

Performance Specification for Automotive Electrical Connector Systems

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PERFORMANCE SPECIFICATION FOR AUTOMOTIVE ELECTRICAL CONNECTOR SYSTEMS

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1. SCOPE

This specification covers performance testing at all phases of development, production, and field analysis of electrical terminals, connectors, and components that constitute the electrical connection systems in road vehicle applications that are: low voltage (0 to 60 VDC) or coaxial. Incomplete (mechanical) specifications for jacketed twisted pair connectors are also provided. These procedures are only applicable to terminals used for in-line, header, and device connector systems. They are not applicable to edge board connector systems, twist-lock connector systems, >60 VAC or DC, or to eyelet terminals.

No electrical connector, terminal, or related component may be represented as having met USCAR specifications unless conformance to all applicable requirements of this specification have been verified and documented. All required verification and documentation must be done by the supplier of the part or parts. If testing is performed by another source, it does not relieve the primary supplier of responsibility for documentation (DVP&R) of all test results and for verification that all samples tested met all applicable acceptance criteria (see 4.3).

NOTICE: If the products tested to 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. 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 variance (with supporting data) to the equipment or procedures contained in this specification. Any such deviation must be documented and included in the final test report. Guidance as to the recommended tests for selected purposes is given in the charts in Appendices C and D.

2. TEST SEQUENCE

See Appendices C and D for required tests and 5.9.2 for 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 this specification.

A glossary of terms is provided in Appendix B. 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 A.

3. REFERENCED DOCUMENTS

3.1 Document Hierarchy

In the event there is a conflict between performance specifications, part drawings, and other related standards or specifications, the OEM must reconcile the differences. Any variance for any reason where the USCAR-2 procedure or criteria is not used must be noted any place where a reference is made to the connector being USCAR-2 compliant. Requirements that typically have priority over conflicting USCAR specifications at North American OEMs are listed below for reference only:

1. Applicable FMVSS or other state and federal requirements.
2. OEM-released applicable part drawing(s).
3. OEM-released product design specification(s).

How to identify a connector as being USCAR-2 compliant:

Connector makers are encouraged to identify when a connector has passed USCAR testing. The following wording is to be used when identifying USCAR compliance: "Connector passes performance requirements of USCAR-2 revision ____." Exceptions to documented USCAR tests are: (list if applicable)." Connector systems that have met the requirements of previous revision levels of USCAR-2 may not meet the requirements of later levels. These components are compliant to the prevailing revision at the time of release of component part. To claim compliance to a newer revision level requires testing and acceptance to the revised version of all changed requirements.

3.2 Part Drawing

The part drawing for each connection system component should contain or reference:

- Dimensional requirements (which must be in GD&T format).
- Performance requirements.
- Component part number.
- Reference to applicable portions of this specification.
- The quantity and part number of terminals used.
- The typical mating connector.
- Maximum permissible temperature sealing, vibration, and ergonomic class (see 5.1.4) for which the part is intended or has been successfully tested.

3.3 Product Design Specification

The product design specification may or may not be an integral part of the part drawing. Instructions must be included in the product design specification for any special tests required for the associated part and for any exceptions or modifications to the general specifications and requirements in this document.

3.4 Test Request/Order

3.4.1 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.

3.4.2 Test Request/Order Instructions

Instructions must be included in the test request/order concerning applicable tests and the order in which the tests are to be performed if different than outlined by this specification.

3.4.3 Performance and Durability Test Instructions

Instructions must be given in the test request/order concerning limits for performance and durability tests, including definition of the conditions under which those limits apply, if they are different than outlined in this specification.

3.5 Documents Mentioned in This Specification

- SAE/USCAR-17 Performance Specification for Automotive Coaxial Connectors
- SAE/USCAR-21 Performance Specification for Cable-to-Terminal Electrical Crimps
- SAE/USCAR-25 Ergonomics Specification for Electrical Connections
- SAE/USCAR-49 Performance Specification for Miniature Automotive Coaxial Connectors
- AIAG MSA-4 Measurement Systems Analysis Reference Manual
- IATF 16949 Automotive Quality Management Standard

4. GENERAL REQUIREMENTS

4.1 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 TS16949 and AIAG policies and practices.

4.2 Sample Documentation

All test samples shall be identified in accordance with the requirements of IATF 16949 and the AIAG MSA-4.

4.3 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.

4.4 Test Conditions and Tolerances

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

Table 4.4 - Tolerances and test conditions

Temperature	±3 °C
Voltage	±5%
Current	±5%
Resistance	±5%
Length	±5%
Time	±5%
Force	±5%
Frequency	±5%
Flow Rate	±5%
Sound	±5%
Speed	±5%
Pressure	±5%
Vacuum	±5%
Rel. Humidity	±5% (when controlled)

2. When specific test conditions are not given elsewhere in this specification, the following basic conditions apply:

- Room temperature = 23 °C ± 5 °C
- Relative humidity = ambient (uncontrolled as in lab ambient conditions)
- Voltage 14.0 VDC ± 0.1 VDC

4.5 Equipment

Neither this list nor the list in each test section is all-inclusive. It is meant to highlight specialized equipment or devices with particular accuracy requirements.

