

Performance Specification for Cable-to-Terminal Electrical Crimps

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PERFORMANCE SPECIFICATION FOR CABLE-TO-TERMINAL ELECTRICAL CRIMPS

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1. SCOPE

This specification defines test methods and requirements for validation of solderless crimped connections. The purpose of this test is to simulate in the lab the stress seen in a typical life (15 years and 150000 miles) for a crimp connection and assure the crimp is mechanically strong and electrically stable. This specification was developed for use with stranded automotive copper wire. Only where specifically mentioned are other constructions or other core materials (aluminum, clad, steel core, etc.) applicable. This specification does not apply to wire types not mentioned, such as coaxial cable crimps, unless a USCAR-21 test is specifically referenced in the test specification for that wire type.

This specification is based on accepted levels of environmental exposure for automotive applications. In any intended vehicle application, if the products covered by this specification are or may be subjected to conditions beyond those described in this document, they must pass special tests simulating the actual conditions to be encountered before they can be considered acceptable for actual vehicle application. Products certified by their supplier as having passed specific applicable portions of this specification are not to be used in applications where conditions may exceed those for which the product has been satisfactorily tested. Any deviation must be documented and included in the final test report.

Crimp applications validated to this specification are intended to supersede crimp information on the component prints. The terminal supplier has the primary responsibility for testing and selection of crimp tooling and to supply detailed crimp information or make crimp tooling available to the wiring assembly supplier actually doing the production crimping. The wiring harness supplier is responsible for validating all crimps produced per this specification.

Environmental exposures called-out in this specification include Thermal Shock and Temperature Humidity Cycling and are used to stress every production terminal and cable combination used under test to simulate field exposure. SAE/USCAR-21 has tests that will detect deficiencies in crimp tooling geometry, plating quality, strand distribution, and cable strand count. SAE/USCAR-21 must be done in addition to a connector system validation such as SAE/USCAR-2 to assure the entire allowable production crimp height range of every combination is acceptable. Testing to a connector system specification also validates what is not tested in SAE/USCAR-21 such as long-term high temperature exposure.

Procedures included within this specification are intended to cover performance testing and development of electrical terminal crimps that are part of the electrical connection systems in low voltage (0 to 48 VDC) road vehicle applications at ambient temperatures of 125 °C maximum. Higher voltages and temperatures may be tested if the OEM customer approves use of these test procedures for use at voltages and temperatures beyond these limits.

1.1 Crimping Parameters

1.1.1 The crimped connection performance is characterized by:

- Visual conformance of crimp attributes including cross-sections.
- Mechanical performance as measured by terminal-to-conductor pull-out force.
- Electrical performance as measured by terminal-to-conductor resistance or voltage drop.

1.1.2 The geometry of a crimp is characterized by:

- Conductor crimp height (CCH)
- Conductor crimp width (CCW)
- Insulation crimp height (ICH)
- Insulation crimp width (ICW)
- Cut-off tab
- End of conductor (wire brush length and height)
- End of insulation
- Bell mouth
- Burr (anvil flash) dimension on the base of the conductor crimp
- Step between the core and insulation wings
- Information on terminal drawing

2. DOCUMENTS

2.1 Document Hierarchy

To claim conformance to this specification, the standard USCAR-21 test report should be used to communicate with OEM when required, and the tooling and process settings used to crimp a terminal/wire application in production must be the same as what was used to make samples submitted for a USCAR-21 test that met all criteria. The tooling and process settings used to meet USCAR-21 may be developed independently and may be different than crimp specifications listed on a terminal drawing or process specification developed by the terminal maker. Note that the settings used for USCAR-21 validation supersede any documentation for crimp settings not aligned to USCAR-21 in order to claim conformance.

2.2 Test Request/Order

2.2.1 Samples, Test Type and Special Tests

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

2.3 Materials and Process Specifications

Suppliers are expected to adhere to the appropriate materials and process that are referenced in this specification and any associated drawings and reference documents. Unless otherwise specified or required by law, suppliers are expected to use the most recent versions of any applicable drawings, reference documents, and standards.

