VOLKSWAGEN AG	**Electric Wiring in Motor Vehicles** Single-Wire, Unshielded	**VW 603 06**
Konzernnorm		

Descriptors: line, cable, wire, low-voltage cable, single-wire, unshielded, electric wiring

Preface

The content of this standard in the present issue has been agreed upon between representatives of Audi AG, BMW AG, DaimlerChrysler AG, Porsche AG and Volkswagen AG. The MS Word file is stored in the Volkswagen AG standards department.

As it is possible that individual automobile manufacturers modify the specifications, exclusive testing according to supply specification LV 112 is not permitted. Instead, the supplier is obliged to ensure that the currently valid in-house standard of the respective automobile manufacturer is available to him.

Deviations with respect to the agreed version of LV 112 are represented *in italics* in the individual in-house standards of the automobile manufacturers. Company-specific as well as informative tests are additionally specified in the Appendix.

The above-mentioned companies agree on mutual recognition of test reports from cable manufacturers as long as the tests are performed by an independent testing institute that is accredited according to DIN EN ISO/IEC 17025. The above-mentioned companies reserve the right to require additional tests. The mutual acceptance of the test reports does not automatically result in a release.

Changes

The following changes have been made as compared to Volkswagen standard VW 603 06: 2001-11:

– Standard completely revised

Previous issues

1990-09; 2001-11

Contents

Fachverantwortung/Responsibility			Normung/Standards (EZTD, 1733)		
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1 Scope

VW 603 06 describes requirements and tests for single-wire, unshielded low-voltage cables in a nominal voltage range between ≤ 60 V and ≤ 600 V.

Thin-walled cables with cross sections ≤ 6 mm²: see Appendices A.1 and A.2

Thick-walled cables with cross sections ≥ 6 mm²: see Appendices A.4 and A.5

It is recommended to use the basic color orange (RAL 2003) for cables used in nominal voltage range between > 60 V and ≤ 600 V.

2 General

VW 603 06 only applies to new designs. Cables already used in standard production do not have to be modified. *Re-testing can be required if new issues of the standard are released.* Subsequent modifications of material, dimensions, manufacturing processes, etc. shall be reported to the respective design engineering departments; these may demand a new release.

The test scope of *VW 603 06* and in individual cases special test conditions must be defined in cooperation with and approved by the responsible engineering departments.

Cables manufactured according to this standard are subject to technical engineering approval (BMG)..

After technical engineering approval has been granted, the cables are only completely released for use in standard production if the assembler has confirmed proper usability in the form of a first-sample test report (EMPB) during first sampling,

e.g.

- *Stripping of the insulation*
- *Crimpability*
- *Ultrasonic weldability*
- *Twistability of the contacts, if applicable*
- *Crimping of contacts*

2.1 Basic supply requirements

Standard part drawings take precedence over this standard.

Approval of first supply and changes according to Volkswagen standard VW 011 55.

First samples must be delivered accompanied by a test certificate containing all data regarding the quality requirements listed below. In addition, the test certificate must contain the company's trade name, the manufacturing period of the cables and the company's recipe number for the insulating material.

Deviations regarding the completeness of the data are only permissible in exceptional cases and only with the agreement of the relevant department.

Long-term tests are a deciding factor for technical engineering release.

Standard production shipments must include the manufacturing date. The manufacturing date must be visible on the cable tags. Different rules may be negotiated between the suppliers and the material testing laboratories or responsible engineering departments.

3 Dimensions and conductor composition

Dimensions and composition of the conductor (see Figure 1) are to be taken from the respective Sections in the Appendix. Unspecified details are to be selected to suit the specific purpose according to ISO 6722.

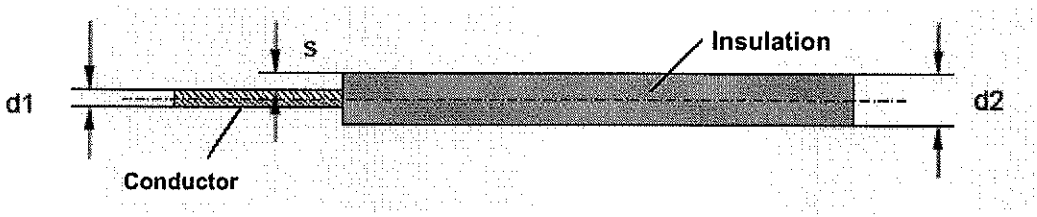

Figure 1 – Composition of the conductor

4 Drawing entry

The drawing entry shall be made in the material specification field or near the title block. The cable shall be described according to DIN 72551-6 and DIN 72551-7.

Example:

Description example of an unshielded low-voltage cable (FL) with thin-walled insulation (R), a nominal conductor cross section of 1.5 mm² (1,5), type A conductor composition (A) with tinned strands, 2X symbol of the insulating material (cross-linked PE) according to DIN 76722, color coding based on DIN 72551-7 in German or English, permanent service temperature (T_O) 125 °C:

Cable <*VW 603 06*> - FLR2X-1,5sn-A RDBU/T125

5 Materials

The properties according to Sections 5.1 to 5.3 shall be guaranteed by the manufacturer.

5.1 Conductor, uninsulated

Strand Cu-ETP1, CW003A *or* Cu-ETP, CW004A acc. to DIN EN 13602

In exceptional cases other Cu materials can be agreed upon.

Conductor, uninsulated: properties see Table 1.

Table 1 – Conductor, properties

Designations				Diameter (nominal dimension)		Tensile strength R_m	Elongation at break A_t or A_{200mm}
Material		Condition		[mm]		[N/mm²]	Single- or multi-core wire %
Code	Number	Single-core wire	Multi-core wire	over	to	min.	min.
Cu-ETP1 Cu-ETP	CW003A CW004A	A010	A008	0.04	0.08	(200)	10
		A015	A013	0.08	0.16	(200)	15
		A021	A019	0.16	0.32	(200)	21
		A022	A020	0.32	0.50	(200)	22
		A024	A022	0.50	1.00	(200)	24
		A026	A024	1.00	1.50	(200)	26
		A028	A026	1.50	3.00	(200)	28
		A033	—	3.00	5.00	(200)	33

Product designation example:

Designation	Standard	Material designation	Condition designation	Surface quality	Diameter nominal dimension [mm]	Delivery
Wire	DIN EN 13602	Cu-ETP-1	A022	P	S0.4	Y

Explanation of the example given above:

Condition designation:	A = annealed
	(R = hard drawn)
Surface finish:	P = not tinned
	A, B, C = tinned
Diameter nominal dimension:	S = single-core wire
	M = multi-core wire
Delivery:	Y = ring
	(Z = coil)

5.2 Conductor, tinned

Properties see Table 2.

Table 2 - Properties

Designations				Diameter (nominal dimension)		Tensile strength R_m	Elongation at break A_t or A_{200mm}
Material		Condition		[mm]		[N/mm²]	Single- or multi-core wire %
Code	Number	Single-core wire	Multi-core wire	over	to	min.	min.
Cu-ETP1 Cu-ETP	CW003A CW004A	A007	A005	0.04	0.08	(200)	7
		A013	A011	0.08	0.16	(200)	13
		A019	A017	0.16	0.32	(200)	19
		A020	A018	0.32	0.50	(200)	20
		A022	A020	0.50	1.00	(200)	22
		A024	A022	1.00	1.50	(200)	24
		A026	—	1.50	3.00	(200)	26
		A031	—	3.00	5.00	(200)	31

5.3 Conductor, other surfaces

Other surfaces (e.g., silver plated) are permissible upon agreement.

5.4 Insulation

The minimum and maximum permanent service temperatures (T_U and T_O) for a load duration of 3,000 h shall be selected according to the temperature classes given in Table 3, or in exceptional cases according to the drawing.

Table 3 – Temperature classes

Class	Permanent service temperature (3,000 h) T_U °C to T_O °C	Short-term temperature (240 h) (T_O + 25) °C	Thermal overload temperature (6 h) (T_O + 50) °C
A	-40 to 85	110 ± 2	135 ± 3
B	-40 to 100	125 ± 3	150 ± 3
B (105)	-40 to 105	130 ± 3	155 ± 3
C	-40 to 125	150 ± 3	175 ± 3
D	-40 to 150	175 ± 3	200 ± 3
E	-40 to 175	200 ± 3	225 ± 3
E(180)	-40 to 180	205 ± 3	230 ± 4
F	-40 to 200	225 ± 4	250 ± 4
G	-40 to 225	250 ± 4	275 ± 4
H	-40 to 250	275 ± 4	300 ± 4

In justified exceptional cases, special temperature classes such as B (105) or E (180) are permissible.

6 Marking and supply specifications

6.1 Packaging marking

Packaging must be marked conform with VDA band 6 part 1 and shall be agreed upon between purchaser and supplier.

6.2 Manufacturer's code

For cross sections ≥ 0.5 mm², the manufacturer's code must be printed or stamped on, for example. For cross sections < 0.5 mm² marking is carried out according to agreement.

6.3 Color coding

Color coding based on DIN 72551-7 in German or English.

Different color coding is permissible upon agreement.

6.4 Supply specifications

If these supply requirements are not met, the goods will be returned at the supplier's expense.

6.4.1 Visual test

The insulations must have no nodes, cracking, blistering or foreign inclusions and must be strippable using a standard commercial stripping machine without leaving a residue and without damage to the conductor.

6.4.2 Testing

According to ISO 6722 (Section "Insulation faults")

After the spark test, the cables shall be tested according to Table 4. The stay time of the cable in the electrical field shall be selected such that each cable section is stressed with at least 18 voltage spikes. When using tubular electrodes, the inside diameter of the electrode must be matched to the cable diameter.

Table 4 - Voltage values

Nominal conductor cross-section [mm^2]	Voltage for 60-V cable [kV]	Voltage for 600-V cable [kV]
< 0.5	3	6
≥ 0.5	5	8

The emphasis in inspection shall be placed on production inspection. The test plans and measured value documentation of the production and output inspections must include information on the measuring equipment used, frequency of measurements, desired values and tolerances for all criteria that are important to the function.

In the case of defects, proceed acc. to Section 6.4.4.

6.4.3 Packaging units

The packaging units shall be agreed upon between purchaser and manufacturer. For a sample agreement see Table 5.

The cables shall be delivered in drums free of damage, optionally in coils. The following requirements must be met:

- The cable must be delivered in one length in the drum *or* coil, the two ends shall be arranged such that they are accessible, do not interfere with processing and cannot be damaged during transport.
- The cable must be removable at a speed of 200 m/min from the drum and at a speed of 420 m/min from the coil into a cable-cutting machine in intermittent operation.

Table 5 - Example of delivered quantities

FL cables		FLR cables	
Nominal cross-section [mm²]	**Delivered quantity [m]**	**Nominal cross-section [mm²]**	**Delivered quantity [m]**
-	-	0.22	12,000 *or* as NPS (Niehof package coil) 24,000
-	-	0.35	12,000
0.5	9,000	0.5	10,000
1.0	6,000	1.0	8,000
1.5	2,000	1.5	7,000
2.5	3,000	2.5	5,000
4.0	2,500	4.0	2,500
6.0	1,600	6.0	1,500

6.4.4 Partial lengths, ties, defects

A prescribed length can be made up of partial lengths in exceptional cases; this must be specially noted.

- Ties used for the partial lengths must not exceed the diameter of the cable and must not tear during processing.
- Ties and defects shall be marked by 30 to 100 mm of stripped insulation.

Maximum permissible quantities per drum or coil at nominal cross section:

- 0.22 / 0.35 / 0.5 / 0.75 mm² 3 ties or defects
- 1.0 / 1.5 / 2.5 mm² 2 ties
- ≥ 4.0 mm² 1 tie

Deviating agreements between cable manufacturer and assembler are permissible. In this case, the vehicle manufacturer shall be informed upon request.

6.4.5 Marking of the delivery unit

The coil or drum marking must be applied so that it is always visible, even when packed on pallets.

Retraceability shall be ensured.

Marking:

- Cable designation according to Section 4
- Manufacturer
- Manufacturer number
- Date of manufacture
- Batch number (optional)
- Cable length
- Position of ties and defects

7 General test conditions

7.1 Test matrix

Section	Test / Test scope	Release test A1	Release test A2	On-site test B	Modification of pre-materials C	Requalification test D	Process test E
6.4.2	Insulation defects in the entire shipment	X	X	X	X	X	X
8.1	Testing of complete cable composition	X	X	X	X	X	
	Outside cable diameter						X
	Conductor resistance	X	X	X	X	X	X
	Insulation wall thickness						X
8.2.1	Density	X			X	X	
8.2.2	Extractable portions	X			X		
8.2.3	Viscosity number/heat-transmission coefficient	X			X		
8.2.4	Temperature at 5% weight loss	X			X		
8.2.5	Ignition residue	X			X		
8.2.6	Thermal stability	X		X	X		
8.2.7	Determination of the infrared spectrum	X	X	X	X	X	
8.2.8	Tensile strength / elongation at tear	X		X	X	X	
8.2.9	Tear propagation strength	X		X	X	X	
8.2.10	Determination of cross-linking density	X	X	X	X	X	X
8.2.11	Microhardness	X			X		
8.3.1	Insulation stripability / secure fit of conductor	X		X	X	X	
8.3.2	Insulation abrasion resistance	X		X	X	X	
8.3.3	Cable-to-cable abrasion resistance	X					
8.3.4	Sliding behavior of the cables	X					
8.3.5	Bending force of the cables	X	X				
8.3.6	Insulation notch strength	X					
8.4	Non-flammability	X			X	X	
8.5.1	Specific insulation resistance	X					
8.5.2	30-minute voltage protection	X					

Section	Test / Test scope	Release test A1	Release test A2	On-site test B	Modification of pre-materials C	Requalification test D	Process test E
8.5.3	1-minute voltage protection	X					
8.6.1	Stress test	X		X		X	X
8.6.2	Insulation shrinkage under heat	X		X		X	
8.6.3	Compressive strength of the insulation under heat	X					
8.6.4	Thermal stability in wound state	X					
8.6.5	Thermal overload	X					
8.6.6	Short-term aging (240 h)	X	X	X	X	X	
8.6.7	Long-term aging (3000 h)	X					
8.6.8	Winding test at low temperatures (-40 °C)	X		X	X	X	
8.6.9	Impact test at low temperatures (-15 °C)	X					
8.6.10	Stability against wiping of the cable marking	X					
8.6.11	Dynamic flexural strength	X					
8.6.12	Kink test	X					
8.6.13	Electrical properties during water immersion	X					
8.6.14	Moist heat, constant	X					
8.6.15	Ozone resistance	X					
9.7	Mycological test	X					
8.8.1	Resistance to agents acc. to ISO 6722	X					
8.8.2	Resistance to operating fluids and wrapping tapes	X					
8.8.3	Resistance to harness components	X					
9	Environmental protection	X[1)]				X[1)]	

1) Proof shall be provided by the cable manufacturer.

