SAE The Engineering Society For Advancing Mobility Land Sea Air and Space®
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SAE/USCAR-21

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PERFORMANCE SPECIFICATION FOR CABLE-TO-TERMINAL ELECTRICAL CRIMPS

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1. SCOPE

IMPORTANT NOTICE: 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.

The Authorized Person is the final authority as to what tests are to be performed on his or her parts and for what purpose these tests are required. He or she is also the final authority for resolving any questions related to testing to this specification and to authorizing any deviations to the equipment or procedures contained in this specification. Any such deviation must be documented and included in the final test report.

1. This specification defines basic test methods and requirements for solder-less crimped connections.
2. Crimp applications validated to this specification supercede any crimp information on Ford, GM, or DaimlerChrysler component prints. It is preferred that the terminal supplier do testing and selection of crimp tooling and supply detailed crimp information or make crimp tooling available to the wiring assembly supplier actually doing the production crimping. If the wiring supplier deviates from this information or it is not available, then the responsibility for testing to this specification or getting approval from the customer with appropriate test data showing that the crimp will function in it's intended circuit lies with the wiring harness supplier
3. New or revised terminals shall be designed to meet this specification.
4. All new crimp applications shall meet this specification. New crimp applications are defined as terminal/wire crimp combinations not previously specified on Ford, GM, or DaimlerChrysler vehicle wiring harness assemblies. Existing crimp applications may be carried over if approved by the customer engineering department.
5. Electrical tests in this specification have been proven by past experience to ensure that crimps will meet the requirements in SAE/USCAR-2 and SAE/USCAR-20 by including Thermal Shock, Temperature Humidity, and Power Current Cycling. Testing and electrical acceptance criteria will detect defects in crimp tooling geometry, plating quality, inadequate strand distribution in the grip, or cable stranding. Crimp applications that have passed SAE/USCAR-2 and SAE/USCAR-20 normally have only passed the nominal crimp height and usually only with the largest gauge size. Therefore, crimps within the production crimp height range may not necessarily pass this test.
6. Procedures included within this specification are intended to cover performance testing at development of electrical terminal crimps that are part of the electrical connection systems in low voltage (0 - 48 VDC) road vehicle applications at ambient temperatures of 125°C maximum. The OEM customer must approve use of these test procedures for use at voltages and temperatures beyond these limits.
7. These procedures are applicable only to terminals used for in-line, header, edge board, and device connector systems.

1.1 Crimping Parameters

1.1.1 The Crimp connection performance is characterized by:

Mechanical performance is measured by terminal to conductor Pull-Out Force.
Electrical performance is measured by terminal-to-conductor Crimp Resistance.

1.1.2 The geometry of a conductor crimp is characterized by:

Conductor crimp height (CCH)
Conductor crimp width (CCW)
Insulation crimp height (ICH)
Insulation crimp width (ICW)
Cut-off
End of conductor
End of insulation
Bellmouth (flare)
Burr (anvil flash) dimension on the base of the conductor crimp
Step between the core and insulation tools
Crimp tooling geometry

2. REFERENCED DOCUMENTS

2.1 Document Hierarchy

In the event there is a conflict between performance standards, part drawings, and other related standards or specifications, the requirements shall be prioritized as follows:

1st-Applicable FMVSS requirements and other applicable state and Federal requirements.
2nd-Applicable part drawings
3rd - Applicable product design specification(s).
4th-Automotive Industry Action Group (AIAG) Production Part Approval Process (PPAP)
5th-Applicable USCAR/EWCAP performance specifications
6th-Other applicable standards and specifications

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 any tests in this specification must include detailed instructions for each change.

2.3 Materials And Processes Standards

Suppliers are expected to adhere to the appropriate Materials and Process Standards 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 Other Referenced Documents

- SAE J1128: Low Tension Primary Cable
- JISC 3406: Low Tension Primary Cable
- ISO/DIS 6722 Low Tension Primary Cable
- AIAG: Measurement Systems Analysis Reference Manual
- SAE/USCAR-2 Performance Specification for Automotive Electrical Connector Systems
- SAE/USCAR-20 Field Correlated Life Test Supplement to SAE/USCAR-2

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 QS-9000 and AIAG policies and practices.

3.2 Sample Documentation

All test samples shall be identified in accordance with the requirements of QS-9000 and the AIAG PPAP.

3.3 Sample Size

Minimum sample sizes are given for each test in this specification. A greater number of samples may be required by the test request/order. However, 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:

A. Temperature = ± 3 °C
B. Voltage = ± 2%
C. Current = ± 1%
D. Resistance = ± 1%
E. Length = ± 1%
F. Time = ± 5%
G. Force = ± 5%
H. Distance = ± 1%
I. Relative Humidity = ± 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 ± 5° C
B. Relative Humidity = Ambient
C. Voltage = 14.0 ± 0.1 VDC

3.6 Equipment

Neither the list shown in Table 3.6, nor the list in each test section is all-inclusive. It is meant to highlight specialized equipment or devices with particular accuracy requirements. Many other items of customary laboratory equipment and supplies will also be required.

DESCRIPTION	REQUIREMENTS
AC or DC Power Supply (Regulated)	⇒ 0-20 V ⇒ 0-100 A
Micro-ohmmeter	⇒ 0-20 mV maximum open circuit voltage ⇒ 0-100 mA maximum test current ⇒ 0.03 mΩ resolution
Digital Multimeter (DMM)	Capable of measuring the following: ⇒ 0-50 Volts DC with an accuracy of 0.5% of full scale ⇒ 0-10 MegOhms with an accuracy of 0.5% of full scale
Current Shunts	100 mA or as required with accuracy of ±1% of nominal
Millivolt Meter	Capable of measuring 0-100 mV DC an accuracy of 0.5mV or better
Thermocouples	Type "J" or "T" as required
Force Tester	Capable of an accuracy of ≤1% of measurement
Data Logger	As Required
Temperature Cycling and/or Thermal shock Chamber	⇒ -40°C to 125°C ⇒ 0% to 98% RH
Forced Air Oven	⇒+85 ±3 °C
Temperature Chamber	⇒-40 +/- 3°C
Temperature/Humidity Chamber	⇒95 to 98% RH at +65 +/- 3°C

Note: 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. For example, a DMM with a range of 0-100 volts could be substituted for one specified as 0-50 volts, with the provision that the accuracy could be maintained as 0.25mV or better.

TABLE 3.6 - Equipment

3.7 Test Order And Set-Up

Diagrams are provided where necessary to clarify the details of the various test procedures. The tests in each section must be performed in the order given unless otherwise specified in the test request/order. Construction details for selected test fixtures and equipment are provided in each section.

3.8 Definitions And Glossary Of Terms

Terms defined in the definitions or glossary are capitalized (i.e. Room Temperature, Steady State, PLR, etc.). A list of definitions is provided in Appendix B. A glossary of terms is provided in Appendix C.

3.9 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.

3.10 Test Repeatability & Calibration

All equipment used for test sample evaluation shall be calibrated and maintained according to the applicable standards and requirements set forth by QS9000 and the AIAG publication Measurement Systems Analysis Reference Manual. Copies of this Manual can be obtained from the AIAG by calling (248) 358-3570 or writing to AIAG, Dept. 77839, Post Office Box 77000, Detroit, MI 48277-0839, Attn: Customer Service. Documentation is to be recorded and retained in accordance with Section 4.1 of this USCAR/EWCAP specification.

A list of instruments and equipment used, date of the last calibration, and when the next calibration is due is to be included in each test report.

3.11 Conformance Determination

Test conformance shall be determined by the performance requirements of the test being conducted. All samples must satisfy the performance requirements regardless of sample age, test cycles, or test temperature, except where a test to failure is specified.

