VOLKSWAGEN

AKTIENGESELLSCHAFT

Group standard

VW 60306-1

Issue 2018-09

Class. No.: 8ME30

Descriptors: cable, copper cable, low-voltage cable

Electrical Cables in Motor Vehicles

Part 1: Copper Cable; Single-Core, Unshielded

Previous issues

VW 60306-1: 2013-04

Changes

The following changes have been made to VW 60306-1: 2013-04:

– Standard completely revised

Contents

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1 Scope

This standard describes the requirements and tests for single-core, unshielded automotive cables for a nominal-voltage range ≤ 60 V DC (voltage class 1 as per table 1).

The aspects to be tested for the respective requirements must be taken from section 8.1.

Table 1 – Voltage classes

Voltage classes		Alternating current (AC)		Direct current (DC)
		V_{rms}	V_{pp}	V_{DC}
Low voltage	1 (A[a)])	≤ 30 V	≤ 42 V	≤ 60 V
High voltage	2	≤ 600 V	≤ 849 V	≤ 1 000 V
High voltage	3 (B[a)])	≤ 1 000 V	≤ 1 414 V	≤ 1 500 V

a) Voltage class designation as per ISO 6469-3

This table was created on the basis of ISO 6469-3. Voltage class 2 is not covered in ISO 6469-3.

2 Symbols and abbreviations

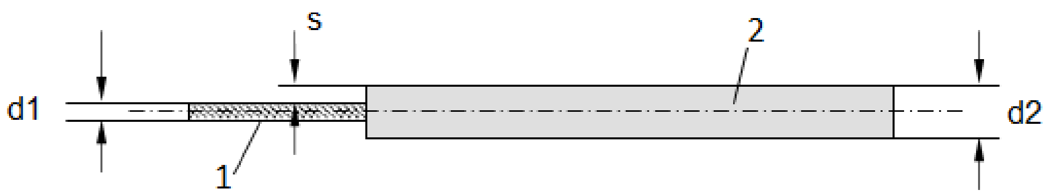
ATR	Attenuated total reflectance
BMG	Build sample approval
DSC	Differential scanning calorimetry
TGA	Thermogravimetric analysis
T_{max}	Maximum long-term service temperature
T_{min}	Minimum long-term service temperature
V_{DC}	Direct-current voltage
V_{pp}	Peak-to-peak voltage value
V_{rms}	Root-mean-square voltage value

3 General

The tests in this standard must be performed in an independent institute accredited as per DIN EN ISO/IEC 17025.

4 Dimensions and cable composition

The dimensions and cable composition (see figure 1) must be taken from appendix A. Unspecified details must be selected as appropriate as per ISO 6722-1.



Legend

1	Conductor
2	Insulation
d1	Conductor diameter
d2	Outer diameter
t	Minimum wall thickness of the insulation

Figure 1 – Cable composition

5 Composition of the code designations

The cable designations are based on DIN 76722.

Example 1:

Designation for an unshielded low-voltage cable (**FL**) with thin-walled insulation (**R**), code for radiation cross-linked PE insulation material (**2X**) as per DIN 76722, a nominal conductor cross section of 1.5 mm^2 (**1,5**), (**/**), a maximum strand diameter of 0.33 mm (**0,33**), with tinned strands (**Sn**), a cable composition of type A (**-A**), and a maximum long-term service temperature T_{max} = +125 °C (**T125**):

FLR2X 1,5/0,33Sn-A T125

Example 2:

Designation for an unshielded low-voltage cable (**FL**), code for silicone insulation material (**2G**) as per DIN 76722, a nominal conductor cross section of 35 mm^2 (**35**), (**/**), with bare strands of max. 0.21 mm (**0,21**), a cable composition of type B (**-B**), and a maximum long-term service temperature T_{max} = +200 °C (**T200**):

FL2G 35/0,21-B T200

6 Materials

The properties as per section 6.1, section 6.2, and section 6.3 must be guaranteed by the manufacturer and apply to the unstranded state.

6.1 Conductor, bare

Strand of Cu-ETP1, CW003A or Cu-ETP, CW004A as per DIN EN 13602. In special cases other Cu materials/alloys can be agreed upon.

Bare Cu conductor: See table 2.

Table 2 – Bare Cu conductor

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

Table 3 – Product designation example

Designation	Standard	Material designation	State designation	Surface finish	Diameter (nominal dimension) in mm	Delivery form
Wire	DIN EN 13602	Cu-ETP-1	A022	P	S0,4	Y

Explanations for the example in table 3 above:

State designation:	A = annealed
	(R = hard drawn)
Surface finish:	P = not tinned
	(A, B = tinned)
Nominal dimension for diameter:	S = single-core wire
	(M = multi-core wire)
Delivery form:	Y = coil
	(Z = spool)

6.2 Conductor, tinned

The surface finish for the tinning must be as per section "Surface finish" in DIN EN 13602.

The tinning must be evaluated by measuring the thickness of the unalloyed coating as per table "Coating requirements" in DIN EN 13602:

– Type A: For strand diameters ≤ 0.2 mm
– Type B: For strand diameters > 0.2 mm

Tinned Cu conductor: See table 4.

Table 4 – Tinned Cu conductor properties

Designations				Diameter (nominal dimension)		Tensile strength R_m	Elongation at break A_t or $A_{200\ mm}$
Material		State		in mm		in N/mm^2	Single- and multi-core wire in %
Code	Number	Single-core wire	Multi-core wire	greater than	to	minimum	minimum
Cu-ETP1 Cu-ETP	CW003A CW004A	A007	A005	0.04	0.08	200	7
		A013	A011	0.08	0.16		13
		A019	A017	0.16	0.32		19
		A020	A018	0.32	0.50		20
		A022	A020	0.50	1.00		22
		A024	A022	1.00	1.50		24
		A026	–	1.50	3.00		26
		A031	–	3.00	5.00		31

6.3 Conductor, other surfaces

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

6.4 Insulation

The minimum and maximum long-term service temperatures (T_{min} and T_{max}) for a load duration of 3 000 h must be selected according to the temperature classes (without mechanical load and not additive) as per table 5 or in exceptional cases as per the drawing.

Table 5 – Temperature classes

Class as per ISO 6722-1	Temperature class	Long-term service temperature (3 000 h) T_{min} °C to T_{max} °C	Short-term temperature (240 h) (T_{max} + 25) °C	Thermal overload temperature (6 h) (T_{max} + 50) °C
A	T85	-40 to +85	+110 ±3	+135 ±3
B	T100	-40 to +100	+125 ±3	+150 ±3
B (105)	T105	-40 to +105	+130 ±3	+155 ±3
C	T125	-40 to +125	+150 ±3	+175 ±3
D	T150	-40 to +150	+175 ±3	+200 ±3
E	T175	-40 to +175	+200 ±3	+225 ±4
E (180)	T180	-40 to +180	+205 ±4	+230 ±4
F	T200	-40 to +200	+225 ±4	+250 ±4
G	T225	-40 to +225	+250 ±4	+275 ±4
H	T250	-40 to +250	+275 ±4	+300 ±4
	Txyz	-40 to xyz	xyz + 25	xyz + 50

In special cases, Txyz enables the classification of intermediate temperatures (e.g., temperature class T135).

7 Marking and delivery conditions

7.1 Container marking

The marking of containers must conform to VDA Volume 6 Part 1 and be agreed upon between purchaser and supplier.

7.2 Manufacturer's code

The product must be marked with a manufacturer's code, e.g., by printing or embossing (raised embossment). Adherence to the minimum wall thicknesses must always be ensured in the process. The manufacturer's code is repeated continuously at a spacing that creates an unprinted area of 200 mm.

For cable cross sections ≤ 0.35 mm^2, a different marking can be arranged in agreement with the appropriate departments.

The marking must clearly indicate a minimum of the following information:

– Cable manufacturer (written out or code letter combination with max. 3 letters)
– Place of manufacture
– Temperature class

The individual letter combinations must have space in between them. Examples:

– COMPANY P T150 (COMPANY: Manufacturer, P: Place of manufacture, T150: Temperature class)
– GG A T125 (GG: Manufacturer's code, A: Place of manufacture, T125: Temperature class)

Exception:

PVC cables with a temperature class of T105 do not have to be marked with "T105".

7.3 Color/color coding

The colors of the aged (6 h, 240 h, and 3 000 h) and unaged cables must be documented in one photo (see also section 9.6.6, section 9.6.7, and section 9.6.8). An evaluation of the color must be indicated under the subitem "Color" in table 8 and table 9.

Only the most noticeable discolorations must be documented as examples for each compound.

The color coding must be based on DIN 72551-7 in German or English.

Different color codes are permissible upon agreement.

7.4 Delivery conditions

7.4.1 Visual inspection

The insulation must not have any nodes, cracks, blisters, or inclusions and must be strippable using standard commercial stripping machines without leaving a residue and without damaging the conductor.

7.4.2 Test for insulation faults

As per ISO 6722-1

After the spark test, the cables must be tested according to table 6. The dwell time of the cable in the electrical field must be selected such that each cable section is loaded with at least 18 voltage spikes. When using tubular electrodes, the inside diameter of the electrode must be matched to the cable diameter.

Table 6 – Voltage values/voltage class 1

Nominal conductor cross section in mm^2	Test voltage in kV
< 0.5	3
≥ 0.5	5

The emphasis for inspection must be placed on production inspection measures. The test plans and measured value documentation for the production and pre-delivery inspections must include information on the measuring equipment used, frequency of measurements, desired values, and tolerances for all criteria that are important to proper functioning.

Flaws must be handled as per section 7.4.3.1.

7.4.3 Packaging units

The packaging units must be agreed upon between the purchaser and the manufacturer. An example of such an agreement can be seen in table 7.

The cables must be delivered in drums free of damage or in coils. The following conditions must be adhered to:

- The cable must be delivered in a drum or coil. The ends must be arranged such that they are accessible, do not disrupt processing, and cannot be damaged during transport.
- The cable must support being pulled out of the drum at a speed of 200 m/min or out of the coil at 420 m/min in intermittent operation on cut-to-length machines.

Table 7 – Example delivery quantities for NPS 400

FLR cables	
Nominal cable cross section in mm^2	Delivery quantity in m
0.35	12 000
0.5	10 000
1.0	8 000
1.5	7 000
2.5	5 000
4.0	2 500
6.0	1 500

7.4.3.1 Partial lengths, joints, flaws

In exceptional cases, a specified length can be composed of partial lengths and must be separately identified as such:

- Joints between the partial lengths must not exceed the diameter of the cable and must not rupture during processing.
- Joints and flaws must be identified by 30 to 100 mm of stripped insulation.

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

0.35 mm^2, 0.5 mm^2, 0.75 mm^2	3 joints or flaws
1.0 mm^2, 1.5 mm^2, 2.5 mm^2	2 joints
≥ 4.0 mm^2	1 joint

7.4.3.2 Delivery unit marking

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

Traceability must be ensured.

The marking must contain the following data:

- Cable designation as per section 5
- Manufacturer
- Manufacturer's number
- Date of manufacture
- Compound number (optional)
- Cable length
- Position of joints and flaws

8 General test conditions

8.1 Test matrix

For test matrix, see table 8.

