VOLKSWAGEN

AKTIENGESELLSCHAFT

Group standard

VW 60306-2

Issue 2013-04

Class. No.: 8ME30

Descriptors: cable, low-voltage cable, aluminum cable, LV 112, LV 112-2

Electric/Electronic Systems

Electric Wiring in Motor Vehicles

Part 2: Aluminum Cable; Single-Wire, Unshielded

Preface

NOTE 1: The Standard numbers stated in the document correspond to the Standards listed in table 1.

Table 1

Work group document number	Volkswagen Standard number	PAG standard number
LV 112-1	VW 60306-1	—
LV 122-1 Supplement 1	VW 60306-1 Supplement 1	—
—	VW 96043	PN 780

VW 60306-2 supersedes PN 14703-3, issue 2008-02.

Deviating and supplementary Volkswagen Group specifications

Supplement to section 10 of LV 112-2:

The environmental requirements set forth in VW 91101 must be met.

Deviating and supplementary Porsche AG specifications

Supplement to section 3 of LV 112-2:

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VWNORM-2012-05p

Cables as per this standard are subject to build sample approval (BMG).

After build sample approval has been granted, the cables are only completely released for use in production if the assembler has confirmed proper usability, e.g. for:

- Stripping
- Crimpability and attachment of the contacts
- Weldability by ultrasonic welding or resistance welding
- Twistability of the cables, if applicable

in the form of a first-sample test report during first sampling.

Supplement to section 10 of LV 112-2:

Emission behavior as per PN 780.

Descriptors: cable, low-voltage cable, aluminum cable

Electric Wiring in Motor Vehicles

Aluminum Cables; Single-Wire, Unshielded

Preface

This Supply Specification (LV) version was prepared by representatives of automobile manufacturers Audi AG, BMW AG, Daimler AG, Porsche AG, and Volkswagen AG in working group 4.3.

This Supply Specification is stored as an MS Word file in the Audi AG Standards department.

No claim is made as to its completeness. The automobile manufacturers may require additional tests as per the respective state of the art at any time.

Since the individual automobile manufacturers may make changes if necessary, only the in-house standards that the automobile manufacturers derive from this LV must be used.

Deviations from this Supply Specification are listed in the in-house standards on the cover sheet (in justified exceptional cases, deviations can be presented in italics in the text of the standard). If modifications of individual test sections are required in individual cases, these modifications must be agreed upon separately between the appropriate departments of the automobile manufacturer and of the supplier.

For general development projects of the automobile manufacturers, test reports will be accepted as long as the tests were performed by an independent institute that is accredited as per DIN EN ISO/IEC 17025. Acceptance of the test reports will not automatically result in a release. Other test reports may be accepted at the discretion of the purchaser.

Contents

1 Scope

This Supply Specification describes requirements and tests for single-wire unshielded vehicle cables with aluminum conductors for a nominal voltage range ≤60 V DC in accordance with voltage class 1 as per LV 112-1.

The test points for the various requirements must be taken from the test matrix in section 8.1.

2 Referenced standards

The following documents cited in this Standard are necessary to its application.

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.

For dated references, only the referenced issue is valid. For undated references, the most recent issue of the referenced document (including all changes) is valid.

DIN 76722	Road Vehicles, Low Voltage Cables; Type Abbreviation
DIN EN 573-1	Aluminium and Aluminium Alloys – Chemical Composition and Form of Wrought Products – Part 1: Numerical Designation System
DIN EN 573-3	Aluminium and Aluminium Alloys – Chemical Composition and Form of Wrought Products – Part 3: Chemical Composition and Form of Products
DIN EN 1715-2	Aluminium and Aluminium Alloys – Drawing Stock – Part 2: Specific Requirements for Electrical Applications
DIN EN ISO 6892-1	Metallic Materials – Tensile Testing – Part 1: Method of Test at Room Temperature
DIN EN ISO/IEC 17025	General Requirements for the Competence of Testing and Calibration Laboratories
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
LV 112-1	Electric Wiring in Motor Vehicles; Copper Cables, Single-Wire, Unshielded
LV 112-1 Supplement 1	List of Chemicals for Compatibility Testing

3 General information

LV 112-2 applies only to new designs. Cables already used in production do not have to be modified. Subsequent modifications of material, dimensions, manufacturing processes, etc., must be reported to the respective engineering departments; these may necessitate a new release.