Table 4.5 - Equipment

Item	Description	Requirements
1	DC Power Supply (Regulated)	0-20 V, 0-150 A
2	Micro-Ohmmeter	0-20 mV, 0-100 mA (Limits the open circuit voltage to 20 mV and current to 100 mA. The micro-ohmmeter must also use either offset compensation or current reversal methods to measure resistance.)
3	Digital Multimeter (DMM)	Capable of measuring the following at an accuracy of ≤0.5% of full scale: ⇒ 0-50 VDC ⇒ 0-10 MΩ
4	Current Shunts	100 mA or as required with accuracy of ±1% of nominal
5	Millivolt Meter	Capable of measuring 0-100 mV DC at 0.5% full scale
6	Thermocouples	Type “J” or “T” and as required
7	Insertion/Retention Force Tester	Capable of 1.0% accuracy, full scale
8	Data Logger	As required
9	Temperature Chamber	-40 to +175 °C or as required by temperature class, 0 to 95% RH
10	Vibration Controller	As required
11	Vibration Table	2640 N (600 pounds) sine, 2200 N (500 pounds) RMS force (certification to V4 level may require larger capacity)
12	Vacuum	As required
13	Megohmmeter	Accuracy <5% of full scale, capable of testing at 500 VDC
14	High Pressure Spray Equipment	See 5.6.7.2
15	Decibel Meter	±1.5 dB “A” scale
16	Seal Retention Test	Variable speed motor with rotating table. See 5.4.13.2.
17	Network Analyzer (for testing coax circuits only)	Per USCAR-17 or USCAR-49 as applicable

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.

4.6 Measurement Resolution

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.

4.7 Test Repeatability and Calibration

All equipment used for test sample evaluation shall be calibrated and maintained according to the applicable standards and requirements set forth by IATF 16949 and the AIAG publication Measurement Systems Analysis Reference Manual. Copies of this manual can be obtained from the AIAG. (See Appendix B for contact information.) Documentation is to be recorded and retained in accordance with 4.1 of this specification.

4.8 Conformance Determination

Conformance shall be determined by the specified requirements of the test being conducted. All samples must satisfy the requirements regardless of sample age, test cycles, or test temperature.

4.9 Disposition of Samples

Should premature nonconformance occur during a test, contact the authorized person to determine if the test is to be continued to gain additional product experience or if testing is to be suspended or terminated. When contact cannot be immediately made, the type of test shall determine the disposition of the samples. If the test order indicates that the test is investigative in nature, continue until the requesting party or parties are available. If the test order is for sample approval or validation, stop the test until the requesting party can be contacted. If the test must be stopped or terminated for any other reason (safety, equipment failure, etc.) the authorized person must be contacted for concurrence before the test is restarted. The test request/order should always specify desired sample disposition at the conclusion of the applicable testing.

4.10 Part Endurance

Successful completion of the requirements of this specification is intended to demonstrate that the design and construction of the components and connector systems tested are capable of operating in their intended vehicle environment and application for 200000 miles.

5. TEST AND ACCEPTANCE REQUIREMENTS

5.1 General

The test procedures that follow were written as steps and intended to be performed as specified in 5.9.3 to 5.9.9 as shown in Appendices C and D.

5.1.1 Performance Requirements

Connection systems must meet all performance test requirements for the appropriate class as listed in 5.1.4.

5.1.2 Dimensional Characteristics

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

5.1.3 Material Characteristics

Parts are intended to be in their “as furnished for vehicle assembly” condition when testing begins, unless specific instructions as to any pre-test “conditioning” are contained in the test request/order. For example, electrical terminals typically have residual die lubricant on them when finally assembled into a vehicle. This same condition must prevail over test samples unless part cleaning is specified in the test request/order.

All material used in each test sample shall conform to the material specifications shown on the latest revision of the applicable part drawing(s). The material hardness specified for electrical terminals refers to the blank strip material and not the finished product because the terminal manufacturing process can modify the hardness values.

5.1.4 Classifications

Components to be tested must be assigned a class from Table 5.1.4.1 according to the expected environment in their intended vehicle application. Include the classifications to use in the test request/order and the report of results.

5.1.4.1 Temperature Classification

Components to be tested must be assigned to a temperature class from Table 5.1.4.1 according to the expected environment in the intended vehicle application. See Appendix E for design notes helpful to proper selection.

Table 5.1.4.1 - Component temperature classes

Temp. Class	Ambient Temperature Range	Typical Application
T1	-40 to + 85 °C	T1 is not recommended for new applications
T2	-40 to +100 °C	Suitable for use in passenger compartment
T3	-40 to +125 °C	Suitable for use in the engine compartment
T4	-40 to +150 °C	Needed for some on-engine applications near hot components
T5	-40 to +175 °C	For use as needed -- no specific applications are identified as T5

5.1.4.2 Sealing Classification

Components to be tested must be assigned a class from Table 5.1.4.2 according to the expected environment in the intended vehicle application.

Table 5.1.4.2 - Component sealing classes

Seal Class	Common Name	Typical Application
S1	Unsealed	S1 is suitable for use in passenger compartment or other dry areas on a vehicle such as the trunk
S2	Sealed	S2 is intended for connectors exposed to water
S2.5	Sealed Against Low Pressure Spray	S2.5 is intended for exposed locations at risk of direct splash
S3	Sealed Against High Pressure Spray	S3 is intended for exposed locations at risk of direct high-pressure splash (or car wash spray)

5.1.4.3 Vibration Classification

Components to be tested must be assigned a class from Table 5.1.4.3 according to their intended vehicle applications. See Tables 5.4.6.3A, B, C, and D for shock and vibration schedules.

Table 5.1.4.3 - Component vibration classes

Class	Common Name	Typical Application	Other Requirements Met
V1	Chassis Profile	Components on sprung portions of vehicle not coupled to engine	None
V2	Engine Profile	Components coupled to engine with no severe vibration possible	Pass on V2 implies pass also for V1
V3	Severe On-Engine	Components subject to severe vibration	Pass on V3 implies pass also for V1 and V2
V4	Extreme Vibration	Used as needed to correlate to extreme vibration areas	Pass on V4 implies pass also for V1 and V2 and V3
V5	Unsprung Component	Wheel-mounted components	None

5.1.4.4 Ergonomic Classification

Components to be tested must be assigned an ergonomic class from the requirements in SAE/USCAR-25. This class designation shall be documented in the test plan and listed on the component drawing.