2.4 Referenced Documents

- SAE/USCAR-2: Performance Specification for Automotive Electrical Connector Systems
- AIAG: Measurement Systems Analysis Reference Manual
- SAE J1128: Low Tension Primary Cable
- SAE J1127: Battery Cable
- ISO 19642 - Road vehicles — Automotive Cables — Dimensions and requirements
- Standard USCAR-21 test report (available at www.uscar.org)

3. GENERAL REQUIREMENTS

3.1 Record Retention

The supplier shall maintain a central file for the storage of laboratory reports and calibration records. Record storage must be in accordance with established (i.e., ISO or AIAG) policies and practices.

3.2 Sample Documentation

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

3.3 Sample Size

Minimum sample sizes are given for each test in this specification. 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. It is permissible to include additional groups of crimp heights to ensure at least 3 consecutive crimp heights (nominal, "+1", and "-1" crimp height tolerance) meet the requirements.

3.4 Default Test Tolerances

Default tolerances, expressed as a percentage of the nominal value unless otherwise indicated:

a. Temperature	$\pm 3\text{ }^{\circ}\text{C}$	e. Length	$\pm 5\%$
b. Voltage	$\pm 5\%$	f. Time	$\pm 5\%$
c. Current	$\pm 5\%$	g. Force	$\pm 5\%$
d. Resistance	$\pm 5\%$	h. 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 basic conditions shall apply:

a. Room Temperature	$23\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$
b. Relative Humidity	Ambient
c. Voltage (DC)	$14.0\text{ V} \pm 0.1\text{ V}$

3.6 Equipment

Table 3.6 highlights specialized equipment or devices with particular accuracy requirements used for USCAR-21 testing. Neither Table 3.6 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 3.6 - EQUIPMENT LIST

DESCRIPTION	REQUIREMENTS
DC Power Supply (Regulated)	⇒ 0~20 V current sized as required
Micro-Ohmmeter	⇒ 0-20 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 (small size ~0.08 mm)
Force Tester	Capable of an accuracy of 1% of measurement
Temperature Cycling Chamber	⇒ -40 to 125 °C, 0 to 98% RH
Thermal Shock Chamber	⇒ -40 °C ± 3 °C to 125 °C (in 5 minutes or less)
Forced Air Oven	⇒ +85 °C ± 3 °C
Temperature Chamber	⇒ -40 °C ± 3 °C
Temp/Humidity Chamber	⇒ 95 to 98% RH at +65 °C ± 3 °C

3.7 Definitions and Glossary

Definitions for technical terms are listed in Appendix B. Abbreviations and acronyms are listed in Appendix C.

3.8 Measurement Resolution

Unless otherwise specified, meters and gages used in measurements of test samples shall be capable of measuring with a resolution one decimal place better than the specified value. For example, 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 the test sample evaluation 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.

3.10 Conformance Determination

Table 5.1 lists the requirements to meet USCAR-21. Test conformance shall be determined by the acceptance criteria of the test being conducted. All samples must satisfy the requirements regardless of sample age, test cycles, or test temperature, except where a test to failure is specified. Additional sample groups with alternate crimp heights may be tested to help determine the nominal and min/max crimp height for a given terminal/wire combination. Three consecutive crimp height groups (nominal, high limit of tolerance, and low limit of tolerance) must meet the requirements but groups tested outside of this range need not pass.

4. TEST AND ACCEPTANCE REQUIREMENTS

4.1 General Testing Requirements

The test procedures in this section were written as stand-alone tests and may be used as such. However, they are normally used in a sequential test format and common sense is required to overcome any redundancies in sample preparation or in 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. (Note: The resistance measurement method for terminals crimped on $>6 \text{ mm}^2$ wire has changed from using 4.5.3 Dry Circuit resistance to 4.5.6 Voltage Drop method to get better measurement accuracy.)

4.1.1 Dimensional Characteristics

Part construction shall conform to the dimensions, shape, and detail attributes specified on the latest revision of the applicable part drawing(s).

4.1.2 Material Characteristics

All material used in each test sample shall conform to the material specifications on the latest revision of the applicable part drawing(s).

