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AKTIENGESELLSCHAFT

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PV 6810

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Descriptors: flat cable, ultrasonic welding, aluminum conductor, aluminum cable

Ultrasonic-Welded Joints for Rigid/Flexible Aluminum Cables

Contents

1 Scope

Ultrasonic-welded joints provide an electrical and mechanical connection between flexible round aluminum cables and rigid flat aluminum cables. In this design, the end of the flat cable extends under the insulation of the round cable. For welds as per figure figure 1, the edge is provided with a

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wide radius in order to protect the insulation of the round cable from damage. The whole welded joint is then protected using a plastic clip and heat-shrink tubing with internal adhesive.

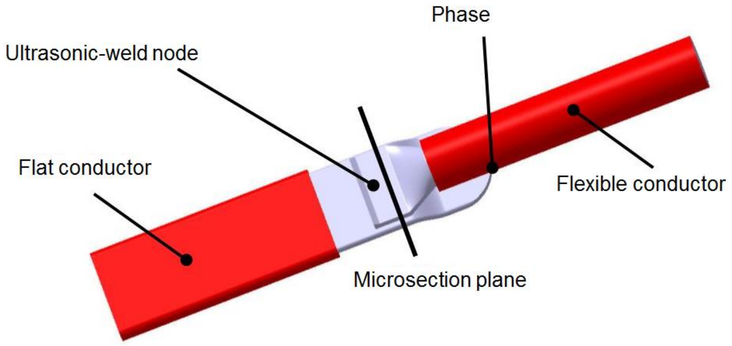

Figure 1 – Microsection plane

Installation location

Luggage compartment, vehicle interior, underbody

Temperature range

The functional temperature range of the whole component for the

luggage compartment, vehicle interior, and underbody is:	T_L = -40 °C
	T_U = +105 °C
The storage temperature range is:	T_L = -40 °C
	T_U = +105 °C

The specified temperatures are based on the installation location of the flat cable. The flat cable must work flawlessly within this temperature range.

2 Terms

Flat cable, flat conductor package	e.g., Al-F-150 mm²
T_L	Lower temperature limit
T_U	Upper temperature limit
Transfer point	e.g., TP M8
Ultrasonic-welded joint	e.g., UWJ 40 mm²
Environmental simulation	ES

3 Description

Ultrasonic-welded aluminum cable as per Test Specification PV 6810

4 Requirements

4.1 Mechanical evaluation

4.1.1 Visual evaluation

The visual evaluation focuses in particular on the properties of the weld node created by the effect of ultrasound from the flexible aluminum cable (see figure 2).

The length of the non-welded strands in front of the weld node must be max. 1 mm. Individual wires that are missing, loose, pushed up, or that project from the weld node are impermissible. A suitable plastic part must be placed over the free wire ends in order to prevent protruding individual wires from puncturing the heat-shrink tubing. The tool structure must be clearly recognizable on the node surface. Burrs that are larger than the largest single wire diameter are impermissible. Cracks or fractures in the weld node are impermissible. The conductor insulation must not be damaged by the welding process. Foreign matter in the weld node is impermissible. It is imperative that the weld area is free of grease and oil. Moisture must be avoided before the welding process.

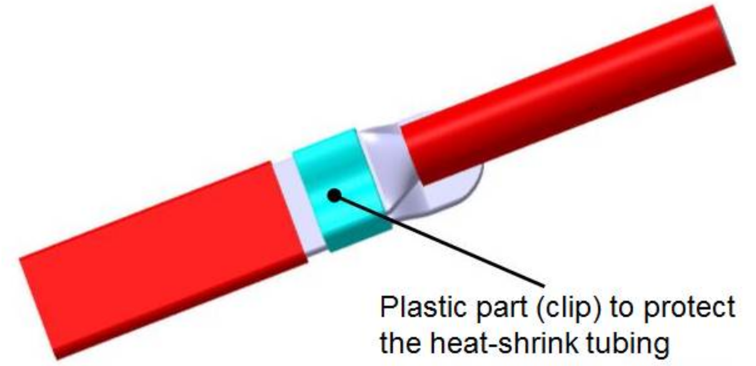

Figure 2 – Weld node

4.1.2 Longitudinal microsection through the welded joint

The objective of taking a longitudinal microsection through the welded joint is to provide information on the quality of the welded joint and information on the metallurgical properties (see figure 3).