Table 8 – Test matrix

Section	Test	Release testing		Location testing	Modification of raw materials	Requalification testing	Process testing	Special testing
	Test scope	A1	A2 B2 C2	B1	C1	D	E	F
Section 7.3	Color	X	X	X	X			
Section 7.4.1	Visual inspection						X	
Section 7.4.2	Test for insulation faults						X	
Section 9.1	**Cable composition inspection**							
Section 9.1.1	Cable outer diameter and minimum wall thickness	X	X	X	X	X	X	
Section 9.1.2	Nominal conductor diameter	X	X	X	X	X	X	
Section 9.1.3	Conductor resistance	X	X	X	X	X	X	
Section 9.1.4	Insulation strippability factor	X	X	X		X		
Section 9.2	**Physical and chemical properties of the insulation**							
Section 9.2.1	Density [a)]	X			X	X		
Section 9.2.2	Thermal stability for PVC	X	X	X	X	X		
Section 9.2.3	Determining the tensile strength and elongation at tear	X	X	X	X	X		
Section 9.2.4.1	Tear propagation resistance/testing on sheet	X		X	X	X		
Section 9.2.4.2	Tear propagation resistance/testing on cable	X		X	X	X		
Section 9.2.5	Determining the degree of cross-linking	X	X	X	X	X	X	
Section 9.3	**Mechanical properties in as-received condition**							
Section 9.3.1	Insulation strippability/secure fit of conductor	X	X	X	X	X	X	
Section 9.3.2	Insulation abrasion resistance	X	X	X	X	X		
Section 9.3.3	Bending force of the cable	X	X	X	X			
Section 9.3.4	Insulation notch strength	X						
Section 9.4	Flame retardance	X			X	X		
Section 9.5	**Electrical properties in as-received condition**							
Section 9.5.1	Volume resistivity of the insulation [a)]	X						
Section 9.5.2	30-minute dielectric strength	X						

Section	Test	Release testing		Location testing	Modification of raw materials	Requalification testing	Process testing	Special testing
	Test scope	A1	A2 B2 C2	B1	C1	D	E	F
Section 9.6	**Mechanical and electrical properties after exposure to mechanical, thermal, or chemical load**							
Section 9.6.1	Stress test [b)]	X		X		X	X	
Section 9.6.2	Insulation shrinkage under heat	X	X	X	X	X	X	
Section 9.6.3	Compressive strength of the insulation under heat	X						
Section 9.6.4	Derating curve	X	X [c)]					
Section 9.6.5	Thermal stability in wound state [b)]	X						
Section 9.6.6.1	Thermal overload T_{max} + 50 °C	X			X			
Section 9.6.6.2	Extreme thermal overload T_{max} + x °C/1 h							X
Section 9.6.7	Winding test after short-term aging (240 h)	X	X	X	X	X		
Section 9.6.8	**Long-term aging (3 000 h)**							
Section 9.6.8.1	Winding test after long-term aging	X						
Section 9.6.8.2	Minimum permissible radius for static routing	X						
Section 9.6.9	Winding test at low temperature (at -40 °C)	X	X	X	X	X		
Section 9.6.10	Impact test at low temperature (-15 °C)	X						
Section 9.6.11	Cable marking resistance to wiping [a)]	X						
Section 9.6.12	Bending fatigue strength	X						
Section 9.6.13	Kink test [b)]	X						
Section 9.6.14	Electrical properties with aging in water	X						
Section 9.6.15	Damp heat, constant (hydrolysis test)	X						
Section 9.6.16	Ozone resistance [a)]							X
Section 9.7	Mycological test [a)]							X
Section 9.8	**Compatibility tests**							
Section 9.8.1	Resistance to chemicals as per ISO 6722-1	X						
Section 9.8.2	Resistance to chemicals	X						

a) The test is only carried out on the largest cable cross section for each compound.

b) It is not to be carried out for cable cross sections > 6 mm^2.

c) Derating except C2

Documentation:

The documentation for tests as per cases A, B, C, and D must be sent to the purchaser. For cases E and F, the cable manufacturer is responsible for documentation and archiving. Submission to the purchaser is necessary only upon request.

Test scope/general specifications:

The reduced test scopes are only permissible if the underlying issued release with the complete test scope is no older than 10 years.

If an issued release is older than 10 years, a requalification as per test scope A – in substantiated cases as per test scope D – must be carried out in agreement with the appropriate department. In this case, the smallest cross section (e.g., 0.35 mm^2) of each compound is tested.

Other agreements can be reached with the appropriate department.

Test scope A1/A2:

Testing for the main place of manufacture or introduction of the following:

- New cables
- Existing cables using a new compound

The procedure in the case of minor compound modifications must be agreed upon with the appropriate departments.

Test scope B1/B2:

Identical compound, different location of same cable manufacturer

Test scope C1/C2:

When the compound composition is unmodified and at least one of the following applies:

- Chemically identical raw materials supplied by different subcontractors
- Change to place of manufacture for compound

Test scope D:

Scope of the tests performed for requalification to renew the BMG release. After no more than 10 years, agreement must be reached with the appropriate department as to whether requalification is necessary.

Test scope E:

Recommended in-process testing (e.g., batch-related or continuously). The supplier is responsible for process reliability.

Test scope F:

Special test scope: Only performed upon request by the appropriate department

Cable cross section allocation:

Test scope A1/B1/C1:	These are performed for cable cross sections of 0.35 mm^2, 0.5 mm^2, 1.5 mm^2, 2.5 mm^2, 4.0 mm^2, and 16 mm^2.
Reduced test scope A2/B2/C2:	All other cable cross sections

Cable composition:

For cable cross sections of 0.5 – 2.5 mm^2, the following applies:

Test results for the asymmetric copper-core composition – B can be used for the symmetric copper-core composition – A in agreement with the appropriate department.

Test matrix for single-core cables that are only used in sheathed cables: See table 9.

Table 9 – Test matrix for single-core cables that are only used in sheathed cables

Section	Test	Release testing		Location testing	Modification of raw materials	Requalification testing	Process testing	Special testing
	Test scope	A1	A2 B2 C2	B1	C1	D	E	F
Section 7.3	Color	X	X	X	X			
Section 7.4.1	Visual inspection						X	
Section 7.4.2	Test for insulation faults						X	
Section 9.1	**Cable composition inspection**							
Section 9.1.1	Cable outer diameter and minimum wall thickness	X	X	X	X	X	X	
Section 9.1.2	Nominal conductor diameter	X	X	X	X	X	X	
Section 9.1.3	Conductor resistance	X	X	X	X	X	X	
Section 9.1.4	Insulation strippability factor	X				X		
Section 9.2	**Physical and chemical properties of the insulation**							
Section 9.2.1	Density [a)]	X			X	X		
Section 9.2.2	Thermal stability for PVC	X	X	X	X	X		
Section 9.2.3	Determining the tensile strength and elongation at tear	X	X	X	X	X		
Section 9.2.4.1	Tear propagation resistance/testing on sheet	X		X	X	X		
Section 9.2.4.2	Tear propagation resistance/testing on cable	X		X	X	X		
Section 9.2.5	Determining the degree of cross-linking	X	X	X	X	X	X	
Section 9.3	**Mechanical properties in as-received condition**							
Section 9.3.1	Insulation strippability/secure fit of conductor	X	X	X	X	X	X	
Section 9.3.2	Insulation abrasion resistance							
Section 9.3.3	Bending force of the cable							
Section 9.3.4	Insulation notch strength							
Section 9.4	Flame retardance							

Section	Test	Release testing		Location testing	Modification of raw materials	Requalification testing	Process testing	Special testing
	Test scope	A1	A2 B2 C2	B1	C1	D	E	F
Section 9.5	**Electrical properties in as-received condition**							
Section 9.5.1	Volume resistivity of the insulation [a)]	X						
Section 9.5.2	30-minute dielectric strength	X						
Section 9.6	**Mechanical and electrical properties after exposure to mechanical, thermal, or chemical load**							
Section 9.6.1	Stress test [b)]	X		X		X	X	
Section 9.6.2	Insulation shrinkage under heat	X	X	X	X	X	X	
Section 9.6.3	Compressive strength of the insulation under heat	X						
Section 9.6.4	Derating curve							
Section 9.6.5	Thermal stability in wound state [b)]							
Section 9.6.6.1	Thermal overload T_{max} + 50 °C	X			X			
Section 9.6.6.2	Extreme thermal overload T_{max} + x °C/1 h							X
Section 9.6.7	Winding test after short-term aging (240 h)	X	X	X	X	X		
Section 9.6.8	**Long-term aging (3 000 h)**							
Section 9.6.8.1	Winding test after long-term aging	X						
Section 9.6.8.2	Minimum permissible radius for static routing	X						
Section 9.6.9	Winding test at low temperature (at -40 °C)	X	X	X	X	X		
Section 9.6.10	Impact test at low temperature (-15 °C)							
Section 9.6.11	Cable marking resistance to wiping [a)]							
Section 9.6.12	Bending fatigue strength							
Section 9.6.13	Kink test [b)]	X						
Section 9.6.14	Electrical properties with aging in water	X						
Section 9.6.15	Damp heat, constant (hydrolysis test)	X						
Section 9.6.16	Ozone resistance [a)]							X
Section 9.7	Mycological test [a)]							X
Section 9.8	**Compatibility tests**							

Section	Test	Release testing		Location testing	Modification of raw materials	Requalification testing	Process testing	Special testing
	Test scope	A1	A2 B2 C2	B1	C1	D	E	F
Section 9.8.1	Resistance to chemicals as per ISO 6722-1	X						
Section 9.8.2	Resistance to chemicals and harnessing tapes							

a) The test is only carried out on the largest cable cross section for each compound.

b) It is not to be carried out for cable cross sections > 6 mm^2.

Documentation:

The documentation for tests as per cases A, B, C, and D must be sent to the purchaser. For cases E and F, the cable manufacturer is responsible for documentation and archiving. Submission to the purchaser is necessary only upon request.

Test scope/general specifications:

The reduced test scopes are only permissible if the underlying issued release with the complete test scope is no older than 10 years.

If an issued release is older than 10 years, a requalification as per test scope A – in substantiated cases as per test scope D – must be carried out in agreement with the appropriate department. In this case, the smallest cross section (e.g., 0.35 mm^2) of each compound is tested.

Other agreements can be reached with the appropriate department.

Test scope A1/A2:

Testing for the main place of manufacture. Introduction of the following:

- New cables
- Existing cables using a new compound

The procedure in the case of minor compound modifications must be agreed upon with the appropriate departments.

Test scopes B through E require a prior release as per A1.

Test scope B1/B2:

Identical compound, different location of same cable manufacturer

Test scope C1/C2:

When the compound composition is unmodified and at least one of the following applies:

- Chemically identical raw materials supplied by different subcontractors
- Change to place of manufacture for compound

Test scope D:

Scope of the tests performed for requalification to renew the BMG release. After no more than 10 years, agreement must be reached with the appropriate department as to whether requalification is necessary.

Test scope E:

Recommended in-process testing (e.g., batch-related or continuously). The supplier is responsible for process reliability.