1. Any engineering development, prototype, or production part may be submitted for test.
2. The samples submitted for test shall be identified by description, part number, and revision letter.
3. For validation testing, all parts are to be in their "as furnished for vehicle assembly" condition when testing begins. This same condition must prevail for test samples.
4. Samples submitted for any test shall be prepared per Appendix E.

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 by a person under cool white fluorescent lighting.

4.2.2 Samples

1. The samples must conform to the requirements of the specified conditioning and any additional measurements that are to be performed.
2. For purposes of comparison and especially when only subtle appearance changes are anticipated, it is desirable to submit an additional sample to serve as a control.

4.2.3 Equipment

1. Video and photographic equipment able to produce clear images.

4.2.4 Procedure

1. Visually examine each test specimen prior to testing and/or conditioning, noting in detail any manufacturing or material defects such as cracks, bending, deformation, etc. Take photographs and/or video recordings of representative samples to be tested and keep a properly labeled control sample.
2. 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 samples, the videos, and/or the photographs, recording any differences in the test report. An additional sample is needed as a control sample.
3. If the terminal supplier's appearance requirements are stricter than those specified below, then the terminal supplier specifications should be applied.
4. Return test samples to requestor after all tests are completed and all data have been obtained.

4.2.5 Acceptance Criteria

1. General Appearance

Confirm the crimping operation does not affect the contact, locking, connector mating, or insertion functions of the terminal. These characteristics are verified as part of USCAR-2 testing. See Figures 4.2.5-1A and 4.2.5-1B for applicable attributes.

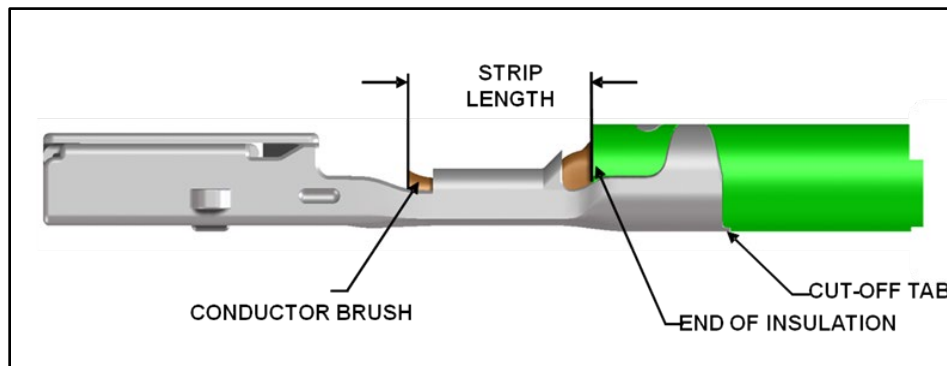


FIGURE 4.2.5-1A - PARTS OF A CRIMP (SIDE VIEW)

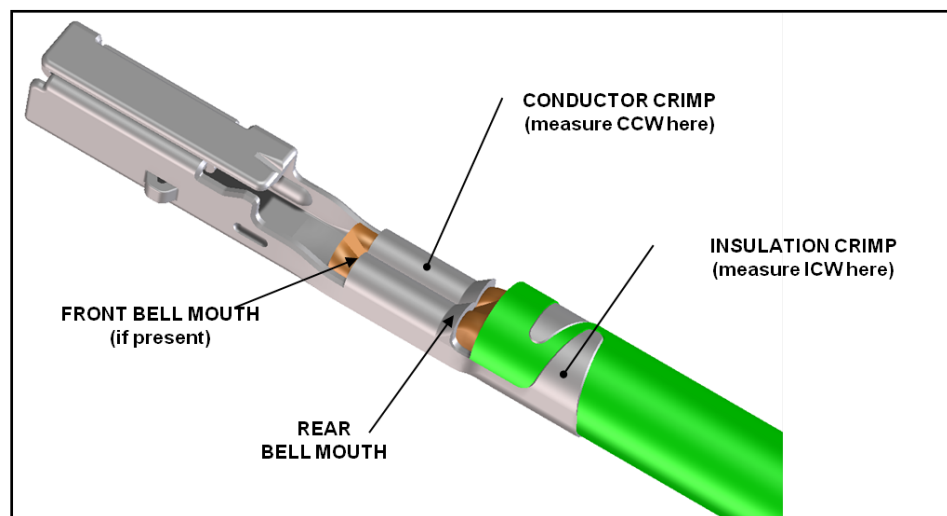


FIGURE 4.2.5-1B - PARTS OF A CRIMP (ISOMETRIC VIEW)

2. End of Conductor

The end of conductor must extend beyond the front edge of the conductor crimp. The insertion and locking functions of the terminal must not be affected by the projecting end of the conductor. Mat seals must not be damaged by the core and may require control of the wire core in front of the core wing. See 4.2.5-6 (in this section - Conductor Crimp) for details.