4. TEST & ACCEPTANCE REQUIREMENTS

4.1 General Testing Requirements

The test procedures that follow 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. Should any conflicts or questions arise concerning procedures and/or requirements, contact the Authorized Person.

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 standards specified on the latest revision of the applicable part drawing(s).

1. Any engineering development, prototype, or production parts may be submitted for test.
2. The samples submitted for test should 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. For example, electrical terminals typically have residual die lubricant on them when finally assembled into a vehicle. 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. A comparison can then be made with other test samples. Examinations in most cases can be accomplished by a person with normal or corrected vision, and normal color sensitivity, under cool white fluorescent lighting. Photographs and/or videos are encouraged as a more complete means of documentation. An appropriately identified untested sample from each test group must be retained for post-test physical comparisons if photographs/video's are not taken.

4.2.2 Samples

1. The samples should 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

Video/photography equipment.

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. When specified in the test request/order, 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. The Authorized Person will need to provide an additional sample for this purpose.
3. If the terminal supplier's appearance requirements are more strict 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 necessary data have been obtained.

4.2.5 Acceptance Criteria

1. General Appearance – Refer to Figure 4.2.5. The crimping operation should not affect the contact, locking, connector mating, or insertion functions of the terminal.

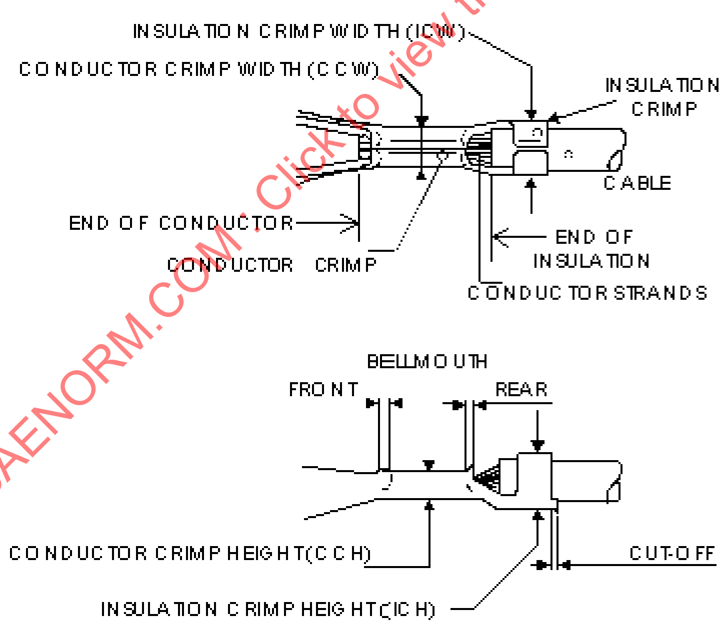


FIGURE 4.2.5 - Appearance Acceptance Criteria

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 (plug through seals) must not be damaged by the core, and may require core depressors and strip length control to depress the core in front of the core wing.

3. End of insulation

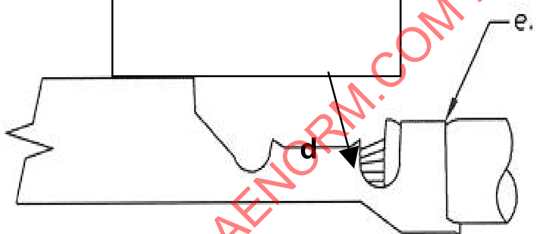
   The end of the insulation must be visible in the window between the conductor crimp wings and the insulation crimp wings such that conductor is visible and should be centralized as much as possible. In no case may insulation be crimped in the conductor crimp.

4. Cut-off

   a. The cut-off length shall not exceed 0.5 mm unless otherwise specified on the component print.
   b. The burr on the cut-off must not exceed 0.3 mm unless otherwise specified on the component print.
   c. The cut-off and burr must not affect the insertion function of the terminal into the connector.

5. Bellmouth (Flare)

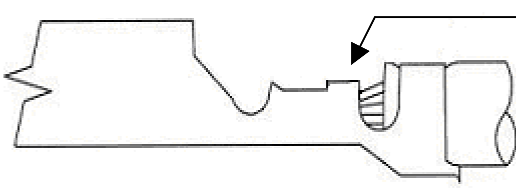
Bellmouth (Flare) is required here.



The conductor crimp (d.) shall have a bellmouth (flare) on the side of the grip nearest the insulation crimp.

The conductor crimp may also have a bellmouth (flare) on the front edge of the conductor crimp, nearest the terminal body.

Bellmouth (flare) on the insulation crimp (e.) should not exceed the insulation crimp tolerances.



Two Stage Conductor Crimp (Flare not required on second stage)

6. Conductor Crimp

   All individual strands must be enclosed in the crimp. Crimps with strands lying outside the crimp or broken off before the crimp, are not permitted.

7. Insulation Crimp

   a. The purpose of the insulation crimp is to add strain relief to the conductor crimp.
   b. The Insulation Crimp must contact the surface of the insulated cable in at least 3 locations around the circumference of the Crimp (three point contact).
   c. The Insulation Crimp dimensions are reference dimensions.
   d. The Insulation Crimp must not interfere with any subsequent operations.
   e. The Insulation Crimp must not interfere with seating of a terminal into a plastic connector cavity
   f. The Insulation Crimp must not damage the cable (see Paragraph 4.3.5-3)

8. Cable Conductor Appearance prior to crimping

   a. Strands shall not be cut, missing, excessively nicked (strand area reduction which may affect pull-out force), or elongated.
   b. Insulation shall not be stuck or imbedded in strands.

9. Individual Cable Seal

   a. The seal must be firmly secured by the insulation crimp.
   b. The seal must show no signs of damage.
   c. The end of the seal neck must be visible in the area between the insulation crimp and the conductor crimp.
   d. The cable insulation must be visible under the seal.

4.3 Cross-Section Analysis

4.3.1 Purpose

Cross-sectional analysis is used as a diagnostic 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 sample for each crimp height to 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

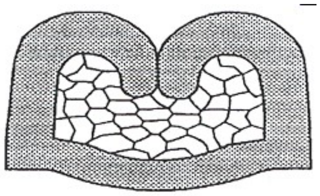
1. Cross-section and photograph each sample for analysis
2. Cross-section analysis shall be performed on all conductor crimp applications at each crimp height setting (nominal, min. and max. tolerance).
3. Cross-sections shall be performed between the serrations, as near to the mid-point of the core crimp as possible.
4. Compare the samples to the acceptance criteria of paragraph 4.3.5.

4.3.5 Acceptance Criteria

Acceptance criteria for the cross-sectioned samples are describe below.