Documentation: The documentation of the tests according to test scope A and test scope B shall be sent to the customer. For test scopes C, D and E the cable manufacturer bears the responsibility for documentation and archiving; they need to be submitted to the customer only upon special request.

Test scope A1/A2: Testing for the main manufacturing site. Presentation of

- new cables or
- already known cables with new compound.

The procedure in the case of minor compound modifications shall be agreed upon with the engineering departments.

Test scope A1: is performed on cross sections 0.35; 0.5; 1.5; 2.5; 4.0 and 16.

The **short test A2** is performed on cross sections 0.22; 0.75; 1.0; 6.0; 10.0 and all further cross sections > 16.

Test scope B: Identical compound, different site of same cable manufacturer

Test scope C: For unchanged compound composition and

- chemically identical pre-materials supplied by different sub-contractors or
- change of compound manufacturing site.

Test scope D: Regularly at least every 5 years.

Test scope E: Recommended process-accompanying test (e.g., batch-related or continuously)

The supplier bears responsibility for process assurance.

7.2 Test climate

If no other test climate is specified, testing will be carried out in the DIN 50014-23/50-2 standard climate.

7.3 Specimens

If not otherwise specified, at least 3 specimens of the cables shall be tested in as-received condition.

Light colors shall be used, not brown or black.

For tests that are directly connected to the manufacturing process for process assurance, the specimens must be aged for at least 16 h beforehand in the DIN 50014-23/50-2 standard climate.

For each test only specimens shall be used which have not been used in previous tests.

If maximum 1 of the 3 specimens fails, the test shall be repeated with 10 specimens and documented. In this case, all of the 10 specimens shall pass the test, i.e. the test is not passed if one more specimen fails in the repeat test.

If more than 1 specimen fails, a repetition with 10 specimens is not possible; the test is considered not passed.

7.4 Rounding of numerical values

The determined numerical values shall be rounded to the number of digits with which the desired values are listed, according to DIN 1333.

8 Tests

The tests described are based on ISO 6722.

Unless otherwise agreed upon, the drawing entry takes precedence over the standard if different specifications are given.

8.1 Cable composition test

The parameters indicated in the relevant Appendices for the cable setup must be tested for. The mean value of the measurements as well as the minimum and maximum values shall be indicated in the test report.

8.1.1 Insulation test wall thickness Sp (thin-walled cables)

The following applies to all nominal conductor cross sections: Sp = minimum wall thickness + 0.02 mm

See Tables A.1, A.2, A.4 *and* A.5.

If the insulation test wall thickness is too small in two cases, a cable batch may be rejected.

In cases of doubt, a microscopic investigation on the metallographic microsection shall be performed.

8.2 Physical and chemical properties of the insulation

The measured values for each cable specimen obtained from the tests described below shall be included as an appendix to the test report and serve as a unique identification of the cable.

8.2.1 Density

Testing according to DIN EN ISO 1183-1, method A

8.2.2 Determination of the extractable portion

For PVC, testing is performed according to DIN EN ISO 6427 (in as-received condition and after 3,000 h). For materials other than PVC it is performed as agreed.

8.2.3 Determination of viscosity

Testing is performed according to DIN EN ISO 1628-2 (in as-received condition and after 3,000 h). For cross-linked materials, this test is not applicable.

If the test according to DIN EN ISO 1628-2 cannot be performed, as an alternative the flow property shall be determined using MFI according to DIN EN ISO 1133 – if this is possible.

8.2.4 Temperature at 5% weight loss

Test according to VDA 675 135 (heating rate 10 °C/min).

8.2.5 Ignition residue

Determination of ignition residue (without chemical treatment) according to VDA 675 130 (in accordance with sample).

8.2.6 Thermal stability

Testing only for PVC according to DIN EN 60811-3-2, Section 9:

Change from pH-value 5 to pH-value 3.

Requirement: > 120 min (grade B, B 105)

8.2.7 Determining the infrared spectrum

The test shall be performed using the ATR (attenuated total reflectance) method in as-received condition.

Test

The cable is cut at an angle of 90° perpendicular t o the longitudinal axis.

The surface of the cable is cleaned using isopropanol. The measurement shall be performed on the cleaned surface.

8.2.8 Determining the tensile strength and elongation at tear

Test according to DIN EN 60811-1-1.

Note: When preparing the specimens, also observe Section 8.7.

8.2.9 Tear propagation strength

Testing only for silicone according to ISO 34-1, method B, procedure (b) (Graves angle test piece with nick).

Requirement:	at least 15 N/mm for temperature class E
	at least 10 N/mm for temperature class F

8.2.10 Determination of cross-linking density

Testing still to be specified (e.g., hot set, DSC, extraction).

For cross-linked materials.

8.2.11 Microhardness

Determination of microhardness according to VDA 675 101 (in accordance with sample).

For especially hard materials this test shall be performed according to agreement.

8.3 Mechanical properties in as-received condition

In general, the cable must be designed such that it can be processed properly and welded using commercial devices. The insulation must not exhibit any blisters, cracks, nodes or inclusions of foreign matter.

8.3.1 Insulation stripability and secure fit of conductor

Insulation stripability requirements

In the case of cables with removable insulation, at least 20 mm of the insulation shall be removable without residues and with no difficulty using standard commercial equipment.

Requirements on secure fit of the conductor

The forces required to strip the insulation on a length of (50 ± 1) mm must be within the limits indicated in Table 6. Deviating values may be agreed upon in individual cases.

Table 6 - Secure fit of conductor

Nominal conductor cross section		**[mm²]**	**0.22**	**0.35**	**0.5**	**0.75**	**1.0**	**1.5**	**2.5**	**4.0**	**6.0**
Force	min.	[N]	3	5	5	5	5	10	10	10	10
Force	max.	[N]	20	30	30	40	40	50	60	70	70

For nominal conductor cross sections > 6.0 mm²: according to the sample

Test

Number of specimens: at least 5

Specimen length: (150 ± 5) mm

The insulation is stripped from the specimen over a length of (50 ± 1) mm, and the stripped end of the conductor is pulled through a sheet with a hole of (conductor diameter + 0.1 mm). Strip rate: 100 mm/min

8.3.2 Insulation abrasion resistance

Requirements

Resistance to abrasion by scraping is defined by the number of complete cycles that are required until the scraping needle has rubbed through the insulation and the electrical contact shuts off the machine. Each specimen is required to reach the minimum number of cycles (see Table 7).

Table 7 - Number of cycles

Nominal conductor cross section	**[mm²]**	**0.22**	**0.35**	**0.5**	**0.75**	**1.0**	**1.5**	**2.5**	**4.0**	**≥ 6.0**
Contact force	[N]	7.00 ± 0.05								
No. of cycles	min.	150	200	300	350	500	1500	1500	1500	1500

Test

Setup and execution according to ISO 6722 (Section on abrasion resistance)

Needle diameter: (0.45 ± 0.01) mm

The test can be stopped as soon as the number of cycles exceeds the minimum number of cycles by 50 %. It must be ensured that the needle is lifted up at the reversal point.

8.3.3 Cable-to-cable abrasion resistance

Requirements

This test shall be performed according to agreement.

Resistance to abrasion by cables rubbing against one another is defined by the number of cycles that are required until the cable insulation has been rubbed through and the electrical contact of the conductors shuts off the machine. The required minimum number of cycles is indicated inTable 8.

Table 8 - Number of cycles

Nominal conductor cross section	**[mm²]**	**0.22**	**0.35**	**0.5**	**0.75**	**1.0**	**1.5**	**2.5**	**4.0**	**6.0**
Weight force	[N]	10	10	12,5	12,5	12,5	12,5	15	15	20
No. of cycles	min.	150	200	300	350	500	1500	1500	1500	1500

This test shall not be performed on nominal conductor cross sections > 6.0 mm².

Test

Test setup see Figure 2

The friction points of the cables must be in the center of the cables (140 ± 14) mm. The diameter of the axle must be greater than 14 times the cable diameter. Two cables of the same material and cross section shall be used as specimens.

The test is performed acc. to DIN EN 3745-511. The moving part of the device is moved back and forth by (6.35 + 0.25) mm peak to peak in the x axis with a frequency of 10 Hz.

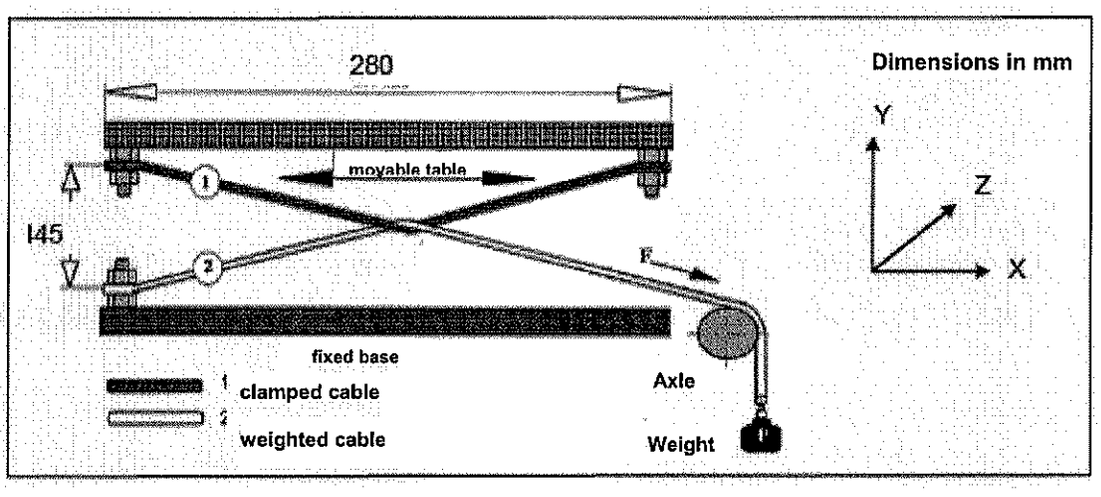

Figure 2 – Abrasion resistance test setup

8.3.4 Sliding behavior of the cables

The test is not relevant to release but serves for data collection. It will become relevant to release as soon as sufficient measured values are available for different insulating materials.

Requirements

The measured values for the maximum tensile force shall be attached to the first-sample test report.

Test

The test device (Figure 3) consists of a variable-width roller that is fixed in place, and a tensile test machine..

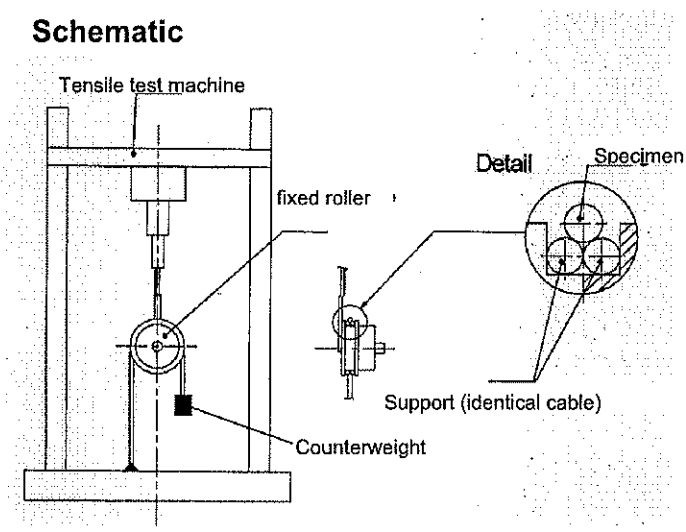

Figure 3 – Sliding behavior test setup

Wind the cable to be tested two turns around the cylindrical part of a test roller with a diameter according to Figure 9. Take care that sufficient tension is applied to this support cable. The winding is pressed together and held by two flanges on the sides.

Place a piece of cable of suitable length from the same manufacturing batch, loaded with a weight according to Table 8, in the gusset of the wound cable, and fix it in a suitable manner to the frame of the tensile test machine.

Then pull the specimen over the wound cable at a speed of 250 mm/min, and determine the maximum measured force for each individual measurement. Perform the measurement twice per specimen. Repeat the test twice more on specimens removed from other cable sections for a total of 6 measured values.

During the tests, the wound cable must not be replaced nor repositioned. Document the mean value as well as the maximum and minimum values in addition to the measured values obtained.

Figure 9 – Sliding behavior test specifications

Nominal conductor cross section	**[mm²]**	**0.22**	**0.35**	**0.5**	**0.75**	**1.0**	**1.5**	**2.5**	**4.0**	**6.0**
Weight force (counterweight)	[N]	5	5	5	5	5	5	5	10	10
Test roller diameter	[mm]	20	20	30	40	40	50	60	80	80

This test shall not be performed on nominal conductor cross sections > 6.0 mm².

8.3.5 Bending force of the cables

Requirements

The bending force must be within the range of values in Table 10. Deviating values may be agreed upon in individual cases.