3. End of Insulation

The end of the insulation must be visible in the window between the conductor crimp wings and the insulation crimp wings such that conductor is visible and should be centralized as much as possible. In no case may insulation be crimped in the conductor crimp wings.

4. Cut-Off Tab

- The cut-off tab length shall not exceed 0.5 mm or 1/2 terminal stock thickness, whichever is greater, unless otherwise specified on the component print.
- The burr on the cut-off tab must not exceed 0.3 mm on terminal stock thickness ≤ 0.8 mm unless otherwise specified on the component drawing. The burr must not exceed 0.6 mm on >0.8 mm stock thickness unless otherwise specified on the component drawing. See Figure 4.2.5C.
- The cut-off and burr must not affect the insertion function of the terminal into the connector.

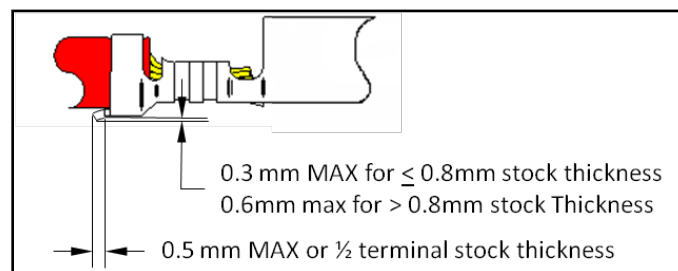


FIGURE 4.2.5C - BURR CRITERIA FOR CUT-OFF TAB

5. Bell Mouth

The conductor crimp shall produce a bell mouth on the side of the crimp nearest the insulation crimp. A front bell mouth is not required, but the conductor crimp may have a bell mouth on the front edge of the conductor crimp, nearest the terminal body. Figures 4.2.5D and 4.2.5E illustrate the max allowed bell mouth and min allowed bell mouth. USCAR does not control these dimensions. Applicable values may be provided by the terminal manufacturer or customer.

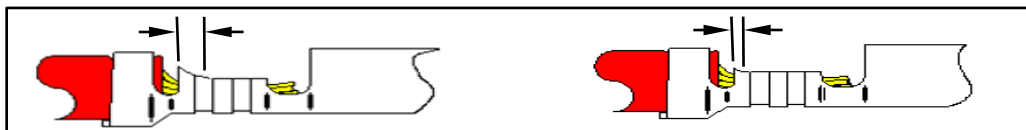


FIGURE 4.2.5D AND 4.2.5E - BELL MOUTH (MAX/MIN)

6. Conductor Crimp

All strands must be enclosed within the crimp; no strands outside the crimp or broken-off before the crimp are allowed. For wires ≤ 3 mm², the wire brush length (ℓ in Figure 4.2.5F) shall not exceed 0.5 mm (beyond the core wings) unless verified as acceptable by the connector manufacturer for a specific connector design or terminal maker for eyelet designs. The wire brush must not interfere with any downstream assembly process (for heat shrink, TPA, etc.).

7. Conductor Crimp When in a Mat Seal

If the crimp is used in a connector with a mat seal, the validation shall comply with the connector supplier's USCAR-2 correlated directions for wire brush length and height. If no connector supplier recommendations are available, the wire brush length shall not exceed 0.5 mm (beyond the core wings) and the strands shall be even with or below the level of the core crimp ("t" in Figure 4.2.5F must be ≤ 0) at all allowable CCH. A front bell mouth (on the brush side of the crimp) shall not be used on a terminal to be loaded through a mat seal. (The top of the bell mouth can be sharp and damage a mat seal during plugging.)