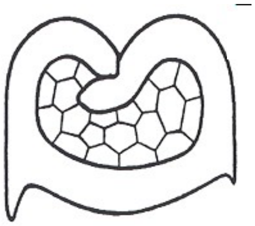
1. Cross-section views of conductor crimp

Conductor crimp attributes considered ideal



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

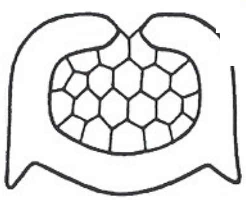
Conductor crimp attributes considered undesirable



Overlapping wings

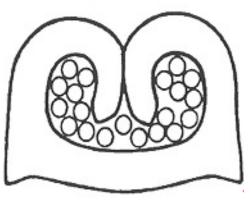
Extreme “ram-horning”

Conductor crimp attributes considered unacceptable

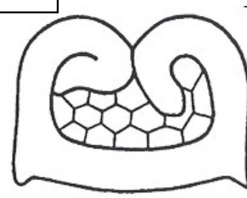


Open wings with conductor exposed or folded down into core but not touching (not locked)

One or both wings (grips) penetrate (“crash”) to the terminal floor or wall

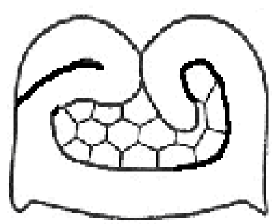


No strand compaction



One or both wing (grip) details do not capture strands

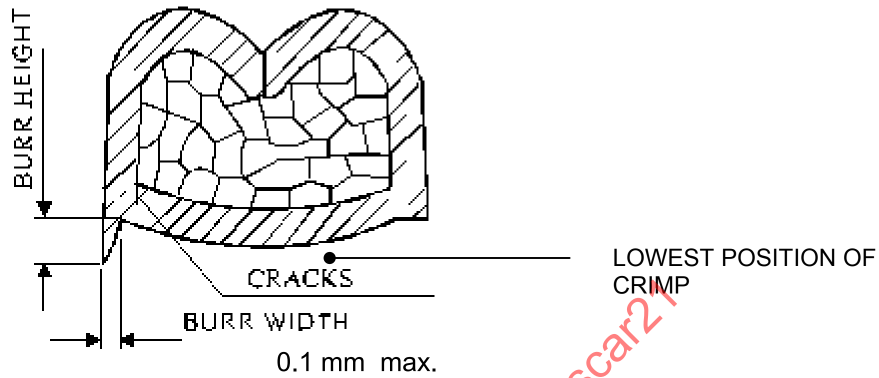
Terminal stock cracked / broken



One or both wings folded back

Note: With OEM customer approval, the above attributes listed as unacceptable may be considered acceptable if it can be shown that all other requirements of this specification are met and past production experience has shown them to be functional in the intended application.

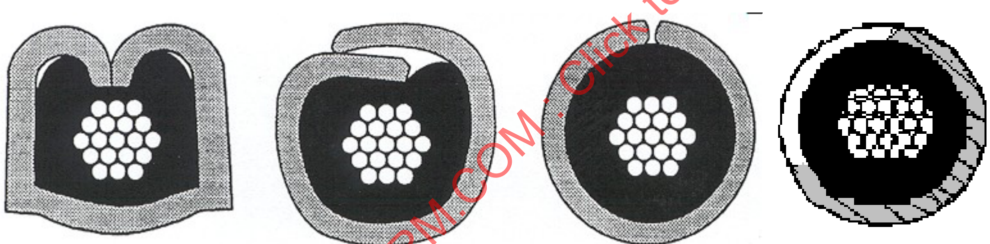
2. Burr on the base of crimp



a. The width of any burr on the base of the crimp must not exceed 0.1mm. (For accurate crimp height measurement, it is recommended that the burr height does not exceed the lowest position of the crimp.)
b. The burr must not cause damage to any subsequent operation. Special care must be taken when using mat seals.

3. Cross-section views of insulation crimp

Standard insulation crimp attributes considered ideal

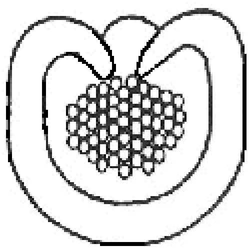


- Symmetric crimp
- No insulation penetration
- Wings (grips) embrace insulation to provide adequate strain relief

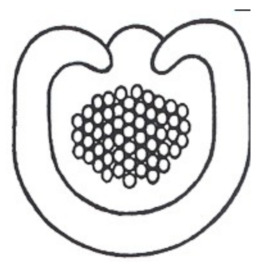
Some examples of non-standard insulation crimps include ”tee-pee” (“tear drop”), ”square”, and ”tall B”.

Refer to the terminal manufacturer’s recommendations for acceptable/unacceptable non-standard insulation crimp attributes.

Insulation crimp attributes considered undesirable

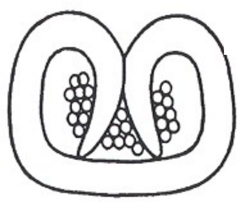


Insulation wings contact conductor (no damage to conductor)

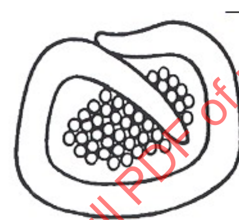


Insulation extruded outward between open insulation wings

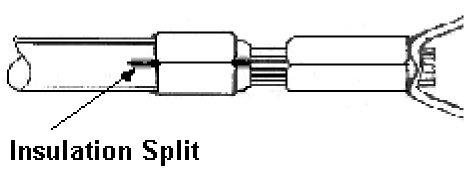
Insulation crimp attributes considered unacceptable

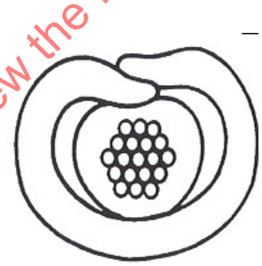


One or both wings (grips) penetrate ("crash") to the terminal floor or wall



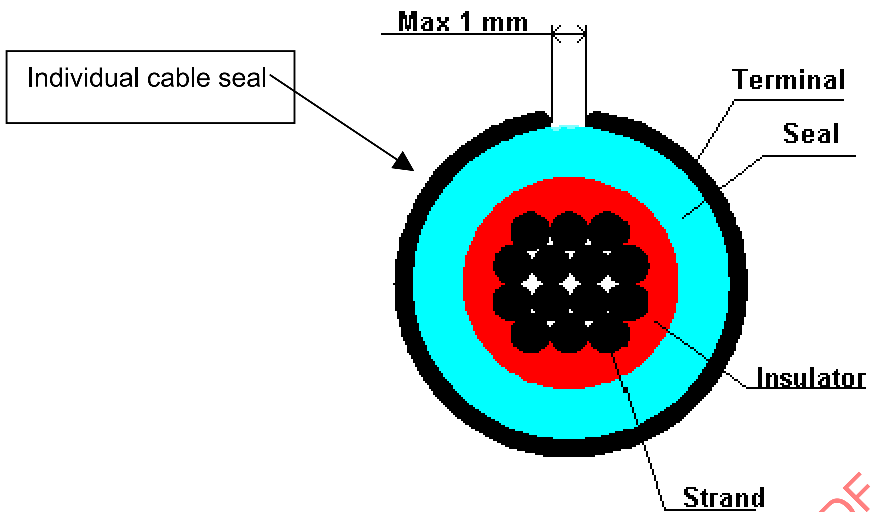
One or both wings (grips) penetrate and damage the conductor



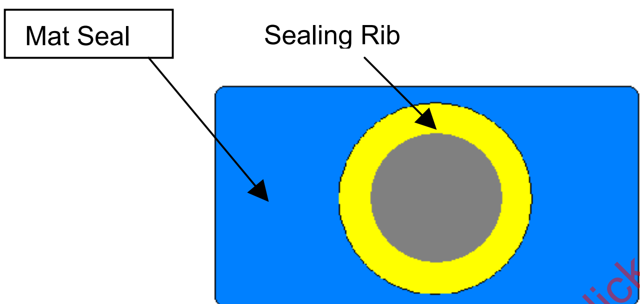


Inadequate strain relief

4. Cable Seals



No nicks or cuts are permitted in the seal neck or in the sealing ribs. Insulation crimp wings are not permitted to penetrate into the seal neck.



Crimped terminal and wire attributes must be designed to avoid damage (such as nicks and cuts) to the sealing ribs when inserting terminated leads through mat seals.