Test scope F:

Special test scope: Only performed upon request by the appropriate department

Cable cross section allocation:

Test scope A1/B1/C1:	The smallest cable cross section of each insulation material is tested.
Reduced test scope A2/B2/C2:	These are performed for all other cable cross sections of each insulation material.

Cable composition:

For cable cross sections of 0.5 – 2.5 mm^2, the following applies:

Test results for the asymmetric copper-core composition – B can be used for the symmetric copper-core composition – A in agreement with the appropriate department.

8.2 Test atmosphere

Unless a different test atmosphere is defined, testing is performed in a standard atmosphere as per Volkswagen standard VW 50554 – 23/50-2.

ISO 6722-1 (section "Ovens") applies to ovens.

8.3 Specimens

Unless otherwise specified, at least 3 specimens of each of the cables must be tested in as-received condition.

The colors brown and black are only used in consultation with the appropriate department.

Unless otherwise specified in the test description, the specimens must be aged prior to the tests for 16 h in a standard atmosphere as per VW 50554 – 23/50-2.

For each test, specimens must be used that were not used in any previous tests.

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

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

8.4 Rounding of numerical values

The determined numerical values must be rounded to the number of digits used to specify the desired values as per DIN 1333.

9 Tests

The described tests are based on ISO 6722-1.

Unless otherwise agreed upon, the drawing note takes precedence over the standard if they contain differing specifications.

9.1 Cable composition inspection

The parameters indicated in the respective appendices for the cable composition must be tested. The mean value of the measurements as well as the minimum and maximum values must be indicated in the test report.

9.1.1 Cable outer diameter and minimum wall thickness

Testing is performed as per DIN EN 60811-203 (cable outer diameter) and DIN EN 60811-201 (minimum wall thickness).

9.1.2 Nominal conductor diameter

Testing is performed on the basis of DIN EN 60811-203.

The inside diameter (nominal conductor diameter) is measured three times at regular distances (for three measurements, the specimen must be further rotated by 60° in each case).

9.1.3 Conductor resistance

Testing as per ISO 6722-1

Requirements as per tables in appendix A

9.1.4 Insulation strippability factor

A rectangle is formed (see figure 2) that runs tangentially to the four outer edges of the cable.

The diagonals of the rectangle intersect at the reference center point for the cable.

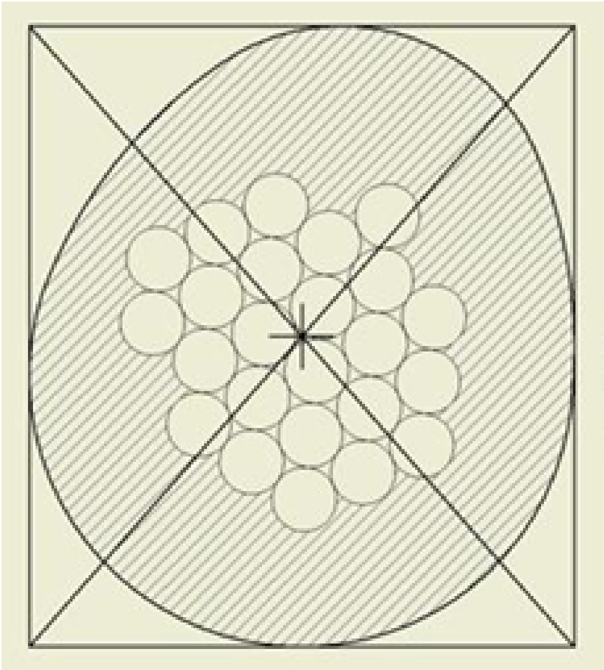


Figure 2 – Determining the reference center point

t_{min} and t_{max} are each measured on an imaginary line from the outer diameter to the reference center point (see figure 3).

t_{min} is the shortest possible uninterrupted distance on one such line within the insulation.

t_{max} is the longest possible uninterrupted distance on one such line within the insulation.

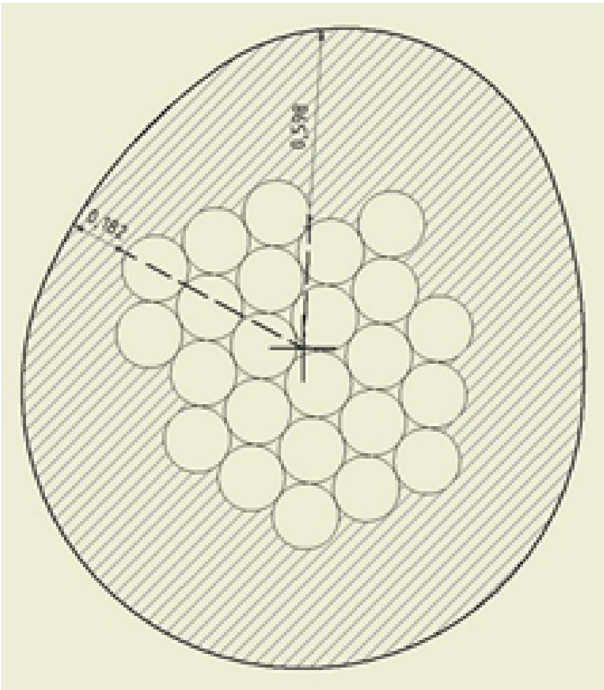


Figure 3 – Distance measurement for t_{min} and t_{max}

Example calculation

$$\text{Insulation strippability factor} = \frac{t_{min}}{t_{max}} \times 100\% \tag{1}$$

$$(\text{Insulation strippability factor} = \frac{0.182}{0.598} \times 100\% = 30.4\%)$$

9.2 Physical and chemical properties of the insulation

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

9.2.1 Density

Testing is performed as per section "Method A – Immersion method" from DIN EN ISO 1183-1.

9.2.2 Thermal stability for PVC

Testing for PVC only is performed as per DIN EN 60811-405:

- Change from pH value 5 to pH value 3
- Requirement: > 140 min (class T105)

9.2.3 Determining the tensile strength and elongation at tear

Testing is performed as per DIN EN 60811-501.

Section 9.7 must also be observed for the number of specimens.

9.2.4 Tear propagation resistance

The tear propagation resistance test is only performed on silicone material or silicone insulation.

9.2.4.1 Testing on sheet

Testing is performed for silicone only as per Method B, procedure (b) from DIN ISO 34-1.

Requirement:

- ≥ 15 N/mm for temperature class E
- ≥ 10 N/mm for temperature class F

9.2.4.2 Testing on cable

Testing is performed on the basis of DIN EN 50525-2-21 on cable cross sections of 25 mm^2 or 35 mm^2 in addition for each material compound variant.

A specimen of insulation must be removed from the cable and used to produce 5 specimens with dimensions as per figure 4 (dimensions in mm). For cables with an outer diameter of less than 10 mm, the specimen width may correspond to the insulation circumference.

The grooves (contour from the copper strands) must be removed from the specimens. This can be done using a suitable paring device to achieve a uniform insulation wall thickness. It must be ensured that only the protruding parts creating the grooves are removed.

As shown in figure 4, a longitudinal cut along the center of the specimen must be produced (e.g., using a sharp razor blade).

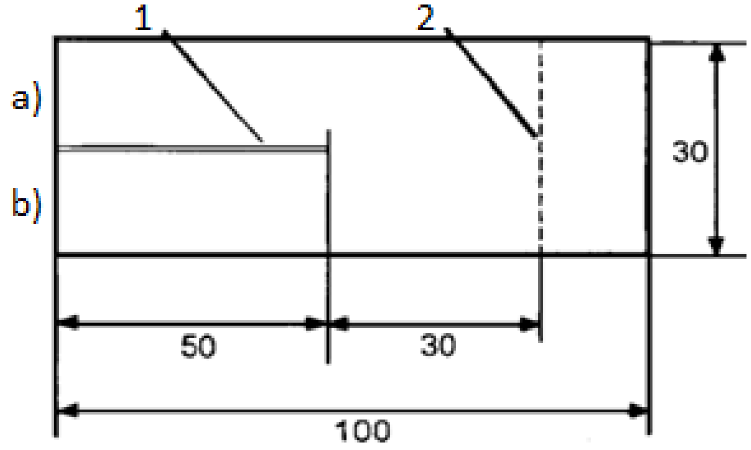
The mean thickness of the specimen must be determined by means of 3 measurements spaced evenly along length of the expected tear.

The halves of the separated specimens must be clamped into the grips of a tensile testing machine as shown in figure 5.

The speed at which the grips move apart must be (250 ±50) mm/min.

To determine the tear propagation resistance, the highest force value in N is divided by the mean thickness of the specimen in mm. The tear propagation resistance is the mean value of the values determined in this manner.

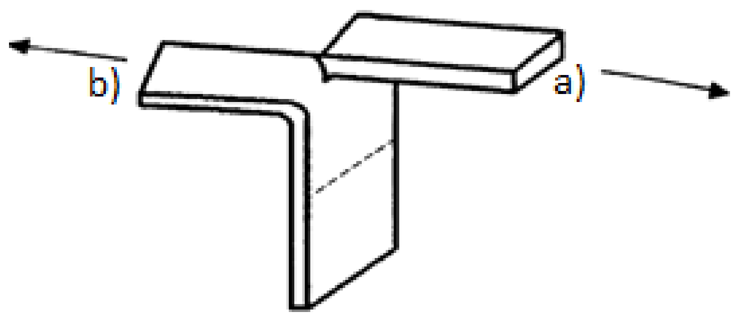
Requirement: As per sample



Legend

1 Cross section
2 Marking line
a) / b) For allocation, see figure 5.

Figure 4 – Insulation specimen dimensions in mm



Legend

a) / b) For allocation, see figure 4.

Figure 5 – Tensile direction for insulation specimen

9.2.5 Determining the degree of cross-linking

Testing for radiation cross-linked cables is performed as per DIN EN 60811-507 at a test temperature of (+200 ±3) °C and a load of 20 N/cm².

Requirements:

Elongation under load	≤ 100%
Elongation after load	≤ 25%

9.3 Mechanical properties in as-received condition

Generally, the cable must be designed such that it can be processed properly. The processing details must be agreed upon between the cable supplier and the cable manufacturer. The insulation must not exhibit any blisters, cracks, nodes, or inclusions of foreign matter.

9.3.1 Insulation strippability/secure fit of conductor

For cables that have to be stripped, it must be possible to strip 20 mm of the insulation cleanly and without difficulty using commercially available tools.

The cables must be strippable using commercially available machines.

For nominal conductor cross sections up to 6.0 mm², the following applies:

The force required to strip the insulation with a length of (50 ±1) mm must be greater than the minimum force specified in table 10.

Table 10 – Secure fit of conductor

Nominal conductor cross section	in mm²	0.35	0.5	0.75	1.0	1.5	2.5	4.0	6.0
Minimum force	in N	5	5	5	5	10	10	10	10

Testing:

Number of specimens:	≥ 5
Specimen length	(150 ±5) mm

The specimen is stripped to a length of (50 ±1) mm and the stripped conductor end is pulled through a panel with a hole (conductor diameter +0.1 mm). The stripping speed is 100 mm/min.