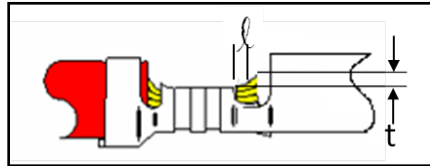


FIGURE 4.2.5F - WIRE BRUSH: STRAND HEIGHT ABOVE CORE CRIMP AND LENGTH

8. Insulation Crimp

The purpose of an insulation crimp is to add strain relief to the crimped conductor. This moves stress between the crimped and uncrimped wire strands into the un-crimped portion of the wire core. The test lab must determine the acceptable ICH range and tooling requirements to meet these requirements and be followed in production. Criteria are:

- The insulation crimp must contact the surface of the insulated cable in at least 3 locations.
- The insulation crimp must not interfere with any subsequent operations.
- The insulation crimp must not push insulation compound under the wire strands (CUS).
- The insulation crimp must not interfere with seating of a terminal into its plastic connector cavity.
- The insulation crimp must not split or damage the cable. Use Figures 4.3.5-3A, B, and C as criteria.
- The bell mouth on the insulation crimp (if used) shall not exceed the insulation crimp tolerances.

9. Cable Conductor Appearance Prior to Crimping

- Strands in stripped wire shall not be cut, missing, excessively nicked (significant strand reduction), or elongated.
- Insulation shall not be stuck or embedded in strands.
- Length as described in Figure 4.2.5G shall meet applicable instructions (not controlled by USCAR-21).

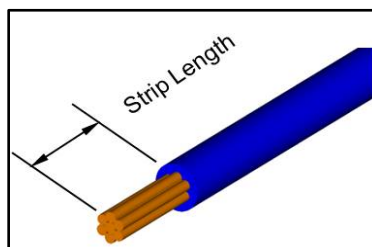


FIGURE 4.2.5G - STRIPPED WIRE LENGTH

10. Individual Cable Seal Crimp

- a. Seal location must meet terminal maker's product specification for lengthwise seal position, if specified. (In addition to achieving the proper position, the seal retention test per 4.6 must pass to assure it is secure.)
- b. The seal ribs must have no damage. See Figure 4.2.5H for what area is called a rib.
- c. The end of the seal neck must be visible in the area between the insulation and the conductor crimps. It is expected that some cable seal designs with no hub at the end of the neck will not be able to pass the retention requirements of Section 4.6. In those cases, a redesigned seal is needed.
- d. The cable insulation must be visible under the seal. See Figure 4.2.5H as an example of correct position.

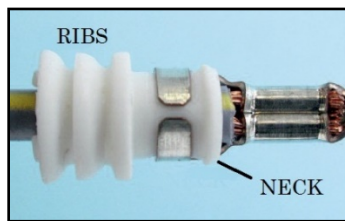


FIGURE 4.2.5H - INDIVIDUAL CABLE SEAL DETAIL

4.3 Cross-Section Analysis

4.3.1 Purpose

Cross-sectional analysis is used as an aid in determining why a crimp passes or fails a portion of this test. Failure to pass an electrical test may be due to uneven strand dispersion, inadequate wing closure, voids, wings bottoming out, etc.

4.3.2 Sample Size

At least one specimen for each crimp height shall be evaluated. Data shall be obtained and recorded for minimum, maximum and nominal production crimp heights.

4.3.3 Equipment

Various specialized equipment exists for cross-sectioning samples. The choice of equipment is up to the supplier, but should be capable of sectioning the crimp with minimal disturbance to the terminal and cable stranding.

4.3.4 Procedure

1. Cross-section and photograph each specimen for analysis.
2. Cross-section analysis shall be performed on all conductor crimp applications at each crimp height setting (nominal, min, and max tolerance).
3. Cross-sections shall be in the area marked in Figure 4.3.4-3, as close to the center as possible. The core section must be made between serrations in the core crimp. Both core and insulation sections are required.