4.4 Conductor Crimp Pull-Out Force

4.4.1 Purpose

This procedure details a standard method to measure the retention capability of crimped connections.

Note: Pull-out force test will not be used to determine electrical performance of the crimp application. It will only be used to determine the mechanical limits of the crimp application for handling purposes

4.4.2 Equipment

1. Measuring device capable of measuring crimp heights and widths.
2. De-crimping tool, or other suitable means of opening insulation crimps without damaging the cable conductor. (Note: it is acceptable to make the samples with the insulation crimp not crimped to avoid this step.)
3. Force tester
4. Cable strippers, long-nose pliers and/or side cutters.

4.4.3 Samples

1. A minimum of 20 samples is required to be tested for each production crimp height. Data shall be obtained and recorded for minimum, maximum, and nominal production crimp heights.
2. Samples shall be applied to appropriate cable with overall length no less than 150 mm.

4.4.4 Procedure

1. Pull-out force test shall be performed on leads with the insulation crimp wings open (not crimped).
2. Pull-out force test shall be performed on taut leads (i.e., remove slack in cable before performing pull-out test to prevent incorrect test results due to “jerking”).
3. Refer to Appendix E, 7-9. Measure and record the conductor crimp and insulation crimp heights and widths in millimeters for each sample.
4. If the insulation crimp is not already open, open the insulation crimp with the de-crimper or other suitable tool so that the pull-out force will reflect only the conductor crimp connection.
5. Visually inspect the de-crimped area to ensure that none of the conductor strands have been damaged. Do not use any samples that have damaged conductor strands.
6. Measure and record pull-out forces in Newtons for each sample.
7. Apply an axial force at a rate between 50 and 250 mm/minute (100 mm/min. is recommended).
8. For double, triple, or multiple crimp setups with conductor sizes within one step, pull the smallest conductor. (e.g. for a .35/.50 double, pull the .35mm^2 wire)
9. For double, triple, or multiple crimp setups with conductor sizes more than one step apart, each cable must be tested. (e.g. for a .50/1.0 double, pull both wires individually)
10. Calculate the mean and standard deviation using the following formulas:

$$\text{Mean } (\overline{X}) = \frac{\sum_{i=1}^{n} X_i}{n}$$

Where X_i = individual pull-out force.
n = number of samples.

$$\text{Standard Deviation (s)} = \sqrt{\frac{\sum_{i=1}^{n} X_i^2 - n\overline{X}^2}{n-1}}$$

Report minimum, maximum, mean ($\overline{X}$), standard deviation (s), and the mean minus three standard deviations ($\overline{X}$ -3s) for each crimp height set.

11. Report any observations from visual examination.

4.4.5 Acceptance Criteria

1. The ($\overline{X}$-3s) value of the pull-out forces are specified in Table 4.4.5. The pull-out forces for unlisted conductor sizes can be defined by linear interpolation, (i.e. read out from plotted values in Table 4.4.5).

Approx. Metric (mm^2)	AWG	($\overline{X}$-3s) And Minimum Pull-out Force (N)
0.22	24	40
0.35	22	50 (Annealed Core)
0.35	22	70 (Hard Drawn Core)
0.5	20	75
0.8	18	90
1.0	16	120
1.5		150
2.0	14	180
2.5		210
3.0	12	240
4.0		265
5.0	10	290
6.0		320
8.0	8	350

TABLE 4.4.5 – Pull-out Force Requirements

4.5 Electrical Performance Tests

4.5.1 Current Cycling of Electrical Terminations (ECC)

4.5.1.1 Purpose

Current cycling is an accelerated aging test that emphasizes the effect of expansion and contraction of terminal interfaces and conductor crimps as a result of thermal cycling. This test is optional (see table 5.1). The Accelerated Environmental Test (paragraph 4.5.2) may be done in place of this test for Power applications. (see table 5.1)

4.5.1.2 Samples

1. Any engineering development, prototype, or production terminal – particularly those intended for high current or “Power” applications – may be submitted for test.
2. Test data will be collected on 10 samples of each crimp height. Data shall be obtained and recorded for minimum, maximum and nominal production crimp heights.
3. In cases where mating terminals are available, apply these to the opposite ends of the test sample cables. These should be a minimum cut length of 150mm. The terminal crimps on the mating terminals may be soldered. Samples are then connected to form a continuous series circuit.

4. Test sample terminals that have no mating terminals should be applied to one end only of the test cable (a minimum cut length of 150 mm). The opposite stripped ends of the samples are then soldered to box or blade of the next sample to form a continuous series circuit.

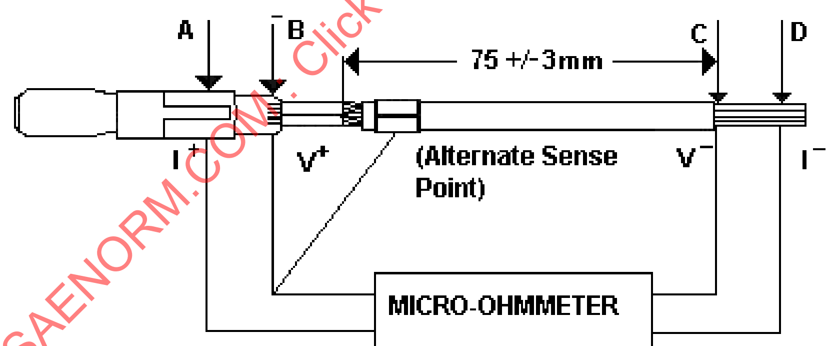
5. Doubles should be terminated with the test terminal on one end only. A mating terminal may be applied (with the crimp soldered) to the other end of the largest size cable. When identical size cables are doubled, cables should be randomly tested.

4.5.1.3 Equipment

1. Power supply – AC or DC current regulated capable of supplying the test current.
2. Cycle timer.
3. Ammeter or current shunt/voltmeter
4. Voltmeter.
5. Voltage sense lead – solid conductor .32 mm or smaller in diameter.
6. Welder – Tweezer Weld TW-3 or similar device.
7. Terminal test board.
8. Sample with solder added to the conductor crimp (soldered sample).

4.5.1.4 Procedure

1. Perform a visual inspection of components per paragraph 4.2.
2. Voltage sense leads are attached to the sample terminals per figure 4.5.1.4. The same location must be used for all samples.



(Note: The V + test lead may be connected to back of insulation wing **if wing does <u>not</u> touch the core)**

FIGURE 4.5.1.4 – Test Lead Attachment

3. Sense leads are also attached to the test cable at a point 75 ± 3 mm from the rear edge of the conductor crimp.
4. Samples are then connected in a series circuit.
5. The samples are then loosely attached to a test board with a minimum of 35mm between single terminals.

6. The series test circuit is connected to the ammeter / current shunt and a timer-controlled power supply. Include the soldered test sample in the circuit (4.5.1.3-8)
   The test duration shall be a minimum of 200 ± 8 hours with the test current cycling on for 45 minutes ± 2 minutes and off for 15 minutes ± 2 minutes.
7. The typical test currents are listed in table 4.5.1.4 unless otherwise specified.

Cable Size*	AWG	Amperes with Cable rated to +55°C
0.22mm²	24	6
0.35mm²	22	10
0.5mm²	20	14
0.8mm²	18	18
1.0mm²	16	22
2.0mm²	14	30
3.0mm²	12	40
5.0mm²	10	65
8.0mm²	8	100

*The test currents for conductors sizes not listed above can be defined by linear interpolation (i.e. read out from plotted values).