9.3.2 Insulation abrasion resistance

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 electric contact shuts off the machine. Each measurement is required to reach the minimum number of cycles (see table 11).

Table 11 – Number of cycles

Nominal conductor cross section	in mm^2	0.35	0.5	0.75	1.0	1.5	2.5	4.0	≥ 6.0 ≤ 25.0
Contact force	in N	7.00 ±0.05							
Number of cycles	minimum	200	300	350	500	1 500	1 500	1 500	1 500

The setup and procedure are as per section "Resistance to abrasion" in ISO 6722-1.

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%. The needle must be lifted off at the reversal point.

9.3.3 Bending force of the cable

The bending force must be within the values specified in table 12 and table 13. Deviating values may be agreed upon in individual cases.

Table 12 – Specifications for the bending force test

Nominal conductor cross section	in mm^2	0.35	0.5	0.75	1.0	1.5	2.5	4.0	6.0
Specimen length (l)	in mm	50				70			
Number of specimens (n)	Quantity	5				3			
Distance (l_V)	in N	20				30			
Maximum bending force	in mm	15	20	25	30	30	40	70	90

Table 13 – Specifications for standard setup

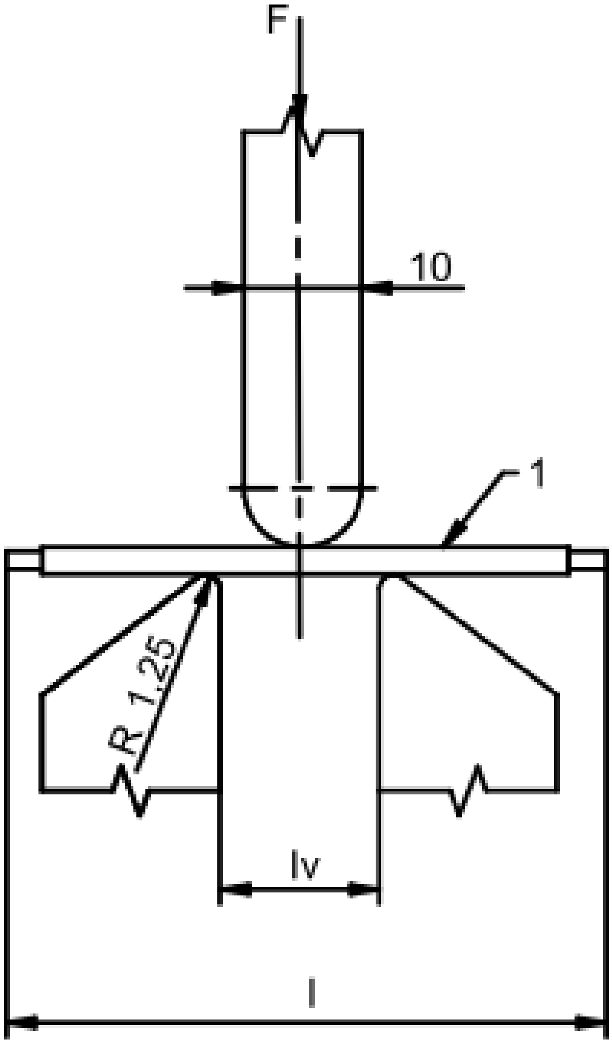
Nominal conductor cross section	in mm^2	10	16	25	35	50	70	95
Specimen length (l)	in mm	150						
Number of specimens (n)	Quantity	1						
Distance (l_V)	in N	100						
Maximum bending force	in mm	15	20	30	50	70	90	110

The test fixture consists of two metal legs, a test punch, and a tensile testing machine. This is shown schematically in figure 6 (dimensions in mm).

The cable specimens (number n and lengths as per table 12 and table 13) are straightened and aged in that position for at least 16 h. Then the n cables are placed next to one another on the metal legs, which are positioned at a distance of l_V as per table 12 and table 13. The upper side of these specimens are marked with a felt-tip pen on the left and the right perpendicular to the longitudinal axis of the cable.

In a tensile testing machine, the test mandrel is pressed onto the cables at a test speed of 100 mm/min. The force required to bend the cables is measured.

Then the cables are straightened by hand and placed back on the legs on the side bearing the marking. The force required to bend the cables is measured again. The mean value of the two measurements is the bending force.



Legend

l	Specimen length
lv	Distance
F	Bending force
1	Cable specimen

Figure 6 – Test fixture for bending force

9.3.4 Insulation notch strength

The penetration force must correspond to the values in table 14.

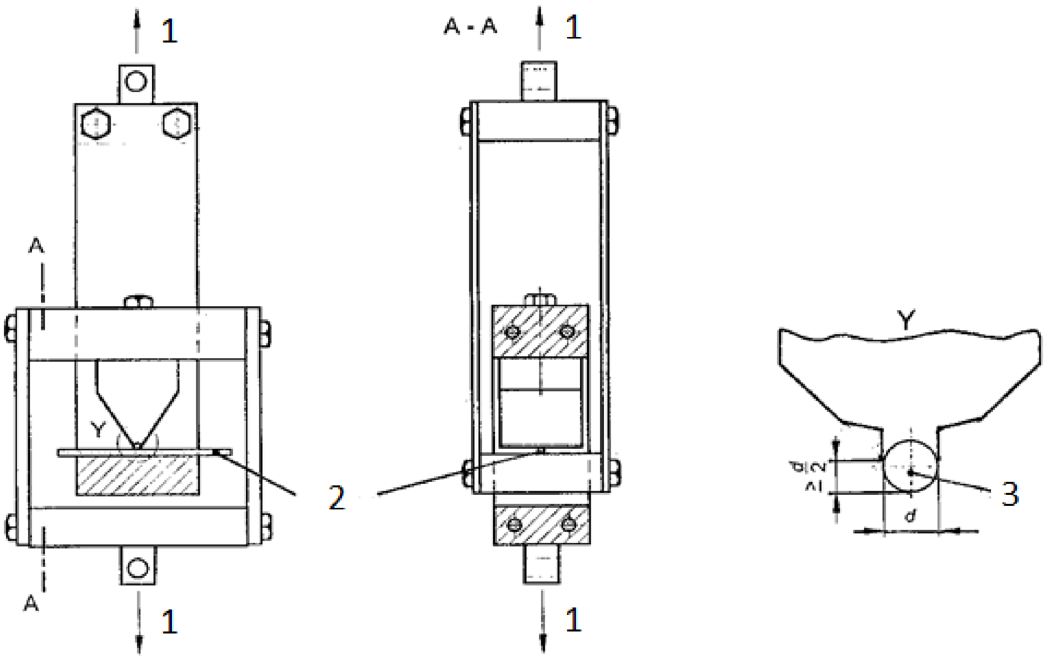
Table 14 – Penetration force

Nominal conductor cross section	in mm²	0.35	0.5	0.75	1.0	1.5	2.5	4.0	6.0
Minimum penetration force	in N	30	40	50	50	60	70	100	120

For nominal conductor cross sections > 6.0 mm²: As per sample

The test fixture (see figure 7) consists of a tensile testing machine or a force measuring instrument, a notching tool (cutter), and an extra-low-voltage circuit. A round spring wire as per section "Abrasion test" of ISO 6722-1 with a needle diameter of (0.45 ±0.01) mm must be used as the notching tool.

The specimen is fastened in the tensile testing machine as per figure 7. The steel wire is pressed through the insulation at a constant speed of ≤ 10 mm/min until the electric contact between the steel wire and the conductor of the specimen shuts off the machine. The axes of the specimen and the cutter must be perpendicular to one another. The force indicated when contact is made is noted. After each reading, the specimen is shifted 10 mm and rotated by 90° about its longitudinal axis until a total of 4 measurements are taken. The penetration force is the mean value of these measurements.



Legend

1 Force
2 Specimen
3 Steel wire

Figure 7 – Test fixture for notch strength

9.4 Flame retardance

Testing and requirements are as per ISO 6722-1.

9.5 Electrical properties in as-received condition

9.5.1 Volume resistivity

The volume resistivity of the insulation must be at least 10^9 Ωmm.

Testing is performed as per ISO 6722-1 (but with a 1% NaCl solution).

9.5.2 30-minute dielectric strength

Dielectric breakdown must not occur.

Testing is performed as per ISO 6722-1.

9.5.3 1-minute dielectric strength measurement (only after exposure to load)

This test is only performed after tests that include a corresponding reference.

According to section 9.5.2, however, a test voltage of 1 kV_{rms} (5 kV for cable cross sections > 6.0 mm^2) is applied for 1 min for the test.

The specimens are aged in a saltwater bath for ≥ 10 min. Different aging durations might apply if the aging in the saltwater bath is explicitly described in a test (see also ISO 6722-1: e.g., 1-min dielectric strength after long-term aging).

9.6 Mechanical and electrical properties after exposure to mechanical, thermal, or chemical load

9.6.1 Stress test

This test applies to cables with an insulation made of fluoropolymers, e.g., FEP and ETFE. Two specimen pieces of sufficient length (2 m) are removed and used to produce the specimens for the stress test.

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

Fluoropolymers of temperature class T200:	FEP:	(+225 ±4) °C
	Radiation cross-linked ETFE:	(+225 ±4) °C
Fluoropolymers of temperature class T175:	ETFE:	(+225 ±4) °C
Fluoropolymers of temperature class T150:	ETFE:	(+200 ±4) °C

Then the pieces are removed, cooled down over a period of at least 16 h in a standard atmosphere as per VW 50554 – 23/50-2, and wound around a mandrel in a tight coil of at least 6 turns that lie very close to one another as per table 15 with the stripped ends fastened in place (see also the example in figure 8). The following values must be ensured: L1 > 60 mm and L2 > 10 mm.

The wound specimens are aged for another 3 h with the mandrel at the cable-specific temperatures specified above. Afterwards, the specimens are cooled down over a period of at least 16 h, the mandrel is removed (without unwinding the cable), and an electrical test is performed on the specimen as per section 9.5.3.

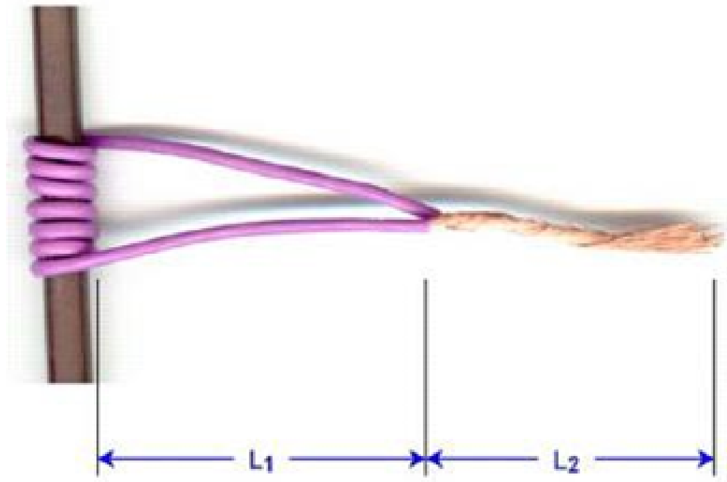


Figure 8 – Winding test example

The test is considered passed if there is no dielectric breakdown during the electrical test as per section 9.5.3.