Table 10 - Bending force test specifications

Nominal conductor cross section	**[mm²]**	**0.22**	**0.35**	**0.5**	**0.75**	**1.0**	**1.5**	**2.5**	**4.0**	**6.0**	**> 6.0**
Specimen length l	[mm]	50					70				150
Number of specimens n		5					3				1
Distance l_V	[mm]	20					30				100
Maximum bending force	[N]	15	15	15	20	20	25	30	50	70	M[1)]
1) According to sample											

Test

The test device consists of two metal legs, a test mandrel and a tensile test machine, and is illustrated schematically in Figure 4.

Straighten out the cable specimens (number n and lengths acc. to Table 10) and age them in this way for at least 16 h. Then place the n cables next to one another on the metal legs, which are located at a distance of l_V acc. to Table 10. Mark the upper side of these specimens with a felt-tip pen on the left and the right perpendicular to the longitudinal axis of the cable.

In a tensile test machine, press the test mandrel onto the cables at a test rate of 100 mm/min. Measure the force required to bend the cables.

Then straighten out the cables by hand and place them back on the legs on the side bearing the marking; then measure the force required to bend the cables once more. The mean value of the two measurements is the bending force.

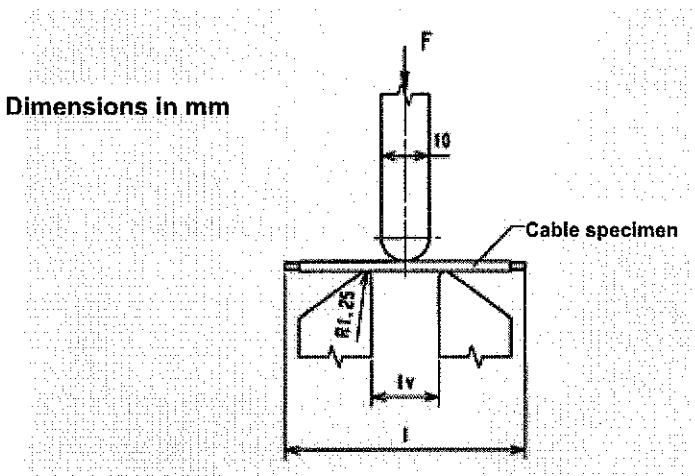

Figure 4 - Bending force test stand

8.3.6 Insulation notch strength

Requirements

The notching force must correspond to the values in Table 11.

Table 11 - Notching force

Nominal conductor cross section	**[mm²]**	**0.22**	**0.35**	**0.5**	**0.75**	**1.0**	**1.5**	**2.5**	**4.0**	**6.0**
Notching force min.	[N]	20	30	40	50	50	60	70	100	120

For nominal conductor cross sections > 6.0 mm²: according to the sample

Test

The test device (Figure 5) consists of a tensile test machine or a force-measuring device, a notching tool (cutter) and a circuit with a low voltage. A round spring wire acc. to DIN EN 10 270-1, dimensional accuracy C with a diameter of 0.45 mm made of X12CrNi177, shall be used for the notching tool.

Fix the specimen in the tensile test machine according to Figure 5. Press the steel wire with a constant speed of max. 10 mm/min through the insulation until the electrical contact between the steel wire and the conductor of the specimen shuts off the machine. The axes of the specimen and the cutter shall be at right angles to one another. The force displayed when contact is made is noted. After each reading, move the specimen 10 mm farther and turn it by 90° about its longitudinal axis, i.e. 4 measurements shall be performed from the mean value of which the notching force is determined.

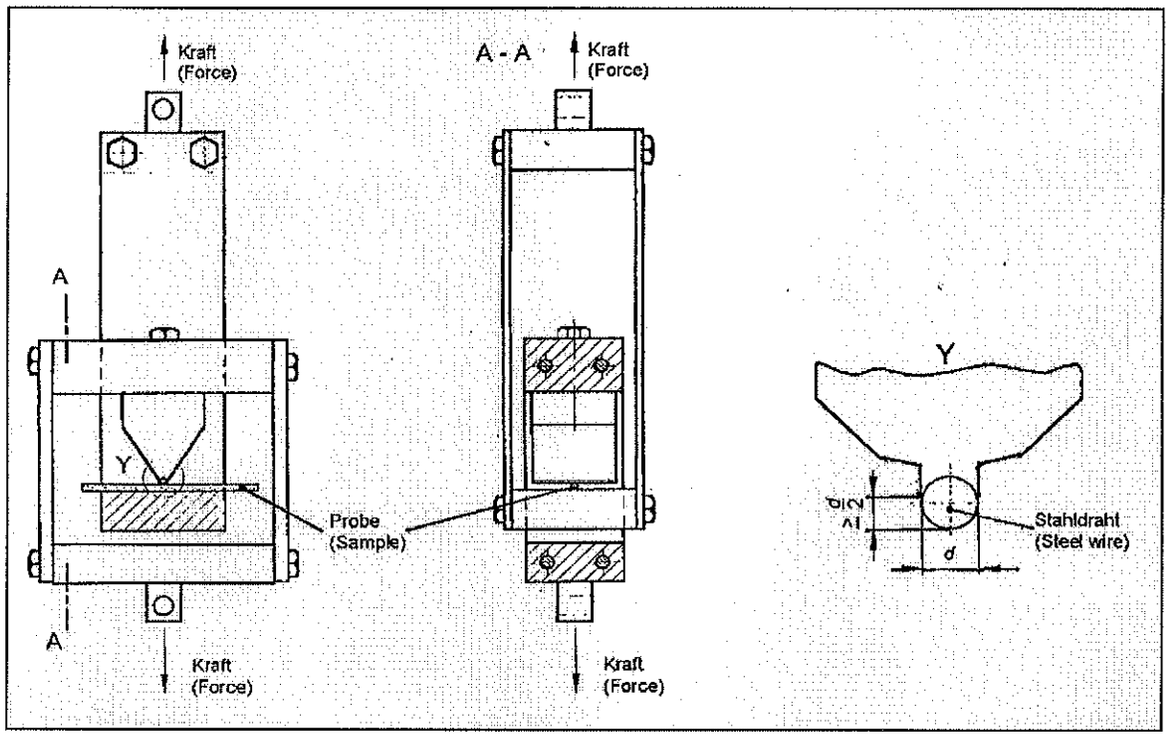

Figure 5 - Notch strength test stand

8.4 Non-flammability

Testing acc. to ISO 6722.

8.5 Electrical properties in as-received condition

8.5.1 Specific insulation resistance

Requirements

Specific insulation resistance: min. 10^9 Ωmm.

Test

According to ISO 6722 (but with 1% NaCl solution).

8.5.2 Measurement of 30-minute voltage protection

Requirements

No electric breakdown must occur.

Test

According to ISO 6722.

8.5.3 Measurement of 1-minute voltage protection (after aging only)

This test is only performed after tests that contain a reference to it.

Requirements and tests

According to Section 8.5.2 (30-minute voltage resistance); however, a test voltage of 1 kV_{eff} (5 kV for cross sections > 6.0 mm²) is applied for 1 minute.

8.6 Mechanical and electrical properties after mechanical, thermal or chemical stress

8.6.1 Stress test

This test applies to the following:

Cables with FEP insulation

Cables with ETFE insulation

Two specimens of sufficient length (approx. 2 m) are removed at least 1 m away from each other, and the insulation is removed from both sides.

The specimens are wound to a coil of 20 cm diameter and aged for 3 h in an oven at the temperature specified below:

FEP +225 °C (± 5 °C)
ETFE +200 °C (± 5 °C)

Subsequently, the specimens are removed from the oven and cooled down to room temperature for at least 16 h. Then, they are wound around a mandrel according to Table 12 in a closed spiral of at least 6 turns lying close to one another, and the ends without insulation are fixed (also see example in Figure 6). L_1 must be > 60 mm and L_2 must be > 10 mm.

The wound specimens including the mandrel are aged for another 3 h at the cable-specific temperatures given above. Let the specimens then cool down for at least 16 h, remove the mandrel (without unwinding the cable), and perform an electrical test according to 8.5.3 on the specimens.

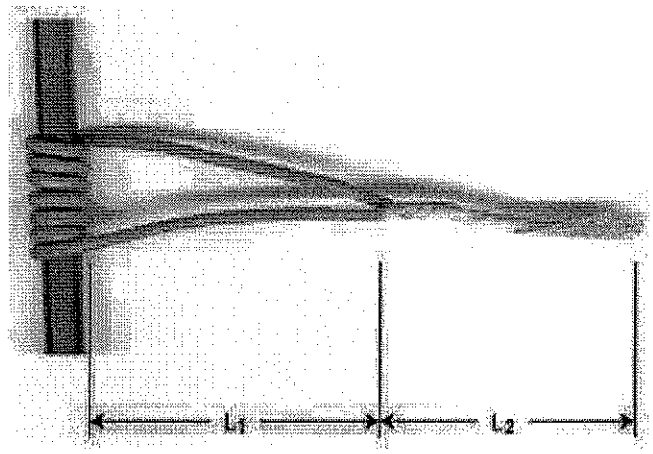

Figure 6 - Example representation of winding test

Evaluation

The test is considered passed if no breakdown occurs during electrical testing according to Section 8.5.3.

Table 12 - Mandrel diameter

Nominal conductor cross section	**[mm²]**	**0.22**	**0.35**	**0.5**	**0.75**	**1.0**	**1.5**	**2.5**	**4.0**	**6.0**
Mandrel diameter acc. to ISO 6722	[mm]	2				3		4	5	

8.6.2 Insulation shrinkage under heat

Requirements and tests

According to ISO 6722.

Test temperature according to Table 3, column: Thermal overload temperature.

8.6.3 Pressure resistance of the insulation under heat

Requirements and tests

According to ISO 6722.

Test temperature according to Table 3, T_O.

8.6.4 Thermal stability in wound state

Requirements

No electric breakdown must occur.

Test

Wind a cable specimen of sufficient length around a mandrel with a diameter acc. to Table 13 in 6 turns that lie very close to one another and tie it in place.

Age the specimen prepared in this way for 1 h in a natural convection oven acc. to DIN 50011-12 at the thermal overload temperature acc. to Table 3 (suspended on the mandrel). After cooling to room temperature, perform the test described in Section 8.5.3 (1-minute voltage protection).

Table 13 - Mandrel diameter

Nominal conductor cross section	**[mm²]**	**0.22**	**0.35**	**0.5**	**0.75**	**1.0**	**1.5**	**2.5**	**4.0**	**6.0**
Mandrel diameter	[mm]	5			9				13	

8.6.5 Thermal overload

Requirements and tests

According to ISO 6722 (thermal overload and winding test at standard climate)
Test temperature according to Table 3.
After the test, the color of the cable shall still be visible.

8.6.6 Short-term aging (240 h)

Requirements and tests

According to ISO 6722 (240-h short-term aging and winding test at -25 °C).
Test temperature according to Table 3.
After the test, the color of the cable shall still be visible.
Additional IR test after short-term aging.

8.6.7 Long-term aging (3,000 h)

Requirements and tests

According to ISO 6722 (3,000-h long-term aging and winding test at standard climate).
Test temperature according to Table 3.
After the test, the color of the cable shall still be visible.
Additional IR test on delivery and after long-term aging.

8.6.8 Low-temperature winding test (-40 °C)

Requirements and tests

According to ISO 6722 (Section on low-temperature winding test (-40 °C), rotating mandrel and weight).

8.6.9 Low-temperature impact test (-15 °C)

Requirements and tests

According to ISO 6722.

However, deviating is testing with a hammer weight of 100 g for cables with cross sections ≤ 0.5 mm².

8.6.10 Resistance of cable marking to wiping

This test only applies to cables with printed markings.

Testing and requirement

According to ISO 6722.

8.6.11 Dynamic flexural strength

This test shall be agreed upon separately for cables with nominal cross sections > 25 mm².

Requirements

While applying the test voltage, no electric breakdown must occur on the specimen, and the conductor of the stripped specimen must show no damage (e.g., strand breakage) on visual inspection.

Test

Age specimens of (200 ± 25) mm length in a natural convection oven acc. to DIN 50011-12 at the service life temperature acc. to Figure 8 for 48 h. Next, clamp the aged specimens in the test device acc. to Figure 7 and store at T_U for at least 4 h. Perform 300 bending cycles (cycle time approximately 3 s at nearly constant jaw speed) in the cold chamber. Then let the specimen warm up to room temperature. Then perform the test acc. to Section 8.5.3 (1-minute voltage protection), followed by a visual inspection.

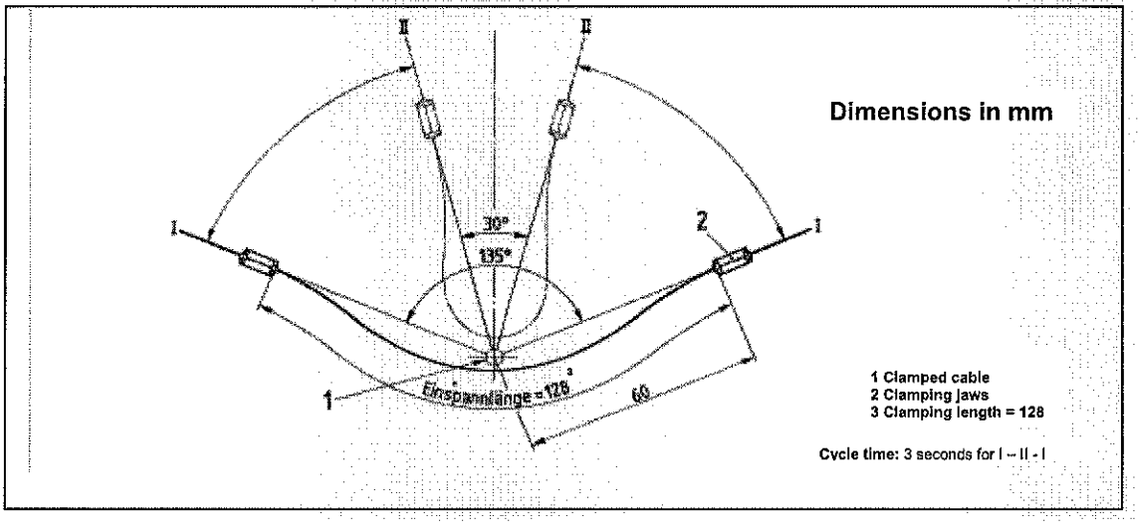

Figure 7 - Flexural strength test stand

8.6.12 Kink test

This test does not apply to cables with cross sections > 6.0 mm².

