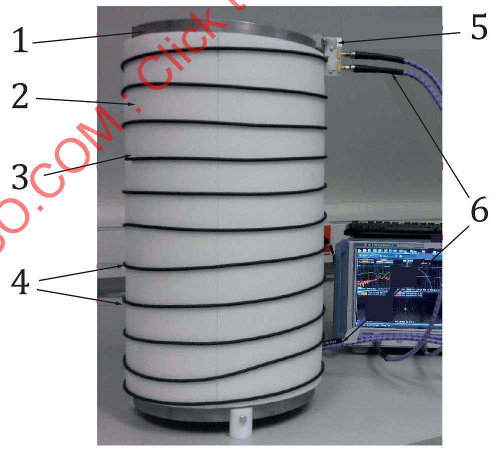
Add a warning "Measured on spool!" and document type and dimension of the spool in the test report.

6.3.5.1.2 Test set up 2, on floor

Measure the cable under test laid out straight on a nonconductive surface. No conductive elements shall be inside a distance of 1,5 m to the cable.

Add a warning "Measured on floor!" in the test report.

6.3.5.1.3 Test set up 3, on metallic drum



Key

1 metallic drum

2 insulation

3 cable under test

4 Inter-winding distance, $L_{i,min}$

5 test fixture

6 coaxial cable to VNA

Figure 17 — Test set up 3 on metallic drum

Loosely wind the cable under test on a metallic drum with an isolation wall thickness w_i = 10 mm on the drum outside.

The dielectric constant ε_r of the used drum insulation material shall be $\varepsilon_r \leq 1,4$.

A loose winding of the cable under test is required to avoid a mechanical impact to the cable during the test at low and high temperatures.

Separate each winding by a minimum of $L_{i,min}$ which will eliminate inter-winding self-coupling for unscreened cables. Calculate the distance of windings at the drum arrangement $L_{i,min}$ as follows:

$$L_{i,min} \geq 3 \times w_i$$

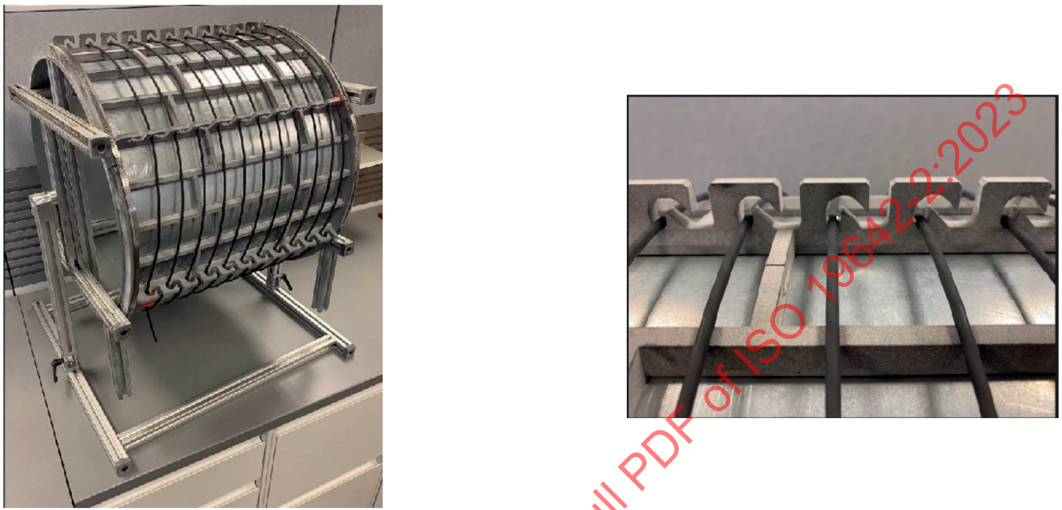


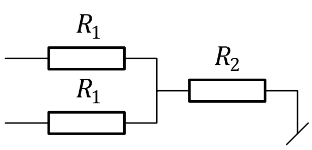
Figure 18 — Test set up 3 on metallic drum, alternative

Ensure low impedance ground reference connections of the used test fixture and the metallic drum with the measurement equipment. Connect the drum ground reference on both ends of the drum.

Measure the cable under test on the test set up 3 according to Figure 17 or Figure 18.

During measurement all pairs of the cable have to be matched to the characteristic impedances (differential mode CIDM and common mode CICM). CIDM is (100 ± 1) Ω and shall be matched in any case by physical impedances. The mean common mode impedance CICM of the defined test setup is (200 ± 2) Ω and shall be validated by a TDR measurement. It should be matched using the internal common mode correction function of the VNA or using an external matching circuit for the measured pair as shown in Figure 19. In case of multi-pair cables, the other non-measured pair(s) should be terminated using a matching circuit as shown in Figure 19 also.

NOTE For Ethernet CIDM = (100 ± 1) Ω and CICM = (200 ± 2) Ω are valid, but other values can apply for different systems.



Key

R_1 = CIDM / 2

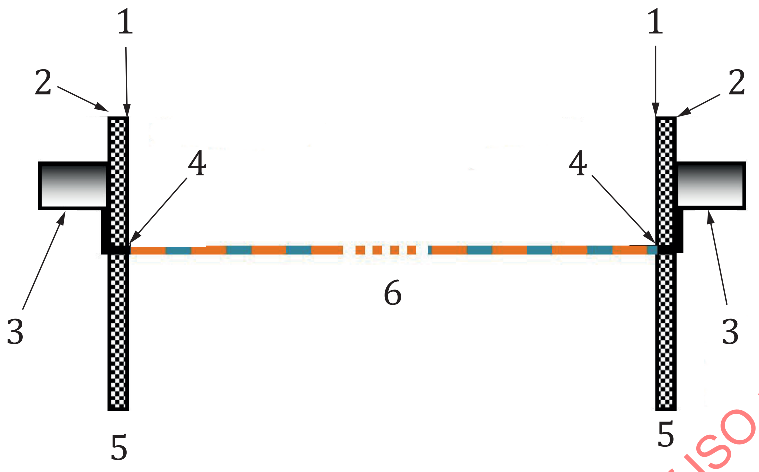
R_2 = CICM – CIDM / 4

Figure 19 — Resistor values for termination network

For UTP and JUTP cables use a test fixture according to Figure 20 or equivalent.

The used test fixture shall have low insertion loss, high symmetry between the two different lines of a pair and very good matching to 50 Ω common mode impedance CICM.

For the evaluation of cable RF parameters reference planes are defined at the end of the cable under test at the connection point of the cable with the test fixture.



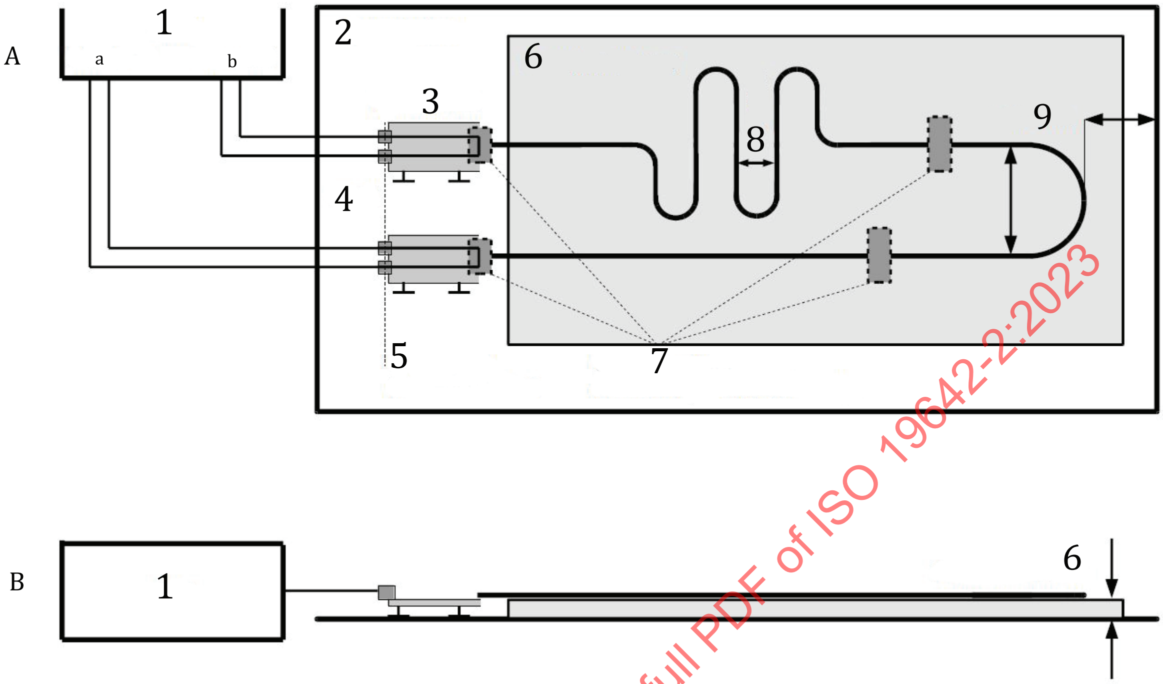
Key

1 calibration reference plane
2 printed circuit board (PCB)
3 RF connector (SMA type)
4 direct soldering of cable ends
5 test fixtures
6 cable under test (CUT)

Figure 20 — Test fixture

Document "Measured according test set up 3, on drum!" in the test report.