Table 15 – Mandrel diameter

Nominal conductor cross section	in mm²	0.35	0.5	0.75	1.0	1.5	2.5	4.0	6.0
Mandrel diameter	in mm	2			3		4	5	

9.6.2 Insulation shrinkage under heat

Testing is performed as per ISO 6722-1 at T_{max}.

The test temperature is as per table 5, column "Thermal overload temperature."

The opening time for placing the components for aging must not exceed 10 s. The aging time starts upon reaching T_{max} + 50 °C.

For specimen preparation, see figure 9.

Figure 9 – Specimen preparation for shrinkage testing

9.6.3 Compressive strength of the insulation under heat

Testing is performed as per ISO 6722-1.

The test temperature is T_{max} until at least one of the 3 specimens fails. The testing until failure is used for data gathering purposes to obtain an overview of differences in material and to determine the "compressive strength under heat temperature."

9.6.4 Determining the derating curve

The current-carrying capacity at the ambient temperature and the measurement for temperature increase of the cable or conductor are determined as per VW 60306-3.

The smallest cable cross section of each mixture/compound used is measured. All cable cross sections (including the measured ones) are calculated as per VW 60306-3.

The maximum permissible resistance and the smallest permissible outer diameter must be used for the calculation.

9.6.5 Thermal stability in wound state

Dielectric breakdown must not occur.

A cable specimen of sufficient length is wound around a mandrel with a diameter as per table 16 with 6 turns that lie very close to one another and tied in place.

The specimen prepared in this manner is aged for 1 h in an oven with natural ventilation at the thermal overload temperature as per section "Ovens", table 5 in ISO 6722-1 (hanging on the mandrel). After cooling down in a standard atmosphere as per VW 50554 – 23/50-2, the test is performed as per section 9.5.3 (1-minute dielectric strength measurement).

Table 16 – Mandrel diameter

Nominal conductor cross section	in mm²	0.35	0.5	0.75	1.0	1.5	2.5	4.0	6.0
Mandrel diameter	in mm	5		9				13	

9.6.6 Thermal overload

9.6.6.1 Thermal overload T_{max} + 50 °C

Testing is performed as per ISO 6722-1.

The test temperature is as per table 5.

The subsequent high-voltage test is performed as per section 9.5.3.

After the test, the color of the cable must still be identifiable.

The colors of the aged and unaged cables must be documented in one photo.

9.6.6.2 Extreme thermal overload T_{max} + x °C/1 h

This test simulates an extreme situation (e.g., short circuit). Therefore, the results of this test alone cannot be used for the cable design in the electrical system.

The test procedure is as per section 9.6.8.1. The subsequent high-voltage test is performed as per section 9.5.3.

The start temperature can be freely selected based on experience.

The start temperature can, for example, be T_{max} + 75 °C.

If all three of the specimens pass this test, the temperature must be increased by 10 °C and the test must be repeated with new specimens. If at least one specimen does not pass the test, the test is stopped.

If at least one specimen is not OK at the start temperature (e.g., T_{max} + 75 °C), the temperature is reduced by 10 °C until all of the specimens are OK.

The start temperature can deviate from T_{max} + 75 °C depending on the material.

The highest temperature at which all three specimens passed the test must be documented in the test report.

NOTE 1: A conclusion on the amperage at which the conductor reaches the temperature determined in this manner can be drawn by means of a calculation or a derating measurement (see VW 60306-3).

9.6.7 Winding test after short-term aging (240 h)

The aging is performed as per ISO 6722-1 at an oven temperature of T_{max} + 25 °C.

The colors of the aged and unaged cables must be documented in one photo.

Winding test, rotating mandrel, and weight at -25 °C as per ISO 6722-1. The subsequent high-voltage test is performed as per section 9.5.3.

After the aging, the color of the cable must still be identifiable.

9.6.8 Long-term aging (3 000 h)

Testing is performed as per ISO 6722-1.

The aging is performed as per ISO 6722-1 at an oven temperature of T_{max}.

The specimens for the subsequent subtests section 9.6.8.1 and section 9.6.8.2 can be aged together in one oven.

The colors of the aged and unaged cables must be documented in one photo.

After the aging, the color of the cable must still be identifiable.

9.6.8.1 Winding test after long-term aging

The winding test is performed as per ISO 6722-1 in a standard atmosphere as per VW 50554 – 23/50-2.

The subsequent high-voltage test is performed as per section 9.5.3.

9.6.8.2 Minimum permissible bending radius for static routing

Long-term aging of the bent specimens is used to verify that the cable can be routed with bending radii greater than or equal to the specified radius.

Dielectric breakdown must not occur.

For each cable, two cable samples with a length of approximately 400 mm have 25 mm of insulation stripped off both ends.

For specimen preparation, see table 17.

Table 17 – Specimen preparation

Maximum cable diameter d_{max} in mm	Smallest permissible bending radius in mm	Maximum winding mandrel diameter in mm	Execution
≤ 3.0 (to 2.5 mm²)	2.0 × d_{max}	–	Wound 360° around itself 3 times, see figure 10
> 3.0 and ≤ 5.0 (from 4.0 mm² to 6.0 mm²)	2.0 × d_{max}	1.5 × d_{max}	Wound 360° around mandrel 2 times, fastened with two cable ties: 1. Cable tie at a distance of half of the produced loop diameter 2. Cable tie at a distance of half of the produced loop diameter, mandrel removed (see figure 11)
> 5.0 (from 6.0 mm²)	3.0 × d_{max}	2.0 × d_{max}	Bent 180° around mandrel, fastened with cable ties: 1. Cable tie at a distance of the produced loop diameter 2. Cable tie at a distance of half of the produced loop diameter, mandrel removed (see figure 12)

The cable ties used must meet the following requirements:

- Their base material must be suitable for the corresponding aging temperature.
- No incompatibility with the insulating material to be tested
- Teeth on outside
- No sharp edges
- Width ≥ 0.8 × d_{max}
- The tightening force must be selected such that no or only minor indentations are produced on the insulation surface in the neutral state.

Figure 10 – d_{max} ≤ 3.0 mm

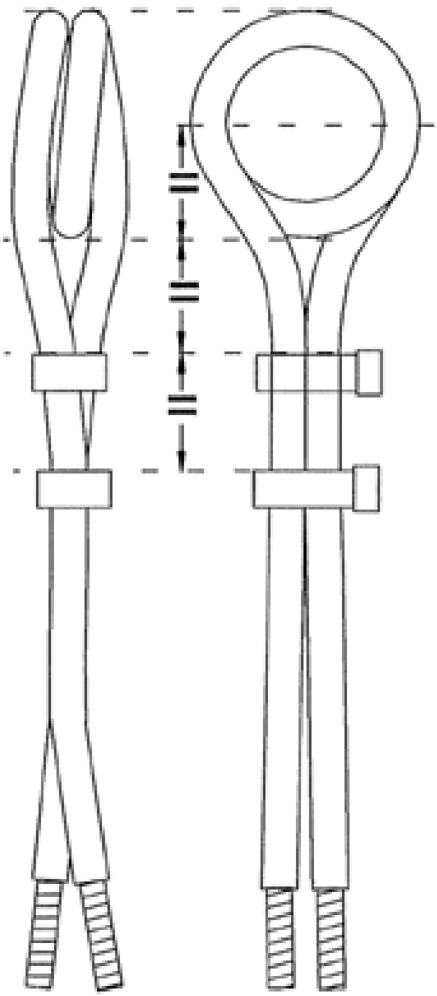


Figure 11 – d_{max} > 3.0 mm and ≤ 5.0 mm

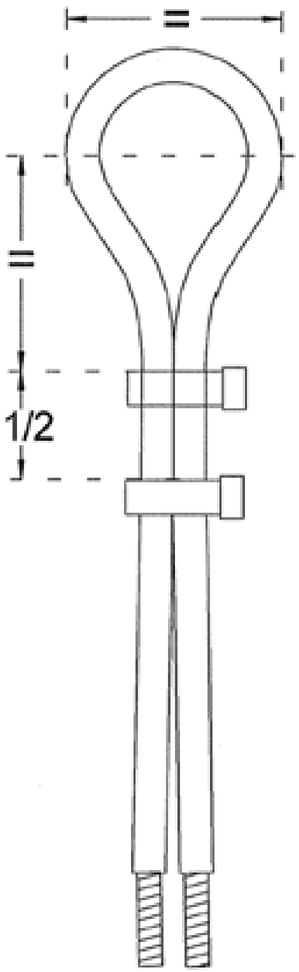


Figure 12 – d_{max} > 5.0 mm

The prepared samples must be aged for 3 000 h as per section 9.6.8. Then the specimens that are still wound and fastened are subjected to a high-voltage test as per the requirements in ISO 6722-1.

9.6.9 Winding test at low temperature (-40 °C)

Testing is performed as per section "Winding test at low temperature -40 °C, rotating mandrel, and weight" in ISO 6722-1.

9.6.10 Impact test at low temperature (-15 °C)

Testing is performed as per ISO 6722-1.

Deviating from this, however, cables with cross sections ≤ 0.5 mm^2 are tested with a hammer mass of 100 g.

9.6.11 Cable marking resistance to wiping

This test only applies to cables with printed markings.

Testing is performed as per ISO 6722-1.

9.6.12 Bending fatigue strength

Number of cycles until failure: As per sample

No visible insulation damage (crack or fracture)

Determining the bending cycles until cable fracture that is detected by measuring the electrical continuity

Based on ISO 14572, but deviating with R 6 × maximum specified outer cable diameter (-20%)

Testing is performed in a standard atmosphere as per VW 50554 – 23/50-2 and at T_{min}.

The insulation must be visually inspected at least once per day.

Specimen length:	≥ 1 m
Sampling rate:	≤ 10 ms
Distance between the bending grips:	1.5 × the maximum specified outer diameter ±0.5 mm
Material of the bending grips:	Stainless steel or aluminum
Loading weight:	1.0 kg/mm^2 (total nominal copper cross section); the minimum weight must not fall below 250 g per cable and the maximum weight must not exceed 12 kg per cable.

The entire cable must be fastened to the test equipment and the loading weight (not just the conductor).

9.6.13 Kink test

This test only applies to cables with cross sections ≤ 6.0 mm^2.

Dielectric breakdown must not occur.