Requirement

No electric breakdown must occur.

Test

Before testing, a test device with an inner bending radius r corresponding to the cable cross section to be tested is selected (Figure 8); the test devices shall utilise the prescribed spacer rings according to Table 14.

Table 14 - Spacer rings

Nominal conductor cross section	**[mm²]**	**0.22**	**0.35**	**0.5**	**0.75**	**1.0**	**1.5**	**2.5**	**4.0**	**6.0**
Bending radius r	[mm]	1.0				1.5			3.0	
Spacer ring thickness	[mm]	1.0	1.1	1.3	1.6	1.8	2.1	2.6	3.3	3.9
Tolerance of spacer ring thickness	[mm]	- 0.1								

Strip 20 mm of insulation from the ends of the at least 200 mm long cable specimens. Clamp the specimen vertically between the jaws of the test device until the spacer rings meet the stop. Then subject the cable to 20 bending cycles. One cycle corresponds to bending the cable 180° to one side until the cable lies flat on the device, bending it 360° to the other side of the test device and returning it 180° to its original position. It must be ensured that as little pulling stress is applied to the cable as possible.

After unclamping the cable specimen, test it as described in Section 8.5.3 (1-minute voltage protection).

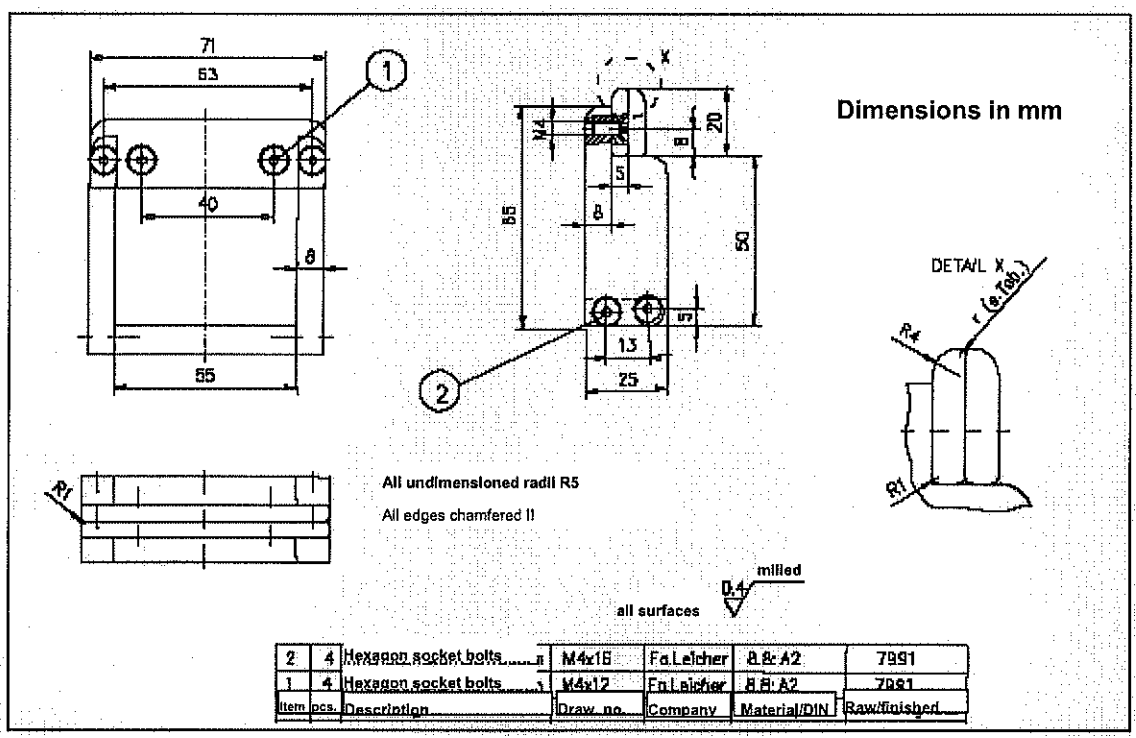

Figure 8 - Kink test stand

8.6.13 Electrical properties during water immersion

Requirements

The insulation resistance (measured according to Section 8.5.1) during water immersion must at least amount to 10^9 Ωmm. This value is measured every 7 days. The length-specific conductor resistance may deviate max. 10 % from the initial value.

After the test, the color of the cable shall still be visible.

Test

Wind a specimen of sufficient length in 10 turns around the center of a mandrel with a diameter according to Table 15. Tie the cable and remove the mandrel.

Table 15 - Mandrel diameter

Nominal conductor cross section	**[mm²]**	**0.22**	**0.35**	**0.5**	**0.75**	**1.0**	**1.5**	**2.5**	**4.0**	**6.0**
Mandrel diameter	[mm]	6				10		15	20	
Nominal conductor cross section	**[mm²]**	**10**	**16**	**25**	**35**	**50**	**70**	**95**	**120**	
Mandrel diameter	[mm]	40	50		75	100			125	

Connect the specimen to the positive terminal of a 48-V DC source and age for 1,000 h in a salt solution (1% NaCl) at a temperature of (85 ± 2)° C; 2 m of the specimen shall be completely immersed.

Electrode surface: (100 ± 10) cm^2

Electrode material: Cu

Immediately after water immersion, test the specimens as described in Section 8.5.3 (1-minute voltage protection).

Additionally, the test shall be performed with reversed polarity on new specimens.

8.6.14 Humid heat, constant (hydrolysis test)

Requirement

No electric breakdown must occur.

After the test, the color of the cable shall still be visible.

Test

Strip the insulation from the ends of a (3,000 ± 50) mm long cable specimen. Lay the cable in rings with a radius ≥ 25 mm, fix to the base plate and age for 3,000 h (1,000 h upon agreement) at a temperature of (85 ± 2) ℃ and a relative humidity of (85 ± 5) %. Subsequently, age the specimen for 30 min at room temperature and wind them within another 30 min according to Section 8.6.7 (winding test). Then test according to Section 8.5.3 (1-minute voltage resistance).

8.6.15 Ozone resistance

Requirements

No electric breakdown must occur.

Test

Wind cable specimens of sufficient length 4 to 6 times around a mandrel with a diameter of 3 x the outside diameter of the cable and affix. The test is performed according to DIN 53509-1, method A.

The specimens are aged (70 + 2) h at standard climate and then 48 h at 40 ℃, with a relative humidity of (55 ± 10) % and an ozone concentration of (50 ± 5) pphm (1 pphm = part per hundred million = 1 part ozone to 108 parts air by volume). After cooling to room temperature, unwind the specimens from the mandrel and test as described in Section 8.5.3 (1-minute voltage protection).

8.7 Mycological test

Requirements

Growth on the insulation must correspond to grade 3 maximum (growth visible with the naked eye, maximum 50 % of the specimen surface must be overgrown) according to DIN EN ISO 846, method A (fungus growth test).

At growth level > 2 the mean values of tensile strength and elongation at tear shall not change by more than 50 %.

Note: Tests that have been evaluated with a growth grade ≤ 1 according to DIN IEC 60068-2-10 Ed.5:1988, test method 1, are still considered passed.

Addition of fungicides without consultation of the relevant engineering departments is prohibited.

Test

Testing shall be performed according to DIN EN ISO 846, method A.

The cables with the largest cross sections shall be used from which the specimens according to Section 8.2.8 have been taken as well. At least 5 specimens of each compound shall be tested.

The specimens shall be cleaned using an ethanol-water mixture according to DIN EN ISO 846, Section 7.1. Test fungus spores shall be applied to the specimens.

Test fungus spores shall be applied to the specimens placed on mineral salt agar in a Petri dish; then, the specimens shall be incubated for 28 days at (29 ± 1) ℃. An intermediate check for fungus growth is allowed after 14 days.

After 28 days of incubation, the specimens shall be checked for fungus growth according to DIN EN ISO 846, Section 9.

Fungus growth shall be evaluated by the grade given in DIN EN ISO 846, Table 4.

If a growth > 2 is determined, a test according to 8.2.8 shall be performed after the mycological test (without copper), and the change in tensile strength and elongation at tear shall be evaluated.

8.8 Compatibility tests

Test scope

In this Section, tests are described that ensure compatibility of the cables with substances occurring in vehicles and in mating parts of the cables. These substances may include the following:

Operating fluids (group of agents according to *VW 603 06*-1)

Wrapping tapes (Table A.6) or

other components of the wiring harness (Table A.7).

8.8.1 Resistance to agents acc. to ISO 6722

To determine swelling and shrinkage, a compatibility test according to ISO 6722, Section "Fluid compatibility" shall be performed (all fluids).

Always the smallest cross section of a compound is tested.

8.8.2 Resistance to operating fluids and wrapping tapes

Tests according to this Section are mandatory; they serve for data collection.

Requirements

The insulation must have no cracks, fractures or other damage impairing function. No electric breakdown must occur in voltage testing.

Resistance at least	1,000 h with respect to agents of group 1 (see *VW 603 06-1*)
Resistance at least	240 h with respect to agents of group 2 (see *VW 603 06-1*). However, testing is performed for 1,000 h (see below).

If individual requirements of these tests are not met, a release is not generally ruled out. The evaluation of the results is performed by the specialist departments of the automobile manufacturers.

If the resistance is less than 1,000 h, the appropriate protection from those agents in Group 2 must be provided in the harness area where the cable is in use (e.g., by means of corrugated pipe, protective hose).

8.8.2.1 Testing on cross sections ≤ 6 mm²

Specimen preparation

Two cables of same material with a cross section of 0.35 mm² each are twisted with each other (twist length approx. 2 cm), wrapped with 50 % overlap with adhesive tape (for test groups 1, 2, 4 and 5), and specimens with a length of 40 cm are cut.

If other compounds are used for cross sections ≤ 6 mm², these shall be tested as well. In this case, always the smallest cross section of a compound is tested according to Table 16.

Test groups

The following test groups shall be prepared; test groups 1 and 3 shall be tested with respect to agents of group 1 as well as to agents of group 2 (*VW 603 06-1*).

Test group 1:

The prepared specimens are wound with a wrapping tape 1 to be selected from Table A.6. The wrapped specimens shall be bent in the center to form a U as to fit in an open test tube (approx. 25 mm in diameter).

The test temperature depends on the temperature class of the cable. A wrapping tape of identical temperature class shall be selected.

If no tape of the identical temperature class is available for a cable temperature class, the next temperature class down shall be selected. In this case, testing is performed at the temperature class of the tape.

Test group 2:

Like test group 1, however, using a wrapping tape 2 to be selected from Table A.6.

Test group 3:

Specimens without wrapping tape.

Test group 4:

Specimens like test group 1, however without aging in agents (zero specimen).

Test group 5:

Specimens like test group 2, however without aging in agents (zero specimen).

Test

At least 4 specimens of test groups 1, 2 and 3 each are immersed for 2 min into the respective agent *(VW 603 06-1)* at standard climate (or modestly greased with lubricating grease, respectively). The cable ends shall not come into contact with the agent. Then, let drip off for 2 minutes (10 minutes in the case of fuels, lubricating grease remains).

Each agent shall be tested separately (no combination of agents).

After completion, 1 specimen each is suspended in a test tube with the cable ends upwards; the test tubes are aged in an oven for 1,000 h at T_o. After 240 h, 480 h, 720 h and 1,000 h, one specimen each is removed and the remaining specimens immersed in the respective agent again. Then let them drip off and age them again.

Immersion is not required for specimens of test groups 4 and 5. Aging at elevated temperature and testing are performed according to the time intervals of test groups 1 to 3.

Storage of the specimens is without direct contact to a possible sump of agent. This prevents the undesired, permanent contact of the specimens with the respective agent since capillary effects, which cause re-feed of the agent to the specimen, shall be avoided. In this way, temporary wetting of the wiring harness with the agent is simulated.

After the test time has elapsed the wiring harness is conditioned at standard climate for at least 3 hours (but maximum 72 hours) and is then tested as follows.

The U-section (lower 30 mm of specimen) and the straight leg section are evaluated separately.

The wound specimen is wrapped around a mandrel with a diameter of 20 mm. Then, a voltage test according to Section 8.5.3 (1-minute voltage protection) is performed.

Failures shall be documented separately for the leg area and the U-section.

Thereafter, the adhesive tape is removed from the specimen, the strands separated and a visual inspection performed. Any visual changes to the cable or wrapping tape must be noted in the test report. If the wrapping tape cannot be removed without apparent damage to the cable, this shall be documented.

One strand is wrapped at least twice tightly around a mandrel with a diameter of 2 mm, the other one around a mandrel with a diameter of 10 mm, then both are visually evaluated. Afterwards, a voltage test according to Section 8.5.3 is performed on each strand.

If the U-section exhibits damage, the damaged part shall be removed and the test be performed on the remaining section.

For cross sections other than 0.35 mm², testing shall be performed according to Table 16.

Table 16

Nominal conductor cross section	Twist length	Test tubes	Winding mandrels after aging		
			Wound, twisted specimen (large)	One strand without adhesive tape (medium)	One strand without adhesive tape (small)
[mm²]	[mm]	[mm]	[mm]	[mm]	[mm]
0.35	20 +3 / - 5	25 ± 2	20	10	2
0.50	20 +3 / - 5	25 ± 2	20	10	2
0.75	25 +3 / - 5	25 ± 2	30	15	2
1.00	30 +3 / - 5	30 ± 2	30	15	3
1.50	35 +3 / - 5	none, freely suspended	35	20	3
2.50	40 +3 / - 5	none, freely suspended	45	25	4
4.00	45 +3 / - 5	none, freely suspended	55	30	5

NOTE on mandrel selection:

The small mandrels are chosen corresponding to long-term aging according to ISO 6722. The medium-sized mandrel corresponds to approximately 7 times the outside diameter of the strand. The large mandrel corresponds to approx. 7 times the outside diameter of the twisted specimen with adhesive tape.

