

Performance Specification for Ultrasonically Welded Wire Terminations

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PERFORMANCE SPECIFICATION FOR ULTRASONICALLY WELDED WIRE TERMINATIONS

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1. SCOPE

This specification defines test methods and performance criteria for ultrasonically welded wire-to-terminal bonds as shown in Figure 1. This specification subjects parts to environmental exposures to simulate a lifetime of field exposure for a road vehicle. Exposures referenced in this specification include thermal shock, temperature humidity cycling, and mechanical stress. This specification is intended to evaluate the strength and performance of the interface between wires and the electrical terminal pad. The graphics used are specific to the linear weld type of process equipment. Validation of the terminal is a separate task (refer to a component validation test such as SAE/USCAR-2).

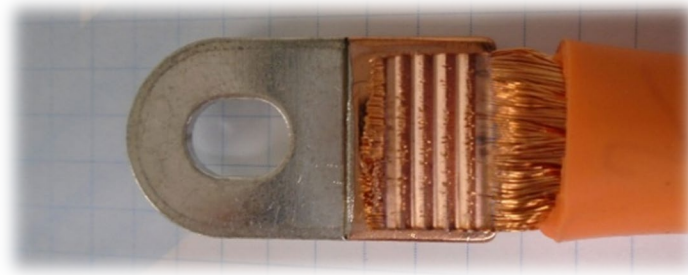


Figure 1 - Wire-to-pad weld configuration

If the weld under test (WUT) is different than described in this section or is subjected to conditions beyond what is typical of automotive use, the test sequence may not be applicable. Ensure that parts used in other conditions are validated for the actual conditions encountered.

Vehicle and product conditions applicable to use of this specification are:

1. **Applicable use:** This specification is applicable where the wire and terminal are part of an electrical connection system used in road vehicles at ambient temperatures from -40 to +150 °C. Applied voltage may be either low (0 to 60 VDC) or high (to 1000 VAC or VDC). USCAR-38 applies to all wire lengths and includes a special test for wires shorter than 500 mm where a weld is done after another component has been assembled to assess potential process damage to the terminal at the other end of the wire. Wire harness makers typically will be given the responsibility to track short wire applications per a statement in the applicable engineering statement of work.
2. **Applicable designs:** The procedures described are applicable to buss, terminal, or device connections, including eyelet and battery terminations comprising either single or multiple wire terminations. Designs with and without crimped insulation wings are applicable.
3. **Applicable multiple wire configurations:** For multi-wire welds, 12 or fewer wires is preferred since having over 12 wires increases the cost and complexity of the weld. A design review is recommended for welds having over 12 wires to see if splitting the splice into smaller pieces is a better choice. Welds of ≥ 20 wires are not applicable (because welds of that complexity require equipment capability assessments beyond the scope of USCAR-38). The ratio of the smallest wire size to the total weld cross-sectional area is recommended to be at least 1:10 (i.e., the smallest cable must be at least 10% of the total cross-sectional area of the weld).
4. **Applicable wire:** This specification was developed using clean, bare, uncoated, stranded automotive wire. Wire with tin coatings, applied lubricants, or contamination is known to affect the mechanical and electrical performance of ultrasonically welded cable terminations, and are not applicable to be evaluated per this specification. USCAR-38 is not applicable for wire-to-wire splice welding (USCAR-45 is applicable).

5. Applicable wire sizes and types: Copper wire sizes between 0.22 to 150 mm² per ISO 6722-1 or ISO 19642-3 and aluminum sizes between 0.5 to 150 mm² per ISO 6722-2 or ISO 19642-4 are applicable. Other wire types may be tested but cannot claim compliance. Examples of “other” wire types are compressed core, compacted core, solid wire core, and center strand materials other than copper, copper alloy, aluminum, or aluminum alloy. Examples of different center strand materials are copper-clad or steel-center-core wires.
6. The validation process described applies only to linear ultrasonic welding, typically with pressure, energy, and amplitude set as inputs and weld time controlled by limiting energy based on “feedback” from process monitoring sensors. Using process feedback assures the energy-per-weld is maintained. If the equipment used to make samples for USCAR-38 testing is different from this description, this specification may need to be modified or may not be applicable.