The longitudinal microsection must be taken approximately through the center of the weld node. To do this, the sample must be embedded and ground. All individual wires must be deformed and interconnected. Since the compression is only moderate, small cavities exist between the individual wires. Individual cavities between single strands must not be interconnected. The degree of compression must be between 85% and 95%. Isolated, small lacks of fusion have no influence on the mechanical strength of the joint and are permissible.

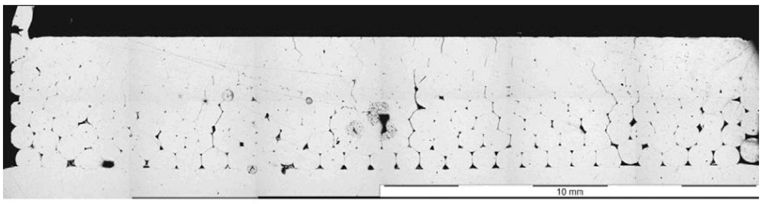

Figure 3 – Microsection through the compressed wires

A microsection analysis of all necessary weld-parameter limits is required for new developments.

4.1.3 Bending test

Bend the cable in the weld node's upper part up by 90° and then back to its initial position 5 times with fixed weld node, applying force to the cable under test at 30 mm from the node. Applying this load must not cause damage to any wires.

4.1.4 Tensile test

The determined axial tensile force is a measure of the mechanical strength of the "flexible aluminum conductor with flat conductor" joint. Depending on the method used, the mechanical strength at the welded joint is lower than that of the cable itself. The values in table 1 are minimum requirements for the strength of the ultrasonic-welded joint:

Table 1 – Minimum pull-out forces

Cross-sectional area	Min. pull-out force (N)
85 mm²	1 800
110 mm²	2 000

Position the DUT with the ultrasonic-welded joint in a horizontal or vertical test stand and load it with force F parallel to the weld surface (see figure 4).

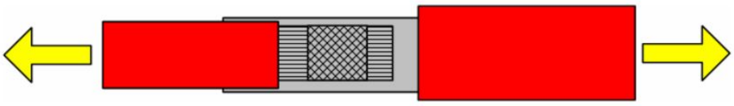

Figure 4 – Schematic diagram showing the tensile test setup

Apply the force at a constant speed of 50 mm/min. Pull the DUT until it fails.

The DUTs must withstand at least the values specified in table 1 before separation occurs.

4.1.5 Peel test

The determined radial tensile force is a measure of the mechanical strength of the "flexible aluminum conductor with flat conductor" joint. Depending on the method used, the mechanical strength at the welded joint is lower than that of the cable itself. The values in table 2 are minimum requirements for the strength of the ultrasonic-welded joint:

Table 2 – Minimum pull-out forces

Cross-sectional area	Min. peel force (N)
85 mm²	415
110 mm²	430

Position the DUT with the ultrasonic-welded joint in a horizontal or vertical test stand and load it with force F vertical to the weld surface (see figure 5). Clamp the flat conductor in a fixed mount that is positioned 30 mm from the weld node.

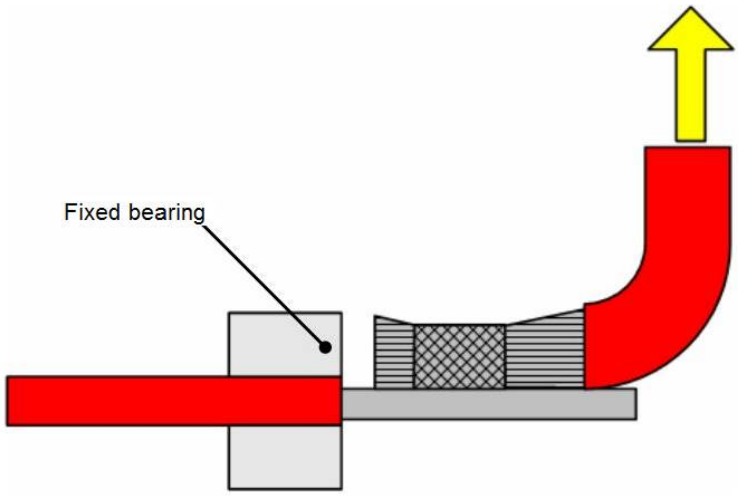

Figure 5 – Schematic diagram showing the shear test setup

Apply the force at a constant speed of 50 mm/min. Pull the DUT until it fails.

The DUTs must withstand at least the values specified above before separation occurs.