The test scope of this supply specification and special test conditions in individual cases must be defined in cooperation with and approved by the responsible engineering departments.

4 Dimensions and cable composition

The dimensions and conductor composition (see Figure 1) must be taken from the pertinent sections in the appendix. Unspecified details must be selected to suit the specific purpose as per ISO 6722-1.

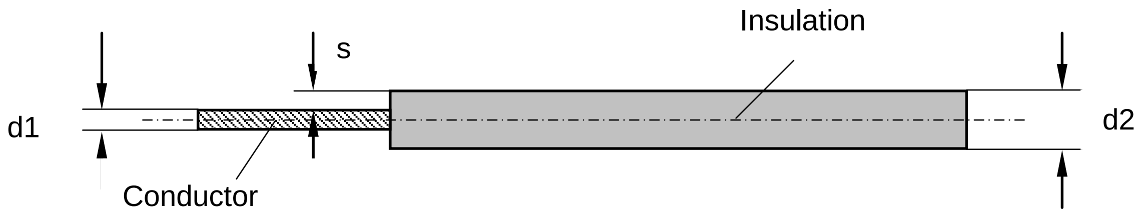

Figure 1 Conductor composition

5 Structure of the code

The cable code is based on DIN 76722.

Example 1:

Designation of an unshielded low-voltage cable (FL) with aluminum conductor material (Al) with thin-walled insulation (R), a nominal conductor cross-section of 10,0 mm² (10), type B conductor composition (B), symbol Y of the insulating material (PVC) as per DIN 76722, long-term service temperature (T_{max}) +105 °C:

FLAlRY 10/0,50-B/T105

6 Materials

The properties as per sections 6.1 to 6.3 must be ensured by the manufacturer and apply to the unstranded state.

6.1 Conductor

6.1.1 Bare aluminum

Strand made of EN AW-1370 [EAl99,7] as per DIN EN 573-1 (chemical composition as per DIN EN 573-3).

In exceptional cases, other Al materials such as EN AW-1350 can be agreed upon.

Bare conductor: The mechanical and electrical properties of the drawn, unstranded strand comply with EN 1715-2.

The properties of a strand of a finished cable must be fulfilled as per Table 1.

Table 1

Tensile strength (Rm)[1)2)] in N/mm²	Elongation at break (A)[1)] in %	Conductivity in S·m/mm²
70 to 120	≥16	≥35,5

[1)] Determined as per DIN EN ISO 6892-1.
[2)] Measured at 200 mm clamping length.

6.1.2 Bare aluminum alloy for cross-sections ≤2,50 mm²

Specification to follow as required.

6.1.3 Joints

The conductors must be free of joints. However, all strands composing the conductors may have welded or soldered joints. Butt joints must be used for strands with a diameter of 0,25 mm or greater.

The distance between two joints of strands measured between the different strands must be greater than 3 m.

6.2 Compression of the conductor

Compression of the conductor that causes deformation of the strands is possible only after consultation.

6.3 Conductor, other surfaces

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

6.4 Insulation

See LV 112-1.

7 Marking and supply specifications

7.1 Packaging marking

See LV 112-1.

7.2 Manufacturer's code

See LV 112-1.

7.3 Color

See LV 112-1.

7.3.1 Color coding

See LV 112-1.

7.4 Supply specifications

See LV 112-1.

7.4.1 Visual inspection

See LV 112-1.

7.4.2 Testing

See LV 112-1.