6.3.5.1.4 Test set up 4, on conducting ground plane



Key

A top view
B side view
1 vector network analyser (VNA)
2 ground plane
3 test fixtures
4 coaxial cables
5 calibration reference plane
6 insulating plane with 10 mm thickness
7 connectors (for channel measurement only)
8 ≥ 30 mm
9 ≥ 30 mm

Figure 21 — Measurement setup using conducting ground plane

Lay the cable under test flat on a test setup according to Figure 21. It consists of a planar metallic surface with an isolation wall thickness w_i = 10 mm on the upper side. The dielectric constant ε_r of the used insulation material shall be $\varepsilon_r \leq 1{,}4$. Avoid sharp bends in the cable under test and make sure that each part of the cable is separated to any other part of itself by a minimum of $L_{i,min}$ which will eliminate inter-cable self-coupling for unscreened cables.

Calculate the distance between each part of the cable to itself $L_{i,min}$ as follows:

$$L_{i,min} \geq 3 \times w_i$$

Ensure low impedance ground reference connections of the used test fixture and the planar metallic surface with the measurement equipment. Connect the planar metallic surface ground reference at least on two opposing ends of the planar metallic surface. Use an appropriate test fixture for connecting the cables under test to the VNA. A test fixture of test set up 3 is recommended.

Document “Measured according test set up 4, on planar metallic surface!” in the test report.

6.3.5.1.5 Test set up 5, on dielectric drum

Measure the device under test (DUT) wound around a drum made from dielectric material according to Figure 22 and the further explanations below.

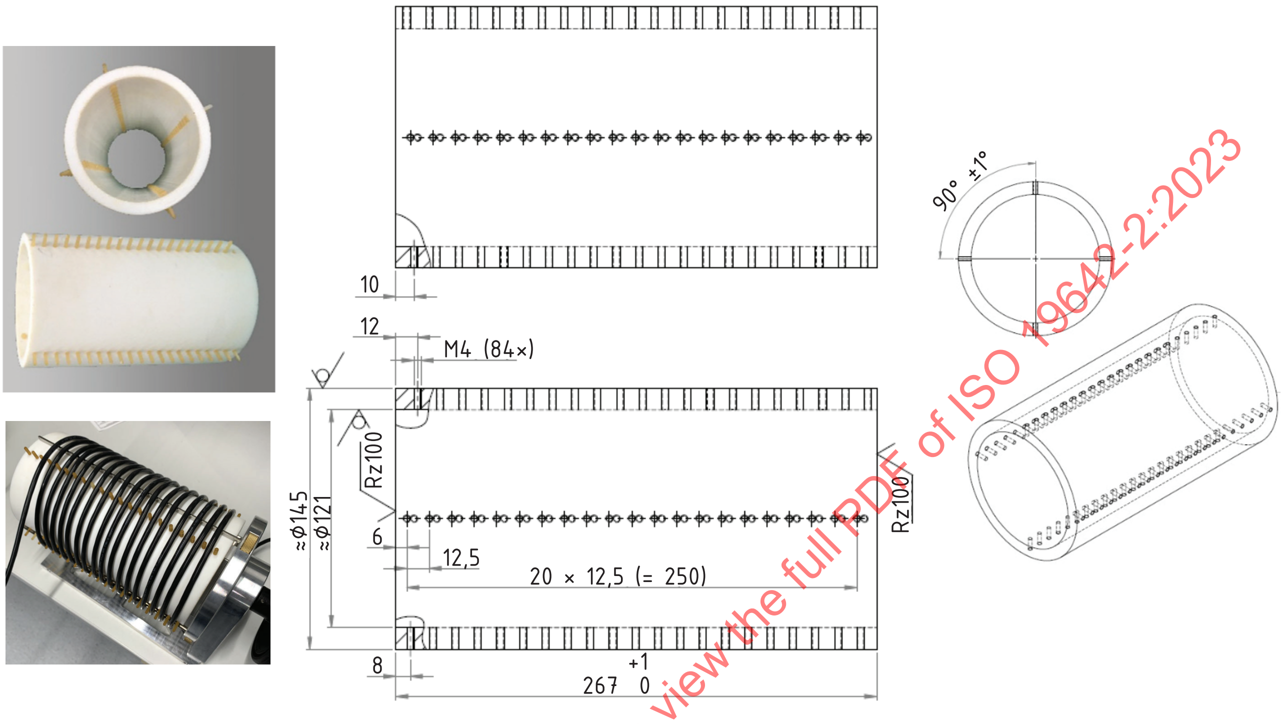


Figure 22 — Dielectric drum

Further explanations:

The drum is built using a nonconductive dielectric material, e.g. PTFE or PVDF. Additionally, it is fitted with hexagonal screws (according to ISO 4017 – M4 * 25 PVDF, colour neutral) also made from nonconductive material used as spacers between the cable loops. The screws are inserted into the drum from the inside. An additional bar, positioned parallel to one of the screw line ups, with round shape (diameter 10 mm) is used on the outside of the drum when winding the DUT on the drum. This bar is removed after winding. Its additional space compensates for thermal expansion of drum and DUT in the oven.

6.3.6 General information on low frequency electrical tests

If not otherwise defined low frequency tests are performed at RT at a frequency of 1 kHz.

Other test measurement frequencies, f, in the range $400\,\text{Hz} \le f \le 1\,500\,\text{Hz}$ are permissible by agreement between customer and supplier. The used measurement frequency and the temperature is to be documented in the test report.

These prescriptions apply to tests 6.3.7, 6.3.8 and 6.3.9.

6.3.7 Resistance unbalance

The resistance unbalance R_{ub} is the difference value in percent of two conductors in a balanced pair.

The resistance of each conductor in the pair shall be measured according to 5.3.1.

The resistance unbalance between conductors of a pair or in the same diagonal of a quad is

$$R_{ub} = \frac{R_{max} - R_{min}}{R_{max} + R_{min}} \times 200$$

Where

R_{ub} is the resistance unbalance in %;

R_{max} is the resistance in Ω of the conductor with the higher resistance value;

R_{min} is the resistance in Ω of the conductor with the lower resistance value.

6.3.8 Capacitance

6.3.8.1 General information

Tests on dielectric materials well known in regard to their dielectric behaviour at different temperatures shall be performed at room temperature. Some dielectric materials, for example PVC, are known for a big influence of temperature on the relative dielectric constant.

6.3.8.2 Samples

The tests are performed on a minimum of three samples.

The length of the samples shall be ≥10 m and shall be documented in the test report.

6.3.8.3 Mutual capacitance

6.3.8.3.1 Unbalanced cables

Perform the test at room temperature according to IEC 61196-1-103 using the definitions in IEC 61196-1 and the general requirements in IEC 61196-1-100.

6.3.8.3.2 Balanced cables

For screened cables, no special test setup is needed.

For unscreened cables use test set up 2, 3 or 4 according to 6.3.5.1.

Perform the test for mutual capacitance at room temperature according to IEC 61156-1.

6.3.8.3.2.1 Report

Calculate capacitance value in pF/m and document the minimum, maximum and mean values in the test report.

6.3.8.4 Bus Capacitance

This test is only applicable for balanced cables.

For screened cables, no special test setup is needed.

For unscreened cables use test set up 2, 3 or 4 according to 6.3.5.1.

Perform the test at room temperature according to ISO 4141-1.

Calculate the bus capacitance value in pF/m and document the minimum, maximum and mean values in the test report.

6.3.8.5 Capacitance unbalance to earth

This test is only applicable for balanced cables.

Perform the test at room temperature according to EN 50289-1-5 using the general requirements in EN 50289-1-1.

Calculate the capacitance unbalance to earth in pF/m and document the minimum, maximum and mean values in the test report.