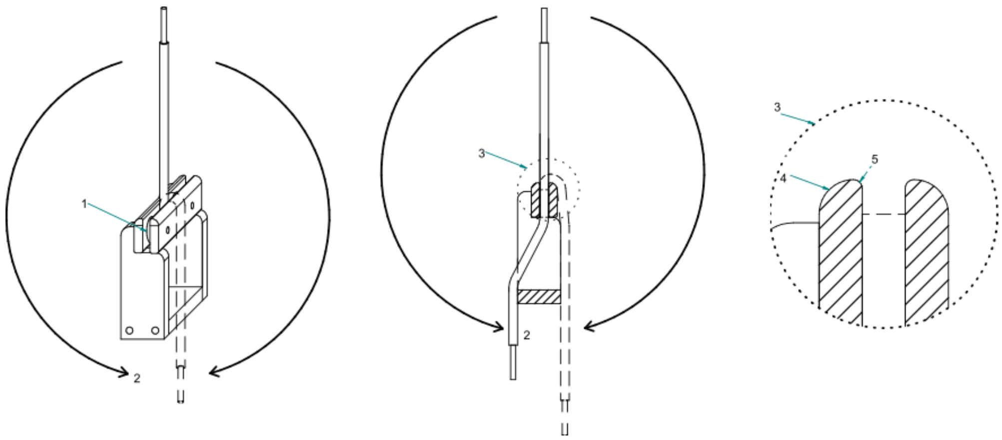
Before the test, the test fixture is selected (see figure 13) such that its inner bending radius r corresponds to the cable cross section to be tested and the specified spacer rings are used as per table 18.

Table 18 – Spacer rings

Nominal conductor cross section	in mm^2	0.35	0.5	0.75	1.0	1.5	2.5	4.0	6.0
Bending radius (r)	in mm	1.0			1.5			3.0	
Spacer ring thickness	in mm	1.1	1.3	1.6	1.8	2.1	2.6	3.3	3.9
Tolerance of spacer ring thickness	in mm	-0.1							

Cable samples with a minimum length of 200 mm must have 20 mm of insulation stripped off the ends. The specimen is routed out of the test fixture perpendicular to the grips and clamped between the grips of the test fixture until the spacer rings meet the block. Then the cable is subjected to 20 bending cycles. One cycle corresponds to bending the cable 180° to one side until the cable meets the fixture, bending it 360° to the other side of the test fixture, and returning it 180° to the initial position. It must be ensured during the test that the cable subjected to as little tensile force as possible.

After unclamping the cable specimen, it is tested as per section 9.5.3 (1-minute dielectric strength measurement).



Legend

1	Spacer ring
2	±180°
3	Close-up view
4	r = 4 mm
5	Bending radius r = as per table 18

Figure 13 – Test fixture for kink test

9.6.14 Electrical properties with aging in water

The insulation resistance (measured as per section 9.5.1) during aging in water must be at least 10^9 Ωmm. This value is measured every 7 days.

After the test, the color of the cable must still be identifiable.

A specimen of sufficient length is wound 10 turns around the center of a mandrel with a diameter as per table 19/table 20. The cable is tied and the mandrel is removed.

Table 19 – Mandrel diameter I

Nominal conductor cross section	in mm^2	0.35	0.5	0.75	1.0	1.5	2.5	4.0	6.0
Mandrel diameter	in mm	6			10		15	20	

Table 20 – Mandrel diameter II

Nominal conductor cross section	in mm^2	10	16	25	35	50	70	95	120
Mandrel diameter	in mm	40	50		75	100			125

Every specimen is connected to the positive terminal of a 48-V DC voltage source and aged for 1 000 h in a salt solution (1% NaCl in deionized water) at a temperature of (+85 ±2) °C in a test vessel made of glass such that 2 m of the specimen is fully immersed. The test vessel with the specimens must be heated uniformly in an external tempering bath. It must be ensured that the specimens and the electrodes in the test vessel do not make contact.

Immersed electrode surface: (100 ±10) cm

Electrode material: Cu

Immediately after aging in water, the specimens are tested as per section 9.5.3 (1-minute dielectric strength measurement).

Only cables with the same insulation material may be aged together in the same tempering bath. The water volume in the test vessel must be from 2 l to 5 l. This must be indicated in the test report. Different water volumes can be used for larger cable cross sections (≥ 10 mm^2). This must be documented in the test report.

If a cable has failed, it must be removed from the tempering bath.

The test must also be performed with reversed polarity on new specimens.

9.6.15 Damp heat, constant (hydrolysis test)

Dielectric breakdown must not occur.

After the test, the color of the cable must still be identifiable.

The insulation is stripped off the ends of a cable specimen that is (3 000 ±50) mm in length. The cable is coiled at a radius ≥ 25 mm, fastened to the support, and aged for 3 000 h at a temperature of (+85 ±2) °C and a relative humidity of (85 ±5)%. Then the specimen is aged for 30 min in a standard atmosphere as per VW 50554 – 23/50-2 and tested within another 30 min as per section 9.6.8.1 (winding and dielectric strength).

9.6.16 Ozone resistance

Dielectric breakdown must not occur.

Cable specimens of sufficient length are wound 4 to 6 turns around a mandrel with a diameter of 3 × the outer diameter of the cable and fastened in place. Testing is performed on the basis of DIN ISO 1431-1, method A. The specimens are aged for (70 +2) h in a standard atmosphere as per VW 50554 – 23/50-2 and then for 48 h at 40 °C, a relative humidity of (55 ±10)%, and an ozone concentration of (50 ±5) pphm (1 pphm = part per hundred millions is equal to 1 part ozone to 10^8 parts air by volume). After cooling down in a standard atmosphere as per VW 50554 –

23/50-2, the specimens are unwound from the mandrel and tested as per section 9.5.3 (1-minute dielectric strength measurement).

9.7 Mycological test

Growth on the insulation not exceed grade 3 (growth visible to the naked eye, up to 50% of the specimen surface may be covered in growth) as per section "Method A: Fungal-growth test" in DIN EN ISO 846.

The mean values for tensile strength and elongation at tear must not change by more than 50% at a growth grade > 2.

NOTE 2: Tests that were previously passed with a growth grade ≤ 1 as per DIN EN 60068-2-10 are still considered passed.

The use of fungicides without consultation with the appropriate department is prohibited.

Testing is performed as per section "Method A: Fungal-growth test" in DIN EN ISO 846.

The cables with the largest cross section from which the specimens were also produced as per section 9.2.3 must be used. At least 5 specimens of each compound must be tested.

The specimens must be cleaned with an ethanol/water solution as per section "Cleaning" in DIN EN ISO 846. They are inoculated with test fungal spores.

The specimens must be inoculated with the test fungal spores on mineral salt agar in a Petri dish and incubated for 28 days at (29 ±1) °C. An intermediate check for fungal growth is permissible after 14 days.

After 28 days of incubation, the specimens must be checked for fungal growth as per section "Assessment" in DIN EN ISO 846.

The fungal growth must be graded as specified in DIN EN ISO 846, table 4.

If a growth > 2 is determined, a test as per section 9.2.3 must be performed after the mycological test (without copper), and the change in tensile strength and elongation at tear must be determined.

9.8 Compatibility tests

This section describes tests that ensure compatibility of the cables with substances occurring in vehicles and their surroundings.

9.8.1 Resistance to chemicals as per ISO 6722-1

To determine the swelling and shrinkage, a compatibility test must be performed as per section "Fluid compatibility", "Test method 2" in ISO 6722-1. Additional testing of resistance to AdBlue must be performed for 48 h at +50 °C as per VW 60306-1 Supplement 1.

The smallest cable cross section of each compound is tested.

For fluoropolymers, the test can be omitted upon prior agreement with the appropriate department.

9.8.2 Resistance to chemicals

The insulation must not have any cracks, fractures, or other damage affecting function. There must not be any dielectric breakdown during the voltage tests.

Resistance of at least:

– 480 h of exposure to chemicals in group 1 (see VW 60306-1 Supplement 1)
– 240 h of exposure to chemicals in group 2 (see VW 60306-1 Supplement 1)

If individual aspects of these tests are not passed, this does not necessarily rule out a release. The results are evaluated by the appropriate department.

If the resistance is less than 240 h, the appropriate protection from the chemicals in group 2 must be provided in the area of the wiring harness (e.g., by means of corrugated tube, protective hose).

9.8.2.1 Testing on cross sections ≤ 2.5 mm^2

If other compounds are used with cable cross sections ≤ 2.5 mm^2, these must be tested as well. In this case, the smallest cable cross section of each compound is tested as per table 21.

The test group is tested for chemicals in group 1 as well as chemicals in group 2 (see VW 60306-1 Supplement 1).

At least 4 specimens of each test group are immersed in the respective chemical for 2 min in a standard atmosphere as per VW 50554 – 23/50-2 (or lightly brushed with grease). The cable ends must not come into contact with the chemical. The chemical is then allowed to drip off for 2 min (10 min for fuels) (grease remains).

Each chemical must be tested separately (chemicals must not be combined).

The specimens are suspended in a test tube with the cable ends pointing upwards and the test tubes are placed in an oven for 480 h of aging at T_{max}. After 240 h and 480 h, two of each of the specimens are removed and the remaining two specimens are aged for the remaining 240 h.

The aging with the chemical AdBlue must also be performed in a climatic chamber at a temperature of (+85 ±2) °C and a relative humidity of (85 ±5)% for 480 h. The rest of the test procedure is the same.

The specimens are aged without direct contact with any potential chemical sump. This prevents the undesired, continuous contact of the specimens with the respective chemical, since capillary effects that cause the chemical to be fed back to the specimen must be avoided. In this way, occasional wetting of the wiring harness with the chemicals is simulated.

After the test period has elapsed, the wiring harness is aged for at least 3 h and no longer than 72 h in a standard atmosphere as per VW 50554 – 23/50-2 and then tested as follows:

– The straight area that had contact with the chemicals is evaluated and documented.
– The specimen is tightly wound around a mandrel with a diameter of 2 mm, visually inspected, and subjected to a voltage test as per section 9.5.3.
– For cable cross sections other than 0.35 mm^2, testing is performed as per table 21.

Table 21 – Overview of winding mandrels

Nominal conductor cross section	Test tubes	Winding mandrels after aging
in mm^2	in mm	in mm
0.35	25 ±2	2
0.50	25 ±2	2
0.75	25 ±2	2
1.00	30 ±2	3

1.50	None, freely suspended	3
2.50	None, freely suspended	4

NOTE 3: The mandrel is selected according to the long-term aging as per ISO 6722-1.

9.8.2.2 Testing on cross sections ≥ 4 mm²

Testing is performed with a cable cross section of 16 mm². If other compounds are used with cable cross sections ≥ 4 mm², these must be tested as well. In this case, the smallest cable cross section of each compound is tested. This test is not required if the compound has already been tested for cable cross sections < 4 mm².

The test groups are divided up and prepared as per section 9.8.2.1.

Testing is performed as for cable cross sections < 4 mm², but with the following differences:

– The length of the specimen is at least 600 mm.

After being immersed in the chemicals in group 1 and 2, the specimens prepared in this manner are suspended in an oven with natural ventilation (bend facing downward) and aged (test tube not required).

Following this, the cable is wound around a mandrel with a diameter of 2 mm as per section 9.6.8. A visual inspection and a voltage test as per section 9.5.3 (1-minute dielectric strength measurement) are then performed.

Visual changes to the cable must be noted in the test report.

10 Environmental protection and safety

In addition to the applicable legal requirements, the requirements in VDA 232-101 (hazardous substance list) must also be met.

11 Applicable documents

The following documents cited are necessary to the application of this document:

Some of the cited documents are translations from the German original. The translations of German terms in such documents may differ from those used in this standard, resulting in terminological inconsistency.

Standards whose titles are given in German may be available only in German. Editions in other languages may be available from the institution issuing the standard.