5.1.5 Testing Headers and Direct Connect Components

Cases frequently arise where only one half of a connector, usually the female half, is available and it mates directly to a Header or to a receptacle in an electrical component or device. This presents special problems for testing. In order to completely test the electrical connection, access must be gained to the terminals in the device or header. Great care must be taken in these cases so as not to introduce leak paths that are not present in the vehicle application. Where this risk is unacceptable, or making the necessary electrical connections is not feasible, the tests normally required to verify connection integrity must be modified.

Another problem sometimes arises due to the length of the terminals or buss bars in the device or header when conducting electrical tests. The general rule is to connect one of the millivolt test leads at the point where the header or device terminal attaches to the circuit board or similar point in the device. The bulk resistance of the terminal "tail" is measured and subtracted during the connection resistance calculation. However, if there is more than one "tail" length involved, but the bulk resistance per unit length is common, it may be more convenient to attach the millivolt leads at a common distance from the connection to be measured.

Therefore, in situations where there is more than 50 mm from the point of contact in the connection nearest to the header or device to the point where the terminal "tail" or buss bar connects to the device, these two options are available. (1) Attach the millivolt lead at a convenient common distance 30 to 50 mm from the contact to be measured. Then subtract the bulk resistance of the selected common length when calculating the resistance of the associated header or device connection. (2) Measure bulk resistance of each individual header terminal or component buss bar from the connection to be measured to the point of millivolt lead attachment and subtract this resistance when calculating the resistance of the associated header or device connection. When attaching millivolt leads, take care that the heat applied does not damage plating or cause stress relaxation in any connection component. Application of an appropriate heat sink may be advisable. See Figure 5.1.5. Placement of the T1 lead in Figure 5.1.5 may be modified as necessary to fit the application. When using a dimension other than the 75 mm $\pm$ 3 mm it is important to measure the resistance of a sample with an equal length of the same wire type and use that result as the deduct value.

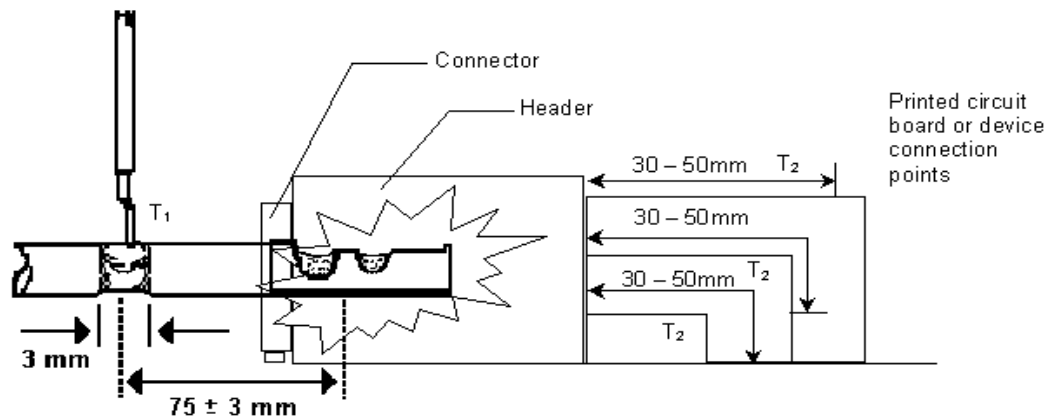


Figure 5.1.5 - Millivolt lead *T1* and *T2* attachment for headers (typical)

It may be that the electrical component or device being connected is not itself capable of withstanding the tests to which the connector is usually subjected. In these cases, samples of just the connector receptacle portion of the device must be obtained. Then the required connections for testing can be made and sealed. Leak paths in devices may need to be sealed in order to test the integrity of mating connectors. Such modifications to the device are appropriate but must be documented in the test report. In any case, the authorized person must be consulted and must approve any deviation from the normal tests of this performance specification.

5.1.6 Terminal Sample Preparation

Terminals used for testing shall be crimped to requirements as defined in SAE/USCAR-21. Crimp dimension physical characteristics and mechanical pull strength shall be within tolerance as it applies to the respective terminal and wire size. Crimp both the conductor and insulation grips unless otherwise specified in the individual test procedures. Use the appropriate cable seal as applicable. Assemble insulation displacement type terminals per their manufacturer's recommended assembly criteria. When testing header-type connectors with mating connectors, prepare samples only for the mating female connector (see 5.1.5). Record the crimp height and width of a representative group of samples of each terminal (except for insulation displacement type terminals) and number samples for tracking and later identification as appropriate. Crimp information (tooling used to prepare samples, crimp dimensions, and wire type) shall be documented in the test report. The following note applies to wire harness fabricators: Production crimps shall be tested, validated, and approved separately per SAE/USCAR-21 based on wire size, stranding, and insulation wall thickness.

5.1.7 Connector and/or Terminal Cycling

5.1.7.1 Purpose

This procedure preconditions a connection system pair or terminal system pair prior to a test sequence. Connectors may be subjected to cycling due to in-plant and/or service repair during the life of the connector. Complete this procedure only once when conducted as part of a test sequence as specified in 5.9.

5.1.7.2 Equipment

None.