6.3.9 Inductance

6.3.9.1 Samples

The test is performed on a minimum of three samples.

The length of the samples shall be ≥ 10 m and shall be documented in the test report.

6.3.9.1.1 Unbalanced cables

Perform the test at room temperature according to IEC 61196-1-114 using the definitions in IEC 61196-1 and the general requirements in IEC 61196-1-100.

6.3.9.1.2 Balanced cables

For screened cables, no special test setup is needed.

For unscreened cables use test set up 2, 3 or 4 according to 6.3.5.1.

Perform the test for inductance at room temperature according to EN 50289-1-12 using the general requirements in EN 50289-1-1.

6.3.9.2 Report

Calculate the inductance in µH/m and document the minimum, maximum and mean values in the test report.

6.3.10 General information on high radio frequency (RF) electrical tests

The tests are performed on a minimum three samples.

If not otherwise stated the length of the samples shall be 10 m and have to be documented in the test report.

The tests shall be performed with matching connectors or with a suitable adapter with the same characteristic impedance as the specimen under test. The tolerance of the characteristic impedance of the connectors / adapters shall be better than ±2 % of the nominal characteristic system impedance.

To eliminate the influence of the connecting hardware gating (see 6.3.10.4) and de-embedding (see 6.3.10.5) techniques are encouraged if agreed between customer and supplier. In this case a remark shall be made in the test report.

6.3.10.1 RF tests in frequency domain

6.3.10.2 General

For the measurements in the frequency domain an appropriate VNA (vector network analyzer) shall be used.

For the measurements in the time domain an appropriate TDR (time domain reflectometer) or a VNA with an TDR option shall be used.

The impedance of the VNA shall match the impedance of the specimen under test. If the impedance of VNA and specimen under test differs, an impedance matching network or balun shall be used.

For unbalanced cables the measurement is performed with an unsymmetrical stimulus generated directly by the VNA.

For balanced cables the needed symmetrical stimuluses are generated using a 4-port VNA with mixed mode S-parameter capability.

For lower frequency application with a maximum of 1 GHz a VNA with suitable baluns (transformers) may be used.

The VNA or TDR shall be switched on ≥1 h before the measurements to ensure a uniform temperature distribution in the apparatus.

Then the VNA or TDR shall be calibrated according to the vendor specified calibration procedure of the measurement system.

The following information shall be documented in the test report:

— type of VNA;

— type of TDR;

— type of calibration standards;

— type of the calibration procedure;

— temperature of VNA;

— temperature of specimen under test;

— type of baluns or impedance matching circuitry, if any;

— type of-connector or adapter used (if needed RF parameters of adapter shall be documented);

— file name of related Touchstone® files (s2p) for 2 port VNA's or (s4p) for 4 port VNA's the actual files shall be made available on request.

6.3.10.3 Sweep parameters

Minimum frequency:	according to the requirement in the relevant part of this document.
Maximum frequency:	according to the requirement in the relevant part of this document.
Number of frequency points:	according to requirements but ≥1 000.
Type of frequency sweep:	logarithmic (preferred) or linear.

6.3.10.4 Gating procedure

To reduce the influence of connectors on the RF measurement test results especially for 6.3.15 the use of the gating techniques is recommended.

When the use of gating has been agreed between customer and supplier use the gating times defined in 6.3.10.4.2.

Document the use of gating and the used gating times in the test report.

6.3.10.4.1 Description of gating procedure

Using fast Fourier transform (FFT) technology frequency domain (F) measurement data are converted to time domain (T) and thus location points [m] in the device under test.

Measurement data in the connector and connecting hardware location section are removed from the data set in time domain (T).

Using inverse FFT the corrected frequency domain (F) data is obtained.

6.3.10.4.2 Determination of gating times

To obtain the needed gating times, in [ns], follow the measurement and calculation steps below:

Step 1: measure the phase velocity of propagation $v_{p\%}$ or v_{pm} of the device under test according to 6.3.11.2.

Step 2: measure the length L_{Cab} of the cable under test and the distance L_{Con} of the connectors from the cable end

Step 3: calculate the time delay t_r of the reflected wave on 1 m of cable

$$t_r = \frac{2\times10^9}{v_{pm}}$$

or

$$t_r = \frac{10^4}{15\times v_{p\%}}$$

where

t_r is the time delay of the reflected wave in ns;

v_{pm} is the phase velocity of propagation in m/s;

$v_{p\%}$ is the phase velocity of propagation in % of velocity of light in vacuum, $c_0 \approx 3\times10^8 \frac{m}{s}$.

Step 4: calculate gating times in ns

$$t_{G1} = L_{Con} \times t_r$$

$$t_{G2} = (L_{Cab} - L_{Con}) \times t_r$$

where

L_{Cab} is the length of cable sample under test in m;

L_{Con} is the distance of connectors from cable end in m;

t_{G1}, t_{G2} are the gating times for cable end 1 and 2 in ns.

Example:

Input: $v_{p\%} = 78{,}4\,\%$ of c_0 alternatively $v_{pm} = 2{,}35\times10^8 \frac{m}{s}$, $L_{Cab} = 10\,m$, $L_{Con} = 0{,}5\,m$

Output: $t_{G1} = 4{,}25\,ns$, $t_{G2} = 80{,}75\,ns$

6.3.10.5 De-embedding

When the use of de-embedding has been agreed between customer and supplier use the following de-embedding procedure for all subsequent frequency domain RF parameter measurements.

a) During the calibration procedure all required frequency domain (F) RF parameters of used connectors and connecting hardware shall be measured at each frequency point with a short in place of the cable under test. The measured data is stored for further calculations.

b) Use the calibrated connectors and connecting hardware for all required frequency domain (F) RF measurements on the cable under test.

c) After measuring the required frequency domain (F) RF parameters of the cables under test the stored data from a) are subtracted at each frequency point to get the corrected measurement data for the cable under test only.

d) Document the use of de-embedding in the test report.

6.3.10.6 RF tests at additional temperatures other than RT

For the measurement at -40 °C or at temperature class rating place the test sample into the oven or climate chamber. The cable ends are then fed through the pass-through hole of the oven or climate chamber to the outside and connected to the measuring device. The length of the cable ends that protrude from the oven or climate chamber shall not exceed a maximum length of 500 mm. Store the samples for at least 4 h at the required test temperature. Then perform the RF measurements.

6.3.11 Velocity of propagation

6.3.11.1 General

6.3.11.1.1 Unbalanced cables

Perform the test using an unsymmetrical stimulus.

Perform the tests for phase propagation velocity v_p and phase constant β at room temperature according to IEC 61196-1-108 using the definitions in IEC 61196-1 and the general requirements in IEC 61196-1-100.

6.3.11.1.2 Balanced cables

For screened cables, no special test setup is needed.

For unscreened cables use test set up 2, 3 or 4 according to 6.3.5.1.

Perform the test using a symmetrical stimulus.

Perform the tests for phase velocity propagation v_p and phase coefficient β at room temperature according to IEC TR 61156-1-2.

6.3.11.2 Phase velocity $v_p(f)$ of propagation

For screened cables, no special test setup is needed.

For unscreened cables use test set up 2, 3 or 4 according to 6.3.5.1.

Document the test set up and the result $v_p(f)$ in form of a table and a diagram.

6.3.11.3 Group velocity $v_g(f)$ of propagation

Calculate the group velocity $v_g(f)$ using the following formulae:

$$v_g(f) = 2 \times \pi \times \frac{df}{d\beta} \approx 2 \times \pi \times \frac{\Delta f}{\Delta \beta} = 2 \times \pi \times \frac{f_1 - f_2}{\beta_1 - \beta_2}$$

where

v_g is the group velocity of propagation in m/s;

f is the frequency in Hz;

f_1 is the frequency 1 for calculation of group velocity;

f_2 is the frequency 2 for calculation of group velocity; $f_2 > f_1$

β is the phase constant in radians/m;

β_1 is the phase constant at frequency f_1;

β_2 is the phase constant at frequency f_2.

Document v_g, β_1, β_2, f_1, f_2 in the test report.