7.4.3 Packaging units

The packaging units must be agreed upon between purchaser and manufacturer.

7.4.3.1 Partial lengths, ties, defects

A specified length can be composed of partial lengths in exceptional cases and must be marked separately.

7.4.3.2 Marking of the delivery unit

See LV 112-1.

8 General Test Conditions

8.1 Test matrix

Section	Testing	Release test			Site test	Change of pre-materials	Requalification test	Process test
	Test scope	**A1**	**A2 B2 C2 Al2**	**Al1**	**B1**	**C1**	**D**	**E**
7.3	Color	X	X	X	X			
7.4.1	Visual inspection	X	X	X	X	X	X	X
7.4.2	Test for insulation faults							X
9.1.1	Outside cable diameter and minimum wall thickness	X	X	X	X	X	X	X
9.1.2	Nominal conductor diameter	X	X	X	X	X	X	X
9.1.3.1	Conductor resistance measurement [4]	X	X	X	X	X	X	X
9.1.3.2	Conductor resistance measurement (conventional) [4]	X	X	X	X	X	X	X
9.1.4	Wall thickness of the insulation	X	X	X	X	X	X	X
9.1.5	Insulation test wall thickness	X	X	X	X	X	X	X
9.2	Density[1]	X				X	X	
9.2	Viscosity number/K-value [1]	X				X		
9.2	Thermogravimetric analysis (TGA) [1]	X				X		
9.2	Differential scanning calorimetry (DSC) [1]	X				X		
9.2	Thermal stability	X	X	X	X	X	X	
9.2	Determination of the infrared spectrum	X	X	X	X	X	X	
9.2	Tensile strength/elongation at tear	X	X	X	X	X	X	

Section	**Testing**	**Release test**			**Site test**	**Change of pre-materials**	**Requalification test**	**Process test**
	Test scope	**A1**	**A2 B2 C2 Al2**	**Al1**	**B1**	**C1**	**D**	**E**
9.2	Tear propagation strength	X			X	X	X	
9.2	Determination of cross-linking density	X	X	X	X	X	X	X
9.2	Microhardness[1)]	X				X		
9.3.1	Insulation stripability/secure fit of conductor	X	X	X	X	X	X	X
9.3.2	Insulation abrasion resistance	X	X	X	X	X	X	
9.3.3	Sliding behavior of the cables[3)]	X						
9.3.4	Bending force of the cables	X	X	X	X	X		
9.3.5	Insulation notch strength	X		X				
9.4	Flame retardance	X		X		X	X	
9.5.1	Specific volume resistance of the insulation[1)]	X						
9.5.2	30-minute dielectric strength	X		X				
9.6.1	Stress test[3)]	X			X		X	X
9.6.2	Insulation shrinkage under heat	X	X	X	X	X	X	X
9.6.3	Compressive strength of the insulation under heat	X		X				
9.6.4	Derating curve	X						
9.6.5	Thermal stability in wound state[3)]	X		X				
9.6.6	Thermal overload	X						
9.6.7	Short-term aging (240 h)	X	X	X	X	X	X	
9.6.8	Long-term aging (3 000 h)	X						
9.6.9	Low-temperature winding test (at -40 °C)	X	X	X	X	X	X	
9.6.10	Impact test at low temperature (-15 °C)	X						
9.6.11	Resistance of cable marking to wiping[1)]	X						
9.6.12	Fatigue strength under alternating bending stresses	X		X				
9.6.13	Kink test[3)]	X						
9.6.14	Electrical properties during aging in water	X		X				
9.6.15	Damp heat, constant	X						
9.6.16	Ozone resistance[1)]	X						

Section	Testing	Release test			Site test	Change of pre-materials	Requalification test	Process test
	Test scope	**A1**	**A2 B2 C2 Al2**	**Al1**	**B1**	**C1**	**D**	**E**
9.7	Mycological test[1)]	X						
9.8.1	Chemical resistance as per ISO 6722-1	X						
9.8.2	Resistance to chemicals and wrapping tapes	X						
9.8.3	Resistance to wiring harness components	X						
10	Environmental protection[2)]	X					X	

1) The test is performed only on the largest cross-section of each compound.
2) Proof must be provided by the cable manufacturer.
3) Must not be performed for cable cross-sections >6 mm².
4) Either test point 9.1.3.1 or 9.1.3.2 is performed.