5.1.7.3 Procedure

1. Completely mate and unmate each connector or terminal pair ten times. Use instructions below as applicable:
 - a. When working with terminals only, use caution to ensure that mating and unmating is done along terminal centerlines to prevent side pressure that may distort either terminal.
 - b. On connectors with shorting bars, complete the dry circuit measurement across the shorted contacts (connector unmated) per 5.3.1. Record the number for later use in calculating the resistance change as part of the dry circuit test procedure.
 - c. If connector under test is a male connector with a manual-resetting pin protection plate, reset the PPP after each unmating per instructions from connector maker.
 - d. If connector under test is a male connector with an automatic-resetting pin protection plate, visually ensure the reset of the PPP after each unmating.
2. Re-mate connectors or terminals for one last time in preparation for future test sequences or follow directions in the respective procedure to follow. If CUT is a bolt-mated connector, do the following after the final mating: Apply a continuous line in permanent marking (i.e., paint) on the bolt head and the connector housing nearby to the bolt head.

NOTE: The purpose of the marking is to locate initial bolt head position relative to the connector to allow an assessment of whether the bolt loosens during environmental testing.

5.1.7.4 Acceptance Criteria

None.

5.1.8 Visual Inspection

5.1.8.1 Purpose

This test is used to document the physical appearance of 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 appropriate 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.

5.1.8.2 Equipment

- Camera
- Video recorder
- Magnification apparatus (as required)

5.1.8.3 Procedure

1. Inspect for defects or non-functionality. Visually examine each test specimen prior to testing and/or conditioning, noting in detail any obvious manufacturing or material defects such as cracks, tarnishing, flash, 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 swelling, corrosion, discoloration, contact plating wear, physical distortions, cracks, loss of mechanical function evident, 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.
3. For CUTs subjected to test sequence Q (see 5.9.7), swelling of cable and seals is permissible within the limits of that specific material specification.
4. If CUT is a bolt-mated connector, find permanent marking line placed on the bolt head in step 5.1.7.2 #2 and assess whether the line is still aligned with the line on the connector housing near the bolt head.

5.1.8.3.1 Contact Surface Examination

At the conclusion of the test sequence M (see 5.9.6), examine terminals with the aid of 10X magnification looking for any evidence of deterioration, cracks, deformities, excessive plating wear, etc., that could affect functionality. When visual inspection follows dry circuit resistance measurement, inspect to the following (suppliers must provide criteria for plating wear pass and fail such as photographs):

- Inspect all male terminals
- Inspect all female terminals with resistance over 75% of resistance criteria
- Inspect no fewer than five female terminals

5.1.8.3.2 Sealing/Environmental Protection (Solution Intrusion)

At the conclusion of the appropriate test sequence as specified in 5.9.7 and 5.9.9, thoroughly dry the samples and then disconnect each mated sample pair and perform the visual inspection of all inside areas and sealing surfaces. When disconnecting the samples, use care not to allow any residual solution to enter the interior of any connector half. Careful examination is required to detect any trace of solution intrusion.

5.1.8.4 Acceptance Criteria

The CUT shall not show any evidence of deterioration, cracks, deformities, etc., that could affect functionality. Additional procedure-specific criteria may be listed under each test.

5.1.9 Circuit Continuity Monitoring

5.1.9.1 Purpose

Some procedures require continuous circuit monitoring of connectors during conditioning. The purpose of circuit monitoring is to detect intermittencies caused by micro-motion and resultant wear or build-up of nonconductive debris at the contact interface. Use this procedure when specified in the individual test.

5.1.9.2 Equipment

- Continuity tester (CT)
- Power supply capable of 100 mA DC

5.1.9.3 Procedure

At least ten individual terminal and five connector pairs must be monitored. On connectors with up to ten cavities, all cavities shall be monitored on the five samples. On connectors with more than ten cavities, all terminal cavities must be represented in the five samples, with a minimum of 50 terminals monitored. Monitored terminal pairs should be distributed as evenly as possible among the connectors tested. Distribution of monitored pairs should be done per the following general patterns. The authorized person shall determine the final monitoring pattern. The pattern shall be documented in the test report.

X					X
			X		
		X			
X					X

X		X		X
X		X		X
X		X		X

A pattern as defined by the “X” marks is suggested if practical

Figure 5.1.9.3 - General pattern for circuit monitoring

NOTE: Monitored terminals shall not be the same samples used for subsequent dry circuit readings for record, since the monitoring equipment may cause the potential across the circuit to exceed 20 mV. Dry circuit readings, however, may be taken as an aid in root-cause diagnosis.

Solder the conductors from each terminal in the CUT in series to form one continuous current path with only two free ends. Solder one of the free conductor ends to a 2 W, 120 Ω ± 1.2 Ω resistor. Solder the “-” (negative) lead to the free end of the resistor and the “+” (positive) lead to the remaining free conductor end of the CUT. Connect the continuity tester across the resistor, making sure that the negative lead of the CT is connected to the negative side of the resistor. Adjust the power supply to provide 100 mA to the circuit. Set the CT to monitor the current through the resistor and record any instance where that current falls below 95 mA. As an option, the CT may be used to monitor one or more terminal pairs instead of the resistor. A reference illustration of the test set-up is shown in Figure 5.1.9.3. Other suitable continuity monitoring equipment may be used. The test fixtures, system layout, and test set-up must be approved by the authorized person prior to testing.