6.3.11.4 Inter-pair skew

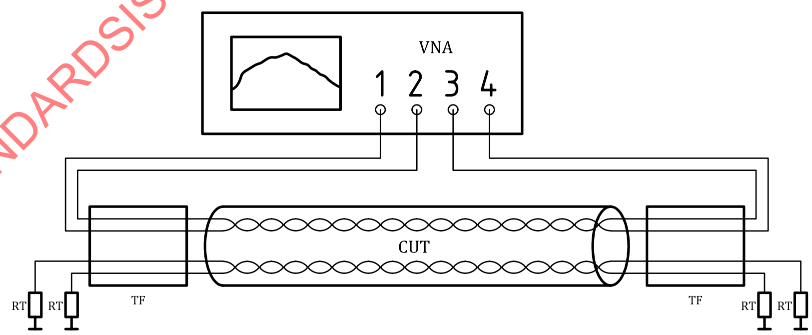
This test is only applicable to balanced cables with more than one pair or quad cables.

Perform the test of phase velocity $v_p(f)$ according 6.3.11.2 for each pair. Calculate the difference of $v_p(f)$ for each corresponding pair at each frequency point and document the result in a diagram over frequency f.

6.3.11.5 In-pair skew

This test is only applicable to balanced cables with more than one pair or quad cables and a specified analogue bandwidth ≥ 300 MHz.

Use a test set up according to Figure 23.



Key

VNA	4 port vector network analyser	TF	test fixture
CUT	cable under test	RT	termination resistor
1, 2, 3, 4	ports 1 to 4		

Figure 23 — Test set up in-pair skew

If needed use test fixtures according to 6.3.5.1. Unused cores in each pair are terminated on both ends by a resistor with half the nominal differential impedance, Z.

Port 1 and 2 are used as a transmitter, port 3 and 4 are used as a receiver (R_e). For the assessed pair the following complex single-ended s-parameters are measured over the whole frequency range:

$\overline{s_{31}}(f)=R_e\left\{\overline{s_{31}}(f)\right\}+j\cdot Z\left\{\overline{s_{31}}(f)\right\}$, transmission from port 1 to port 3

$\overline{s_{32}}(f)=R_e\left\{\overline{s_{32}}(f)\right\}+j\cdot Z\left\{\overline{s_{32}}(f)\right\}$, transmission from port 2 to port 3

$\overline{s_{41}}(f)=R_e\left\{\overline{s_{41}}(f)\right\}+j\cdot Z\left\{\overline{s_{41}}(f)\right\}$, transmission from port 1 to port 4

$\overline{s_{42}}(f)=R_e\left\{\overline{s_{42}}(f)\right\}+j\cdot Z\left\{\overline{s_{42}}(f)\right\}$, transmission from port 2 to port 4

NOTE Complex numbers are denoted by the over score "¯" sign.

On the receiving ports 3 and 4 the measured complex s-parameters are super positioned. The 180° signal phase difference between the cores in differential transmission mode is taken into account by subtracting the measured complex values according to the following formulae:

$$\overline{P_3}(f)=\overline{s_{32}}-\overline{s_{31}}$$

$$\overline{P_4}(f)=\overline{s_{41}}-\overline{s_{42}}$$

For both ports 3 and 4 the phase information Φ_P of the super positioned s-parameters shall be evaluated as expanded phase as defined in IEC TR 61156-1-2:2009+AMD1 :2014, 5.4.3:

$\Phi_{P3}=\angle\left[\overline{P_3}(f)\right]$, in [°]

$\Phi_{P4}=\angle\left[\overline{P_4}(f)\right]$, in [°]

The transition time t_{delay} of the signals on the ports is:

$t_{d,P3}(f)=\dfrac{\Phi_{P3}\{f\}}{360°\cdot f}$, in [s]

$t_{d,P4}(f)=\dfrac{\Phi_{P4}\{f\}}{360°\cdot f}$, in [s]

The in-pair skew $t_{ip}(f)$ is calculated from the absolute value of the difference:

$t_{ip}(f)=\left|t_{d,P3}(f)-t_{d,P4}(f)\right|$, in [s].

The in-pair (intra-pair) skew **cannot** be scaled to length. A recalculation to [s/m] is **not** permissible.

Document the in-pair skew $t_{ip}(f)$ in a diagram over frequency f. The unit of the Y-axis shall be [ps] and the unit of the X-axis shall be [Mhz] starting with 300 MHz.

6.3.11.6 Propagation delay

6.3.11.6.1 Purpose

This test is intended to determine the cable propagation delay per meter.

6.3.11.6.2 Test specimen

Prepare a test specimen of 10 m in length.

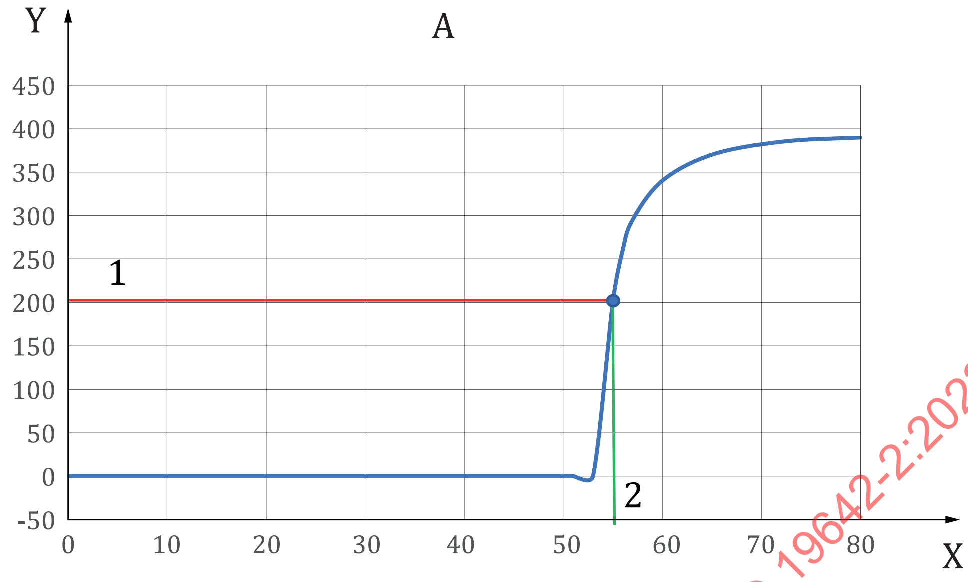
6.3.11.6.3 Test method

Use a measuring device with a time domain analysis function (either a time domain reflectometer TDR with time domain transfer (TDT) function or a vector network analyser VNA with a time domain analysis function). Place a specimen of 10 m length on a test setup according to either Figure 17 or Figure 21. For screened RF cables no special test setup is needed. Connect the measuring device to the test setup using the defined test fixtures. Measure the propagation delay using TDT function of the measuring device (stimulus input on near end, measurement on far end). If not otherwise specified use the measurement system setup parameters according to Table 9.

Perform a calibration of the test setup input including the determination of the propagation delay of the connecting hardware. Insert the specimen under test and determine the time at which the amplitude of the signal passed through the test specimen has risen to 50 % of the full amplitude of the applied rectangular wave according to Figure 24.

Table 9 — Recommended VNA or TDR settings

Parameter	UTP, JUTP	STP	Coax
Rise time, max. or depending on protocol	500 ps	500 ps	500 ps
Rise time range	10 % – 90 %	10 % – 90 %	10 % – 90 %
Stimulus	differential mode	differential mode	common mode
Amplitude of stimulus, nom.	400 mV	400 mV	200 mV
Measurement bandwidth, for VNA measurement	1 kHz	1 kHz	1 kHz
Logic port impedance differential mode, nom.	100 Ω	100 Ω	
Logic port impedance common mode, nom.	200 Ω		50 Ω



Key

X Time, *t*, [ns]

Y voltage, *U*, [mV]

1 test voltage fixed to 200 mV

2 t_t transmission time in [ns]

A voltage *U*(*t*)

Figure 24 — Delay time readout

Correct the measured transmission time t_t by subtracting the propagation delay values of the connecting hardware obtained during calibration. The value in [ns/m] calculated from the measured and corrected transmission time divided by 10 m shall be the propagation delay per 1 meter.

6.3.11.6.4 Documentation of results

Document the following parameters in the test report:

— used test setup;

— type of measurement system;

— type of calibration standards, if any;

— type of the calibration procedure, if any;

— propagation delay correction value for connecting hardware;

— temperature of measurement system;

— temperature of specimen under test;

— type of baluns (transformers) or impedance matching circuitry, if any;

— type of-connector or adapter used (if needed RF parameters of adapter shall be documented);

— obtained measurement result.

6.3.12 Characteristic impedance in frequency domain (CIF)

6.3.12.1 Samples

The test is performed on a minimum of three samples.

The length of the samples shall be ≥ 10 m and shall be documented in the test report.

6.3.12.2 Unbalanced cables (CICMF)

Measure the mutual capacitance between inner conductor and screen at 1 kHz according 6.3.8.3.