Documentation: The documentation of the tests as per test scopes A, Al, B, and C must be sent to the purchaser. For test scopes D and E, the cable manufacturer bears the responsibility for documentation and archiving; submission to the purchaser is only necessary upon special request.

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

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

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

A prerequisite for test scopes B to E and Al is a release as per A1.

Test scope Al1/Al2: Testing for the main manufacturing site.

Is performed if the insulation materials have already been tested and released with other conductor materials.

Test scope B1/B2: Same compound, different site of the same cable manufacturer.

Test scope C1/C2: 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 reliability.

Cross-section assignment:

Test scope A1/Al1/B1/C1: is performed on the smallest cross-section and 2,5 mm², 4 mm², 16 mm², 60 mm², and 120 mm².

Short test A2/Al2/B2/C2: All other cross-sections.

8.2 Test atmosphere

See LV 112-1.

8.3 Specimens

See LV 112-1.

8.4 Rounding of numerical values

See LV 112-1.

9 Tests

See LV 112-1.

9.1 Cable composition check

See LV 112-1.

9.1.1 Outside cable diameter and minimum wall thickness

See LV 112-1.

9.1.2 Nominal conductor diameter

See LV 112-1.

9.1.3 Conductor resistance

Either method 9.1.3.1 or 9.1.3.2 can be used.

In disputed cases, measurement method 9.1.3.1 must be used.

9.1.3.1 Conductor resistance measurement

9.1.3.1.1 General information

The measurement of the conductor resistance is more difficult for aluminum conductors than for copper, because the unavoidable aluminum oxide layer prevents an even distribution of the measurement current and proper tapping of the measurement voltage if the contacting is not correct. Therefore, the oxide layer must be removed before the measurement is performed.

9.1.3.1.2 Test sample

A piece of cable with a length of 1,10 m is stripped 70 mm at both ends. The stripped cable ends are first dipped in a flux and then dipped in a solder bath while taking the necessary precautions (skin protection, eye protection). The length of the produced solder layer must be at least 60 mm so that the voltage tapping points, which are 1 m apart from each other, are reliably covered.

The flux is composed as follows:

- Diethanolamine 45% to 65%
- Fluoroboric acid 11% to 13%
- Diethylenetriamine 14% to 17%

The solder bath contains the following constituents:

- Tin 80% to 90%
- Zinc 10% to 20%
- Other metals ≤1%

9.1.3.1.3 Test procedure

The resistance measurement must be performed as per ISO 6722-1.

The formula in ISO 6722-1 with temperature coefficients corrected for aluminum must be used for the temperature compensation of the measured value:

$$R_{L,20} = \frac{R_L}{L\left[1 + K_T(T - 20)\right]}$$

Symbol	Description	Unit
$R_{L,20}$	Conductor resistance at +20 °C	Ω
R_L	Measured conductor resistance	Ω
K_T	Temperature coefficient (4,05 for Al99,7)	$10^{-3}\cdot 1/K$
T	Measured temperature	°C
L	Length between the voltage taps (usually 1 m)	m

9.1.3.1.4 Requirements

The corrected values must correspond to the specified values in the tables in the appendix.

9.1.3.2 Conductor resistance measurement (conventional)

9.1.3.2.1 General information

As an alternative to the method as per section 9.1.3.1, the method as per section 9.1.3.2 is also permissible for measuring the conductor resistance.