TABLE 4.5.1.4 - Test Current for Current Cycling

8. If test currents are not known, then, at room temperature:
   Attach thermocouples to samples at a point on the under-side and just in front of the crimp. Welding or epoxy is permissible.

   a. Apply 0.50 Amps to the circuit.
   b. Allow the circuit to come to steady state temperature (At least 10 minutes.)
   c. Measure the temperature, and calculate the temperature rise.
      If the temperature rise is less than the maximum temperature rise recommended by the terminal supplier or 55°C, whichever is lower, then increase the current in 0.50 Amp steps until that temperature is reached.

9. The current at which the maximum temperature rise recommended by the terminal manufacturer or 55°C, whichever is lower, is reached is the test current.
10. An acceptable alternative to a, b, and c above is to perform the “Maximum Test Current Capability” test identified in USCAR-2.
11. Measure voltage drop after 2 hours ± 1 hour and at the completion of the test (200 hours ± 8 hours). The samples should be energized for a minimum of 30 minutes to allow for temperature stabilization. Measurements are taken between points B & C. (see Figure 4.5.1.4)
12. Measure the voltage drop across the soldered sample.
13. Crimp interface voltage drop is equal to the voltage drop recorded in step 11 less the soldered sample value measured in step 12.

14. Record:

   a. All voltage drop measurements, and all calculated resistance values.
   b. Average, low, and high resistance values for each data set.
   c. Description of samples.
   d. Conditions of test.
   e. Instruments used, the date of last calibration, and when the next calibration is due.
   f. Soldered sample resistance value if applicable.
   g. Temperature rise on at least one part in the nominal CCH group
   h. Observations.

4.5.1.5 Acceptance Criteria

1. All samples within 3 consecutive crimp heights representing the lower, nominal, and upper specification limits per the conductor crimp height tolerances of Appendix E, Table E-1 must satisfy one of the following two acceptance criteria upon completion of the electrical current cycling test (ECC)

   a. Maximum allowable resistance = 0.55 milliOhms, or $0.011x(\rho_1+\rho_2)/(2d)$ milliOhms, whichever is greater. (Allow 11 times the initial calculated crimp resistance)
   b. Allowable resistance change = 0.33 milliOhms, or 0.0099 x $(\rho 1+\rho 2)/(2d)$ milliohms (Allow 9.9 times the initial calculated crimp resistance), whichever is greater.

   Where ρ_1 = The resistivity of the conductor in micro-ohm-mm²/mm (For copper conductor, ρ_1 = 17.2 micro-ohm-mm²/mm per the International Annealed Copper Standard)
   ρ_2 = The resistivity of the base terminal material in micro-ohm-mm²/mm
   d = The diameter of a circle with the same area as the total cross sectional area of the conductor in mm.
   $(\rho_1+\rho_2)/2d$ = Theoretical Crimp Resistance based upon geometry and resistivity of terminal and cable.

   c. Refer to Appendix D, Table D-1 and D-2 for the calculated values for typical referenced alloys.

4.5.2 Accelerated Environmental Test

4.5.2.1 Purpose

This procedure describes the testing of electrical components when subjected to sequential environmental exposure.

4.5.2.2 Samples

A minimum of 10 terminal samples of each crimp height shall be tested. Data shall be obtained and recorded for minimum, maximum and nominal production crimp heights. Minimum cable length for samples is 150mm.

4.5.2.3 Equipment

1. Micro-ohmmeter
2. Humidity chamber.
3. Forced air.
4. Temperature chamber.
5. An automatic temperature/humidity cycling chamber may be used as an alternative to items 2, 3, and 4 above.

4.5.2.4 Procedure

Complete the test procedure per figure 4.5.2.4

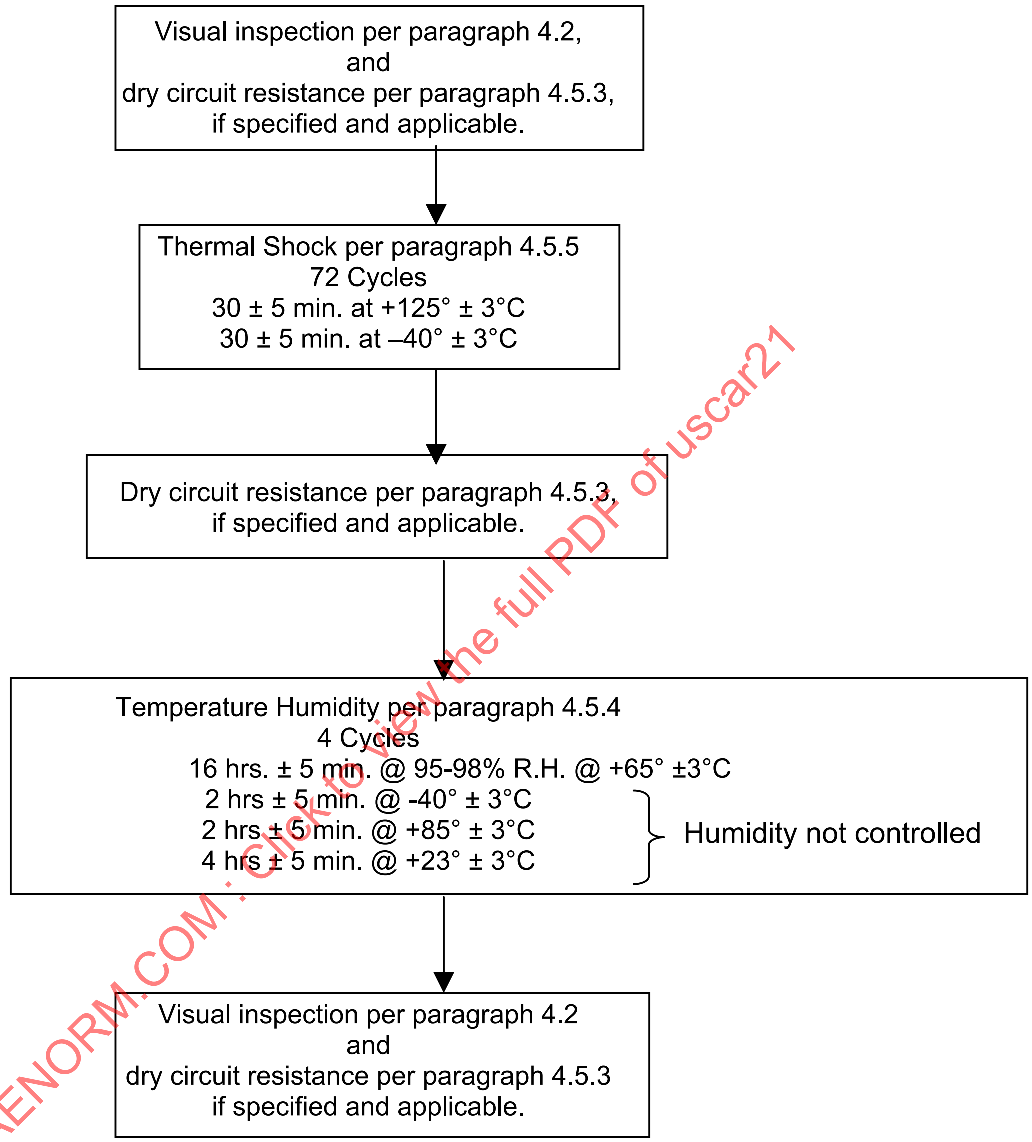


FIGURE 4.5.2.4 - Accelerated environmental test sequence [flow diagram]

4.5.2.5 Acceptance Criteria

1. All samples within 3 consecutive crimp heights representing the lower, nominal, and upper specification limits must satisfy one of the following acceptance criteria upon completion of the Accelerated aging test (ENV).

   a. Maximum allowable resistance = 0.55 milliOhms, or
      $0.011x(\rho_1+\rho_2)/(2d)$ milliOhms, whichever is greater. (Allow 11 times the initial calculated crimp resistance)
   b. Allowable resistance change = 0.33 milliOhms, or
      $0.0099 \times (\rho 1+\rho 2)/(2d)$ milliohms (Allow 9.9 times the initial calculated crimp resistance), whichever is greater.