Measure the velocity of phase propagation for common mode transmission according 6.3.10.4 using an unsymmetrical stimulus.

6.3.12.3 Balanced cables (CIDMF)

For screened cables, no special test setup is needed.

For unscreened cables use test set up 2, 3 or 4 according to 6.3.5.1.

Measure the mutual capacitance between the two cores in a pair respectively the two cores in the diagonal of a quad at 1 kHz according 6.3.8.3.

Measure the velocity of phase propagation for differential mode transmission according 6.3.10.4 using a symmetrical stimulus.

6.3.12.4 Calculation

Calculate the characteristic impedance for every frequency point according to the following formula:

$$Z_c(f) = \frac{10^{-12}}{v_p(f) \times C'}$$

where

$Z_c(f)$	is the characteristic impedance in Ω;
f	is the frequency in MHz;
$v_p(f)$	is the phase velocity in m/s;
C'	is the mutual capacitance in pF/m.

Document the result in a diagram $Z_c(f)$.

6.3.13 Characteristic impedance in time domain (CIT)

6.3.13.1 Unbalanced cables (CICMT)

Perform the test according to IEC 61196-1-116 for common mode transmission using an unsymmetrical stimulus.

6.3.13.2 Balanced cables (CIDMT)

For screened cables, no special test setup is needed.

For unscreened cables use test set up 2, 3 or 4 according to 6.3.5.1.

Perform the test for differential mode transmission using a symmetrical stimulus.

6.3.13.3 Test

For the determination of the impedance in relation to the position in the cable a TDR (time domain reflectometer) is to be used. It measures the impedance at a certain location in the cable at the maximum available frequency range of the used test equipment. But it does not give information on the behavior of the impedance at other frequency points.

Example for the use of this test: When performing bending tests measurements with this method give information on a change of the impedance at the bending point thus indicating possible degradation.

The impulse rise time t_r of the TDR shall be adjustable.

The length of the leading slope of the test signal shall be $t_r \leq t_{r,max}$.

$$t_{r,\,max} = \frac{0{,}35}{f_{max}}$$

where

t_r is the impulse rise time of the TDR;

$t_{r,\,max}$ is the maximum permissible impulse rise time of the TDR;

f_{max} is the maximum available frequency range of the used test equipment.

EXAMPLE For a 6 GHz system the maximum permissible impulse rise time is 58 ps.

The TDR shall be switched on ≥ 1 h before the measurements to ensure a uniform temperature distribution in the apparatus. Then the TDR is to be calibrated according to the vendor specified calibration procedure of the measurement system.

The near end of the cable under test is connected in a suitable form to the TDR. The used connecting cables shall have a low attenuation and have the same impedance as the TDR.

The far end of the cable under test stays open.

Using a constant factor k (typical proportional to $1/\sqrt{\varepsilon_r}$) the time-axis can be converted to a length-axis (length scale of the cable under test). Thus, the impedance in relation to the position in the cable can be obtained. By iteration with different cable lengths the factor k can be determined, if needed.

Remark: With bigger distance from the test equipment and / or measurement head and higher attenuation values of the cables the obtained impedance value increases. This increase is relatively small when using short low attenuation connecting cables and commonly used cables under test (max 2,0 m). Nevertheless, the impedance should not be treated as an absolute value but the change of the impedance before and after stress is the discriminating factor.

The following information is to be documented in the test report:

— type of TDR;

— temperature of TDR;

— rise time;

— temperature of specimen under test;

— type of connector or adapter used;

— travel time(s) / position(s) of the interesting point(s) in ns / mm from input point;

— impedance at the point(s) of interest:

  — in new state;

  — after stress;

  — change calculated in percentage.

6.3.14 Insertion loss, (IL)

6.3.14.1 Unbalanced cables, (ILCM)

Perform the test for common mode transmission using an unsymmetrical stimulus.

Perform the tests for attenuation constant at room temperature according to IEC 61196-1-113 using the definitions in IEC 61196-1 and the general requirements in IEC 61196-1-100.

6.3.14.2 Balanced cables, (ILDM)

For screened cables, no special test setup is needed.

For unscreened cables use test set up 2, 3 or 4 according to 6.3.5.1.

Perform the test for differential mode transmission using a symmetrical stimulus.

Perform the tests for insertion loss IL at RT using a 4-port VNA according to IEC TR 61156-1-2.

For frequencies ≤ 1 GHz the test for insertion loss IL at RT may be performed using a 2 port VNA using baluns according to EN 50289-1-8 using the general requirements in EN 50289-1-1.

6.3.14.3 Report

Document the return loss RL (f) in a table at selected frequencies and as a continuous diagram over frequency.

6.3.15 Return loss, (RL)

6.3.15.1 Unbalanced cables, (RLCM)

Perform the test for common mode transmission using an unsymmetrical stimulus.

Perform the tests for return loss RL at RT according to IEC 61196-1-112 using the definitions in IEC 61196-1 and the general requirements in IEC 61196-1-100.

6.3.15.2 Balanced cables, (RLDM)

For screened cables, no special test setup is needed.

For unscreened cables use test set up 2, 3 or 4 according to 6.3.5.1.

Perform the test for differential mode transmission using a symmetrical stimulus.

Perform the tests for return loss RL at RT according to IEC TR 61156-1-2.

6.3.15.3 Report

Document the return loss RL (f) in a table at selected frequencies and as a continuous diagram over frequency.

6.3.16 Unbalance attenuations

6.3.16.1 Test

For screened cables, no special test setup is needed.

For unscreened cables use test set up 2, 3 or 4 according to 6.3.5.1.

Perform the required test(s) following the definitions in ISO 19642-1 and the test procedures defined in IEC TR 61156-1-2.

6.3.16.2 Report

Document the measured values of the required test(s) in a table at selected frequencies and as a continuous diagram over frequency.

6.3.17 Near-end crosstalk, NEXT

For screened cables, no special test setup is needed.

For unscreened cables use test set up 2, 3 or 4 according to 6.3.5.1.

Perform the test for differential mode transmission using a symmetrical stimulus.

Perform the tests for NEXT at RT according to IEC TR 61156-1-2.

6.3.17.1 Report

Document the return loss NEXT (f) in a table at selected frequencies and as a continuous diagram over frequency

6.3.18 Far-end crosstalk, FEXT

For screened cables, no special test setup is needed.

For unscreened cables use test set up 2, 3 or 4 according to 6.3.5.1.

Perform the test for differential mode transmission using a symmetrical stimulus.

Perform the tests for FEXT at RT according to IEC TR 61156-1-2.

6.3.18.1 Report

Document the return loss FEXT (f) in a table at selected frequencies and as a continuous diagram over frequency

6.3.19 PS alien near-end crosstalk, PS-ANEXT – exogenous crosstalk

Use a test setup following the requirements of the test specification.

Perform the test for differential mode transmission using a symmetrical stimulus.

Perform the tests for PS-ANEXT at RT according to IEC TR 61156-1-2.

6.3.19.1 Report

Document the return loss PS-ANEXT (f) in a table at selected frequencies and as a continuous diagram over frequency

6.3.20 PS attenuation to alien far-end crosstalk ratio, PS-AACR-F - exogenous crosstalk

Use a test setup following the requirements of the test specification.

Perform the test for differential mode transmission using a symmetrical stimulus.

Perform the tests for PS-AACR-F at RT according to IEC TR 61156-1-2.

6.3.20.1 Report

Document the return loss PS-AACR-F(f) in a table at selected frequencies and as a continuous diagram over frequency.

6.4 Mechanical tests

6.4.1 Strip force of sheath

6.4.1.1 Purpose

This test is intended to verify that the force required to remove the sheath from the core stranding or from the screen (for screened and coaxial cables) meets customer requirements.

6.4.1.2 Test specimen

Prepare the test specimen according to 5.4.1. 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 50 mm.

Perform the test according to 5.4.1 removing the sheath with a undisturbed length BC (according to Figure 2) of 50 mm in the same action with 250 mm/min.

6.4.1.3 Test

Perform the test according to 5.4.1. A metal plate is provided with a round hole equal to the approximate inside diameter of the sheath. If the 50 mm section of sheath buckles when sliding, prepare new test specimens with the undisturbed length of sheath equal to 25 mm and repeat the procedure.

6.4.2 Cyclic bending

6.4.2.1 Purpose

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

6.4.2.2 Test specimens

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

6.4.2.3 Test

Perform the test according to 5.4.4 Connect the individual conductors and the screen, if present, in series for the detection of interruption of electrical continuity.