The measurement of the conductor resistance is more difficult for aluminum conductors than for copper, because the unavoidable aluminum oxide layer prevents an even distribution of the measurement current and proper tapping of the measurement voltage if the contacting is not correct. To compensate for this effect, it must be ensured that all strands of the conductor are contacted while the current is fed in. This is ensured, for example, by using the contact elements used in production. If contacting close to production is not performed, it must be ensured in any case that the oxide layers on the strand surfaces of the feed-in point are penetrated, which can be achieved by strong mechanical deformation and/or roughening of the strand surfaces, for example. The same applies to the voltage tapping as applicable, but in this case contact resistances to the measuring tip are less crucial due to the high-impedance measurement. It must also be ensured that the voltage is measured at some distance from the current feed-in.

9.1.3.2.2 Test sample

A piece of cable with a length of approx. 3,5 m is stripped 260 mm at both ends, or the sheath is removed at the voltage measuring point. The ends may be provided with a contact or directly contacted as described in section 9.1.3.2. The finished test specimen must be aged at room temperature for at least 4 h.

9.1.3.2.3 Test device

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

9.1.3.2.4 Test procedure

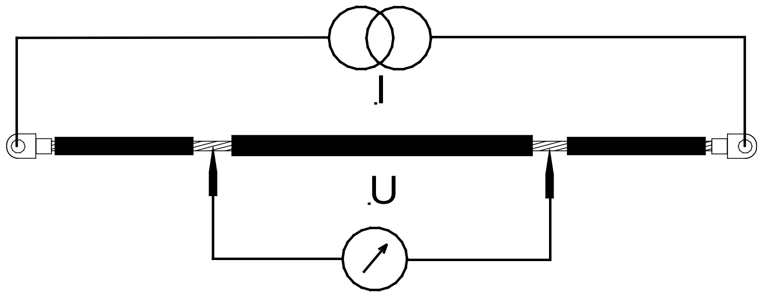

Figure 2 Illustration of the current and voltage measurement

A defined current flows through the contact, and this defined current must be selected so that it does not lead to a noticeable temperature increase. The resulting voltage is measured with a high-impedance voltage measuring device by means of two test contacts, which directly contact the stripped conductor. The two test contacts must be arranged at a distance of approx. 1 m. The temperature of the test specimen must also be determined during the measurement.

The conductor resistance must be calculated as per the following formula:

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

Symbol	Description	Unit
R_L	Conductor resistance	Ω
U	Measured voltage	V
I	Applied current	A

To compensate for the temperature coefficient of the conductor material and the actual measured length between the test contacts, the measured value must be corrected as per the following formula:

$$R_{L,20} = \frac{R_L}{L[1 + K_T(T - 20)]}$$

Symbol	Description	Unit
$R_{L,20}$	Conductor resistance at +20 °C	Ω
R_L	Measured conductor resistance	Ω
K_T	Temperature coefficient (4,05 for Al99,7)	$10^{-3} \cdot 1/K$
T	Measured temperature	°C
L	Length between the voltage taps (usually 1 m)	m

9.1.3.2.5 Requirements

The corrected values must correspond to the specified values in the tables in the appendix.

9.1.4 Wall thickness of the insulation

See LV 112-1.

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

See LV 112-1.
See tables in Appendix A.

9.2 Physical and chemical properties of the insulation

See LV 112-1.

9.3 Mechanical properties in as-received condition

Generally, the conductor must be designed so that it can be processed properly.
The insulation must not exhibit any blisters, cracks, knots, or inclusions of foreign matter.

9.3.1 Insulation stripability and secure fit of conductor

See LV 112-1.

9.3.2 Insulation abrasion resistance

See LV 112-1.

9.3.3 Sliding behavior of the cables

See LV 112-1.

9.3.4 Bending force of the cables

See LV 112-1.

9.3.5 Insulation notch strength

See LV 112-1.

9.4 Flame retardance

Test as per ISO 6722-1.

9.5 Electrical properties in as-received condition

See LV 112-1.
The cable must be contacted as per section 9.1.3, or as in production.