   Where ρ_1 = The resistivity of the conductor in micro-ohm-mm²/mm
   (For copper conductor, ρ_1 = 17.2 micro-ohm-mm²/mm per the International Annealed Copper Standard)
   ρ_2 = The resistivity of the base terminal material in micro-ohm-mm²/mm
   d = The diameter of a circle with the same area as the total cross sectional area of the conductor in mm.
   $(\rho_1+\rho_2)/2d$ = Theoretical Crimp Resistance based upon geometry and resistivity of terminal and cable.

   Refer to Appendix D, Table D-1 and D-2 for the calculated values for typical referenced alloys.

4.5.3 Dry Circuit Termination Resistance of Static Contacts

4.5.3.1 Purpose

1. This procedure covers measuring the termination resistance of static contacts under dry circuit conditions, which will not alter that resistance by breakdown of insulating films or softening of contact asperities.
2. Dry circuit conditions require that the maximum voltage impressed across the test sample be limited to 20 millivolts, and the maximum current through the sample be limited to 100 milliamperes. Performance at these levels is indicative of interface performance at any lower level of excitation.

4.5.3.2 Samples

1. A minimum of 10 samples of each crimp height shall be submitted for test. Data shall be obtained and recorded for minimum, maximum and nominal production crimp heights.
2. Terminals should be applied to 150mm minimum length cable.
3. Prepare resistance measurement points on the test samples at a point on the cable 75 ± 3mm from the rear edge of the terminal conductor crimp.
4. Apply solder to measuring point D, figure 4.5.3.4 (stripped end of wire) to obtain consistent readings.

4.5.3.3 Equipment

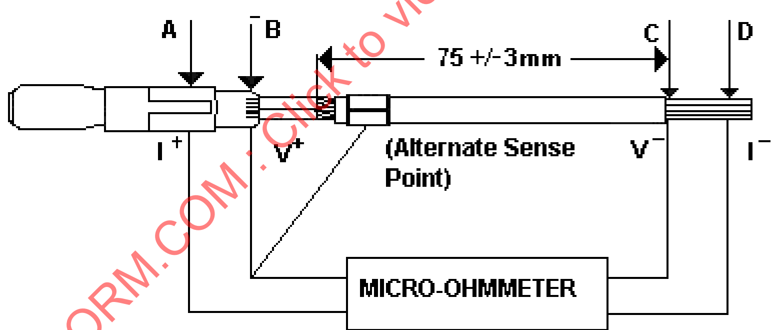
Micro-ohmmeter

4.5.3.4 Procedure

1. Perform a visual inspection of components per paragraph 4.2.
2. Measurements shall be made on thoroughly dry samples without cleaning or rinsing of corrosion products.
3. Relative movement of samples should be minimized to reduce effects of movement on measured values.
4. Measure and record the resistance of a sample with a soldered crimp. The measurement is made at a point 75± 3mm from the rear edge of the terminal conductor crimp.
5. Measure and record the resistance between the cable measuring point D and point B on the terminal, just in front of the conductor crimp (see Figure 4.5.3.4).
6. Calculate and record the crimp resistance. The crimp resistance is equal to the overall resistance measured in step 5, less the soldered sample resistance measured in step 4.

4.5.3.5 Acceptance Criteria

Maximum Dry Circuit Resistance shall meet the maximum allowable resistance shown in Appendix D, Table D-1



(Note: The V + test lead may be connected to back of insulation wing if wing does not touch the core)

FIGURE 4.5.3.4 - Dry Circuit Measurement Points

4.5.4 Accelerated Temperature / Humidity Cycle Conditioning – 24 hour cycle

4.5.4.1 Purpose

1. This procedure defines an accelerated version of temperature/humidity cycle conditioning.
2. Accelerated temperature/humidity cycling conditioning may be used to determine the effect of sequential exposure to high humidity and high and low temperature environments on electrical and electronic components.
3. High and low temperature and high humidity environments may promote corrosion of metals, degrade properties of other materials, and establish electrical bridging between circuits.

4.5.4.2 Samples

Prepare samples per para 4.5.3.2.

4.5.4.3 Equipment (Recommendations only)

1. Humidity chamber.
2. Forced air oven.
3. Temperature chamber.
4. Automatic temperature/humidity cycling chamber. This equipment may be used as an alternative to that listed in paragraphs 1, 2, and 3 above.

4.5.4.4 Procedure

1. Expose test samples to temperature/humidity cycling as follows:

   a. 16 hours @ 95-98 percent relative humidity at +65 ± 3 °C. This is the only step where humidity is controlled.
   b. 2 hours @ -40 ± 3 °C.
   c. 2 hours @ +85 ± 3 °C.
   d. 4 hours @ +23 ± 3 °C.

   Humidity not controlled

   e. This constitutes one complete temperature/humidity cycle.
   f. Maximum transfer time of samples from one environmental chamber to the next during the defined cycle is 5 minutes.
   g. All time periods listed in the defined cycle have a tolerance of ± 5 minutes
   h. Four cycles of the environmental exposure described above constitutes a complete temperature/humidity cycling test.

4.5.4.5 Acceptance Criteria

This is a conditioning procedure only. There are no acceptance criteria.

4.5.5 Test procedure - Thermal Shock Conditioning

4.5.5.1 Purpose

This test specification details the procedure for testing the functional reliability of electrical and electronic components when subjected to alternating high and low temperature environments. Rapid transfer between the two environments tests the component's ability to withstand drastic temperature changes.

4.5.5.2 Samples

1. Make certain that the cable insulation can withstand the rigors of the test conditions.
2. Prepare samples per para. 4.5.3.2.

4.5.5.3 Equipment

Thermal shock chamber or separate hot and cold chambers.

4.5.5.4 Procedure

1. Perform visual examination per paragraph 4.2.
2. Perform dry circuit resistance, per paragraph 4.5.3.
3. Set controls to the necessary temperatures, dwell times, and number of cycles.
4. Allow the chambers sufficient time to achieve the programmed temperature.
5. Place the samples in the transfer basket. Insure that the test samples cannot jam the transport mechanism.
6. Start the test program per figure 4.5.5.4.

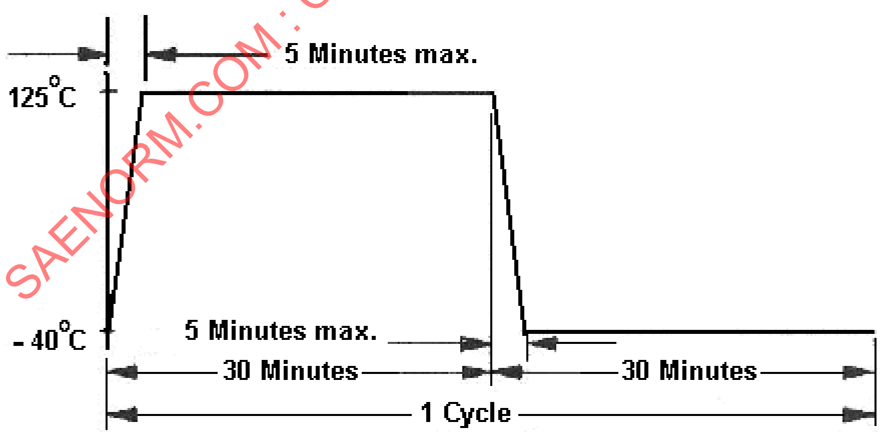


FIGURE 4.5.5.4 - Thermal Shock Programming and Operation

7. When test program is complete, shut off the thermal shock chamber and remove samples.
8. Perform visual examination per paragraph 4.2.
9. Perform dry circuit resistance per paragraph 4.5.3.
10. Include in the report:
    - Operating temperatures, dwell times, and number of cycles tested
    - Report on evaluation tests, if performed.