6.4.3 Flexibility

6.4.3.1 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.

6.4.3.2 Purpose

This test is intended to measure and quantify cable flexibility.

6.4.3.3 Test specimen

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

6.4.3.4 Test

Perform the test according to 5.4.5.

6.4.4 Cyclic bending test for RF cables

6.4.4.1 Purpose

This test is performed to measure the RF properties after a defined number of bending cycles. The number of cycles is to be agreed between customer and supplier.

6.4.4.2 Test specimens

Prepare two test specimens with a minimum length of 10 m.

6.4.4.3 Test

A mass of 0,5 kg/mm^2 times the total cross-sectional area of the conductors and the screen has to be attached to the cable. The weight shall consist of two halves with a double V-shaped hole in the middle. This will allow the use of the same weight on cables with different overall diameters.

For the weight do not use conductive or magnetic materials. Join the two halves with an adhesive tape on the outside.

The radius of the round outline of the mandrel according to Figure 25 is fixed to 25 ± 0,5 mm independent of the cable under test.

Roll up the cable end (loop diameter d ≥ 200 mm) and fix it with an adhesive tape if needed. Make sure the cable length between the lower edge of the weight and the rolled up cable is greater than 250 mm.

A bending cycle consists of:

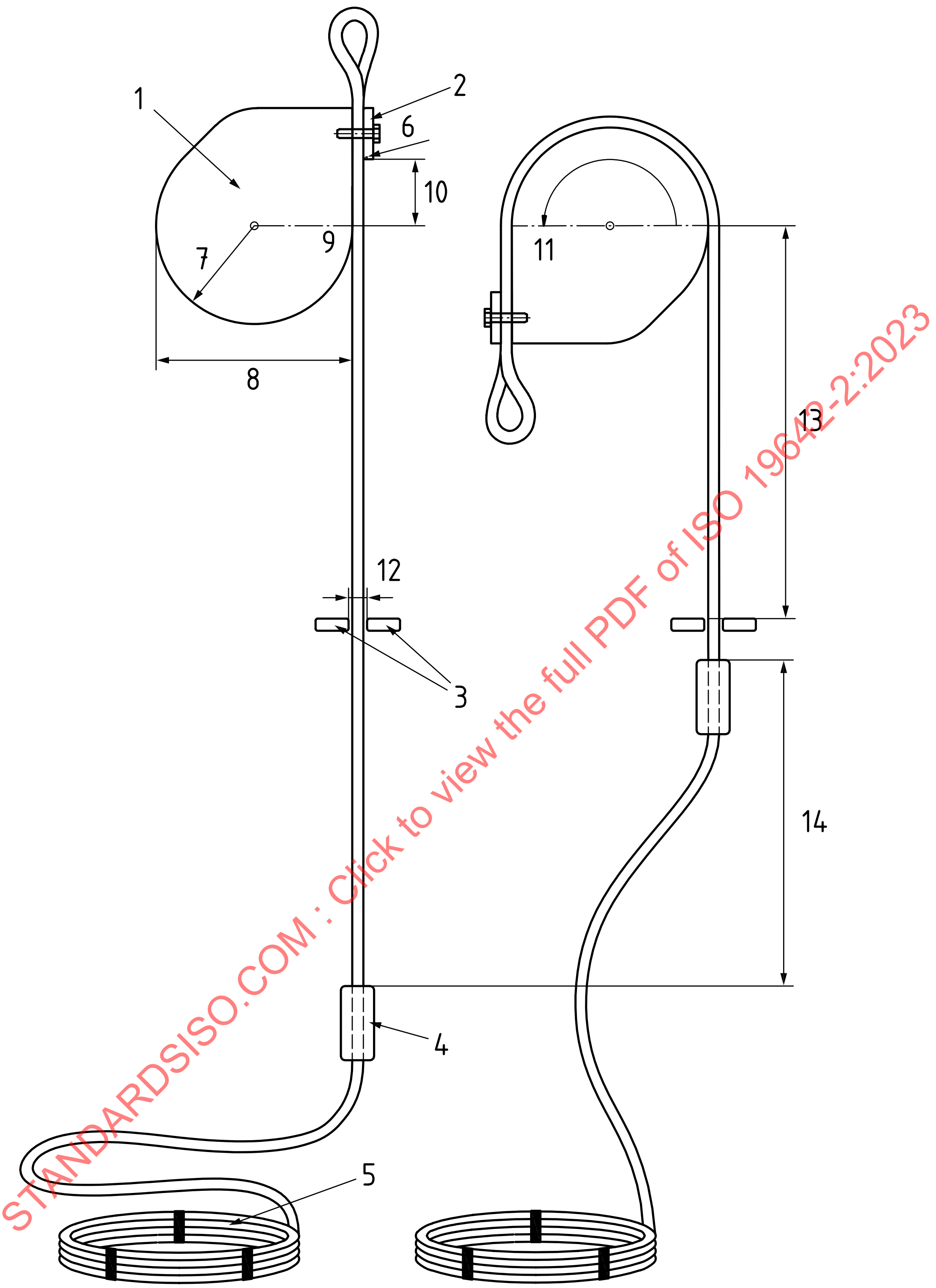
a) start in 0° position;

b) turn mandrel counter clockwise to 180° position;

c) turn mandrel back clockwise to 0° position.

Rate of bending: 6 ± 1 cycles per minute.

Perform the test sequence defined in the relevant part of this standard (at the defined temperatures and with the defined number of bending cycles) using the apparatus according to Figure 25. Connect the individual conductors and the screen, if present, in series for the detection of interruption of electrical continuity.



Key

1 proprietary mandrel with 50 ± 1 mm diameter (respectively 25 ± 0,5 mm radius)
2 plate for cable fixture, edges shall have a radius ≥ 0,5 mm
3 cable guide, the hole shall be 0,2 mm bigger than the maximum overall cable diameter
4 weight
5 rolled up excessive cable
6 radius ≥ 0,5 mm
8 50 ± 1 mm
9 0°
10 ≥ 15 mm
11 180°
12 D_{max} + 0,2 mm
13 100 ± 1 mm

7	radius ± 0,5 mm	14	~ 85 mm

Figure 25 — Cyclic bending test for RF cables

6.4.4.4 RF-tests after cyclic bending

After completion of the complete test sequence without failure, perform the specified electrical RF tests following the requirements in the relevant part of this document. The test results are only obtained at the end of the test sequence at RT.

When performing the Screening effectiveness tests according to 6.3.3 the bending point is to be within the coupling length.

6.4.5 Dynamic bending tests for RF cables

6.4.5.1 General

These tests A and B are normally only performed on special request of the OEM.

They are only necessary for assessing special installation positions (e.g. hatch back door interface). Very likely the parameters of the test have to be adjusted for the actual application.

Influencing factors are bending radius, stress by weight, temperature and number of cycles.

6.4.5.2 Sample preparation

The bending point is situated (2 ± 0,5) m away from the connection to the RF measurement equipment.

6.4.5.3 RF-tests after dynamic bending tests

The test results are only obtained at the end of the test sequence.

When performing the Screening effectiveness tests according to 6.3.3 the bending point is to be within the coupling length.

6.4.5.4 Test A, torsion test

6.4.5.4.1 Purpose

This test is performed to measure the RF properties after a defined number of torsion cycles. The number of cycles shall be defined in the requirements specification for this test.

6.4.5.4.2 Test description

A minimum 3 samples have to be tested.

New samples have to be used for each test.

The cable is clamped 2 times. In between the clamps the cable forms a quarter circle in free space between the clamps. The lower clamp is fixed the other is rotated in the cable axis ±90° and thus twists the cable. See Figure 26 below.

If not otherwise specified use dimensions according to Table 10.