9.5.1 Specific volume resistance

See LV 112-1.

9.5.2 Measurement of 30-minute dielectric strength

See LV 112-1.

9.5.3 Measurement of 1-minute dielectric strength (only after aging)

See LV 112-1.

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

The cable must be contacted as per section 9.1.3, or as in production.

9.6.1 Stress test

See LV 112-1.

9.6.2 Insulation shrinkage under heat

See LV 112-1.

9.6.3 Pressure resistance of the insulation under heat

See LV 112-1.

9.6.4 Determination of the derating curve

See LV 112-1.

9.6.5 Thermal stability in wound state

See LV 112-1.

9.6.6 Thermal overload

See LV 112-1.

9.6.6.1 Thermal overload T_{max} +50 °C

See LV 112-1.

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

See LV 112-1.

9.6.7 Short-term aging (240 h)

See LV 112-1.

9.6.7.1 Winding test after short-term aging

See LV 112-1.

9.6.7.2 Determination of the infrared spectrum after short-term aging

See LV 112-1.

9.6.7.3 Determination of tensile strength and elongation at tear after short-term aging

See LV 112-1.

9.6.8 Long-term aging (3 000 h)

See LV 112-1.

9.6.8.1 Winding test after long-term aging

See LV 112-1.

9.6.8.2 Determination of the infrared spectrum after long-term aging

See LV 112-1.

9.6.8.3 Determination of tensile strength and elongation at tear after long-term aging

See LV 112-1.

9.6.8.4 Minimum permissible bend radius for static routing

See LV 112-1.

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

See LV 112-1.

Cross-sections >120 mm² must be tested on the basis of ISO 6722-1 with a mandrel (diameter ≤5 × maximum outer diameter of the cable), a winding speed of 0,2 $^{+0}_{-1}$ s, a load of 30 kg, and at least 0,5 turns.

In addition, the strands of the stranded wire must be visually inspected for cracks with the naked eye.

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

See LV 112-1.

Cross-sections >120 mm² must be tested on the basis of ISO 6722-1 with a hammer mass of 400 g.

9.6.11 Resistance of cable marking to wiping

See LV 112-1.

9.6.12 Fatigue strength under alternating bending stresses

See LV 112-1.

9.6.13 Kink test

See LV 112-1.

9.6.14 Electrical properties during aging in water

See LV 112-1.

A test specimen of sufficient length is wound at least 2 turns around the center of a mandrel with a diameter ≤7 x the outer diameter of the cable.

9.6.15 Damp heat, constant (hydrolysis test)

See LV 112-1.

9.6.16 Ozone resistance

See LV 112-1.

9.7 Mycological test

See LV 112-1.

9.8 Compatibility tests

See LV 112-1.

9.8.1 Chemical resistance as per ISO 6722-1

See LV 112-1.

9.8.2 Resistance to chemicals and wrapping tapes

See LV 112-1.

Always the smallest cross section of a compound is tested.

9.8.2.1 Testing on cross sections ≤2,5 mm²

See LV 112-1.

Always the smallest cross section of a compound is tested.

9.8.2.2 Testing on cross-sections ≥4 mm²

See LV 112-1.

9.8.3 Resistance to wiring harness components

See LV 112-1.

The contacts/cable lugs of LV 112-1 listed in the tables are replaced with suitable production contacts for aluminum conductors.

9.8.3.1 Testing on cross-sections ≤6 mm²

See LV 112-1.

9.8.3.2 Testing on cross sections >6 mm²

See LV 112-1.