8.8.2.2 Testing on cross sections > 6 mm²

Specimen preparation Testing is performed on 16 mm² cross section. If other compounds are used for cross sections > 6 mm², these shall be tested as well. In this case, always the smallest cross section of a compound is tested. This test is not required if the compound has already been tested for cross sections ≤ 6 mm².

Test groups

See Section 8.8.2.1.

Test

Testing is performed as for cross sections ≤ 6 mm², but with following adaptations:

Specimen length: at least 600 mm

Only one cable is wrapped with adhesive tape; this cable is then bent around a mandrel (mandrel diameter 5 to 5.5 times the outside cable diameter). The legs are fixed using the same wrapping tape (see Figure 9).

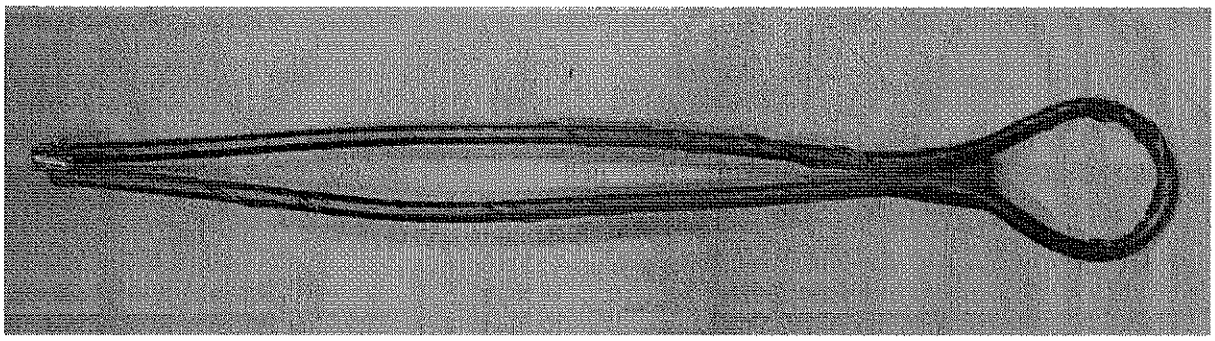

Figure 9 – Specimen

After immersion in the prescribed agents, the specimens prepared like this are aged suspended in a natural convection oven with the bend facing downwards (test tube not required).

The adhesive tape is removed. Then, the cable is wound around a mandrel according to Section 8.6.7. Subsequently, a visual test and a voltage test according to Section 8.5.3 (1-minute voltage protection) are performed.

Any visual changes to the cable or wrapping tape must be noted in the test report. If the wrapping tape cannot be removed without apparent damage to the cable, this shall be documented.

8.8.3 Resistance to harness components

Tests according to this Section are mandatory; they serve for data collection. If individual requirements of these tests are not met, a release is not generally ruled out. The evaluation of the results is performed by the specialist departments of the automobile manufacturers.

Sample wiring harnesses with material combinations according to Table A.7 shall be manufactured. For detailed material combinations and testing temperatures see A8 et sqq.

The components shall be fixed to come into direct contact with the cable insulation. Hoses shall be filled at least 60 %.

As a rule, testing shall be performed at the temperature corresponding to the temperature class of the cable, provided that the component belongs to the same (or a higher) temperature class as the cable.

If the component belongs to a lower temperature class, the respective sample wiring harness shall be tested at the lower temperature.

Testing shall be performed according to the detailed test diagrams for different temperature classes given in Table A8 et sqq., and documented. If necessary, manufacturer and ordering designation of the components shall be adapted.

Requirements

The insulation must have no cracks, fractures or other damage impairing function. There must be no electric breakdown in subsequent voltage testing.

Discoloration and contraction (e.g. in the seal area) as well as damaged or destroyed components shall be documented.

8.8.3.1 Testing on cross sections ≤ 6 mm²

Specimen preparation

Each sample wiring harness consists of 6 cables with lengths of (300 to 400) mm and cross sections of 0.35 mm² (3 cables) and 2.5 mm² (3 cables). The cables are fixed on both sides with contact parts. The wiring harness contains further components according to Table A8 et sqq. Always 5 identical sample wiring harnesses shall be manufactured (4 wiring harnesses for aging at elevated temperature, 1 wiring harness as reference).

Test

The sample wiring harnesses prepared in this way are aged for 3,000 h at the temperatures given in Table A8 et sqq. in a natural convection oven acc. to DIN 50011-12 so that there is no contact with the oven walls or other metallic objects (see Figure 10).

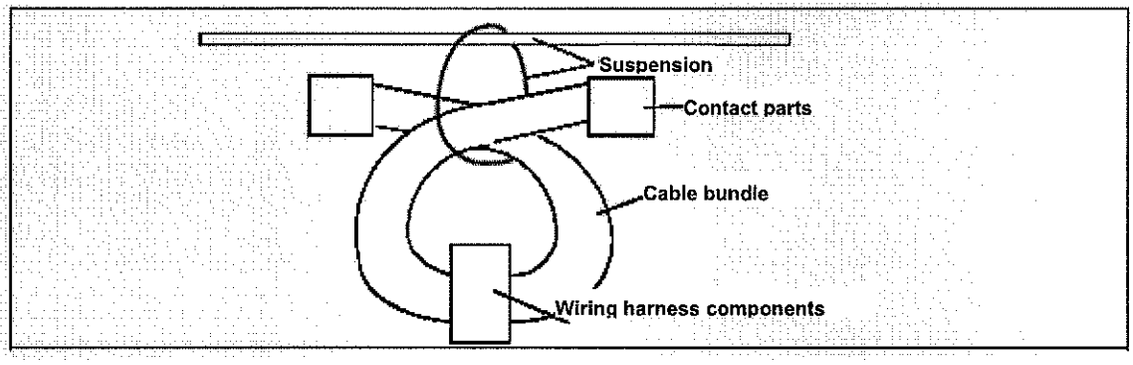

Figure 10 - Wiring harness

The test is considered passed after 1,500 h. Remove the first sample wiring harness for testing after 1,500 h, then every 500 h.

Then, wind the cable specimen around a mandrel with a diameter acc. to Table 17, inspect it visually, unwind it and perform a voltage test acc. to Section 8.5.3 (1-minute voltage protection).

If winding is impossible due to the specimen shape (e.g., cable outlet in casting compounds, shrink tubes, etc.), perform the following evaluation:

Each external single cable is bent by ± 90° around the half mandrel according to Table 17 at the outlet point (if possible in opposite direction; see Figure 11).

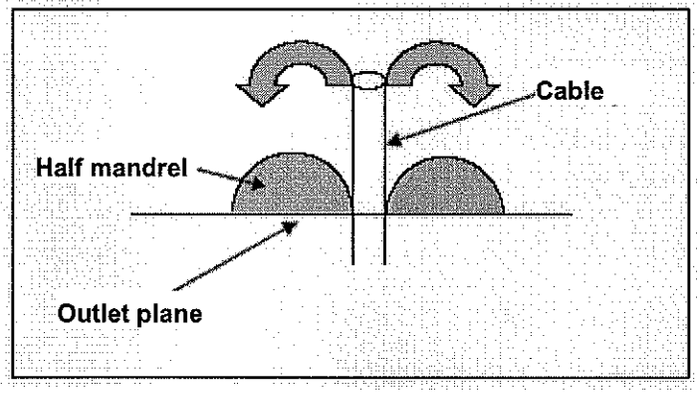

Figure 11 - Bending configuration

Table 17 - Mandrel diameter

Nominal conductor cross section	**[mm²]**	**0.35**	**2.5**
Mandrel diameter	[mm]	6	15

8.8.3.2 Testing on cross sections > 6 mm²

Specimen preparation

Testing is performed on 16 mm² cross sections. If other compounds are used for cross sections > 6 mm², these shall be tested as well. In this case, always the smallest cross section of a compound is tested. This test is not required if the compound has already been tested for cross sections ≤ 6 mm².

On principle, testing is performed according to Section 8.8.3. However, the following modifications shall apply:

Specimen length: approx. 600 mm

Only one cable shall be used.

As described in Section 8.8.3.1, the adapted component is attached to the cable cross section, or adhesive tape is applied.

Then the specimens are bent – as described in Section 8.8.3.1 – bonded together with Teflon tape, and suspended in the oven.

Test

Before removal of the components, the specimen is visually inspected. Then the cable is wound around a mandrel according to Section 8.6.8.

Perform a visual inspection and a voltage test according to Section 8.5.3 on the wound specimen.

On specimens with shrinkdown plastic tubes and longitudinal water sealing (if winding test is not possible), the transition is evaluated and voltage protection is tested according to Section 8.5.3 after the specimen has been bent once in both directions around the half mandrel (90° each).

Any visual changes to the cable, contacts, components or wrapping tape must be noted in the test report. If the wrapping tape cannot be removed without apparent damage to the cable, this shall be documented.

9 Environmental protection and safety

The materials shall meet the requirements of VDA 232-101 (list of hazardous substances) and comply with the current legal specifications.

Environmental standard VW 911 00 must be observed.

Emission behavior according to VW 501 80 and according to usage guideline No. 3211 issued by the Audi laboratory in Ingolstadt, Germany must be complied with.

10 Referenced standards[1]

DIN 1333	Presentation of Numerical Data
DIN 50011-12	Artificial Climates in Technical Applications; Air Temperature as a Climatological Quantity in Controlled-Atmosphere Test Installations
DIN 50014	Climates and Their Technical Application; Standard Atmospheres
DIN 51604-2	Methanolic FAM Testing Fluid for Polymer Materials; Composition and Requirements
DIN 53509-1	Testing of Rubber – Determination of Resistance to Ozone Cracking – Part 1: Static Conditions
DIN 72551-6	Road Vehicles – Low-Tension Cables – Part 6: Single-Core, Unscreened, with Thin Insulation Wall; Dimensions, Materials, Marking
DIN 72551-7	Road Vehicles – Low-Tension Cables – Part 7: Colours and Colour Marking of Low-Tension Cables
DIN 76722	Road Vehicles, Low Voltage Cables; Type Abbreviation
DIN EN 590	Automotive Fuels – Diesel – Requirements and Test Methods
DIN EN 3745-511	Aerospace Series – Fibres and Cables, Optical, Aircraft Use; Test Methods – Part 511: Cable to Cable Abrasion
DIN EN 10270-1	Steel Wire for Mechanical Springs – Part 1: Patented Cold Drawn Unalloyed Steel Wire
DIN EN 13602	Copper and Copper Alloys - Drawn, Round Copper Wire for the Manufacture of Electrical Conductors
DIN EN 14214	Automotive Fuels – Fatty Acid Methyl Esters (FAME) for Diesel Engines – Requirements and Test Methods
DIN EN 60684-3	Flexible Insulating Sleeving – Part 3: Specifications for Individual Types of Sleeving
DIN EN 60811-1-1	Insulating and Sheathing Materials of Electric Cables – Common Test Methods – Part 1-1: General Application; Measurement of Thickness and Overall Dimensions; Test for Determining the Mechanical Properties
DIN EN 60811-3-2	Insulating and Sheathing Materials of Electric and Optical Cables - Common Test Methods - Part 3-2: Methods Specific to PVC Compounds - Loss of Mass Test - Thermal Stability Test
DIN EN ISO 846	Plastics – Evaluation of the Action of Microorganisms
DIN EN ISO 1133	Plastics – Determination of the Batch Mass Flow Rates (MFR) and the Batch Volume Flow Rates (MVR) of Thermoplasts
DIN EN ISO 1183-1	Plastics – Methods for Determining the Density of Non-Cellular Plastics – Part 1: Immersion Method, Liquid Pyknometer Method and Titration Method
DIN EN ISO 1628-2	Plastics – Determination of the Viscosity of Polymers in Dilute Solution Using Capillary Viscosimeters – Part 2: Poly(vinyl Chloride) Resins

[1] In this Section terminological inconsistencies may occur as the original titles are used.