1.1 Conformance Requirements

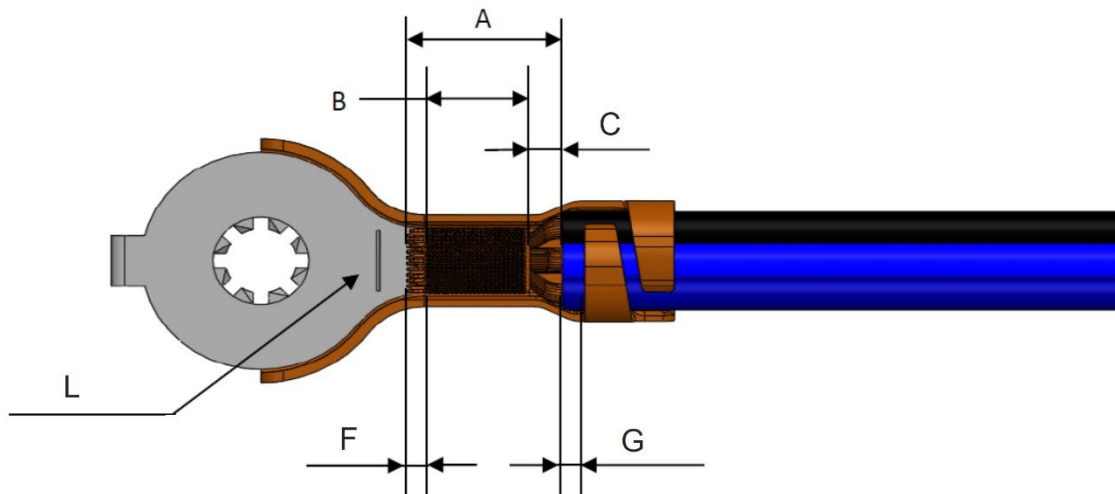
To claim conformance to this specification, the weld characteristics used to ultrasonically terminate a cable to a component must be traceable to a satisfactory SAE/USCAR-38 test report. The specific cable and component configuration (including stranding, actual cable cross-sectional area, component base material, and thickness as well as the tooling description) must be detailed in the report.

1.2 Ultrasonic Weld Characteristics

1.2.1 Ultrasonically welded termination bond performance is characterized by:

1. Mechanical bond strength (measured by cable-to-component tensile and peel strength).
2. Electrical connection quality (measured by cable-to-component resistance or voltage drop).
3. Consistent weld attributes and parameters (characterized by these attributes, with some shown in Figure 2).

- | | |
|---|--|
| A. Strip length | K. Weld position |
| B. Weld bond length | L. Terminal position limit |
| C. Weld bond width | M. Tooling profile or part number |
| D. Insulation crimp height | N. Cable part number |
| E. Insulation crimp width | O. Number or cables being welded |
| F. Wire brush limit | P. Terminal part number |
| G. End of insulation limit | Q. Wire core material (plating on wire) |
| H. Wire prep (strip length and alignment) | R. Welder manufacturer and model |
| J. Weld bond height | S. Welder supplier part number for horn, anvil and gathering blocks, and fixture |



NOTE: This graphic shows process and quality parameters. See Appendix C for a list of “design” parameters recommended to develop the correct tooling and process settings.

Figure 2 - Key parameters of the wire-to-pad configuration

2. REFERENCED DOCUMENTS

2.1 Normative References (required to perform tests)

SAE/USCAR-2 Performance Specification for Automotive Electrical Connector Systems

SAE/USCAR-21 Performance Specification for Cable-to-Terminal Electrical Crimps

2.2 Informative References

SAE J1128 Low Voltage Primary Cable

SAE J1127 Low Voltage Battery Cable

ISO 6722 Automotive Cable

ISO 19642 Automotive Cable

AIAG Measurement Systems Analysis Reference Manual

2.3 Test Request Documentation

The laboratory test request/order must provide location and documentation of test samples, identify the type of test to be performed, and describe any special tests that are not a part of this specification. Any revisions or deviations from any tests in this specification must include detailed instructions for each change.

Note that sample groups with different weld dimensions need be tested per the method of Appendix D. Care must be taken to identify all samples correctly with the process settings used to weld them. Note that the selection of the process settings to be tested are not controlled in this document; selection of settings is done prior to submitting samples for USCAR testing.

No specific format for the report is required, as long as the required information is provided. Since some customers have requirements for specific report formatting, it is recommended an agreement on report format is made before testing.

3. GENERAL REQUIREMENTS

3.1 Record Retention

The supplier shall maintain a central file for the storage of laboratory reports and calibration records. Such record storage must be in accordance with established ISO and AIAG policies and practices.