Table 10 — Dimensions of test setup

Diameter of CUT	Radius *r* of quarter circle	Cable length between midpoint of the clamps
≤ 3,0 mm	75 mm	118 mm
≤ 4,5 mm	110 mm	173 mm
≤ 6,5 mm	160 mm	250 mm
> 6,5 mm	200 mm	314 mm

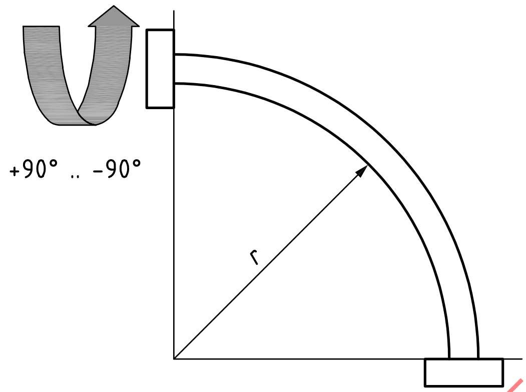
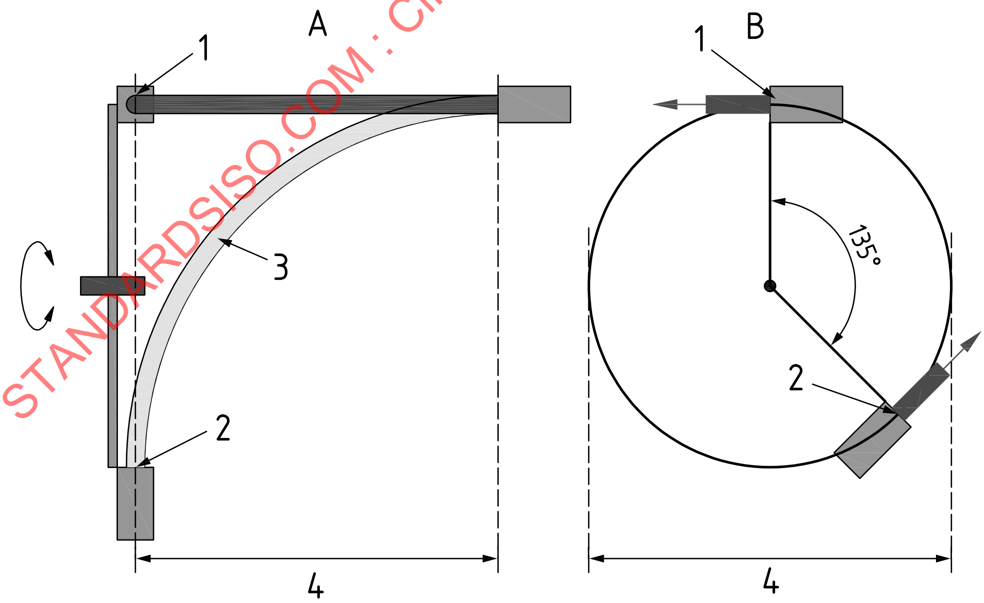


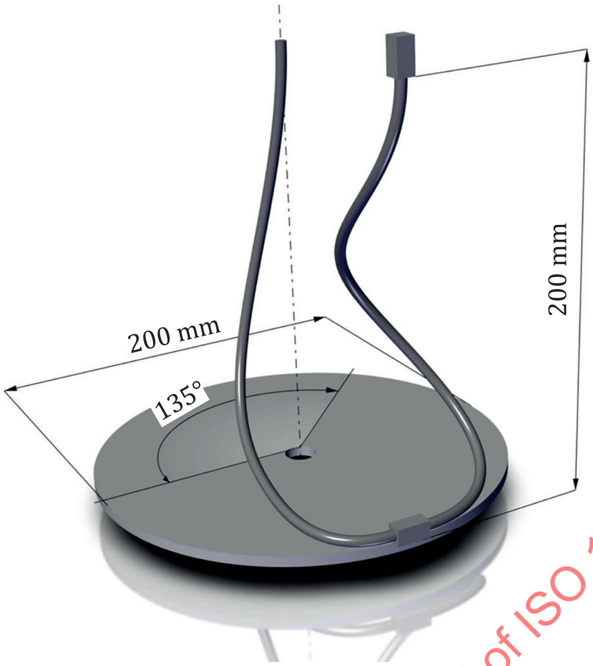
Figure 26 — Torsion test rig

6.4.5.5 Test B, Combined torsion and bending test

6.4.5.5.1 Purpose

This test is performed to measure the RF properties after a defined number of combined torsion and bending cycles. The number of cycles is defined in the requirements specification for this test.





Key

A side view

B top view

1 cable with clamp – position 1

2 cable with clamp – position 2

3 cable under test (CUT)

4 200 mm

Figure 27 — Combined torsion and bending test rig

By the test rig in Figure 27 the cable is stressed by torsion and bending at the same time.

The stressed part is defined as the section between the clamps (inner edge to inner edge). It starts 1 700 ± 10 mm from the near cable end and extends for a cable length of 300 ± 3 mm. In position 1 the cable is installed so that the direction of the cable axis follows the tangent of the discs edge. On both sides a maximum of 1 m each may be outside the oven.

6.4.5.5.2 Test description

A new sample is to be used. The length of the samples is 4,0 m.

The setup according to Figure 27 complies with the following drawing parameters:

— diameter of disk 200 mm;

— vertical distance 200 mm;

— turning angle 135°;

— position 1: cable middle point of upper clamp is positioned above the start of the stressed area in the lower clamp;

— position 2: disk turned in regard to position 1 for 135° in UZS (top view).

6.4.5.5.3 Definition of 1 cycle

One cycle consists of the time t_1 for the rotation from position 1 to position 2, a break period t_{BP1}, the time t_2 for the rotation from position 2 back to position 1 and a second break period t_{BP2}:

$$t_{cycle} = t_1 + t_{BP1} + t_2 + t_{BP2}$$

The times t_1 and t_2 for the rotations are identical and shall be about 1 to 2 s.

The break periods t_{BP1} and t_{BP2} are identical and shall be chosen so that the time for one cycle is 15 ± 1 s.

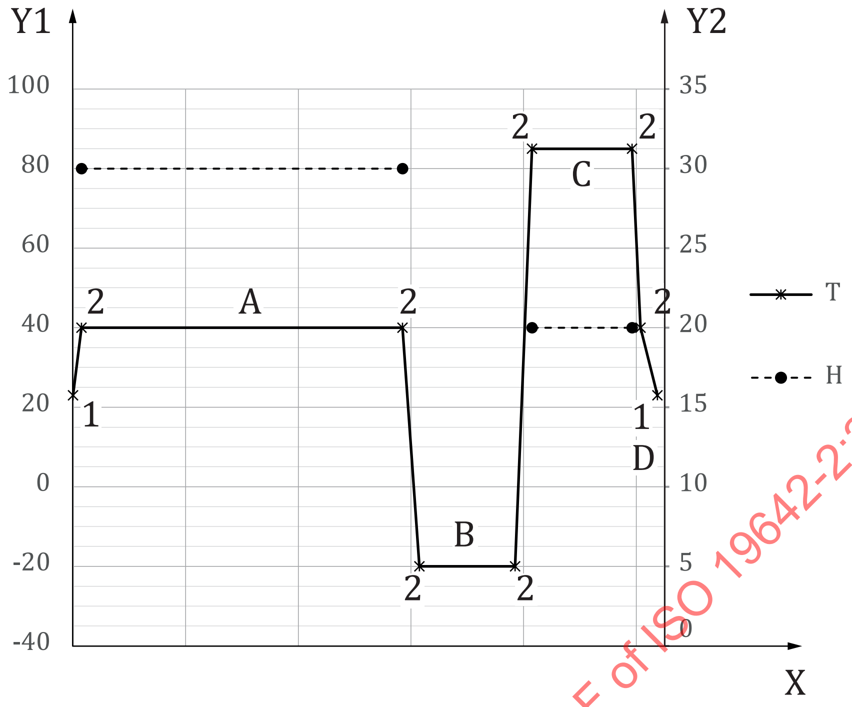
6.4.5.5.4 Test cycles

Perform the test according to Table 11 and Figure 28.

Cycle numbers in each group CG1 … CG4 have to be defined in the relevant part of this document.

Table 11 — Cycles to be performed

Number of cycles in the group	Temperature and humidity	Action
Start	Room temperature	RF tests on new cable
		Heat up, change ≥2 K/min, no cycles
CG1	+40 °C / 30 % RH	optional RF tests at start and end of cycles
		Cool down, change ≥2 K/min, cycles proceed
CG2	-20 °C / RH unspecified	optional RF test at start and end of cycles
		Heat up, change ≥2 K/min, cycles proceed
CG3	+85 °C / 20 % RH	optional RF tests at start and end of cycles
		Cool down, change ≥2 K/min, cycles proceed
	+40 °C / 30 % RH	optional RF test
CG4		optional Cool down, change ≥2 K/min, cycles proceed
	Room temperature	RF tests after complete test



Key

X cycles
Y1 temperature, [°C]
Y2 relative humidity, [%]
T temperature
H relative humidity
A CG1
B CG2
C CG3
D CG4
1 mandatory RF test
2 optional RF test

Figure 28 — Diagram of temperature, humidity and RF test points

6.4.5.5.5 RF measurement

During the measurement the cycling is stopped. The measurement is to be performed and documented in both positions.