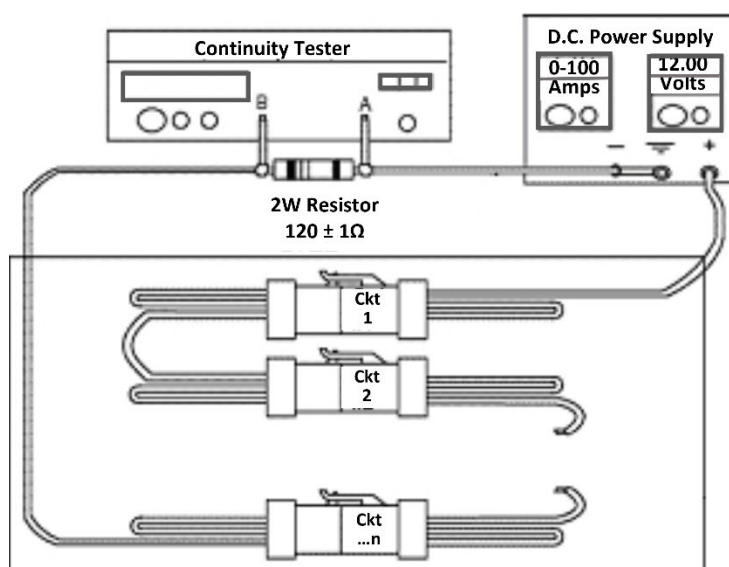


Figure 5.1.9.3 - Connector environmental test set-up

5.1.9.4 Acceptance Criteria

Where continuity monitoring is required during any conditioning procedure, there must be no loss of electrical continuity (any instance of the resistor current dropping below 95 mA), for more than 1 μ s. If one or more terminal pairs are monitored, rather than the series resistor, there must be no instance in which the resistance of any terminal pair exceeds 7.0 Ω for more than 1 μ s. Figure 5.1.9.4 illustrates the acceptance criteria graphically.

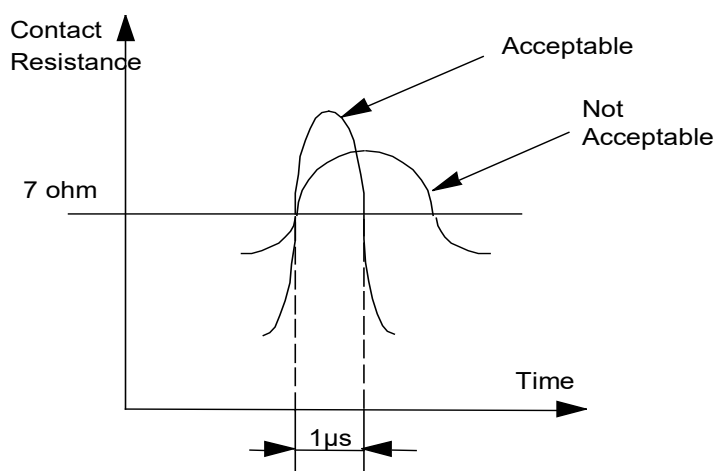


Figure 5.1.9.4 - Intermittency measurement

5.1.10 Mat Seal Sample Preparation

5.1.10.1 Purpose

This procedure preconditions a multi-cavity (mat) seal of a sealed connection system to ensure the sealing performance within the design-intent cable size range and that the terminal does not damage the seal during service operations.

5.1.10.2 Equipment

None.

5.1.10.3 Samples

Prepare two sets of ten CUT samples. Number each connector pair.

1. Ten samples prepared with terminal samples per 5.1.6 using the smallest conductor size and insulation thickness applicable to the design of the terminal to be tested and to fully populate the CUTs.
2. Ten samples prepared with terminal samples per 5.1.6 so that all but one cavity in each connector is populated with a terminal crimped to the largest applicable conductor size. The one exception is the cavity located farthest from the connector center. Fill that cavity with the appropriate terminal crimped to the smallest applicable conductor size.

5.1.10.4 Procedure

Select ten cavities at random among each sample set per 5.1.10.3 and record the connector and cavity numbers. Remove and re-insert the terminals in the selected cavities twice (insert-remove-insert-remove-insert).

5.1.10.5 Acceptance Criteria

None.

5.2 Terminal Mechanical Tests

5.2.1 Terminal to Terminal Engage/Disengage Force

5.2.1.1 Purpose

This test determines the engage and disengage forces of compatible male and female terminal pairs. Determination of the number of terminals that can be packaged in each connector design without exceeding allowable mating force limits is dependent on this information. Note that this test is written so that only the first engagement and the last (tenth) disengagement are recorded and used to verify compliance with the acceptance criteria.

5.2.1.2 Equipment

- Insertion/retention force tester with peak reading feature
- Polished steel gage (optional)

5.2.1.3 Procedure

1. Completely identify and number each terminal to be tested. A minimum of 20 samples (ten male and ten female) are required. If the optional step 8 is to be used, at least an additional ten female terminal samples will be required.
2. Fixture one male and one female terminal so that proper alignment is achieved during testing.
3. Engage the mating terminals at a uniform rate not to exceed 50 mm/min. The force shall be applied parallel to the centerlines of the terminals. Proper alignment of the terminals is critical to avoid side loads and binding which can adversely affect the force measurement.
4. Record the peak force required to completely engage the terminal to its mating part. This is for information and is not used in the acceptance criteria.

5. Disengage the mated terminals at a uniform rate not to exceed 50 mm/min. The force shall be applied parallel to the centerlines of the terminals.
6. Repeat steps 3 and 5 nine more times at a rate not to exceed 100 mm/min (no readings are taken). Record the tenth disengage force reading taken at a rate not to exceed 50 mm/min. This force is recorded for information and is not used in the acceptance criteria.
7. Repeat steps 2 to 6 for each pair (one male and one female) of sample terminals.
8. (Optional gage test) Repeat steps 2 to 7 except use the applicable gage in place of the male terminals. Use new female terminals. The applicable gage is to be of polished steel made to within 0.01 mm of nominal. Surface finish must be 0.076 to 0.305 μm (3 to 12 μin). Polish direction must be parallel to the blade/pin length. Test the additional ten production female terminal samples to determine the force correlation between polished gage and actual samples.

5.2.1.4 Acceptance Criteria

Complete the visual examination per 5.1.8 noting any wear of the contact surfaces. No base material should be exposed.