4.5.5.5 Acceptance Criteria

1. Samples shall meet the acceptance criteria of the Dry Circuit Test, Para. 4.5.3
2. Samples shall meet the acceptance criteria of the Visual Inspection, Para 4.2.3

5. VALIDATION REQUIREMENTS FOR CRIMPED TERMINALS - SUMMARY

5.1 Validation Test Requirements

Test	Requirement Paragraph Number.	Design Validation (Yes/No)	Minimum Conformance to Tolerance
Cable/Terminal/Crimp Tooling Identification traceable to Performance Testing	Appendix E	Y	100%
Compaction (Verified in production by Terminal, Cable, and crimp tool dimensions usually controlled by specific part numbers and traceable to validation testing.)	Appendix E, 1-2	Y	100%
Appearance	4.2.5		
- end of conductor	4.2.5-2	Y	100%
- end of insulation	4.2.5-3	Y	100%
- cut off	4.2.5-4	Y	100%
- bellmouth	4.2.5-5	Y	100%
- conductor crimp	4.2.5-6	Y	100%
- insulation crimp	4.2.5-7	Y	100%
- individual cable seal	4.2.5-9	Y	100%
-conductor crimp lock (top)	4.2.5-5	Y	100%
- terminal bend and twist due to crimping	Appendix E	N	100%
Crimp geometry	Appendix E		
- Conductor and insulation crimp height and width (CCH, CCW, ICH, ICW)	Appendix E, 7-9	Y	100 %
- cross-section requirements	4.3	Y	100%
Mechanical performance - Pull out force (Final OEM's quality assurance approval form process validation may be required.)	4.4	Y	-3s>Limit
Electrical performance	4.5		
For Power Applications: - Electrical testing Current Cycling – (ECC) or accelerated environmental testing (ENV)	4.5.1 or 4.5.2	Y	100%
For Low Energy Applications: - Accelerated Environmental testing (ENV)	4.5.2	Y	100%
For Low Impedance Applications: Validation should be done on bare copper wire to optimize crimp parameters (Production on Tinned Wire is optional) - Accelerated Environmental testing	4.5.2	Y	100%

TABLE 5.1 - Tests to be Used for Validation

5.1.1 The validation requirements listed in Table 5.1 shall be conducted to demonstrate tha the design intent is met.

5.1.2 The requirements should be conducted in the order shown in Table 5.1, to avoid unnecessary testing.

5.2 Special Applications And Exclusions

5.2.1 Special applications and variances from this specification require customer approval. Solder, sonic weld, or other processes that have proven to create an electrically stable application may be excluded from some or all of the crimp validation testing based on experience and/or sound engineering judgment. Pull-out force testing and cross-sections [PTX] are required for all validations.

5.3 Other Crimp Validation Methods

5.3.1 Reference [REF] - The application is the "same as" another similar application already validated to meet the circuit and/or customer requirements

5.3.2 “Same as" is defined as having the same:

- terminal stock thickness
- material (alloy and temper)
- the same terminal plating
- the same terminal conductor wing dimensions and features [serrations, etc.]
- the same conductor core cross sectional area

5.3.3 Cables with the same conductor core construction, but differences in the insulation may be considered the “same” for conductor crimp validation purposes. The Insulation Crimp must be reviewed against the cross section requirements for final validation

5.3.4 Customer Waiver Letter [CWL] - The customer has authorized the use of the terminal crimp as specified in a waiver letter.

5.3.5 Engineering Judgment [ENJ] – Engineering Judgment may be used in lieu of validation testing based upon past experience, knowledge, and/or testing. The basis of this judgment shall be documented. Engineering judgment shall not be used to accept applications that have failed crimp validation testing. All cases where Engineering Judgment is used must be reviewed and approved by the OEM customer.

APPENDIX A
CRIMP DESIGN RECOMMENDATIONS

A. Recommended Terminal Wing/Cable Loading for new terminal designs or revisions to meet the performance requirements of this specification is shown in Table A.

Terminal Wing/Cable Loading Ranges		
Cable Range	SAE	DIN
0.20 - 0.22	X	X
0.35 - 0.50	X	X
0.75 - 1.25	X	X
1.5 - 2.5		X
2.0 - 3.0	X	
4.0 - 6.0	X	X

TABLE A-1 - Recommended Wing/Cable Loading

B. Crimp Engineering Guidelines

The following guidelines are intended only to assist in passing the requirements of this specification and are based upon previous experience from terminal suppliers:

1. The terminal supplier determines double application terminals.
2. Core wings that have features to break oxides and minimize cable strand movement will give better electrical results. Sharp cornered serrations are preferred.
3. Tin or silver plating is the optimum design for 10 year/150K life. Avoid nickel, stainless steel inter-metallic (thermic tin) or gold in core wings. The design should provide for adequate free tin at end of life. Nickel plated high temperature wire also may not pass this electrical testing and may require specific changes in acceptance criteria based upon circuit application sensitivity (i.e. O_2 sensor circuits)
4. Optimum 10 year/150K life is obtained with similar alloys, tempers used for spring members and contact arms. This maintains crimp wing normal force with time and temperature. It also provides strength to resist crimp wing relaxation due to movement and stresses applied during vehicle life.
5. Wing blank width should be designed to provide for uniform strand dispersion for the gauge size recommended. This is necessary for optimum electrical strand contact, pulls, and nuisance free use of crimp force process monitors.
6. Crimp electrical performance should be done separately from connector testing. This is done so that a low and stable milli-ohm acceptance criteria can detect the loss of strand contacts in the crimp. Crimps that meet this criteria must then be able to pass USCAR tests in connectors.

7. Pull testing must only be used to determine mechanical strength. The pull standard must not be too high resulting in over compaction and poor electrical results. Usually the best electrical performance is on the tight side of the pull vs. crimp height curve (ref. Figure A-1). Insulation wings/grips must be designed to minimize insulation penetration and provide for optimum crimp processability.
8. The preferred insulation crimp geometry is the traditional "F" or "B" crimp. Overlapping, diagonal cut bypassing wings, or butting wings may be used, but may be sensitive to crimp processing conditions. It is usually best to tool specific grip wings for heavy-wall, regular-wall, thin-wall and/or Extra Thin Wall insulations.
9. Where possible, grip wings should be designed for European, US, and/or Asian cable constructions.
10. A typical mechanical/electrical vs. crimp height curve is shown in Figure A-1.