DIN EN ISO 6427	Plastics – Determination of Matter Extractable by Organic Solvents (Conventional Methods)
DIN EN ISO/IEC 17025	General Requirements for the Competence of Testing and Calibration Laboratories
DIN IEC 60068-2-10	Environmental Testing – Part 2-10: Tests; Test J and Guidance: Mould Growth
ISO 34-1	Rubber, Vulcanized or Thermoplastic; Determination of Tear Strength Part 1: Trouser, Angle and Crescent Test Pieces
ISO 6722	Road Vehicles – 60 V and 600 V Single-Core Cables – Dimensions, Test Methods and Requirements
VDA 232-101	Liste für deklarationspflichtige Stoffe im Automobilbau – Inhaltsstoffe in Bauteilen und Werkstoffen (List of Substances which are Subject to Mandatory Declaration – Substances Contained in Components and Materials; only available in German)
VDA 675 101	Elastomer-Bauteile in Kraftfahrzeugen; Prüfverfahren zur Identifikation, Härte, Mikrohärteprüfung (IRHD) (Rubber Components in Motor Vehicles; Test Methods for Identification; Hardness; Microhardness Test (IRHD); only available in German)
VDA 675 130	Elastomer-Bauteile in Kraftfahrzeugen; Prüfverfahren zur Identifikation, Glührückstand ohne chemische Behandlung (Elastomer Components in Motor Vehicles; Test Methods for Identification; Ignition Residue without Chemical Treatment – only available in German)
VDA 675 135	Elastomer-Bauteile in Kraftfahrzeugen, Prüfverfahren zur Identifikation, Thermogravimetrie TGA (Elastomer Components in Motor Vehicles; Test Methods for Identification; Thermogravimetry TGA – only available in German)
VDA Volume 6 Part 1	Qualitätsmanagement in der Automobilindustrie – Teil 1: QM-Systemaudit; Grundlage DIN EN ISO 9001 und DIN EN ISO 9004-1 (Quality Management in the Automotive Industry – Part 1: QM system audit; based on DIN EN ISO 9001 and DIN EN ISO 9004-1; only available in German)
VW 603 06-1	*List of Agents for Compatibility Testing*
VW 911 00	*Environmental Standard for Vehicles; Vehicle Parts, Materials, Operating Fluids; Policy, Specifications*
VW 501 80	*Components in Passenger Compartment; Emission Behavior*

A.1 Conductor setup, symmetrical, type A (normative)

Table A.1 – Conductor composition, symmetrical, type A

Nominal conductor cross section	Strand		Conductor						Cable						
	Number	Diameter	Diameter d1	Twist length	Cross section[1]		Resistance at 20 °C Strands uninsulated (tin plated[3])		Outside diameter d2		Wall thickness of insulation s	c_{pk} value (based on s)	Test wall thickness s_P	Concentricity factor K[2]	Weight[4]
[mm²]		[mm]	[mm]	[mm]	[mm²]		[mΩ/m]		[mm]		[mm]		[mm]	[%]	[g/m]
		max.	max.	max.	max.	min.	max.	min.	max.	Perm. dev.	min.	min.	min.	min.	≈
0.22	7	0.21	0.70	27	0.219	0.202	84.8	77.9	1.2		0.20		0.22		3.1
0.35		0.26	0.80	27	0.358	0.329	52.0	47.8	1.3	-0.1	0.20		0.22		4.5
0.5		0.19	1.00	45	0.501	0.461	37.1	34.1	1.6		0.22		0.24		6.6
0.75		0.23	1.20	45	0.753	0.692	24.7	22.7	1.9			1.33		45	9.0
1.0	19	0.26	1.35	50	1.006	0.924	18.5	17.0	2.1	-0.2	0.24		0.26		11
1.5		0.32	1.70	60	1.461	1.346	12.7	11.7	2.4						16
2.5		0.41	2.20	75	2.442	2.249	7.6	7.0	3.0	-0.3	0.28		0.30		26

1) Calculated with a value of specific electrical conductivity of 58.5 Sm/mm², quality control by means of resistance measurement
2) K [%] = $(s_{min}/s_{max})*100$, s_{max} must not be located opposite s_{min}. s_{min}: minimum wall thickness; s_{max}: maximum wall thickness
3) For resistance values of tin plated conductors see ISO 6722.
4) Weight according to sample, values given in Table apply to PVC

A.2 Conductor composition, asymmetrical, type B (normative)

Table A.2 – Conductor composition, asymmetrical, type B

Nominal conductor cross section	Strand		Conductor						Cable						
	Number	Diameter	Diameter d1	Twist length	Cross section[1]		Resistance at 20 °C Strands uninsulated (tin plated[4])		Outside diameter d2		Wall thickness of insulation s	c_{pk} value (based on s)	Test wall thickness s_P	Concentricity factor K [2]	Weight[5]
[mm²]		[mm]	[mm]	[mm]	[mm²]		[mΩ/m]		[mm]		[mm]		[mm]	[%]	[g/m]
		max.	max.	max.	max.	min.	max.	min.	max.	Perm. dev.	min.	min.	min.	min.	≈
0.35	12	0.21	0.90	Not specified	0.358	0.329	52.0	47.80	1.4	-0.2	0.20	1.33	0.22	45	4.5
0.5	16		1.00		0.501	0.461	37.1	34.10	1.7		0.22		0.24		6.6
0.75	24		1.20		0.753	0.692	24.7	22.70	1.9		0.24	≥ 1.0 [3]	0.26		9.0
1.0	32		1.35		1.006	0.924	18.5	17.00	2.1						11
1.5	30	0.26	1.70		1.461	1.346	12.7	11.70	2.4	-0.3					16
2.5	50		2.20		2.442	2.249	7.6	7.00	3.0		0.28		0.30		26
4.0	56	0.31	2.75		3.957	3.637	4.7	4.32	3.7		0.32		0.34		42
6.0	84		3.30		5.998	5.514	3.1	2.85	4.3						61

1) Calculated with a value of specific electrical conductivity of 58.5 Sm/mm², quality control by means of resistance measurement
2) K [%] = $(s_{min}/s_{max})*100$, s_{max} must not be located opposite s_{min}. s_{min}: minimum wall thickness; s_{max}: maximum wall thickness
3) In the transition period a c_{PK} value ≥ 1.0 will be accepted for cables ≥ 0.75 mm²
4) For resistance values of tin plated conductors see ISO 6722.
5) Weight according to sample, values given in Table apply to PVC

A.3 Conductor composition, asymmetrical, type b, used up to March 2005 – not for new designs

Table A.3 – Conductor composition, asymmetrical, type B

Nominal conductor cross section	Strand		Conductor						Cable						
	Number	Diameter	Diameter d1	Twist length	Cross section[1]		Resistance at 20 °C Strands uninsulated		Outside diameter d2		Wall thickness of insulation s	c_{pk} value (based on s)[2]	Test wall thickness s_P	Concentricity factor K[3]	Weight[4]
[mm²]		[mm]	[mm]	[mm]	[mm²]		[mΩ/m]		[mm]		[mm]		[mm]	[%]	[g/m]
	min.	max.	max.	max.	max.	min.	max.	min.	max.	Tol.	min.	min.	min.	min.	≈
6.0	84	0.31	3.4		5.998	5.514	3.100	2.852	5.0	-0.6	0.64		0.66		68
10.0	80	0.41	4.5		10.21	9.392	1.820	1.674	6.5		0.80		0.82		127
10.0	290	0.21	4.5		10.21	9.392	1.820	1.674	6.5	-0.6	0.80		0.82		127
16.0	126	0.41	6.3	Not	16.02	14.73	1.160	1.067	8.3	-0.6	0.80		0.82		182
25.0	196	0.41	7.8	specified	25.01	23.00	0.743	0.683	10.4	-0.7	1.04	≥ 1.33	1.06	45	279
35.0	276	0.41	9.0		35.26	32.43	0.527	0.484	11.6	-0.6	1.04		1.06		385
50.0	396	0.41	10.5		50.49	46.45	0.368	0.338	13.5	-0.6	1.20		1.22		534
70.0	360	0.51	12.5		71.74	66.00	0.259	0.238	15.5	-0.8	1.20		1.22		760
95.0	2850	0.21	14.8		94.80	87.21	0.196	0.180	18.0	-1.0	1.28		1.30		911
120.0	3650	0.21	16.5		121.4	111.7	0.153	0.140	19.7	-1.0	1.28		1.30		1146

1) Calculated with a value of specific electrical conductivity of 58.5 Sm/mm², quality control by means of resistance measurement
2) In the transition period a c_{PK} value ≥ 1.0 will be accepted for cable cross sections ≥ 0.75 mm²
3) K [%] = $(s_{min}/s_{max})*100$, s_{max} must not be located opposite s_{min}.
4) Weight according to sample, values given in Table apply to PVC
NOTE: s_{min} = minimum wall thickness; s_{max} = maximum wall thickness

A.4 Conductor composition, asymmetrical, finely stranded (f), type B with reduced outside diameters

Table A.4 – Conductor composition, asymmetrical, finely stranded (f), type B

Nominal conductor cross section	Strand[6]		Conductor						Cable						
	Quantity[5]	Diameter	Diameter d1	Twist length	Cross section[1]		Resistance at 20 °C Strands uninsulated		Outside diameter d2		Wall thickness of insulation s	c_{pk} value (based on s)[2]	Test wall thickness s_P	Concentricity factor K[3]	Weight[4]
[mm²]		[mm]	[mm]	[mm]	[mm²]		[mΩ/m]		[mm]		[mm]		[mm]	[%]	[g/m]
	nom.	max.	max.	max.	max.	min.	max.	min.	max.	Perm. dev.	min.	min.	min.	min.	≈
6.0	84	0.31	3.4		5.998	5.514	3.100	2.852	5.0	-0.6	0.64		0.66		68
10.0	80	0.41	4.5		10.21	9.392	1.820	1.674	6.5	-0.6	0.80		0.82		127
16.0	126	0.41	5.5	Not	16.02	14.73	1.160	1.067	7.5	-0.6	0.80		0.82		182
25.0	196	0.41	7.0	spec.	25.01	23.00	0.743	0.683	9.6	-0.8	1.04	≥ 1.33	1.06	45	279
35.0	276	0.41	8.3		35.26	32.43	0.527	0.484	10.9	-1.0	1.04		1.06		385
50.0	396	0.41	9.8		50.49	46.45	0.368	0.338	12.8	-1.0	1.20		1.22		534
70.0	360	0.51	11.6		71.74	66.00	0.259	0.238	14.6	-1.0	1.20		1.22		760
95.0	475	0.51	13.8		94.80	87.21	0.196	0.180	17.0	-1.2	1.28		1.30		911
120.0	608	0.51	15.1		121.4	111.7	0.153	0.140	18.3	-1.2	1.28		1.30		1146

1) Calculated with a value of specific electrical conductivity of 58.5 Sm/mm², quality control by means of resistance measurement
2) In the transition period a c_{PK} value ≥ 1.0 will be accepted
3) K [%] = $(s_{min}/s_{max})*100$, s_{max} must not be located opposite s_{min}. NOTE: s_{min} = minimum wall thickness; s_{max} = maximum wall thickness
4) Weight according to sample, values given in Table are only approximate values and apply to PVC
5) Slight deviations concerning the number of wires are permissible (+/-5%) as long as the electrical resistance values and the maximum strand diameter are adhered to.
6) Other diameters and numbers of wires may be used if agreed upon between customer and supplier.

A.5 Conductor composition, asymmetrical, extra-finely stranded (ff), type B

Table A.5 – Conductor composition, asymmetrical, extra-finely stranded (ff), type B

Nominal conductor cross section	Strand[6]		Conductor						Cable						
	Quantity[5]	Diameter	Diameter d1	Twist length	Cross section[1]		Resistance at 20 °C Strands uninsulated		Outside diameter d2		Wall thickness of insulation s	c_{pk} value (based on s)[2]	Test wall thickness s_P	Concentricity factor K[3]	Weight[4]
[mm²]		[mm]	[mm]	[mm]	[mm²]		[mΩ/m]		[mm]		[mm]		[mm]	[%]	[g/m]
	nom.	max.	max.	max.	max.	min.	max.	min.	max.	Perm. Dev.	min.	min.	min.	min.	≈
6.0	183	0.21	3.4	Not specified	5.998	5.514	3.100	2.852	5.0	-0.6	0.64	≥ 1.33	0.66	45	68
10.0	305	0.21	4.5		10.21	9.392	1.820	1.674	6.5	-0.6	0.80		0.82		127
16.0	500	0.21	6.3		16.02	14.73	1.160	1.067	8.3	-0.9	0.80		0.82		182
25.0	790	0.21	7.8		25.01	23.00	0.743	0.683	10.4	-1.2	1.04		1.06		279
35.0	1090	0.21	9.0		35.26	32.43	0.527	0.484	11.6	-1.5	1.04		1.06		385
50.0	1600	0.21	10.5		50.49	46.45	0.368	0.338	13.5	-1.5	1.20		1.22		534
70.0	2175	0.21	12.5		71.74	66.00	0.259	0.238	15.5	-1.5	1.20		1.22		760
95.0	3000	0.21	14.8		94.80	87.21	0.196	0.180	18.0	-1.8	1.28		1.30		911
120.0	3700	0.21	16.5		121.4	111.7	0.153	0.140	19.7	-1.8	1.28		1.30		1146

1) Calculated with a value of specific electrical conductivity of 58.5 Sm/mm^2, quality control by means of resistance measurement.
2) In the transition period a c_{PK} value ≥ 1.0 will be accepted.
3) K [%] = (s_{min}/s_{max})*100, s_{max} must not be located opposite s_{min}. NOTE: s_{min} = minimum wall thickness; s_{max} = maximum wall thickness.
4) Weight according to sample, values given in Table are only approximate values and apply to PVC.
5) Slight deviations concerning the number of wires are permissible (+/-5%) as long as the electrical resistance values and the maximum strand diameter are adhered to.
6) Other diameters and numbers of wires may be used if agreed upon between customer and supplier.