5.2.2 Terminal Bend Resistance

5.2.2.1 Purpose

This test checks for terminal resistance to bending or breaking during crimping, assembly, or service. Insufficient bend strength for the conductor size selected can lead to a high incidence of terminal damage during the assembly process. Since terminal material thickness varies so widely, and the bending force can be applied in any direction, only minimum values have been assigned to this test. Actual bending force values in each of three directions are recorded and it is then up to the authorized person to evaluate the results and determine the suitability of the tested terminal for its intended application.

NOTE: This test is not applicable to terminals where the wire attachment is 90 degrees to the direction of insertion.

5.2.2.2 Equipment

- Steel mounting fixture(s) appropriate to the terminal(s) under test
- Crosshead-style force tester with measurement capability (or weights) capable of forces in Table 5.2.2.4

5.2.2.3 Procedure

1. From Figure 5.2.2.3-1, determine which design style most closely resembles the TUT.
2. For style "A" terminals, prepare a total of at least 15 samples. For style "B" terminals, prepare a minimum of 30 terminals, to test both bend locations.

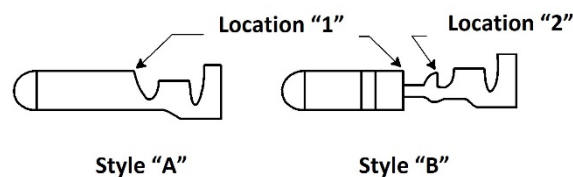


Figure 5.2.2.3-1 - Terminal design style

3. Number each terminal. Use at least five new samples for each test sequence, steps 6 to 9.
4. Mount the TUT in a fixture taking care that location "1" is positioned as shown in Figure 5.2.2.3-2.
5. Apply force to the sample as shown in Figure 5.2.2.3-2, then release. The required forces by terminal nominal size are listed in Table 5.2.2.4.
6. Inspect the area around the bend using at least 10X magnification. Note in the test report any signs of metal cracking or tearing. Straighten the terminal to its original position and re-inspect the terminal for cracks.

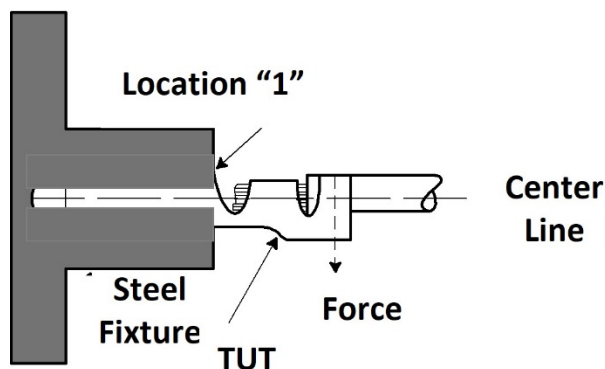


Figure 5.2.2.3-2 - Terminal bend test

7. Select a new batch of at least five samples and mount them in the test fixture with the terminal rotated 180 degrees from the position shown in Figure 5.2.2.3-2. Repeat steps 5 to 7.

Table 5.2.2.4 - Applied bending force by terminal size

Nominal Blade Size (mm)	Applied Force (N)
≤0.5 to <0.64	3.0
0.64 to <1.5	4.0
1.5 to <2.8	7.0
2.8 to <6.3	10.0
6.3 to <9.5	15.0
9.5 to <14.5	20.0
≥14.5	30.0

8. Select a new batch of at least five samples and mount them in the test fixture with the terminal rotated 90 degrees from the position shown in Figure 5.2.2.3-2. Repeat steps 5 to 7. Since terminals are typically symmetrical in this "side to side" direction, it is not necessary to test both directions. If the TUT is not symmetrical in this direction, it may be necessary to test both ways.
9. For terminal style "B" designs (see Figure 5.2.2.3-1), repeat steps 5 to 9 with each TUT mounted such that location "2" is firmly retained at the edge of the fixture.

5.2.2.4 Acceptance Criteria

The TUT must not tear when subjected to the applied force. If the TUT was bent from its original position during the test, it must not tear or crack when straightened to its original position.

NOTE: Most terminal and connector manufacturers have internal documentation regarding minimum terminal straightness required for successful processing and quality. Consult the respective supplier(s) for these requirements. This test does not override these requirements.

5.3 Terminal - Electrical Tests

5.3.1 Dry Circuit Resistance

5.3.1.1 Purpose

This test determines the combined resistance of the two conductor crimps (or single crimp in the case of a header connector) and the contact interface of a mated terminal pair in a connector, under low-energy conditions.

5.3.1.2 Equipment

- Micro-ohmmeter

5.3.1.3 Procedure

Take care to avoid any mechanical disturbance of mated terminal samples submitted for this test. Such disturbance could rupture any insulating film which may have developed on the contact surfaces. If for any reason the terminals submitted for this test are already contained in their mated connector housings, do not disconnect them unless otherwise directed by the authorized person. This procedure is typically used for mated connectors but can also be used for mated terminal pairs outside of a connector housing. Measure all conductors under test. For coax, measure center and outer conductor. For twisted pair cable, measure both cables.

NOTE: Since this test is done to detect the presence of thin insulating films that may have developed on the contact surfaces during field service or environmental type stress tests, it is important that no other electrical test be performed on the samples prior to this test.