VW 50554	Standard Atmospheres and Room Temperatures; Requirements on Standard Atmospheres
VW 60306-1 Supplement 1	Electrical Cables for Motor Vehicles – Part 1: Copper Cable; Single-Core, Unshielded
VW 60306-3	Determining Current Capacity of Vehicle Cables
VW 75210-2	High-Voltage, Shielded, Sheathed Cables for Motor Vehicles and Their Electric Drives; Requirements and Tests
DIN 1333	Presentation of numerical data

DIN 72551-7	Road vehicles - Low-tension cables - Part 7: Colours and colour marking of low-tension cables
DIN 76722	Road vehicles - Electrical cables - Design rule for abbreviation codes
DIN EN 13602	Copper and copper alloys - Drawn, round copper wire for the manufacture of electrical conductors
DIN EN 50525-2-21	Electric Cables – Low Voltage Energy Cables of Rated Voltages up to and including 450/750 V (U0/U) – Part 2-21: Cables for General Applications – Flexible Cables with Crosslinked Elastomeric Insulation; German version EN 50525-2-21:2011
DIN EN 60068-2-10	Environmental testing - Part 2-10: Tests - Test J and guidance: Mould growth
DIN EN 60811-201	Electric and Optical Fibre Cables – Test Methods for Non-Metallic Materials – Part 201: General Tests – Measurement of Insulation Thickness (IEC 60811-201:2012); German version EN 60811-201:2012
DIN EN 60811-203	Electric and Optical Fibre Cables – Test Methods for Non-Metallic Materials – Part 203: General Tests – Measurement of Overall Dimensions (IEC 60811-203:2012); German version EN 60811-203:2012
DIN EN 60811-405	Electric and Optical Fibre Cables – Test Methods for Non-Metallic Materials – Part 405: Miscellaneous Tests – Thermal Stability Test for PVC Insulations and PVC Sheaths (IEC 60811-405:2012); German version EN 60811-405:2012
DIN EN 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 60811-501:2012); German version EN 60811-501:2012
DIN EN 60811-507	Electric and Optical Fibre Cables – Test Methods for Non-Metallic Materials – Part 507: Mechanical Tests – Hot Set Test for Cross-Linked Materials (IEC 60811-507:2012); German version EN 60811-507:2012
DIN EN ISO/ IEC 17025	General requirements for the competence of testing and calibration laboratories
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 846	Plastics - Evaluation of the action of microorganisms
DIN ISO 1431-1	Rubber, vulcanized or thermoplastic - Resistance to ozone cracking - Part 1: Static and dynamic strain testing
DIN ISO 34-1	Rubber, vulcanized or thermoplastic - Determination of tear strength - Part 1: Trouser, angle and crescent test pieces
ISO 14572	Road vehicles - Round, sheathed, 60 V and 600 V screened and unscreened single- or multi-core cables - Test methods and requirements for basic- and high-performance cables
ISO 6469-3	Electrically propelled road vehicles - Safety specifications - Part 3: Protection of persons against electric shock

ISO 6722-1	Road vehicles - 60 V and 600 V single-core cables - Part 1: Dimensions, test methods and requirements for copper conductor cables
VDA 232-101	Global Automotive Declarable Substance List
VDA Volume 6 Part 1	Quality Management in the Automotive Industry – Part 1: QM System Audit, Serial Production

12 Bibliography

[1] Regulation ECE R10 can be found at Regulation No 10 of the Economic Commission for Europe of the United Nations (UN/ECE) – Uniform Provisions Concerning the Approval of Vehicles with Regard to Electromagnetic Compatibility [2017/260].

[2] Directive 2011/65/EU can be found at Directive 2011/65/EU on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment.

[3] Directive 2014/53/EU can be found atDirective 2014/53/EU on the Harmonisation of the Laws of the Member States Relating to the Making Available on the Market of Radio Equipment and Repealing Directive 1999/5/EC .

Appendix A (normative)

The following are included in the appendix:

Table A.1 "FLR – Cable composition, symmetric, type A with reduced wall thickness"

Table A.2 "FLR – Cable composition, symmetric, type A with ultra-thin wall thickness"

Table A.3 "FLR – Cable composition, asymmetric, type B with reduced wall thickness"

Table A.4 "FLR – Cable composition, asymmetric, type B with reduced wall thickness (intermediate cable cross sections)"

Table A.5 "FLR – Cable composition, asymmetric, finely stranded/flexible, type B"

Table A.1 – FLR – Cable composition, symmetric, type A with reduced wall thickness

Nominal conductor cross section	Strand		Conductor								Cable						
	Quantity	Diameter	Diameter d1 [a]	Lay length	Cable cross section for bare conductor [b]		Resistance at 20 °C, strands [a]		Resistance at 20 °C, tinned strands		Outer diameter d2		Wall thickness of the insulation t	C_{pk} value (based on t)	Test wall thickness t_{test}	Insulation strippability factor A [c]	Weight [d]
mm²	Pieces	mm	mm	mm	mm²		mΩ/m		mΩ/m		mm		mm		mm	%	g/m
		maximum	maximum	maximum	minimum	maximum	maximum	minimum	maximum	minimum	maximum	Permissible deviation	minimum	minimum	minimum	minimum	
0.35 [e]	7	0.27	0.80	27	0.332	0.358	52.0	48.1	55.5	51.4	1.3	-0.10	0.20		0.22		4.6
0.50	19	0.20	1.00	45	0.465	0.502	37.1	34.4	38.2	35.4	1.6	-0.20	0.22		0.24		6.3
0.75	19	0.24	1.20	45	0.698	0.754	24.7	22.9	25.4	23.5	1.9	-0.20	0.24		0.26		9.2
1.0	19	0.27	1.35	50	0.932	1.01	18.5	17.1	19.1	17.7	2.1	-0.20	0.24		0.26		12
1.5	19	0.33	1.70	60	1.36	1.47	12.7	11.8	13.0	12.0	2.4	-0.20	0.24	≥ 1.33	0.26	45	17
2.5	19	0.41	2.20	75	2.27	2.45	7.60	7.04	7.82	7.24	3.0	-0.30	0.28		0.30		27
2.5	37	0.30	2.20	75	2.27	2.45	7.60	7.04	7.82	7.24	3.0	-0.30	0.28		0.30		27
4.0	37	0.38	2.75	75	3.66	3.95	4.71	4.36	4.85	4.49	3.7	-0.30	0.32		0.34		43
6.0	37	0.45	3.40	75	5.49	5.93	3.14	2.91	3.23	2.99	4.3	-0.30	0.32		0.34		63

a) Measurement accuracy: 50 µm

b) Calculated with a specific electrical conductivity value of 58.0 Sm/mm², quality control through resistance measurement

c) The insulation strippability factor is determined as per section 9.1.4. The provisional target value is at least 45%. The insulation strippability factor can be between 35% and 45% transitionally in consultation with the appropriate department.

d) Weight according to sample; the values in the table apply to PVC.

e) The resistance values for a cable cross section of 0.35 mm^2 deviate significantly from ISO 6722-1.

Table A.2 – FLR – Cable composition, symmetric, type A with ultra-thin wall thickness

Nominal conductor cross section	Strand		Conductor						Cable						
	Quantity	Diameter	Diameter d1 [a)]	Lay length	Cable cross section for bare conductor [b)]		Resistance at 20 °C, bare strands (tinned [c)])		Outer diameter d2		Wall thickness of the insulation t	C_{pk} value (based on t)	Test wall thickness t_{test}	Insulation strippability factor A [d)]	Weight [e)]
mm²	Pieces	mm	mm	mm	mm²		mΩ/m		mm		mm		mm	%	g/m
		maximum	maximum	maximum	minimum	maximum	maximum	minimum	maximum	Permissible deviation	minimum	minimum	minimum	minimum	
0.35 [f)]	7	0.27	0.80	27	0.332	0.358	52.0	48.1	1.20	-0.10	0.16	≥ 1.33	0.17	45	4.3
0.50	19	0.20	1.00	45	0.465	0.502	37.1	34.4	1.40	-0.10	0.16		0.17		5.8
0.75	19	0.24	1.20	45	0.698	0.754	24.7	22.9	1.60	-0.15	0.16		0.17		8.4
1.0	19	0.27	1.35	50	0.932	1.01	18.5	17.1	1.75	-0.15	0.16		0.17		11
1.5	19	0.33	1.70	60	1.36	1.47	12.7	11.8	2.10	-0.20	0.16		0.17		16
2.5	19	0.41	2.20	75	2.27	2.45	7.60	7.04	2.70	-0.20	0.20		0.21		26
2.5	37	0.30	2.20	75	2.27	2.45	7.60	7.04	2.70	-0.20	0.20		0.21		26

a) Measurement accuracy: 50 µm

b) Calculated with a specific electrical conductivity value of 58.0 Sm/mm², quality control through resistance measurement

c) The resistance values for tinned conductors must be taken from ISO 6722-1.

d) The insulation strippability factor is determined as per section 9.1.4. The provisional target value is at least 45%. The insulation strippability factor can be between 35% and 45% transitionally in consultation with the appropriate department.

e) Weight according to sample; the values in the table apply to PVC.

f) The resistance values for a cable cross section of 0.35 mm² deviate significantly from ISO 6722-1.

Table A.3 – FLR – Cable composition, asymmetric, type B with reduced wall thickness

Nominal conductor cross section	Strand		Conductor								Cable						
	Quantity [a]	Diameter	Diameter d1 [b]	Lay length	Cable cross section for bare conductor [c]		Resistance at 20 °C, bare strands		Resistance at 20 °C, tinned strands		Outer diameter d2		Wall thickness of the insulation t	C_{pk} value (based on t)	Test wall thickness t_{test}	Insulation strippability factor A [d]	Weight [e]
mm²	Pieces	mm	mm	mm	mm²		mΩ/m		mΩ/m		mm		mm		mm	%	g/m
		maximum	maximum	maximum	minimum	maximum	maximum	minimum	maximum	minimum	maximum	Permissible deviation	minimum	minimum	minimum	minimum	
0.35 [f]	12	0.21	0.90	Not specified	0.332	0.358	52.0	48.1	55.5	51.4	1.3	-0.10	0.20	≥ 1.33	0.22	45	4.6
0.50	16	0.21	1.00		0.465	0.502	37.1	34.4	38.2	35.4	1.6	-0.20	0.22		0.24		6.3
0.75	24	0.21	1.20		0.698	0.754	24.7	22.9	25.4	23.5	1.9	-0.20	0.24	> 1.0 [g]	0.26		9.2
1.0	32	0.21	1.40		0.932	1.01	18.5	17.1	19.1	17.7	2.1	-0.20	0.24		0.26		12
1.5	30	0.26	1.70		1.36	1.47	12.7	11.8	13.0	12.0	2.4	-0.20	0.24		0.26		17
2.5	50	0.26	2.20		2.27	2.47	7.60	7.04	7.82	7.24	3.0	-0.30	0.28		0.30		27
4.0	56	0.31	2.75		3.66	3.95	4.71	4.36	4.85	4.49	3.7	-0.30	0.32		0.34		43
6.0	84	0.31	3.40		5.49	5.93	3.14	2.91	3.23	2.99	4.3	-0.30	0.32		0.34		63
10	80	0.41	4.50		9.47	10.2	1.82	1.69	1.85	1.71	5.8	-0.40	0.48		0.50	Not applicable	111
16	126	0.41	5.50		14.9	16.1	1.16	1.07	1.18	1.09	7.0	-0.50	0.52		0.54		171
25	196	0.41	7.00		23.2	25.1	0.743	0.688	0.757	0.701	8.7	-0.50	0.52		0.66		160
35	276	0.41	8.30		32.7	35.3	0.527	0.488	0.538	0.498	10.4	-0.60	0.64		0.82		368
50	396	0.41	9.80		46.9	50.6	0.368	0.341	0.375	0.347	12.2	-0.70	0.72		0.74		524
70	360	0.51	11.6		66.6	71.9	0.259	0.240	0.264	0.244	14.4	-0.90	0.80		0.82		743
95	475	0.51	13.8		88.0	95.0	0.196	0.181	0.200	0.185	16.7	-1.00	0.88		0.90		979

a) Minor deviations are permissible:
- For 50 strands ±5% in adherence to the resistance and the maximum strand diameter
- For ≤ 50 strands, no deviation is permissible.