4.1.6 Vibration test in as-installed position with superimposed temperature

Perform the vibration test with DUTs approx. 400 mm in length that are ultrasonically-welded on both sides, as shown in figure 6. The ultrasonic-welded joint is protected by a heat-shrink tubing with internal adhesive. The test duration is 120 h. The temperature changes during the vibration test must be performed as follows:

4 h at -40 °C/4 h at 105 °C (incl. the times for the temperature change)

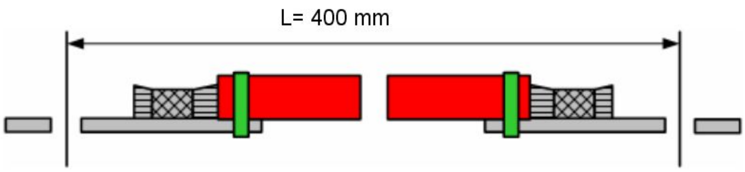

Figure 6 – Schematic diagram showing the vibration test setup (without heat-shrink tubing)

The oscillation profile to be used must be taken from Volkswagen standard VW 80101, section 4.1.4. (For the vibration profile, see figure 7; for the power spectral density (PSD), see table 3).

Severity 1 must be used.

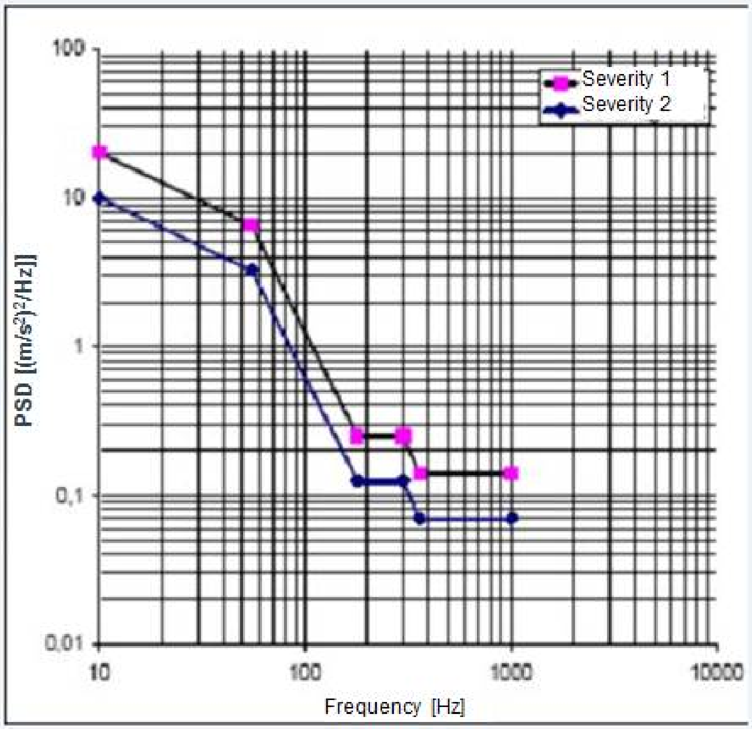

Figure 7

Table 3 – PSD

Frequency	PSD, severity 1	PSD, severity 2, lowered by -3 dB	PSD, severity 3, lowered by -6 dB
(Hz)	(m/s²)²/Hz	(m/s²)²/Hz	(m/s²)²/Hz
10	20	10	5
55	6,5	3,25	1,625
180	0,25	0,125	0,0625
300	0,25	0,125	0,0625
360	0,14	0,07	0,035
1 000	0,14	0,07	0,035

4.1.7 Mechanical shock test

Test based on DIN EN 60068-2-27 "Environmental testing - Part 2-27: Tests - Test Ea and guidance: Shock". Test the ultrasonic-welded joint in as-installed position. Set up the test as per the setup used for the vibration test.

Perform all shocks at room temperature ISO 554 -23 °C/50% rel. humidity.

Test type	Half-sine
Acceleration	a = 30 g; t = 6 ms

The shock direction must be against the direction of movement.

Perform 800 shocks.

4.2 Electrical tests

4.2.1 Voltage-drop test

Perform the voltage-drop test with flexible aluminum cables with a length of approx. 1 000 mm (as in the vibration test). For the test setup, see figure 8. Measuring the exact length of the DUT (the measuring points) is a prerequisite for determining the voltage drop.

The use of an ultrasonic-welded joint means that it is not possible to measure any conventional contact resistances between the flexible aluminum cable and the flat conductor. The total voltage drop (ΔV_{total}) is therefore derived from the internal resistance of the aluminum material over the measuring length.