3.2 Sample Documentation

All test samples shall be identified in accordance with established (i.e., ISO or AIAG) policies and practices.

3.3 Sample Size

Minimum sample sizes are given for each test in this specification in Table 9. No part or device may be represented as having met this specification unless the minimum sample size has been tested and all samples of the group tested have met the applicable acceptance criteria for that test. It is never permissible to test a larger group then select the minimum sample size from among those that passed and represent that this specification has been met.

3.4 Default Test Tolerances

Default tolerances, expressed as a percentage of the nominal value unless otherwise indicated, are shown in Table 1.

Table 1 - Default test tolerances

Description	Tolerance	Description	Tolerance
Temperature	$\pm 3\text{ }^{\circ}\text{C}$	Length	$\pm 5\%$
Voltage	$\pm 5\%$	Time	$\pm 5\%$
Current	$\pm 5\%$	Force	$\pm 5\%$
Resistance	$\pm 5\%$	Relative Humidity	$\pm 5\%$

3.5 Test Default Conditions

When specific test conditions are not given either in the product design specification, the test request/order, or elsewhere in this specification, the following conditions apply:

1. Room Temperature: $23\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$
2. Relative Humidity: Ambient
3. Voltage: $14.0\text{ VDC} \pm 0.1\text{ VDC}$

3.6 Equipment

Table 2 highlights specialized equipment or devices, with accuracy requirements, used for USCAR-38 testing. Neither Table 2 nor the list in each test section is all-inclusive; items of customary laboratory equipment and supplies will also be required. Use of equipment with a lesser range is acceptable for specific tests where the required range for that test can be met. The equipment range specified does not preclude use of equipment with a larger range, but the accuracy must remain within the specified tolerance.

Table 2 - Equipment list

Description	Requirements
DC Power Supply (Regulated)	0~20 V current sized as required
Micro-Ohmmeter	20 mV maximum open circuit voltage 100 mA maximum test current 0.01 mΩ resolution
Digital Multimeter (DMM)	Capable of measuring 0.001-50 VDC with accuracy of 0.5% of measurement
Millivolt Meter	Capable of measuring 0-100 mV DC with accuracy of 0.5 mV
Thermocouples	Type "J" or "T" as required (wire size ~0.08 mm)
Force Tester	Capable of an accuracy of 1% of measurement
Thermal Shock Chamber	-40 to 150 °C ± 3 °C (in 5 minutes or less)
Oven (alternate to thermal shock chamber)	+150 °C ± 3 °C
Temperature Chamber (alternate to thermal shock chamber)	-40 °C ± 3 °C
Video/Photography Equipment	As required to make clear pictures, including cross-section micrographs

3.7 Definitions and Abbreviations

A list of definitions is in Appendix A. A list of abbreviations used in this document is in Appendix B.

3.8 Measurement Resolution

Unless otherwise specified, meters and gages used in measurements of the test sample(s) shall be capable of measuring with a resolution one decimal place better than the specified value. For example, even though a wire diameter specified as 0.1 mm might actually be the same as one specified as 0.10 mm, calipers capable of 0.01 mm resolution may be used to measure the first wire but a micrometer with 0.001 mm resolution is required to measure the second wire.

3.9 Test Repeatability and Calibration

All equipment used for testing shall be calibrated and maintained along with periodic gage "R&Rs," in accordance with individual test facility certification requirements and applicable standards. The AIAG publication "Measurement Systems Analysis Reference Manual" can be used as a guideline. A list of instruments and equipment used for the USCAR test, date of the last calibration, and when the next calibration is due is to be included in each USCAR test report.

4. TEST PROCEDURES AND ACCEPTANCE CRITERIA

4.1 General Testing Requirements

The test procedures in this section are stand-alone tests and may be used as such. However, they are normally used as a sequential test. Knowledge of test group construction is required to overcome any redundancies in sample preparation or procedures. For example, if samples have already been prepared for the preceding test in a sequence, it should be obvious that the sample preparation step for that individual test (included so that test can be used as a stand-alone test) should be skipped. The general testing requirements are:

1. Part submitted for test shall conform to the dimensional characteristics specified on the applicable engineering drawing(s) of the part.
2. Any engineering development, prototype, or production part may be submitted for test provided the design is documented.
3. Identify the samples submitted for test by description, part number, and revision level where applicable.
4. Parts must be representative of the process used in production. For example, terminals may have residual die lubricant on them so this same condition must prevail for test samples. (Similarly, if the terminal for the WUT is plated or coated, it is not permissible to remove the plating or coating or to clean the samples prior to performing the welding process unless these additional processes are a documented part of the volume production weld process. Cable core and insulation cannot be cleaned for the same reason.) Equipment and tooling used to make samples must be production-intent. This is critical since ultrasonic welding is sensitive to process and material conditions.
5. USCAR recommends that samples submitted for test be prepared per Appendix C. However, sample preparation is beyond the scope of this document and any properly documented samples may be tested.