For the measurement of the attenuation the second end of the cable under test has first to be kept near the axis of the turn before it is brought out of the climatic chamber.

For the measurement of the impedance in relation to the position in the cable the TDR method according to 6.3.13 is to be used. The minimum and maximum of the impedance is to be plotted against the cycle count.

6.4.6 Test for assessment of minimum bending radius

The used bending radius is to be documented.

The sample is to be wound one time in closed uniform turns around the mandrel. A sufficient tension is to be applied to make sure the sample touches the mandrel.

The test consists of one time wrapping and unwrapping.

The diameter of the mandrel and the numbers of turns in the spiral and have to be taken from the relevant requirement specification.

The test is performed at room temperature.

After test unwrap the cable from the mandrel and perform the RF tests according to the requirements.

6.4.7 Strip force of screen

6.4.7.1 Purpose

This test is intended to verify that the force required to remove the screen together with the sheath (screen + sheath composite) from the core stranding meets customer requirements.

Remark: this test is only defined for single inner conductor coaxial cables. It is not applicable to cables with more than one inner core.

6.4.7.2 Test specimen

Prepare the test specimen according to 5.4.1. Prepare three test specimens of 150 mm (alternatively 200 mm, when the measured force is too small) from a cable test specimen 3 m in length. Take the test specimens at 1 m intervals.

Follow Figure 29.

a) Remove 100 mm of outer jacket and approximately 90 mm of the screen material.

b) Fold the exposed screen material back over the outer jacket material remaining on the specimen. The undisturbed length of screen + sheath composite shall be 50 mm (alternatively 100 mm, when the measured force is too small).

c) Perform test according to 6.4.7.4.

6.4.7.3 Test

Use a plate with a hole diameter of the approximate inside diameter of the screen. For screens built up from a multitude of elements (braid, foil, separator) make sure the hole fits to the innermost element of the screen.

Perform the test according to 6.4.1 removing screen + sheath with a undisturbed length of screen + jacket BC (according to Figure 2) of 50 mm (alternatively 100 mm, when the measured force is too small) in the same action with 250 mm/min.

Record the max force to pull the dielectric core from the screen and the used undisturbed length (50 or 100 mm).

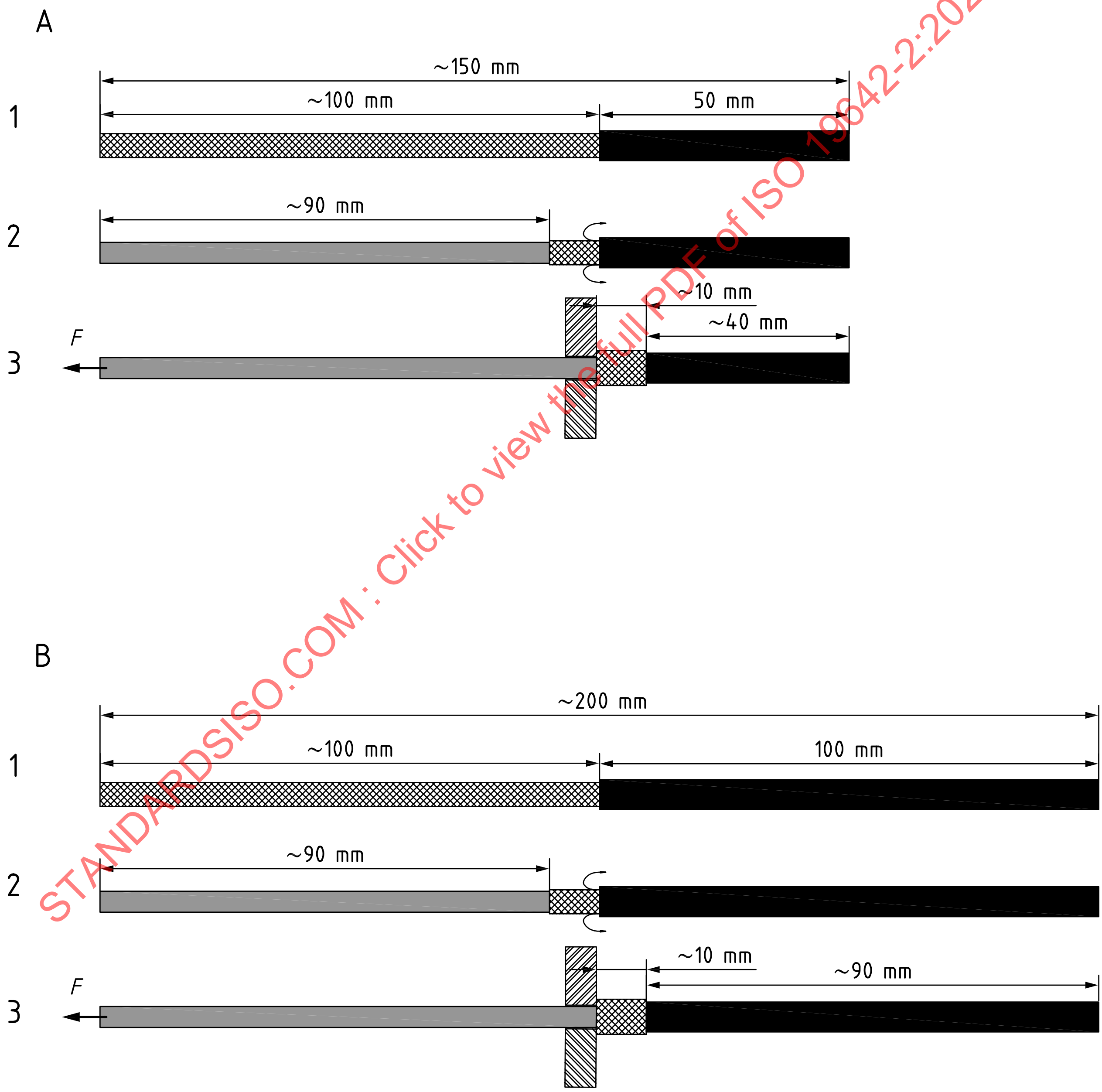
6.4.7.4 Strip force tests for coaxial cables overview

For a single inner conductor coaxial cable three different strip force test are be defined in ISO 19642-1:

a) Strip force between inner conductor and dielectric cable insulation. Carefully remove screen and sheath before performing the test.
Then perform the test according to 5.4.1 with a undisturbed length of the dielectric insulation BC of 50 mm (alternatively 100 mm, when the measured force is too small) and a pull off rate of 250 mm/min.

b) Strip force between dielectric cable core and the screen together with the sheath (screen + sheath composite)
Perform the test according to 6.4.7 with a undisturbed length of the screen + sheath composite BC of 50 mm (alternatively 100 mm, when the measured force is too small) and a pull off rate of 250 mm/min.

c) Strip force between screen and sheath.
Perform the test according to 6.4.1 with an undisturbed length of the jacket of 50 mm (alternatively 100 mm, when the measured force is too small) and a pull off rate of 250 mm/min.



Key

A 50 mm undisturbed length

B 100 mm undisturbed length

Figure 29 — Sample preparation strip force of screen

6.4.8 Abrasion test of sheath

6.4.8.1 General

This test is applicable to screened and unscreened cables. It is only performed when required in the relevant cable specification of this standard family. Either scrape abrasion or sandpaper abrasion test may be performed.

6.4.8.2 Purpose

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

6.4.8.3 Test specimen

Prepare one test specimen of 1 m in length. Remove 100 mm of sheath from one end of the cable and 25 mm of the insulation from each exposed core. Twist the stripped ends of the cores together. If a screen is present, it shall be twisted together with the cores.

6.4.8.4 Test procedure

6.4.8.4.1 Screened cables

Connect the twisted ends and the screen to the conductor detection terminal of the test equipment. The test is terminated, when the tests system detects connection of the sandpaper or needle with the screen.

6.4.8.4.2 Unscreened cables

Perform the test with the minimum required length of sandpaper or number of scrape abrasion cycles according to the relevant requirement specification.

Perform a visual inspection of the stressed surface. The test is passed if no hole is visible using an optical instrument with 10 fold magnification.

6.4.8.5 Sandpaper abrasion test

Perform the test according to 5.4.2.4. Apply an additional mass of 4 kg. A 2 kg mass may substitute the 4 kg mass if found necessary.

6.4.8.6 Scrape abrasion test

Perform the test according to 5.4.2.5. Apply a total vertical force of (7,00 ± 0,05) N.

6.5 Environmental tests

6.5.1 Test specimen preparation and winding tests

6.5.1.1 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.