A.6 Survey of wrapping tapes

Table A.6 – Survey of wrapping tapes

Wrapping tape 1 (film)	**Temperature** [1)]	**Material**	**Adhesive base**
Beiersdorf Tesa 4173	105 °C	Plasticized PVC	Rubber
Coroplast 651 MSX	125 °C	Plasticized PVC	Acrylate
Wrapping tape 2 (textile)			
Beiersdorf Tesa 51608 / 51609	105 °C	PET nonwoven	R ubber
Certoplast 514	125 °C	PET fabric	Rubber
Coroplast 837 X	150 °C	PET woven fabric with smooth surface	Acrylate

1) Temperature values correspond to service life temperature resistance (3,000 h aging)

A.7 Bill of materials, component compatibility

Table A.7 – Bill of materials, component compatibility

Ser. no.	Designation [5]	Material [4]
1 [1]	Contact part, quick-connect receptacle (tin plated)	CuSn, Sn
2 [2]	Contact part, circular receptacle (tin plated)	CuFe2, Sn
3 [3]	Contact part, circular receptacle (silver plated)	CuFe, Ag
4	Cable lug (tin plated)	CuSn, Sn
5 [1]	Single core seal	Silicone
6 [2]	Single core seal	Silicone
7 [2]	Circular connector housing with single core sealing (25-way)	PBT+15% GF
8 [3]	Circular receptacle housing with single core sealing (8-way)	PA 6.6
9 [1]	Socket housing with single core sealing (6-way)	POM
10	Shrinkdown plastic tube with adhesive	Synthetic-rubber-based adhesive
11	Shrinkdown plastic tube	PE modified
12	Insulating hose	PVC acc. to DIN EN 60684-3
13 [2]	PUR insulating hose	PUR
14	Braided sleeving (Revitex VSC)	Silicone-coated glass braid
15	Corrugated pipe	PP modified
16	Cable tie (assembled with force-free contact of cable tie) and corrugated pipe	PA66
17	Comb connector sleeving	Thermoplastic melting material based on polyamide
18	Longitudinal water sealing 3M-butyl (install with grommet)	Butyl rubber
19	Grommet	EPDM, Shore A60
20	Wrapping tape Certoplast 608	PVC tape, acrylate adhesive
21	Wrapping tape Coroplast Y512	PVC tape (polyolefin), acrylate adhesive
22	Wrapping tape Coroplast 837 X	PET fabric, acrylate adhesive
23	Current standard and special cables of insulating materials other than the material of the cable to be tested (see Table 2 "Application properties" in LV 312)	Acc. to agreement, e.g. PVC (Pb-free), FEP, ETFE, XPE, PP, PUR, etc. Temperature class 125 °C only for insulating materials with resistance thereto

1) 2) 3) The contact parts, housings and single core seals marked with the same numbers are matched to each other. The diameters of the cable protection systems (corrugated hose, shrinkdown plastic tube and braided sleeving, etc.) shall be matched to the sample wiring harness, if applicable.
4) The material used is decisive for testing.
5) Specifications given in these columns are for information purposes.

Table A.8 – Bill of materials, component compatibility for cables of temperature class B 105℃

e.g., PVC	The material used is decisive for testing.	5 sample wiring harnesses each	Test temperature										
			105 ℃										
			1	2	3	4	5	6	7	8	9	10	11
Cable	Test cables 0.35 mm² and 2.50 mm², 3x 0.35 mm², 3x 2.50 mm²												
Contacts / cable lugs	CuSn, Sn quick-connect receptacle, Kostal 221 24 49207 0	No. 1	6	5		6		6		6	6		
	CuFe2, Sn circular receptacle, Tyco, 0-0928985-2	No. 2		6	5	6	6		6		6	6	
	CuFe, Ag circular receptacle, Tyco, 0-0927788-2	No. 3	5		5		6	6	6	6		6	
	CuSn, Sn cable lug, Lear, 25168 331 322	No. 4	1	1	1								
Seals	Silicone, single wire seal, Kostal, 108 00 444523	No. 5	6										
	Silicone, single wire seal, Tyco, 0-082890-1	No. 6		6									
Connector housing	PBT+15% GF circular connector housing, Tyco, 2-0963295-1	No. 7		1									
	PA 6.6, circular connector housing, Tyco, 1-0828736-1	No. 8			1								
	POM, socket housing, Hirschmann, 972-537-001	No. 9	1										
Components	Synthetic rubber based, shrinkdown plastic tube, DSG Canusa, 621 0000 090	No. 10			1								
	PE modified, shrinkdown plastic tube, DSG Canusa, 14/1 45TR Al 50mm	No. 11		1									
	PVC 9248 acc. to DIN 40621, insulating hose, HC, 2125013	No. 12	1										
	PUR, insulating hose, Sahlberg, 6435641	No. 13		1									
	Silicone coated glass braid, braided sleeving, Relats, VSR 25 NW6	No. 14				1							
	PP modified, corrugated pipe, Fränkische Rohrwerke, Uniwell	No. 15					1						
	PA 66, cable tie, Hellermann, 111-019 50 PA 66, corrugated pipe, Fränkische Rohrwerke 400008 08	No. 16						1					
	Thermoplastic hot-melt adhesive, cavity connector sleeving, Henkel, Macromelt 6208 N	No. 17					1						
	Butyl rubber, longitudinal water sealing, Hellermann, DSG, 460-05029/19-1.5/105AL 30mm	No. 18							1				
	EDPM Shore A60, grommet, WOKO, 02 5539	No. 19							1				
	PVC, acrylate adhesive, wrapping tape, Certoplast, 608/609 19mm	No. 20				1							
	Polyolefin, acrylate adhesive, wrapping tape, Coroplast Y 512 19mm	No. 21						1					
	PET, acrylate adhesive, wrapping tape, Coroplast 837X 19mm	No. 22						1					
	Silicone, cables (class E/F)	No. 23a										1	
	ETFE, cables (class D)	No. 23a1									1		
	X-PE, cables (class D)	No. 23b									1		
	PP, cables (class C)	No. 23c								1			
	X-PE, cables (class C)	No. 23d								1			
	PVC, cables (class B 105℃)	No. 23e											
	TPE-S, cables (class C)	No. 23f								1			

Table A.9 – Bill of materials, component compatibility for cables of temperature class C 125℃

e.g., XPE	The material used is decisive for testing.	5 sample wiring harnesses each	Test temperature										
			125 ℃								105 ℃		
			1	2	3	4	5	6	7	8	9	10	11
Cable	Test cables 0.35 mm² and 2.50 mm², 3x 0.35 mm², 3x 2.50 mm²												
Contacts / cable lugs	CuSn, Sn quick-connect receptacle, Kostal 221 24 49207 0	No. 1	6	5		6		6	6		6	6	
	CuFe2, Sn circular receptacle, Tyco, 0-0928985-2	No. 2		6	5	6	6		6	6		6	6
	CuFe, Ag circular receptacle, Tyco, 0-0927788-2	Nr.3	5		6		6	6		6	6		6
	CuSn, Sn cable lug, Lear, 25168 331 322	No. 4	1	1	1								
Seals	Silicone, single wire seal, Kostal, 108 00 44452 3	No. 5	6										
	Silicone, single wire seal, Tyco, 0-082890-1	No. 6		6									
Connector housing	PBT+15% GF circular connector housing, Tyco, 2-0963295-1	No. 7		1									
	PA 6.6, circular connector housing, Tyco, 1-0828736-1	No. 8			1								
	POM, socket housing, Hirschmann, 972-537-001	No. 9	1										
Components	Synthetic rubber based, shrinkdown plastic tube, DSG Canusa, 621 0000 090	No. 10			1								
	PE modified, shrinkdown plastic tube, DSG Canusa, 14/1 45TR Al 50mm	No. 11		1									
	PVC 9248 acc. to DIN 40621, insulating hose, HC, 2125013	No. 12									1		
	PUR, insulating hose, Sahlberg, 6435641	No. 13		1									
	Silicone coated glass braid, braided sleeving, Relats, VSR 25 NW6	No. 14				1							
	PP modified, corrugated pipe, Fränkische Rohrwerke, Uniwell	No. 15					1						
	PA 66, cable tie, Hellermann, 111-019 50 PA 66, corrugated pipe, Fränkische Rohrwerke 400008 08	No. 16	1										
	Thermoplastic hot-melt adhesive, cavity connector sleeving, Henkel, Macromelt 6208 N	No. 17					1						
	Butyl rubber, longitudinal water sealing, Hellermann, DSG, 460-05029/19-1.5/105AL 30mm	No. 18											
	EDPM Shore A60, grommet, WOKO, 02 5539	No. 19											
	PVC, acrylate adhesive, wrapping tape, Certoplast, 608/609 19mm	No. 20											
	Polyolefin, acrylate adhesive, wrapping tape, Coroplast Y 512 19mm	No. 21	1										
	PET, acrylate adhesive, wrapping tape, Coroplast 837X 19mm	No. 22	1										
	Silicone, cables (class E/F)	No. 23a								1			
	ETFE, cables (class D)	No. 23a1							1				
	X-PE, cables (class D)	No. 23b							1				
	PP, cables (class C)	No. 23c						1					
	X-PE, cables (class C)	No. 23d											
	PVC, cables (class B 105℃)	No. 23e											
	TPE-S, cables (class C)	No. 23f						1					

Table A.10 – Bill of materials, component compatibility for cables of temperature class D 150℃

e.g., XPE	The material used is decisive for testing.	5 sample wiring harnesses each	Test temperature										
			150 ℃			125 ℃					105 ℃		
			1	2	3	4	5	6	7	8	9	10	11
Cable	Test cables 0.35 mm^2 and 2.50 mm^2, 3x 0.35 mm^2, 3x 2.50 mm^2												
Contacts / cable lugs	CuSn, Sn quick-connect receptacle, Kostal 221 24 49207 0	No. 1	6	6		6	5			6	6	6	
	CuFe2, Sn circular receptacle, Tyco, 0-0928985-2	No. 2		6	6		6	5	6			6	6
	CuFe, Ag circular receptacle, Tyco, 0-0927788-2	No. 3	5		6	5		6	6	6	6		6
	CuSn, Sn cable lug, Lear, 25168 331 322	No. 4	1			1	1	1					
Seals	Silicone, single wire seal, Kostal, 108 00 44452 3	No. 5				6							
	Silicone, single wire seal, Tyco, 0-082890-1	No. 6	6				6						
Connector housing	PBT+15% GF circular connector housing, Tyco, 2-0963295-1	No. 7					1						
	PA 6.6, circular connector housing, Tyco, 1-0828736-1	No. 8						1					
	POM, socket housing, Hirschmann, 972-537-001	No. 9				1							
Components	Synthetic rubber based, shrinkdown plastic tube, DSG Canusa, 621 0000 090	No. 10						1					
	PE modified, shrinkdown plastic tube, DSG Canusa, 14/1 45TR Al 50mm	No. 11					1						
	PVC 9248 acc. to DIN 40621, insulating hose, HC, 2125013	No. 12									1		
	PUR, insulating hose, Sahlberg, 6435641	No. 13					1						
	Silicone coated glass braid, braided sleeving, Relats, VSR 25 NW6	No. 14	1										
	PP modified, corrugated pipe, Fränkische Rohrwerke, Uniwell	No. 15							1				
	PA 66, cable tie, Hellermann, 111-019 50 PA 66, corrugated pipe, Fränkische Rohrwerke 400008 08	No. 16				1							
	Thermoplastic hot-melt adhesive, cavity connector sleeving, Henkel, Macromelt 6208 N	No. 17							1				
	Butyl rubber, longitudinal water sealing, Hellermann, DSG, 460-05029/19-1.5/105AL 30mm	No. 18									1		
	EDPM Shore A60, grommet, WOKO, 02 5539	No. 19										1	
	PVC, acrylate adhesive, wrapping tape, Certoplast, 608/609 19mm	No. 20										1	
	Polyolefin, acrylate adhesive, wrapping tape, Coroplast Y 512 19mm	No. 21				1							
	PET, acrylate adhesive, wrapping tape, Coroplast 837X 19mm	No. 22	1										
	Silicone, cables (class E/F)	No. 23a			1								
	ETFE, cables (class D)	No. 23a1		1									
	X-PE, cables (class D)	No. 23b											
	PP, cables (class C)	No. 23c								1			
	X-PE, cables (class C)	No. 23d								1			
	PVC, cables (class B 105℃)	No. 23e											1
	TPE-S, cables (class C)	No. 23f								1			

Table A.11 – Bill of materials, component compatibility for cables of temperature class F 200℃

e.g., silicone	The material used is decisive for testing.	5 sample wiring harnesses each	Test temperature										
			150 ℃			125 ℃					105 ℃		
			1	2	3	4	5	6	7	8	9	10	11
Cable	Test cables 0.35 mm² and 2.50 mm², 3x 0.35 mm², 3x 2.50 mm²												
Contacts / cable lugs	CuSn, Sn quick-connect receptacle, Kostal 221 24 49207 0	No. 1	6	6		6	5			6	6	6	
	CuFe2, Sn circular receptacle, Tyco, 0-0928985-2	No. 2		6	6		6	5	6			6	6
	CuFe, Ag circular receptacle, Tyco, 0-0927788-2	No. 3	5		6	4		6	6	6	6		6
	CuSn, Sn cable lug, Lear, 25168 331 322	No. 4	1			1	1	1					
Seals	Silicone, single wire seal, Kostal, 108 00 44452 3	No. 5				6							
	Silicone, single wire seal, Tyco, 0-082890-1	No. 6	6				6						
Connector housing	PBT+15% GF circular connector housing, Tyco, 2-0963295-1	No. 7					1						
	PA 6.6, circular connector housing, Tyco, 1-0828736-1	No. 8						1					
	POM, socket housing, Hirschmann, 972-537-001	No. 9				1							
Components	Synthetic rubber based, shrinkdown plastic tube, DSG Canusa, 621 0000 090	No. 10						1					
	PE modified, shrinkdown plastic tube, DSG Canusa, 14/1 45TR Al 50mm	No. 11					1						
	PVC 9248 acc. to DIN 40621, insulating hose, HC, 2125013	No. 12									1		
	PUR, insulating hose, Sahlberg, 6435641	No. 13					1						
	Silicone coated glass braid, braided sleeving, Relats, VSR 25 NW6	No. 14	1										
	PP modified, corrugated pipe, Fränkische Rohrwerke, Uniwell	No. 15							1				
	PA 66, cable tie, Hellermann, 111-019 50 PA 66, corrugated pipe, Fränkische Rohrwerke 400008 08	No. 16				1							
	Thermoplastic hot-melt adhesive, cavity connector sleeving, Henkel, Macromelt 6208 N	No. 17							1				
	Butyl rubber, longitudinal water sealing, Hellermann, DSG, 460-05029/19-1.5/105AL 30mm	No. 18									1		
	EDPM Shore A60, grommet, WOKO, 02 5539	No. 19										1	
	PVC, acrylate adhesive, wrapping tape, Certoplast, 608/609 19mm	No. 20										1	
	Polyolefin, acrylate adhesive, wrapping tape, Coroplast Y 512 19mm	No. 21				1							
	PET, acrylate adhesive, wrapping tape, Coroplast 837X 19mm	No. 22	1										
	Silicone, cables (class E/F)	No. 23a											
	ETFE, cables (class D)	No. 23a1		1									
	X-PE, cables (class D)	No. 23b			1								
	PP, cables (class C)	No. 23c								1			
	X-PE, cables (class C)	No. 23d								1			
	PVC, cables (class B 105℃)	No. 23e											1
	TPE-S, cables (class C)	No. 23f								1			