b) Measurement accuracy: 50 µm

c) Calculated with a specific electrical conductivity value of 58.0 Sm/mm², quality control through resistance measurement

d) The insulation strippability factor is determined as per section 9.1.4. The provisional target value is at least 45%. The insulation strippability factor can be between 35% and 45% transitionally in consultation with the appropriate department.

e) Weight according to sample; the values in the table apply to PVC.

f) The resistance values for a cable cross section of 0.35 mm² deviate significantly from ISO 6722-1.

g) A C_{pk} value ≥ 1 will be accepted transitionally.

Table A.4 – FLR – Cable composition, asymmetric, type B with reduced wall thickness (intermediate cable cross sections)

Nominal conductor cross section	Strand		Conductor								Cable						
	Quantity [a]	Diameter	Diameter d1 [b]	Lay length	Cable cross section for bare conductor [c]		Resistance at 20 °C, bare strands		Resistance at 20 °C, tinned strands		Outer diameter d2		Wall thickness of the insulation t	C_{pk} value (based on t)	Test wall thickness t_{test}	Insulation strippability factor A [d]	Weight [e]
mm²	Pieces	mm	mm	mm	mm²		mΩ/m		mΩ/m		mm		mm		mm	%	g/m
		maximum	maximum	maximum	minimum	maximum	maximum	minimum	maximum	minimum	maximum	Permissible deviation	minimum	minimum	minimum	minimum	
Intermediate cable cross sections > 10 mm²																	
12 [f]	96	0.41	4.80	Not specified	11.3	12.3	1.52	1.41	1.60	1.48	6.5	-0.30	0.48	1.00	0.50	45	131
20 [f]	153	0.41	6.10		18.1	19.5	0.955	0.884	0.999	0.925	7.8	-0.40	0.52		0.54		205
30 [f]	225	0.41	7.40		26.6	28.8	0.647	0.599	0.684	0.633	9.6	-0.50	0.64		0.66		303
40 [f]	308	0.41	8.60		36.5	39.4	0.473	0.438	0.500	0.463	11.1	-0.50	0.72		0.74		413
60 [f]	463	0.41	10.50		54.7	59.1	0.315	0.292	0.333	0.308	13.3	-0.60	0.80		0.82		614
85 [f]	418	0.51	13.20		78.7	85.0	0.219	0.203	0.232	0.215	15.3	-0.70	0.80		0.82		874

a) Minor deviations are permissible:
- For 50 strands ±5% in adherence to the resistance and the maximum strand diameter
- For ≤ 50 strands, no deviation is permissible.

b) Measurement accuracy: 50 µm

c) Calculated with a specific electrical conductivity value of 58.0 Sm/mm², quality control through resistance measurement

d) The insulation strippability factor is determined as per section 9.1.4. The provisional target value is at least 45%. The insulation strippability factor can be between 35% and 45% transitionally in consultation with the appropriate department.

e) Weight according to sample; the values in the table apply to PVC.

f) ISO 6722-1 for intermediate cable cross sections; use in agreement with the appropriate department

Table A.5 – FLR – Cable composition, asymmetric, finely stranded/flexible, type B

Nominal conductor cross section	Strand: Quantity a)	Strand: Diameter	Conductor: Diameter d1 b)	Conductor: Lay length	Conductor: Cable cross section for bare conductor c)		Conductor: Resistance at 20 °C, bare strands		Conductor: Resistance at 20 °C, tinned strands		Cable: Outer diameter d2		Cable: Wall thickness of the insulation t	Cable: C_{pk} value (based on t)	Cable: Test wall thickness t_{test}	Cable: Insulation strippability factor A d)	Cable: Weight e)
mm²	Pieces	mm	mm	mm	mm²		mΩ/m		mΩ/m		mm		mm		mm	%	g/m
	nominal	maximum	maximum	maximum	minimum	maximum	maximum	minimum	maximum	minimum	maximum	Permissible deviation	minimum	minimum	minimum	minimum	
0.35	45	0.11	0.90	Not specified	0.332	0.358	52.0	48.1	55.5	51.4	1.4	-0.20	0.20	≥ 1.33	0.22	45	4.5
0.50	63		1.00		0.465	0.502	37.1	34.4	38.2	35.4	1.6		0.22		0.24		6.6
0.75	94		1.20		0.698	0.754	24.7	22.9	25.4	23.5	1.9		0.24	> 1.0 f)	0.26		9.0
1.0	125		1.40		0.932	1.01	18.5	17.1	19.1	17.7	2.1						11
1.5	182		1.70		1.36	1.47	12.7	11.8	13.0	12.0	2.4						16
2.5	304		2.20		2.27	2.45	7.60	7.04	7.82	7.24	3.0	-0.30	0.28		0.30		26
4.0	500		2.85		3.66	3.95	4.71	4.36	4.85	4.49	3.7		0.32		0.34		42
1.5	48	0.21	1.70		1.36	1.47	12.7	11.8	13.0	12.0	2.4	-0.20	0.24		0.26		16
2.5	74		2.20		2.27	2.45	7.6	7.04	7.82	7.24	3.0	-0.30	0.28		0.30		26
4.0	123		2.75		3.66	3.95	4.71	4.36	4.85	4.49	3.7		0.32		0.34		42
6.0	184		3.40		5.49	5.93	3.14	2.91	3.23	2.99	4.3		0.32		0.34		61
10	318		4.50		9.47	10.2	1.82	1.69	1.85	1.71	5.8	-0.40	0.48		0.50		118
16	504		5.50		14.9	16.1	1.16	1.07	1.18	1.09	7.0	-0.50	0.52		0.54		174

Nominal conductor cross section	Strand		Conductor								Cable							
	Quantity a)	Diameter	Diameter d1 b)	Lay length	Cable cross section for bare conductor c)		Resistance at 20 °C, bare strands		Resistance at 20 °C, tinned strands		Outer diameter d2		Wall thickness of the insulation t	C_{pk} value (based on t)	Test wall thickness t_{test}	Insulation strippability factor A d)	Weight e)
mm²	Pieces	mm	mm	mm	mm²		mΩ/m		mΩ/m		mm		mm		mm	%	g/m
	nominal	maximum	maximum	maximum	minimum	maximum	maximum	minimum	maximum	minimum	maximum	Permissible deviation	minimum	minimum	minimum	minimum	
25	784		7.00		23.2	25.1	0.743	0.688	0.757	0.701	8.8	-0.60	0.52		0.54		263
35	1 106		8.30		32.7	35.3	0.527	0.488	0.538	0.498	10.5	-0.70	0.64		0.66		377
50	1 582	0.21	10.5	Not specified	46.9	50.6	0.368	0.341	0.375	0.347	12.6	-0.80	0.72	> 1.0 f)	0.74	45	529
70	2 240		12.5		66.6	71.9	0.259	0.240	0.264	0.244	14.9	-0.90	0.80		0.82		747
95	2 964		14.7		88.0	95.0	0.196	0.181	0.200	0.185	17.2	-1.00	0.88		0.90		983

a) Minor deviations are permissible:
- For 50 strands ±5% in adherence to the resistance and the maximum strand diameter
- For ≤ 50 strands, no deviation is permissible.

b) Measurement accuracy: 50 µm

c) Calculated with a specific electrical conductivity value of 58.0 Sm/mm², quality control through resistance measurement

d) The insulation strippability factor is determined as per section 9.1.4. The provisional target value is at least 45%. The insulation strippability factor can be between 35% and 45% transitionally in consultation with the appropriate department.

e) Weight according to sample; the values in the table apply to PVC.

f) A C_{pk} value ≥ 1 will be accepted transitionally.

Explanations for table A.1 to table A.5:

The cable cross section is calculated with a specific electrical conductivity value of 58.0 Sm/mm^2 in place of 58.5 Sm/mm^2. The quality is controlled by means of resistance measurement. The geometric data for the conductor (conductor diameter, wire diameter, wire quantity, etc.) remain the same.

Electrical conductivity measurements on automotive cables have shown that the previously accepted conductivity of 58.5 Sm/mm^2 must be corrected to 58.0 Sm/mm^2. This makes it necessary to adjust the cable cross sections calculated on the basis of conductivity to existing products.

Furthermore, with the underlying conductivity of 58.0 Sm/mm^2, the maximum strand diameter must also be around 0.01 mm higher than previously specified. This does not change the strand diameters that are actually supplied. The adjustment is based on ISO 6722-1, which already uses the conductivity of 58.0 Sm/mm^2.

Starting from 20.0 mm^2, the outer single-core diameters in table 7 do not match those in VW 75210-2 (standard is currently being prepared). An adjustment is not desired, because changes to existing contacting systems must be avoided.

The outer single-core diameters in VW 75210-2 (standard is currently being prepared) match those in ISO 6722-1.

Intermediate cable cross sections:

For the calculation of intermediate cable cross sections, it has been demonstrated that the outer cable diameters as per ISO 6722-1 (up to and including 60.0 mm^2) can only be reliably achieved with bunch-stranded assemblies. Therefore, it was assumed when calculating the maximum outer cable diameter for all of the assemblies (table 3, table 4, table 5, table 6, and table 7) that a bunch is used.

Calculation of resistances and cable cross sections:

Starting on the basis of the maximum resistance value, the minimum cable cross section is calculated using the conductor electrical conductivity of, for example, 58.0 Sm/mm^2. Then the maximum cable cross section is calculated (8% higher than the minimum cable cross section). The minimum resistance is calculated from the maximum cable cross section using the specific electrical conductivity specified above.

The resulting factors are as follows regardless of the initial values (maximum resistance and specific electrical conductivity):

- Minimum resistance = maximum resistance - (maximum resistance × 7.407%)
- Minimum cable cross section = 1 000 / (specific electrical conductivity × maximum resistance)

  The resistance is specified in mΩ/m.
- Maximum cable cross section = minimum cable cross section + (8% × minimum cable cross section)