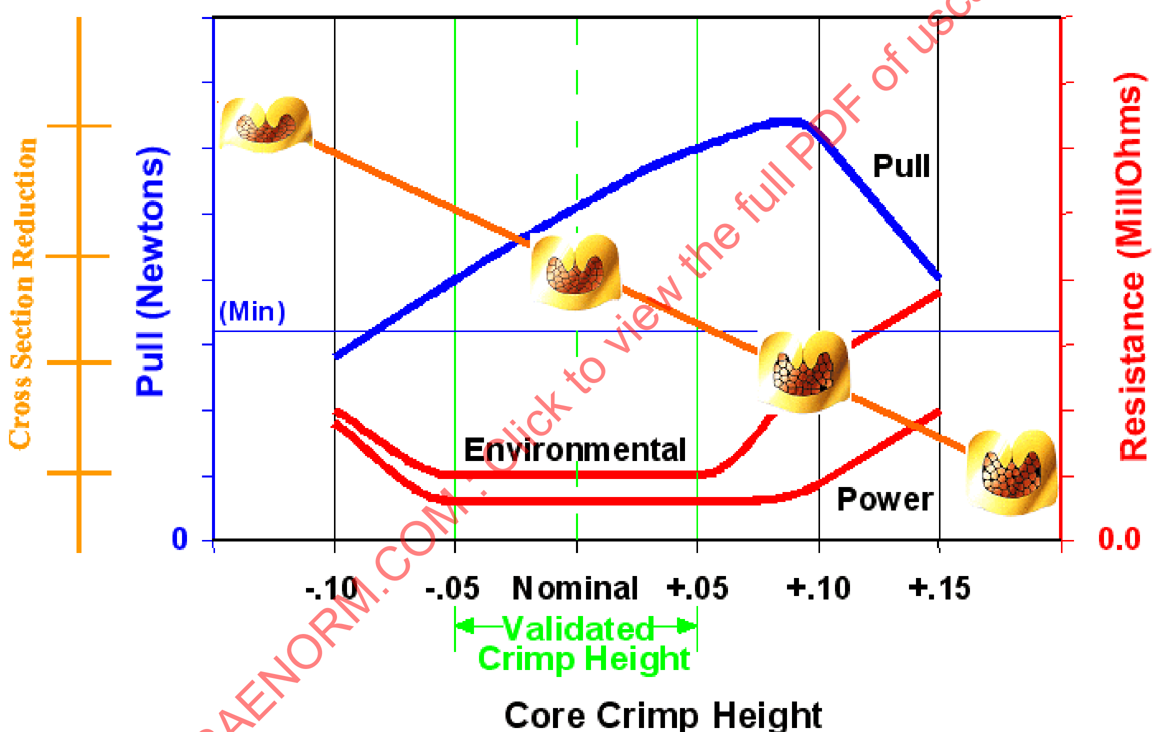
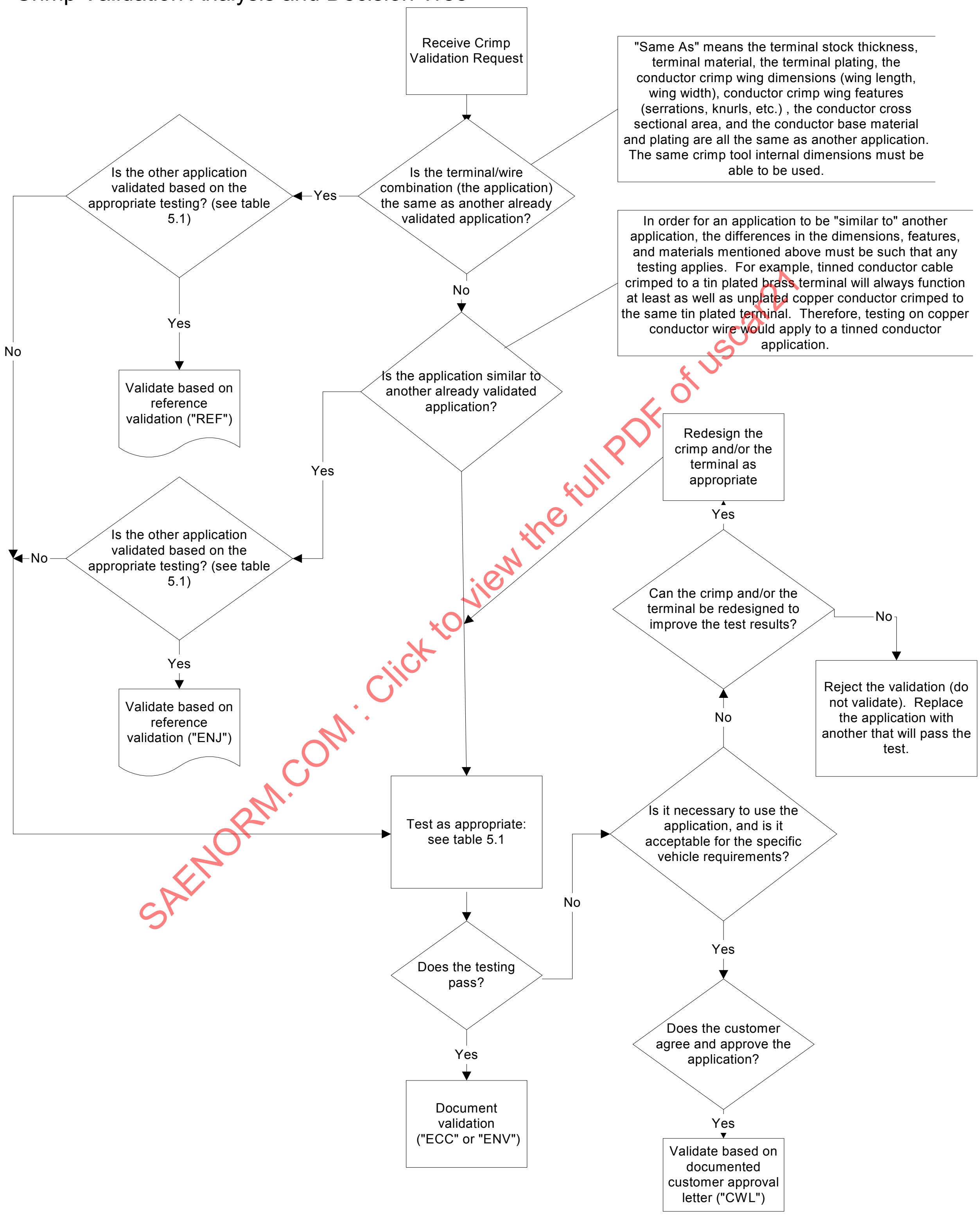


FIGURE A1

C. Crimp Validation Analysis and Decision Tree



APPENDIX B
DEFINITIONS

CABLE
An assembly made up of several strands of wire (the conductor) and its insulating covering manufactured to a specific cable specification.

COMPACTION
The reduction in cross sectional area of the combination of the terminal and cable conductor caused by crimping the terminal onto the conductor.

CONDUCTOR CRIMP FEATURES
Shapes in the conductor crimp wings, such as serrations, meant to improve the electrical connection between the terminal and the conductor.

CONDUCTOR
A part of a cable which has the specific function of carrying electrical current.

CRIMP ONLY
An application in which the only method used to connect a terminal to a cable is the terminal crimp. That is, no solder, welding or other methods are used.

CRIMPING
The physical attachment, or the process of assembling terminals to cable or components. It involves the terminal conductor/insulation crimp wings, the crimp tools, and the crimp dimensions in conjunction with the various application methods [crimp only, re-flow solder, sonic weld, etc.]

CRIMPING FORCE
The force applied by the press through the crimping tools for the re-shaping of the terminal wings around the stripped conductor during the crimping process.

DESIGN VALIDATION
Tests that are conducted to demonstrate that the design intent is met. Manufacturing must be aware of the crimp design parameters and maintain them in production.

GRIP
(Syn.: Crimp) The connection between a terminal and a cable made by deforming the grips (wings), wrapping them around the cable in a manner that creates a permanent contact.

GRIPS
(Syn.: Wings) Those parts of a terminal that are wrapped around the conductor strands or cable insulation layer making a good electrical and/or mechanical connection.

INSULATION
That part of a cable that electrically separates the conductor from the external environment. The purpose of the insulation crimp is to provide proper strain relief preventing movement to the conductor crimp.