4.2 Visual Inspection

4.2.1 Purpose

This test is used to document the physical appearance of test samples and to assist in the evaluation of the effects of environmental conditioning on test samples using descriptions, photographs, and/or videos. Examinations in most cases can be accomplished using available lighting in the lab.

4.2.2 Sample Size

Size will vary depending on configuration. See Table 9.

4.2.3 Equipment

1. Photographic equipment able to take general and cross-section micrograph pictures.
2. Video equipment able to take general component pictures.

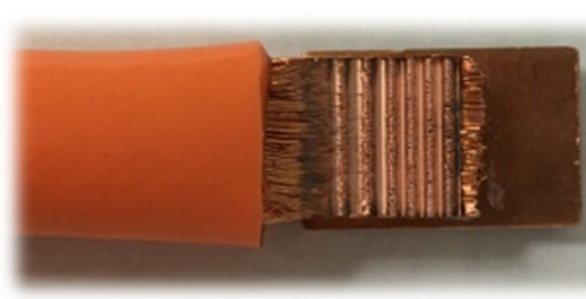
4.2.4 Procedure

1. If inspection is being done prior to testing, examine the weld bond area per the criteria in 4.2.5. Note any manufacturing or material defects such as poor wire-to-weld transition, loose strands, cut strands, or long strands that interfere with component function. Take photographs and/or video recordings of one representative sample to be tested and keep as an untested part sample. (Only one photo is required for the WUT. The photo step does not have to be repeated even if called for in different test paths.)

2. If inspection is being done after testing and/or conditioning, re-examine each test sample and note in detail any observable changes such as physical distortions, cracks, etc. Compare the tested and/or conditioned samples to the control sample, the videos, and/or the photographs, recording any differences in the test report.

4.2.5 Acceptance Criteria

All samples submitted shall meet the criteria of this section and not show any defect described in Table 3. If the component supplier's appearance requirements are stricter than those specified, then the component supplier requirements shall apply. Note that the descriptions are generic and specific terminals will need to have customized quality criteria developed and agreed to by the customer. Figure 3 illustrates an ideal weld bond and Table 4 illustrates acceptable but not ideal weld bonds for reference. The criteria given are based on weld bond robustness only and do not consider application-specific failure criteria related to part appearance or interference with neighboring parts.



ON AN IDEAL WELD:

- All strands are welded.
- Weld bond is contained by terminal (w/ clearance on sides).
- All wires reach the end of the weld nugget.
- Strands beyond the weld nugget do not interfere with functional areas nearby (terminal, eyelet, heat shrink, etc.).
- Bond has no scorching, foreign material, or contamination.

Figure 3 - Ideal weld bond appearance

1. General Appearance and Function

The welding operation shall not change the terminal such that it interferes with device function. Weld must not result in interference between wire and covers, eyelet studs, or parts added in follow-on operations. A design review must be performed separate from this test to assure no interference is possible with mating components at all tolerances.

2. End of Wire Core

- a. In sealed applications, the end of the wire core shall not present any sharp surfaces that may damage a seal during a connector assembly or seal application processes. Customer and supplier determine what test is applicable. USCAR-2 provides tests to validate sealing that may be applicable.
- b. Strip length shall be sufficient to keep cable insulation out of the weld area and be long enough to allow wire strands to extend to the end of the weld area.

3. Insulation Grip

For single-wire welds, the insulation grip (if present) shall meet the criteria in SAE/USCAR-21, 4.2.5, Step 8 for general visual appearance and 4.3.5, Step 3 for cross-section attributes. (The insulation grip adds strain relief to the weld bond. Terminal makers are encouraged to provide insulation grips for terminals that have a total wire cross section of 6 mm² or smaller. The insulation grip moves the point of highest stress between welded and un-welded wire strands away from the weld bond area.)

For multi-wire welds with an insulation grip present, apply the inspection method of USCAR-21, 4.2.5, Step 8 and 4.3.5, Step 3. Any cable can be used provided it is a production-intended wire for the application.