

Performance Specification for Welded Wire-to Wire Splices

SAE/USCAR-45
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**PERFORMANCE SPECIFICATION FOR
WELDED WIRE-TO-WIRE SPLICES**

Notice about interim revisions: Editorial updates or clarifications may be made as “interim revisions” if the EWCAP review team determines that a formal revision is not needed. Interim revisions are documented as “revision letters” and are available on the USCAR website at: <http://ewcap.uscarteams.org/revisions.html>

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1. SCOPE

SAE/USCAR-45 defines test methods and performance requirements for ultrasonically-welded wire-to-wire splices for automotive applications. Face-to-face, butt splice, and center strip configurations per Figure 1 can be tested. The tests

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defined in this specification subject samples on test to stresses that simulate a lifetime of exposure for a road vehicle. Stresses called out in this specification include thermal shock, temperature/humidity cycling and mechanical stress from different directions.

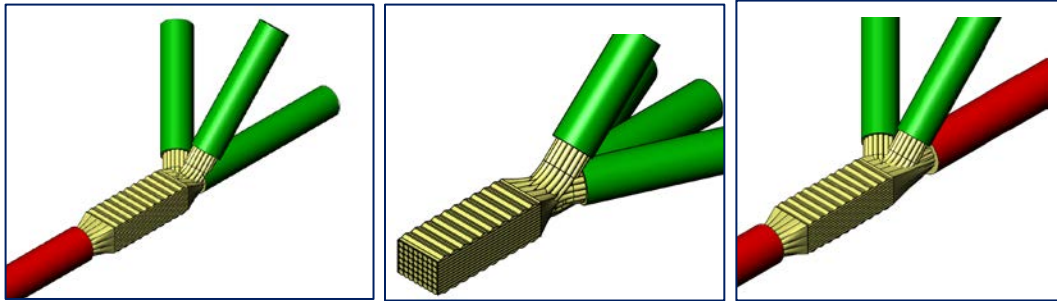


**FIGURE 1 - APPLICABLE SPLICE CONFIGURATIONS:
FACE-TO-FACE SPLICE (LEFT), BUTT SPLICE (CENTER), AND CENTER STRIP (RIGHT)**

1.1 Applicability

The vehicle and product conditions applicable to use of this specification are:

- 1) Applicable vehicle environments: USCAR-45 is applicable where the wire and terminal are part of an electrical connection system used in road vehicles at ambient temperatures from -40°C to $+125^{\circ}\text{C}$. It is applicable to applied voltages that are either low (0 - 60 VDC) or high (to 600V). This is a design validation (DV) specification; process controls are not covered. (Wire harness makers typically will be given the responsibility to develop processes and perform process controls.) The procedures described are applicable to wire-to-wire splices but do not consider placement of the splice within a wire harness. For example, rules on the minimum distance between welded splices in a harness is not evaluated in this specification.
- 2) Applicable weld configurations: USCAR-45 is known to be applicable for face-to-face and butt splices as described in Figure 1. Validation is possible for weld configurations not meeting the above design limits but we do not have experience beyond the design range listed below. Outside this range, an engineering assessment is needed to determine whether the USCAR-44 testing is applicable.
 - a) The total number of wires in the splice ≤ 12
 - b) The difference in wire count on opposing sides of a splice ≤ 8 (exception: butt splice and center strip configurations)
 - c) The ratio of the smallest wire size to the total weld cross-sectional area is a minimum ratio of 1:10. (This means the smallest cable must be at least 10% of the total cross-sectional area of the weld... needed to detect small wire).
- 3) Applicable wire and cable: USCAR-45 is applicable for individual wires between 0.13mm^2 and 50mm^2 per ISO 19642-3. This specification was developed using clean, bare, uncoated, stranded automotive copper wire. Wires with tin coatings, applied lubricants, or contamination are known to affect the mechanical performance of ultrasonically welded splices and may not be applicable for USCAR-45 validation. There are no specific limitations on wire insulation type. Wires with silicone-based water blocking gel in them are not applicable to USCAR-45 validation.
- 4) Applicable manufacturing processes: The validation process described applies to linear ultrasonic welding and has sections specifically designed to apply to processing with linear ultrasonic welding equipment. If the equipment used to make samples for USCAR-45 testing is different from this description, USCAR-45 may need to be modified or may not be applicable. If the weld under test is different than what is listed as applicable or is subjected to conditions beyond typical automotive use, an engineering assessment is required to determine applicability of USCAR-45 is applicable.

1.2 Weld features

Table 1 lists the features that define a weld. Figure 2 illustrates weld features that are also key measurable dimensions (with letters A through E matching ID letters of Table 1). Weld features are developed prior to USCAR-45 testing; USCAR-45 does not provide a method for development of the tooling and the weld schedule (process settings) used to make the WUT. Weld parameter development should be done using sound engineering practices such as application of historical lessons with similar parts, use of equipment maker's recommendations, and analysis of results with trial parts. Testing a weld that has been developed properly has an increased chance that the samples submitted for test will pass.