Table A.12 – Bill of materials, component compatibility for cables of temperature class B 105℃ (large cross sections)

e.g., PVC	The material used is decisive for testing.	5 sample wiring harnesses each	Test temperature 105 ℃										
			1	2	3	4	5	6	7	8	9	10	11
Cable	Test cable = 16 mm² (1x cross section)												
Contacts / cable lugs	CuSn, Sn flat contact, (order no. N 102 146 01), without	No. 1	1		2		2		2		2		
	CuSn, Sn flat contact, (order no. N 102 146 02), with SEAL	No. 2		1		2		2		2		2	
	Omitted	No. 3											
	CuSn, Sn cable lug, (order no. N 107 017 2), AMP no. 0-444 305-1	No. 4	1	1									
Seals	Silicone, single-wire seal (order no. 357 972 744 B)	No. 5	2	2									
	Omitted	No. 6											
Connector housing	PBT fuse adapter (order no. 3A0 937 501A) Lisi autom. no. 1388	No. 7	1										
	PA 6.6 fuse adapter (order no. 3A0 937 501) Lisi autom. no. 1439	No. 8		1									
	Omitted	No. 9											
Components	Synthetic rubber based, shrinkdown plastic tube, DSG Canusa, 621 191 510 5C	No. 10			1								
	PE modified, shrinkdown plastic tube, DSG Canusa, 6-1.4/1.45TR.AL50mm 6240060011G	No. 11		1									
	PVC, insulating hose, Tyco NETM-2000-NR-10-0	No. 12	1										
	PUR, insulating hose, Sahlberg, 303-109 14x0.6x15.6 1185	No. 13		1									
	Silicone-coated glass braid, braided sleeving, Federal Mogul Textalu 1202 5-55 ALU	No. 14				1							
	PP modified, corrugated pipe, Fränkische Rohrwerke, Uniwell	No. 15					1						
	PA 66, cable tie, Hellermann, 111-019 50 PA 66, corrugated pipe, Fränkische Rohrwerke 400008 08	No. 16						1					
	Omitted	No. 17											
	Butyl rubber, longitudinal water sealing, Hellermann, Tyton 460-05039	No. 18							1				
	EDPM Shore A60, grommet, WOKO, 02 5539	No. 19							1				
	PVC, acrylate adhesive, wrapping tape, Certoplast, 608/609 19mm	No. 20				1							
	Polyolefin, acrylate adhesive, wrapping tape, Coroplast Y 512 19mm	No. 21						1					
	PET, acrylate adhesive, wrapping tape, Coroplast 837X 19mm	No. 22						1					
	Silicone, cables (class E/F)	No. 23a											1
	ETFE, cables (class D)	No. 23a1										1	
	X-PE, cables (class D)	No. 23b										1	
	PP, cables (class C)	No. 23c									1		
	X-PE, cables (class C)	No. 23d									1		
	PVC, cables (class B 105℃)	No. 23e											
	TPE-S, cables (class C)	No. 23f									1		

Table A.13 – Bill of materials, component compatibility for cables of temperature class C 125℃ (large cross sections)

e.g., XPE	The material used is decisive for testing.	5 sample wiring harnesses each	Test temperature										
			125 °C								105 ℃		
			1	2	3	4	5	6	7	8	9	10	11
Cable	Test cable = 16 mm² (1x cross section)												
Contacts / cable lugs	CuSn, Sn flat contact, (order no. N 102 146 01), without	No. 1	1		1			2	2		2		
	CuSn, Sn flat contact, (order no. N 102 146 02), with SEAL	No. 2		1		2	2			2		2	2
	Omitted	No. 3											
	CuSn, Sn cable lug, (order no. N 107 017 2), AMP no. 0-444 305-1	No. 4	1	1	1								
Seals	Silicone, single-wire seal (order no. 357 972 744 B) Veritas no. F18363	No. 5	2	2									
	Omitted	No. 6											
Connector housing	PBT fuse adapter (order no. 3A0 937 501A) Lisi autom. no. 1388	No. 7	1										
	PA 6.6 fuse adapter (order no. 3A0 937 501) Lisi autom. no. 1439	No. 8		1									
	Omitted	No. 9											
Components	Synthetic rubber based, shrinkdown plastic tube, DSG Canusa, 621 191 510 5C	No. 10			1								
	PE modified, shrinkdown plastic tube, DSG Canusa, 6-1.4/1.45TR.AL50mm 6240060011G	No. 11		1									
	PVC, insulating hose, Tyco NETM-2000-NR-10-0	No. 12									1		
	PUR, insulating hose, Sahlberg, 303-109 14x0.6x15.6 1185	No. 13		1									
	Silicone-coated glass braid, braided sleeving, Federal Mogul Textalu 1202 5-55 ALU	No. 14				1							
	PP modified, corrugated pipe, Fränkische Rohrwerke, Uniwell	No. 15					1						
	PA 66, cable tie, Hellermann, 111-019 50 PA 66, corrugated pipe, Fränkische Rohrwerke 400008 08	No. 16	1										
	Omitted	No. 17											
	Butyl rubber, longitudinal water sealing, Hellermann, Tyton 460-05039	No. 18									1		
	EDPM Shore A60, grommet, WOKO, 02 5539	No. 19										1	
	PVC, acrylate adhesive, wrapping tape, Certoplast, 608/609 19mm	No. 20										1	
	Polyolefin, acrylate adhesive, wrapping tape, Coroplast Y 512 19mm	No. 21	1										
	PET, acrylate adhesive, wrapping tape, Coroplast 837X 19mm	No. 22	1										
	Silicone, cables (class E/F)	No. 23a								1			
	ETFE, cables (class D)	No. 23a1							1				
	X-PE, cables (class D)	No. 23b							1				
	PP, cables (class C)	No. 23c						1					
	X-PE, cables (class C)	No. 23d											
	PVC, cables (class B 105℃)	No. 23e											1
	TPE-S, cables (class C)	No. 23f						1					

Table A.14 – Bill of materials, component compatibility for cables of temperature class D 150℃ (large cross sections)

e.g., XPE	The material used is decisive for testing.	5 sample wiring harnesses each	Test temperature										
			150 ℃			125 ℃					105 ℃		
			1	2	3	4	5	6	7	8	9	10	11
Cable	Test cable = 16 mm² (1x cross section)												
Contacts / cable lugs	CuSn, Sn flat contact, (order no. N 102 146 01), without seal AMP no. 962 832.1	No. 1	1	1		1			2		2		
	CuSn, Sn flat contact, (order no. N 102 146 02), with seal AMP no. 962 938.1	No. 2		1	2		1	2		2		2	2
	Omitted	No. 3											
	CuSn, Sn cable lug, (order no. N 107 017 2), AMP no. 0-444 305-1	No. 4	1			1	1	1					
Seals	Silicone, single-wire seal (order no. 357 972 744 B) Veritas no. F18363	No. 5				2	2						
	Omitted	No. 6											
Connector housing	PBT fuse adapter (order no. 3A0 937 501A) Lisi autom. no. 1388	No. 7				1							
	PA 6.6 fuse adapter (order no. 3A0 937 501) Lisi autom. no. 1439	No. 8					1	2					
	Omitted	No. 9											
Components	Synthetic rubber based, shrinkdown plastic tube, DSG Canusa, 621 191 510 5C	No. 10						1					
	PE modified, shrinkdown plastic tube, DSG Canusa, 6-1.4/1.45TR.AL50mm 6240060011G	No. 11					1						
	PVC, insulating hose, Tyco NETM-2000-NR-10-0	No. 12									1		
	PUR, insulating hose, Sahlberg, 303-109 14x0.6x15.6 1185	No. 13					1						
	Silicone-coated glass braid, braided sleeving, Federal Mogul Textalu 1202 5-55 ALU	No. 14	1										
	PP modified, corrugated pipe, Fränkische Rohrwerke, Uniwell	No. 15							1				
	PA 66, cable tie, Hellermann, 111-019 50 PA 66, corrugated pipe, Fränkische Rohrwerke 400008 08	No. 16				1							
	Omitted	No. 17											
	Butyl rubber, longitudinal water sealing, Hellermann, Tyton 460-05039	No. 18									1		
	EDPM Shore A60, grommet, WOKO, 02 5539	No. 19										1	
	PVC, acrylate adhesive, wrapping tape, Certoplast, 608/609 19mm	No. 20										1	
	Polyolefin, acrylate adhesive, wrapping tape, Coroplast Y 512 19mm	No. 21				1							
	PET, acrylate adhesive, wrapping tape, Coroplast 837X 19mm	No. 22	1										
	Silicone, cables (class E/F)	No. 23a			1								
	ETFE, cables (class D)	No. 23a1		1									
	X-PE, cables (class D)	No. 23b											
	PP, cables (class C)	No. 23c								1			
	X-PE, cables (class C)	No. 23d								1			
	PVC, cables (class B 105℃)	No. 23e											1
	TPE-S, cables (class C)	No. 23f								1			

Table A.15 – Bill of materials, component compatibility for cables of temperature class F 200℃ (large cross sections)

e.g., XPE	The material used is decisive for testing.	5 sample wiring harnesses each	Test temperature										
			150 ℃			125 ℃					105 ℃		
			1	2	3	4	5	6	7	8	9	10	11
Cable	Test cable = 16 mm² (1x cross section)												
Contacts / cable lugs	CuSn, Sn flat contact, (order no. N 102 146 01), without seal AMP no. 962 832.1	No. 1	1	1		1			2		2		
	CuSn, Sn flat contact, (order no. N 102 146 02), with seal AMP no. 962 938.1	No. 2		1	2		1	2		2		2	2
	Omitted	No. 3											
	CuSn, Sn cable lug, (order no. N 107 017 2), AMP no. 0-444 305-1	No. 4	1			1	1	1					
Seals	Silicone, single-wire seal (order no. 357 972 744 B) Veritas no. F18363	No. 5				2	2						
	Omitted	No. 6											
Connector housing	PBT fuse adapter (order no. 3A0 937 501A) Lisi autom. no. 1388	No. 7				1							
	PA 6.6 fuse adapter (order no. 3A0 937 501) Lisi autom. no. 1439	No. 8					1	2					
	Omitted	No. 9											
Components	Synthetic rubber based, shrinkdown plastic tube, DSG Canusa, 621 191 510 5C	No. 10						1					
	PE modified, shrinkdown plastic tube, DSG Canusa, 6-1.4/1.45TR.AL50mm 6240060011G	No. 11					1						
	PVC, insulating hose, Tyco NETM-2000-NR-10-0	No. 12									1		
	PUR, insulating hose, Sahlberg, 303-109 14x0.6x15.6 1185	No. 13					1						
	Silicone-coated glass braid, braided sleeving, Federal Mogul Textalu 1202 5-55 ALU	No. 14	1										
	PP modified, corrugated pipe, Fränkische Rohrwerke, Uniwell	No. 15							1				
	PA 66, cable tie, Hellermann, 111-019 50 PA 66, corrugated pipe, Fränkische Rohrwerke 400008 08	No. 16				1							
	Omitted	No. 17											
	Butyl rubber, longitudinal water sealing, Hellermann, Tyton 460-05039	No. 18									1		
	EDPM Shore A60, grommet, WOKO, 02 5539	No. 19										1	
	PVC, acrylate adhesive, wrapping tape, Certoplast, 608/609 19mm	No. 20										1	
	Polyolefin, acrylate adhesive, wrapping tape, Coroplast Y 512 19mm	No. 21				1							
	PET, acrylate adhesive, wrapping tape, Coroplast 837X 19mm	No. 22	1										
	Silicone, cables (class E/F)	No. 23a											
	ETFE, cables (class D)	No. 23a1		1									
	X-PE, cables (class D)	No. 23b			1								
	PP, cables (class C)	No. 23c								1			
	X-PE, cables (class C)	No. 23d								1			
	PVC, cables (class B 105℃)	No. 23e											1
	TPE-S, cables (class C)	No. 23f								1			

A.8 Electrical wiring (classification) (informative)

For cables within the system, a 6-digit standard part drawing which has a 0 at the end applies to each cross section and insulating material. The released cables are entered in the table according to their colors.

Example:

Standard part drawing		*N*	*0*	*3*	*7*	*1*	*3*	*0*	
Cable		*N*	*0*	*3*	*7*	*1*	*3*	*9*	*6*
Insulating material	*PVC vulcanized*								
Cross section	*1.5mm²*								
Basic color	*Black*								
Code color	*Green*								

Code numbers for the nominal conductor cross sections

0 = 0.5 mm²	*5 = 4.0 mm²*
1 = 0.75 mm²	*6 = 6.0 mm²*
2 = 1.0 mm²	*7 = 0.14 mm²*
3 = 1.5 mm²	*8 = 0.22 mm²*
4 = 2.5 mm²	*9 = 0.35 mm²*

Standard part numbers for nominal conductor cross sections larger than 6.0 mm² are assigned unsystematically.

Code numbers for the colors (basic and code colors)

0 = white	*(wt)*
1 = yellow	*(ye)*
2 = white-green	*(wtgn) for code color only*
3 = red	*(rd)*
4 = violet	*(vi)*
5 = blue	*(bu)*
6 = green	*(gn)*
7 = gray	*(gr)*
8 = brown	*(br)*
9 = black	*(bl)*

If the basic and code color have the same code, the cable is single-colored.

For all cables that cannot be assigned to the system, all cable cross sections must be given a 6-digit number. Basic and code colors are controlled with the suffix. The colors are assigned in the order in which they are called for, e.g.,:

Cable green	*N 1*
Cable yellow	N 2