10 Environmental protection and safety

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

Appendix A (normative)

**Table A.1 FLALR asymmetric conductor composition type B for cross-sections ≤95 mm² with reduced wall thickness
FLAL asymmetric conductor composition type B for cross-sections >95 mm², thick-walled**

Nominal conductor cross-section		Strand 6)	Conductor							Line						
Al cross-section	Copper equivalent with respect to R_{20}	Quantity 5)	Diameter	Diameter d_1	Twist length	Cross-section 1)		Resistance at +20 °C (R_{20})		Outer diameter		Wall thickness of insulation s	C_{pk} value (based on s) 2)	Test wall thickness s_P	Concentricity factor K 3)	Weight 4)
in mm²	in mm²		in mm	in mm	in mm	in mm²		in mΩ/m		in mm		in mm		in mm	in %	in g/m
nom.	nom.	nom.	max.	max.	max.	max.	min.	max.	min.	max.	Tol.	min.	min.	min.	min.	≈
1,5	0,9	19	0,32	1,70		1,47	1,36	21,2	19,6	2,4	-0,2	0,24		0,26		6,53
2,5	1,5	19	0,43	2,20		2,45	2,27	12,7	11,8	3,0	-0,3	0,28		0,30		10,8
4	2,4	30	0,42	2,75		3,95	3,66	7,85	7,27	3,7	-0,3	0,32		0,34		16,6
6	3,7	45	0,42	3,40		5,93	5,49	5,23	4,84	4,3	-0,3	0,32		0,34		22,9
10	6,1	50	0,52	4,50		10,2	9,47	3,03	2,81	5,8	-0,4	0,48		0,50		43,5
16	9,8	78	0,52	5,50		16,1	14,9	1,93	1,79	7,0	-0,5	0,52		0,54		61,4
25	15,3	122	0,52	7,00	not specified	25,1	23,2	1,24	1,15	8,7	-0,5	0,52	≥1,33	0,54	45	90,9
35	21,4	172	0,52	8,30		35,3	32,7	0,878	0,813	10,4	-0,6	0,64		0,66		130
50	30,6	247	0,52	9,80		50,6	46,9	0,613	0,568	12,2	-0,7	0,72		0,74		173
70	42,8	351	0,52	11,6		71,9	66,6	0,432	0,400	14,4	-0,9	0,80		0,82		242
95	58,1	463	0,52	13,8		95,0	88,0	0,327	0,303	16,7	-1,0	0,90		0,92		311
120	73,4	304	0,72	15,4		122	113	0,255	0,236	18,8	-1,2	1,28		1,22		482
160	97,9	398	0,72	19,0		159	147	0,195	0,181	22,5	-2,0	1,28		1,30		569

1) Calculated with a value of the specific electrical conductivity of 35,5 Sm/mm^2 +2% as per ISO 6722-1, quality control through resistance measurement.

2) In the transition period, a c_{PK} value of ≥1,0 is acceptable.

3) K in % = (s_{min}/s_{max})*100, s_{max} must not be located opposite s_{min}. 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 are permissible: for >50 strands, ±5% as long as the electrical resistance and the maximum strand diameter are adhered to. Deviations are not permissible for ≤50 strands.

6) Other strand diameters and strand quantities may be used if they are agreed upon between OEM development departments and the supplier.

Table A.2 FLALR asymmetric conductor composition type B with reduced wall thickness, intermediate cross-sections

Nominal conductor cross-section		Strand [6)]	Conductor							Line						
Al cross-section	Copper equivalent with respect to R_{20}	Quantity [5)]	Diameter	Diameter d_1	Twist length	Cross-section [1)]		Resistance at +20 °C (R_{20})		Outer diameter		Wall thickness of insulation s	C_{pk} value (based on s) [2)]	Test wall thickness s_P	Concentricity factor K [3)]	Weight [4)]
in mm²	in mm²		in mm	in mm	in mm	in mm²		in mΩ/m		in mm		in mm		in mm	in %	in g/m
nom.	nom.	nom.	max.	max.	max.	max.	min.	max.	min.	max.	Tol.	min.	min.	min.	min.	≈
Intermediate cross-sections																
12	7,3	60	0,52	4,80		12,3	11,3	2,53	2,34	6,5	-0,5	0,48		0,50		45,9
20	12,2	95	0,52	6,10		19,5	18,1	1,59	1,47	7,8	-0,5	0,52		0,54		65,0
30	18,4	141	0,52	7,40		28,8	26,6	1,08	1,00	9,6	-0,6	0,64		0,66		99,8
40	24,5	193	0,52	8,60	not specified	39,4	36,5	0,788	0,730	11,1	-0,7	0,72	≥1,33	0,74	45	136
60	36,7	289	0,52	10,5		59,1	54,7	0,525	0,486	13,3	-0,8	0,80		0,82		199
85	52,0	420	0,52	13,2		85,0	78,7	0,365	0,338	15,3	-0,9	0,90		0,92		291