1. Prepare samples per 5.1.6 using the cable size per the appropriate test sequence (see Table 5.9) applicable to the terminal to be tested. If terminals being tested are already inserted into a connector housing, omit this step.
2. For terminals that have been subjected to prior testing, do not disconnect their connector housings or remove any terminal from its housing.
3. Measure and record the resistance across 150 mm of the conductor to be used for the test. For tests using a header terminal as one half of the test connection, see 5.1.5 and measure only 75 mm (this is a recommended length for most applications) of the conductor.
4. For attachment points exceeding 75 mm per side, the extra wire resistance shall be measured and subtracted per step 8. Record the conductor resistance.
5. Choose the preferred method of taking measurements (e.g., soldered sense lead or probe) and document the method chosen. Figure 5.3.1.3 shows lead locations before mating terminals or inserting terminal into the connector. Sense lead must be soldered for all stranded cables. For header connectors, T_2 is attached to the header terminal per 5.1.5. Millivolt leads must be no larger than 0.22 mm². Note that Figure 5.3.1.3 shows an unplugged female (on left) and male (on right) terminal, but the same method of voltage probe attachment applies to terminals in connectors.

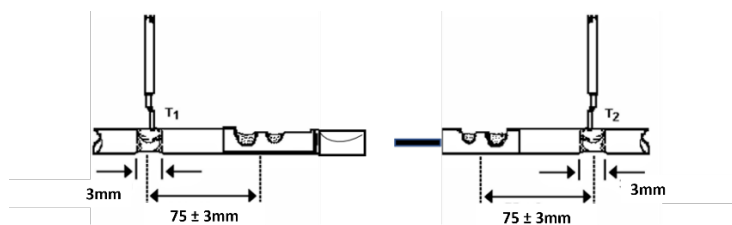


Figure 5.3.1.3 - Typical millivolt lead locations

6. If sample is a terminal with no connector housing, the male terminal must be inserted to a precise depth into the female. Standard practice is that, in the worst case, there must be at least 1 mm of excess insertion between the rearmost contact point with the female terminal and the start of any lead-in taper on the male terminal, as illustrated in Figure 5.3.1.4. This dimension is to be calculated from the terminal drawings by the authorized person, taking into account the worst-case tolerances. Each male terminal is to be suitably marked so test personnel can make the one and only mating of the test terminal pairs to the correct depth. Score marks or any other marking that might introduce contaminants or alter the strength or conductivity of the male terminal or the interface are not permitted.

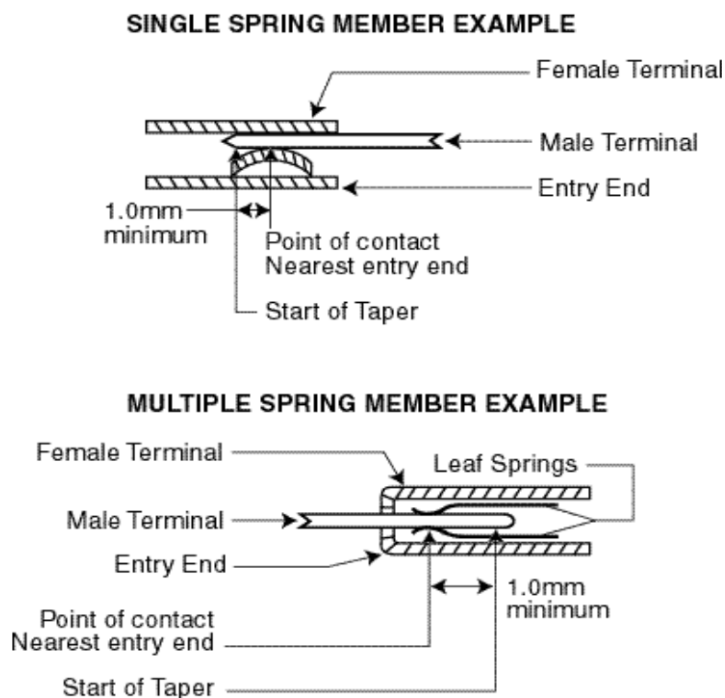


Figure 5.3.1.4 - Terminal insertion

7. If sample under test is a terminal pair with no connectors, provision must be made for mounting them on an electrically nonconductive surface in such a manner that the mechanical stability of the male to female interface can be maintained.
8. Carefully mate the test connector or terminal pair. If the sample under test is a terminal, follow these additional instructions: Mate to the appropriate depth, as specified in step 5 above. Use caution to ensure that mating is done along terminal centerlines to prevent side pressure that may distort either terminal. Secure the TUT to the mounting surface so that the correct insertion depth is maintained throughout the test.

9. Using the appropriate equipment, measure and record the resistance between T_1 and T_2 , as shown in Figure 5.3.1.3. Then deduct the conductor resistance to find the total connection dry circuit resistance.
10. Verify conformance to the acceptance criteria of 5.3.1.4.

NOTE: Taking both initial and post-test dry circuit resistance measurements is suggested. Initial values are for information only and do not have pass/fail requirements. These values can be used to compute resistance change.

5.3.1.4 Acceptance Criteria

The total connection resistance calculated in step 9 must not exceed the values listed in Table 5.3.2.4.

For connectors with shorting bars, the change in connection series resistance of both contacts while in the “shorted” position shall be $<40\text{ m}\Omega$. Other requirements may apply depending on the purpose of the shorting circuit.

5.3.2 Voltage Drop

5.3.2.1 Purpose

This test determines the voltage drop associated with the electrical resistance of the conductor crimp(s) and contact interface regions at specific current conditions. This voltage drop is then used to calculate the total connection resistance of the CUT. Voltage drop test does not apply to coax or JTP circuits.