TABLE 1 - KEY WELD FEATURES

ID	DESCRIPTION
A.	Weld bond length
B.	Wire brush
C.	Wire transition (uninsulated unbonded length)
D.	Weld bond width
E.	Weld bond height
F.	Wire strip length and alignment
G.	Tooling profile
H.	Construction and quantity of cables welded
I.	Wire core material (including plating on wire)
J.	Weld equipment specifications

1.3 Splice performance

The capability of a splice is characterized by the key attributes listed below.

1. Acceptably high mechanical tensile bond strength (measured by tensile strength of the cable-to-cable junction).
2. Acceptably high mechanical peel strength (measured by peel strength of the cable-to-cable junction).
3. Stable electrical connection (measured by resistance or voltage drop).
4. Consistent attributes and parameters of the weld and its assembly process.

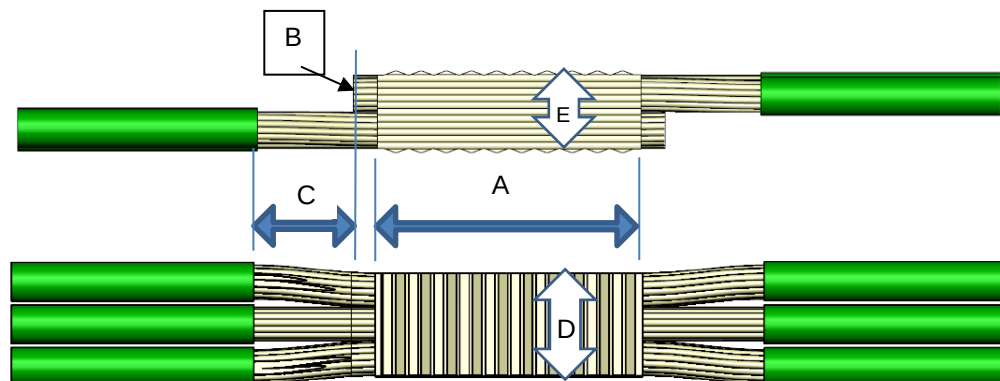


FIGURE 2 - WELD FEATURES PER TABLE 1- SIDE VIEW (ABOVE) AND TOP VIEW (BELOW)

2. REFERENCE DOCUMENTS

2.1 Normative References

ISO 19642-3 Primary Cable (Copper core wire, stranded, formerly ISO 6722-1)

2.2 Informative References

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.

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 in Table 10. 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 2. Some default conditions are also listed. When specific test tolerance or condition is not given either in the product design specification, the test request/order or elsewhere in this specification, the default condition applies.

TABLE 2 - DEFAULT TEST TOLERANCES

DESCRIPTION	TOLERANCE	DEFAULT CONDITION
Temperature	$\pm 3^{\circ}\text{C}$	$23 \pm 5^{\circ}\text{C}$
Relative Humidity	$\pm 5\%$	Ambient
Voltage	$\pm 5\%$	$14.0 \pm 0.1\text{V}$
Current	$\pm 5\%$	
Resistance	$\pm 5\%$	
Length	$\pm 5\%$	
Time	$\pm 5\%$	
Force	$\pm 5\%$	
Force tester speed	+150 mm/min. - 50 mm/min.	100 mm/min.

3.5 Equipment

Table 3 highlights specialized equipment or devices with particular accuracy requirements used for USCAR-45 testing. Neither the table 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 3 - EQUIPMENT LIST

DESCRIPTION	REQUIREMENTS
DC Power Supply (Regulated)	0~20V. Current capability as required per Table 9 for the wire size of the WUT
Milli-Ohmmeter	20 mV max. open circuit voltage, 100 mA max. current, 0.01 mΩ resolution and 1% accuracy.
Digital Multimeter (DMM)	Capable of measuring 0.001-50 Volts DC with accuracy of 0.5% of measurement
Millivolt Meter	Capable of measuring 0-100 mV DC with accuracy of 0.5 mV
Force Tester	Capable of an accuracy of 1% of measurement
Thermal Shock Chamber	Capable of -40 to 125°C ± 3C, switching between temperatures in 5 min. or less.
Video/photography equipment	As required to make clear pictures, including cross-section micrographs

3.6 Definitions and Abbreviations

Terms defined in the definitions section are capitalized (i.e. Room Temperature, Steady State, etc.). A list of definitions and abbreviations are in Appendix A.

3.7 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.

3.8 Test Repeatability and Calibration

All equipment used for testing shall be calibrated and maintained along with periodic gage R&R's 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 test, date of the last calibration, and when the next calibration is due is to be included in each test report.

4. TEST PROCEDURES AND 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 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.