1) Calculated with a value of the specific electrical conductivity of 35,5 Sm/mm^2 +2% as per ISO 6722-1, quality control through resistance measurement.

2) In the transition period, a c_{PK} value of ≥1,0 is acceptable.

3) K in % = (s_{min}/s_{max})*100, s_{max} must not be located opposite s_{min}. 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 are permissible: for >50 strands, ±5% as long as the electrical resistance and the maximum strand diameter are adhered to. Deviations are not permissible for ≤50 strands.

6) Other strand diameters and strand quantities may be used if they are agreed upon between OEM development departments and the supplier.

Table A.3 Al conductor asymmetric conductor composition type B (lang lay cables), old nominal cross-sections

Nominal conductor cross-section		Strand [6]		Conductor						Line						
	Only for comparison	Quantity [5]	Diameter	Diameter d1	Twist length	Cross-section [1]		Resistance at +20 °C		Outside diameter		Wall thickness of insulation s	C_{pk} value (based on s) [2]	Test wall thickness s_P	Concentricity factor K [3]	Weight [4]
Al	Cu	Al	Al	Al	Al	Al		Bare Al & Cu		Al		Al	Al	Al	Al	Al
in mm²	in mm²		in mm	in mm	in mm	in mm²		in mΩ/m		in mm		in mm		in mm	in %	in g/m
nom.	nom.	nom.	max.	max.	max.	max.	min.	max.	min.	max.	Tol.	min.	min.	min.	min.	≈
10	6	49	0,51	4,3		9,81	9,09	3,10	2,87	6,5	-0,6	0,8		0,82		50
17	10	84	0,51	5,5		16,7	15,5	1,82	1,69	7,7	-0,7	0,8		0,82		74
27	16	133	0,51	7,0		26,2	24,3	1,16	1,07	9,9	-0,8	1,04		1,06		118
42	25	210	0,51	9,0	not specified	40,9	37,9	0,743	0,688	11,9	-1	1,04	≥1,33	1,06	45	169
59	35	294	0,51	10,6		57,7	53,5	0,527	0,488	14,0	-1,0	1,2		1,22		233
85	50	420	0,51	12,9		82,7	76,5	0,368	0,341	16,3	-1,2	1,2		1,22		314
120	70	608	0,51	15,1		117	109	0,259	0,240	18,8	-1,4	1,28		1,30		428
160	95	798	0,51	17,9		155	144	0,196	0,181	21,6	-1,4	1,28		1,30		548

1) Calculated with a value of the specific electrical conductivity of 35,5 Sm/mm², quality control through resistance measurement.
2) In the transition period, a c_{PK} value of ≥1,0 is acceptable.
3) K in % = (s_{min}/s_{max})*100, s_{max} must not be located opposite s_{min}. 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 are permissible: for >50 strands, ±5% as long as the electrical resistance and the maximum strand diameter are adhered to. Deviations are not permissible for ≤50 strands.
6) Other diameters and numbers of wires may be used if agreed upon between purchaser and supplier.
Note: The nominal cross-sections correspond to the rounded max. Al cross-sections in the table analogously to the procedure for Cu.
By means of this procedure, the same resistance is achieved when the specified nominal cross-sections for Al and Cu are used.