The total increase in the contact resistance must not exceed 0,1 mΩ after all tests.

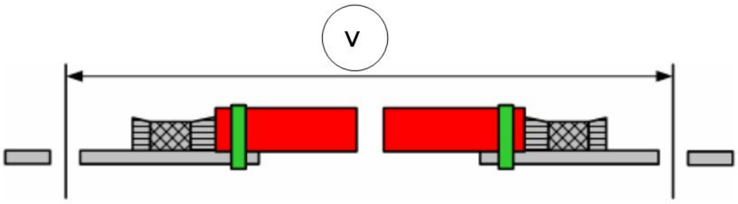

Figure 8 – Schematic diagram showing the voltage-drop test

4.2.2 Temperature increase by means of current

The objective of this test is to provide information on the electrical quality of the welded joint at different currents and temperatures. For the temperature saturation, see table 4. When applying different currents, perform the measurement until the system reaches its steady state (in this case: standard value (ΔT) for PVCM insulation with flat aluminum cable).

Table 4 – Temperature saturation

Test current (A)	Temperature saturation (°C)		
	80 mm²	110 mm²	150 mm²
100	15	10	10
200	35	21	21
400	85	66	64

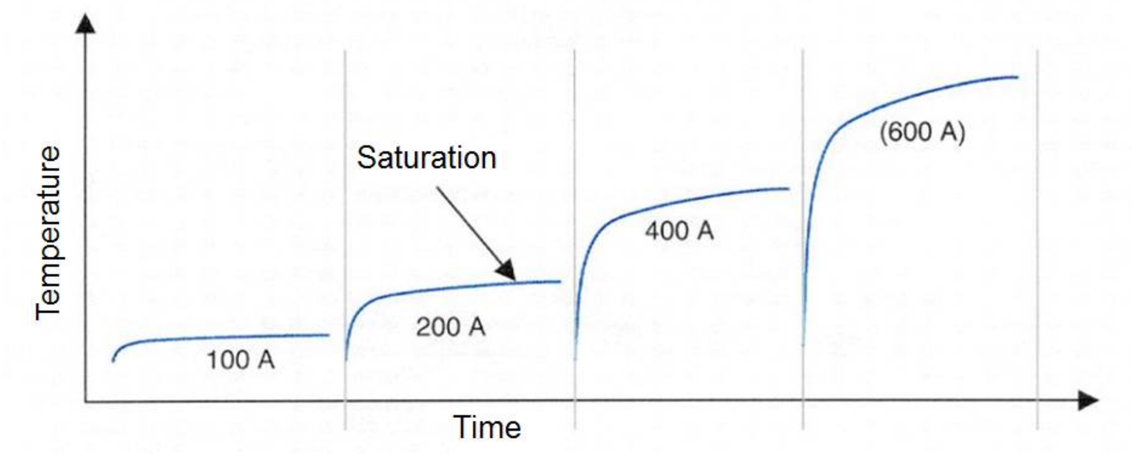

Figure 9 – Current heating

Apply different amperages (100 A, 200 A, 400 A, and 600 A (at 110 mm² and 150 mm² only)) to the DUTs (see figure 9). Load the system with current until it reaches a stable temperature range. At the same time, determine the temperature increase as a function of time and current.

4.2.3 Continuous-current test

Pass current through the DUT so that an overtemperature of 80 °C is achieved at the welded joint and on the cable. Ensure that the initially determined current is kept constant during the test. The test duration is 30 cycles. One cycle comprises 18 h loading with current and 6 h rest.

4.3 Climatic tests

4.3.1 Salt spray test with hot and humid aging.

The test verifies function under realistic ambient conditions and results in accelerated aging of the components. The test is based on PV 1210 and is also a combination test consisting of:

- Salt spray test as per DIN EN ISO 9227
- Room-temperature phase at 40% to 60% relative humidity
- Hot and humid aging at +40 °C and 98% relative humidity

The duration of the test is 60 cycles. One cycle comprises:

- 4 h salt spray fog
- 4 h room temperature phase
- 16 h hot and humid aging

At the end of every week, the severity of the corrosion on the DUTs must be visually evaluated (microsections).

The DUTs must be unprotected at the ultrasonic-welded joints.

4.3.2 Thermal shock test

This test is used for fast aging of the DUTs and for verifying that fast changes in temperature do not cause mechanical impairment of the ultrasonic-welded joint despite different temperature expansion coefficients.