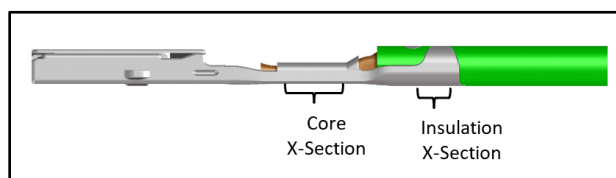
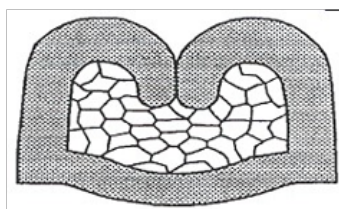


FIGURE 4.3.4-3 - CRIMP CROSS-SECTION LOCATIONS

4.3.5 Acceptance Criteria

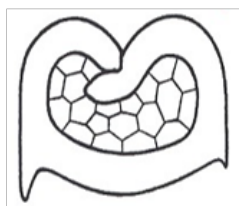
1. Cross-section views of conductor crimps must comply with Figure 4.3.5-1. Note that with OEM customer approval, unacceptable attributes may be deemed acceptable for that customer if it is shown that all other requirements are met. Each customer needs to approve variances separately since one customer cannot approve a variance for a different customer. OEM is expected to only approve with technical understanding of the cause and severity of the condition. See 5.2 for customer approval process

Conductor crimp attributes considered ideal

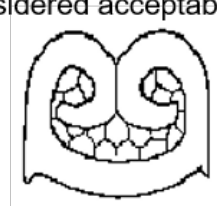


- Symmetric
- Compaction of all strands (no round strands)
- Wings touch only conductor
- Terminal stock free of cracks / breaks
- Core wings "Locked" (no gap) at top of crimp

Conductor crimp attributes considered acceptable but not ideal

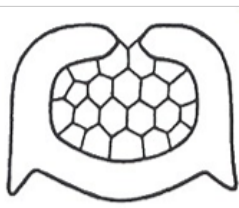


Overlapping wings



Extreme "ram-horning"

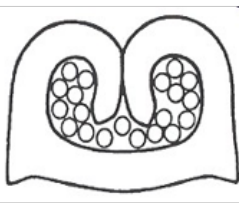
Conductor crimp attributes that are unacceptable



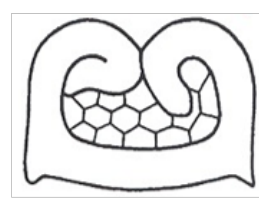
Open wings with core exposed or folded down into core but not touching (not locked)



One or both wings penetrate ("crash") to the terminal floor or wall



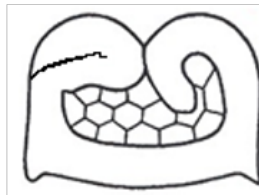
Low / No strand compaction. Round strands in core crimp are never acceptable



One or both wing details do not capture strands



Terminal stock cracked / broken



One or both wings folded back

FIGURE 4.3.5-1 - CONDUCTOR CRIMP CROSS-SECTION CRITERIA

2. The width of the burr on the base of a crimp must not exceed 0.1 mm for ≤ 0.8 mm thick terminal stock or 15% of stock thickness for > 0.8 mm stock. (For accurate crimp height measurement, it is recommended that the burr height not exceed the lowest position of the crimp.) The burr must not cause damage to any subsequent operation. Special care must be taken when using mat seals that can be cut by a burr. Seals are validated per USCAR-2 for each connector design.

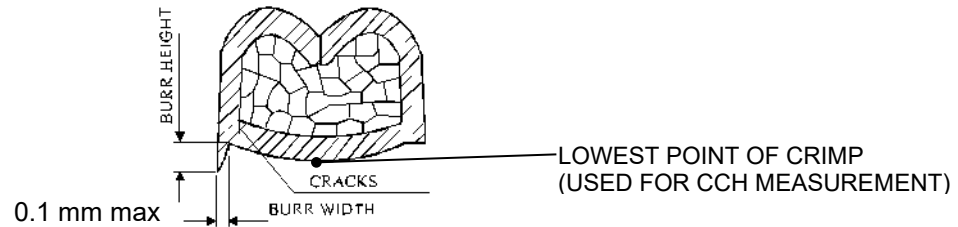


FIGURE 4.3.5-2 - CONDUCTOR CRIMP BURR DETAIL

3. Insulation cross-section (with no cable seal) must meet ideal views shown in Figure 4.3.5-3A or acceptable views in Figure 4.3.5.3B. No unacceptable cross-section views as shown in Figure 4.3.5-4C are allowed. For acceptance criteria on non-standard insulation crimp designs, refer to the terminal manufacturer's recommendations; some insulation crimps serve as a functional part of the terminal/cavity retention system and functional failures will result from non-compliance.