The test consists of 100 cycles.

Age the DUT in a forced-air oven at 130 °C for 45 min.

Next, remove it and swing it from side to side in cold water (0 °C) within the acclimatization period (<5 s) until temperature equalization. The next cycle begins immediately afterwards.

If a temperature test chamber with acclimatization facility is used, perform 50 cycles in the temperature range between 130 °C and -40 °C, with an acclimatization period of <10 s. The DUTs must be aged until the upper/lower temperatures are reached.

The DUTs must be unprotected at the ultrasonic-welded joints.

5 Applicable documents

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.

PV 1210	Body and Add-on Parts; Corrosion Test
VW 80101	Electrical and Electronic Assemblies in Motor Vehicles; General Test Conditions
DIN EN 60068-2-27	Environmental testing - Part 2-27: Tests - Test Ea and guidance: Shock
DIN EN ISO 9227	Corrosion tests in artificial atmospheres - Salt spray tests
ISO 554	Standard atmospheres for conditioning and/or testing; Specifications

Appendix A (informative) Test sequence A

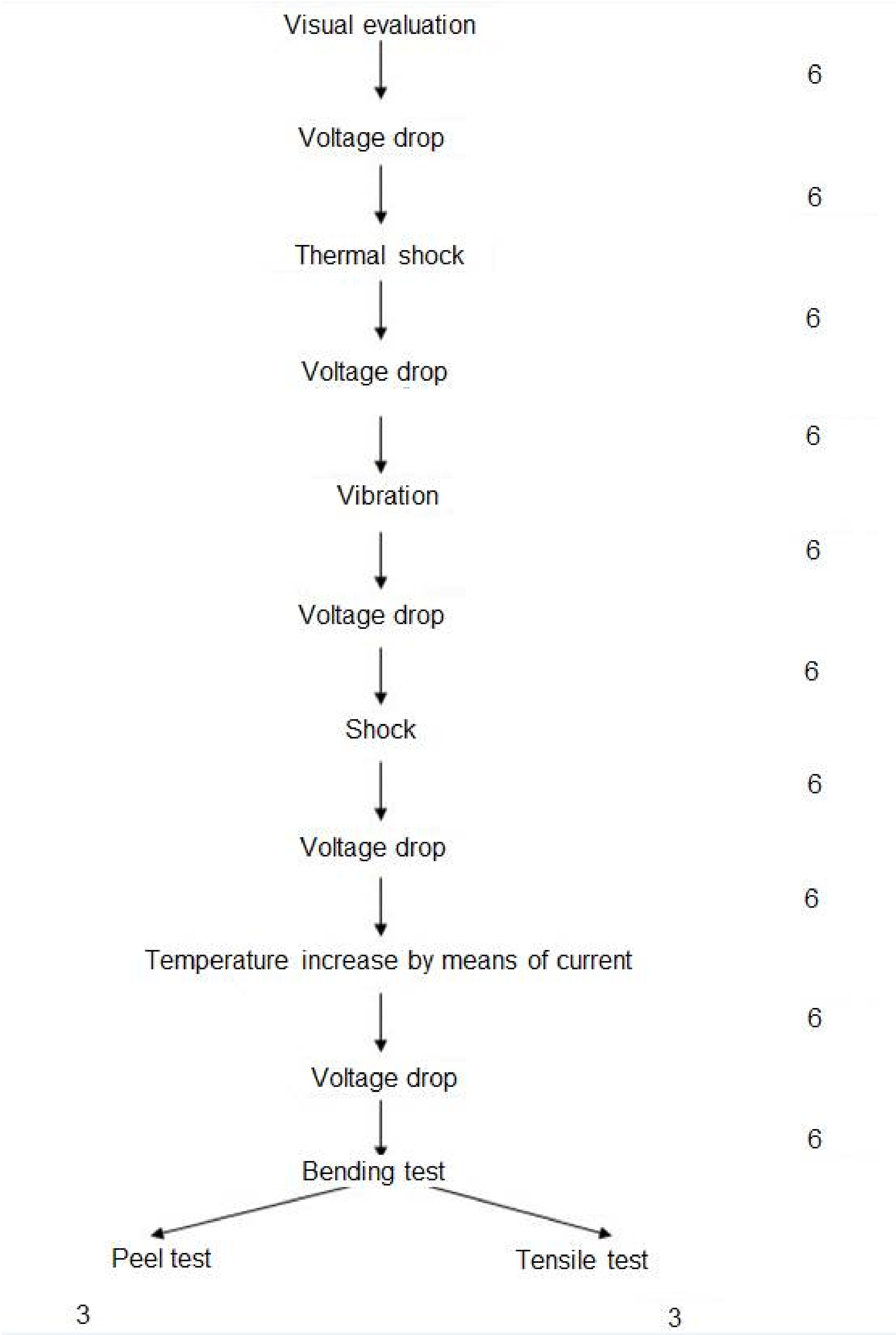

Figure A.1

Appendix B (informative) Test sequence B

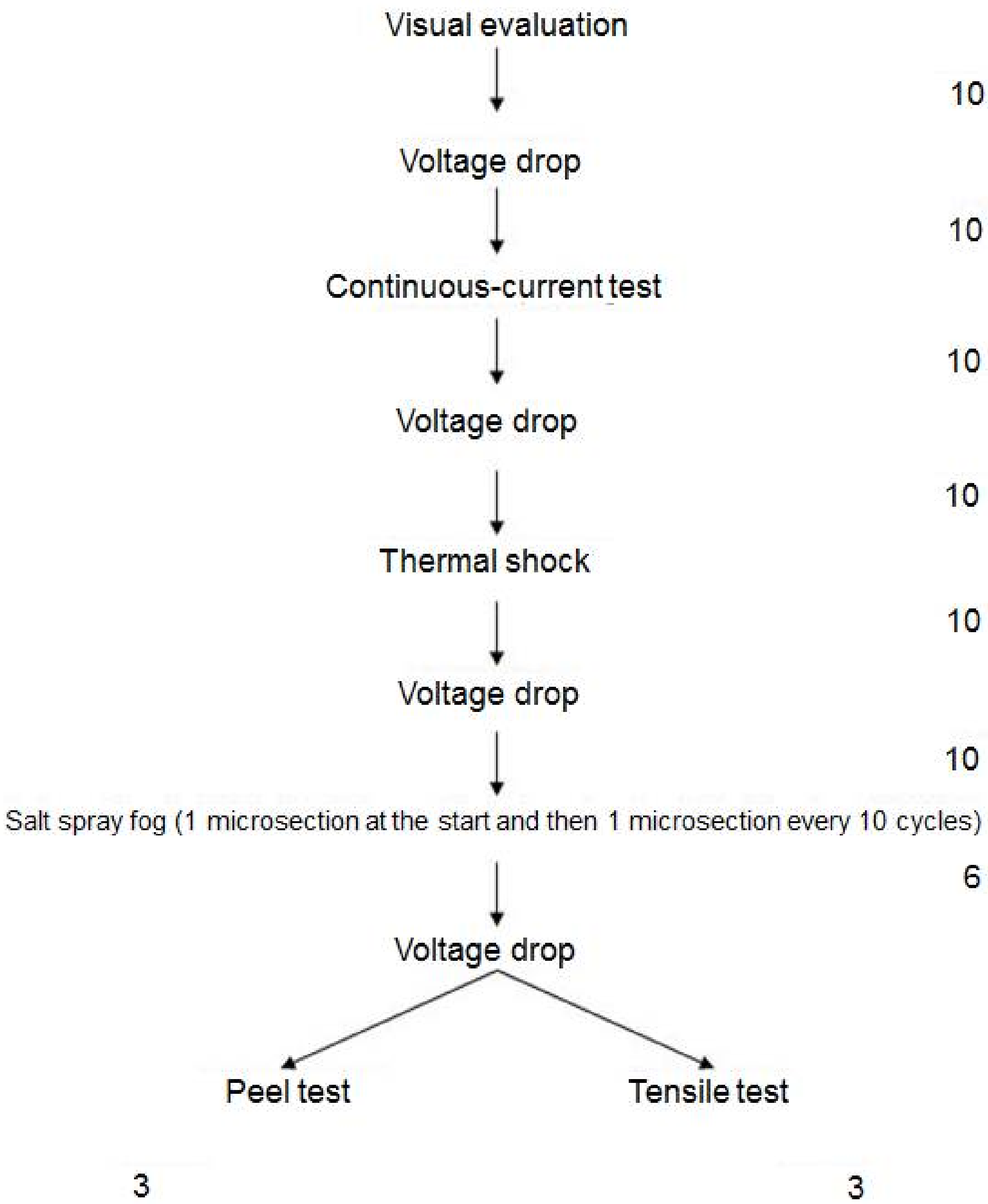

Figure B.1