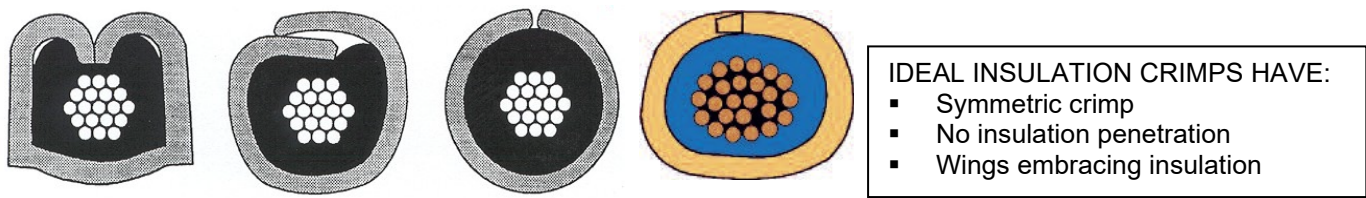


FIGURE 4.3.5-3A - IDEAL INSULATION CRIMP CROSS-SECTIONS FOR DIFFERENT STYLE DESIGNS

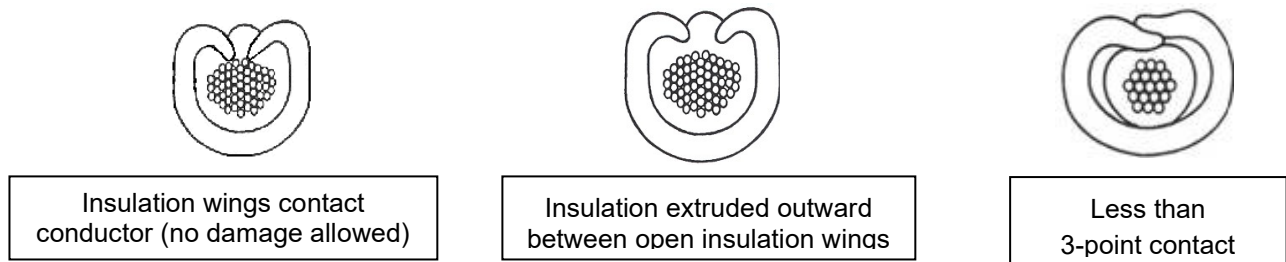


FIGURE 4.3.5-3B - ACCEPTABLE BUT NOT IDEAL INSULATION CRIMPS

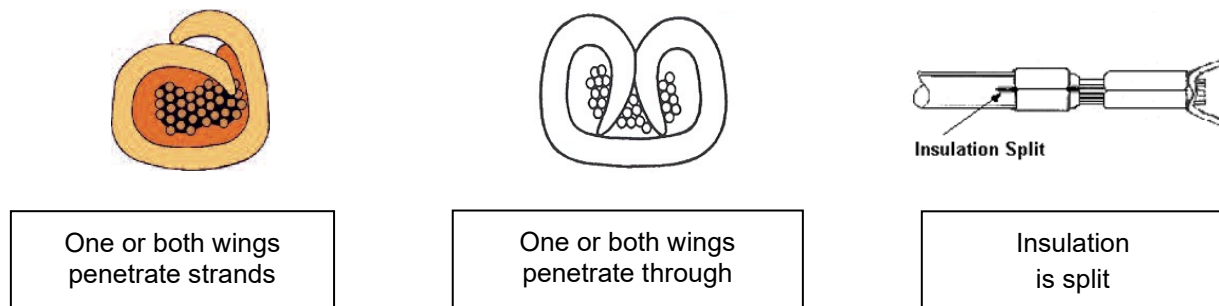


FIGURE 4.3.5-3C - UNACCEPTABLE INSULATION CRIMPS