5.3.2.2 Equipment

- Digital multimeter (DMM)
- DC power supply (0 to 20 VDC at 0 to 150 A)
- Current shunts

5.3.2.3 Procedure

1. Prepare samples per 5.1.6, using the cable size per the appropriate table test sequence. If terminals being tested are already inserted into a connector housing, omit this step.
2. If testing terminals outside of connectors, the male terminal must be inserted to a precise depth into the female. Standard practice is that, in the worst case, there must be at least 1 mm of excess insertion between the rearmost contact point with the female terminal and the start of any lead-in taper on the male terminal, as illustrated in Figure 5.3.1.4. This dimension is to be calculated from the terminal drawings by the authorized person, taking into account the worst-case tolerances. Each male terminal is to be marked so test personnel can make the final mating of the test terminal pairs to the correct depth. Score marks or any other marking that might introduce contaminants or alter the strength or conductivity of either terminal or the interface are not permitted. If testing terminals inserted into connectors (such as when performing test groups M, N, O, or P), the connector housings control terminal location and no special depth control is used.

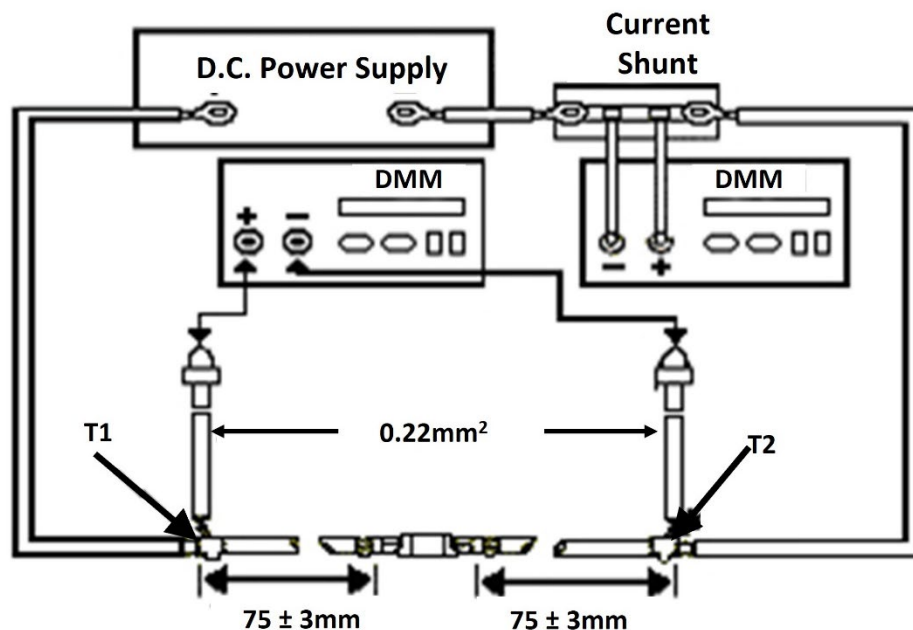


Figure 5.3.2.3 - Typical current resistance test set-up

3. If testing terminals outside of connectors, provision must be made for mounting on an electrically nonconductive surface in such a manner that the mechanical stability of the male to female interface can be maintained.
4. Carefully mate the test terminal or connector under test. If testing terminals outside of connectors, mate the terminal pair to the appropriate depth, as specified in step 2 above. Use caution to ensure that mating is done along terminal centerlines to prevent side pressure that may distort either terminal. Secure the TUT to the mounting surface so that the correct insertion depth is maintained throughout the test.
5. Assemble the test circuit shown in Figure 5.3.2.3. Adjust the power supply to provide a test current at the lower of 50 A or 5 A/mm² of conductor cross section. (Refer to ISO 19642-3, SAE J1127, or SAE J1128 for assistance to determine the cross-sectional area of the conductor.) More than one terminal or connector pair may be tested in series. See Figure 5.3.1.3 for connection resistance millivolt lead locations, for placement of the millivolt test leads. Record the test current used.
6. Measure and record the millivolt drop across the conductors only using the test current determined in step 5 (the conductors will be 150 mm of the conductor size and insulation type to be used during the test for in-line connections; for header type connectors, see 5.1.5 and measure the millivolt drop across only 75 mm of the conductor used). For attachment points exceeding 75 mm ± 3 mm per side, the extra wire resistance shall be measured and subtracted per step 9. It is recommended to attach sense leads for vibration beyond the initial retention point which will result in >75 mm leads.
7. Choose the preferred method of taking measurements (soldered sense lead or probe) and document the method chosen. In either case, the sense point T₁ (see Figure 5.3.1.3) must be soldered for all stranded cable. For header type connectors, T₂ is attached to the header terminal per 5.1.5. All millivolt leads must be no larger than 0.22 mm².
8. Set the power supply for the current determined in step 5 and wait 30 minutes minimum to ensure that the test current stabilizes at the appropriate value. Allow sufficient time for all other test equipment to warm and stabilize per the manufacturer's recommendations.

9. Using the test current determined in step 5, measure and record the millivolt drop (mVD) readings between test points T_1 and T_2 . Use these values in Equation 1 to calculate the voltage drop across the entire connection, including the crimp(s) and terminal interface. In the case of header type connectors, T_2 is attached to the “tail” of the header connector per 5.1.5.

$$\text{mVD of crimp and terminal} = \text{mVD } (T_1 - T_2) - [\text{mVD Conductor(s) measured in step 6}] \quad (\text{Eq. 1})$$

Use these results to verify conformance to the acceptance criteria of 5.3.2.4. Values for terminal sizes between 0.50 mm and 9.5 mm but not in the table are calculated by interpolation.

NOTE: These values apply both before and after any environmental or mechanical conditioning and to field samples.

5.3.2.4 Acceptance Criteria

For in-line connectors, the mVD values calculated in step 9 shall meet requirements per Table 5.3.2.4.

NOTE: The values in the table defined as total connection resistance are for “crimp and terminal” measurements (T_1 to T_2 in Figure 5.3.2.3) less the appropriate conductor resistance. For headers, total connection resistance values are the “crimp- to- tail” (T_1 to T_2 in Figure 5.1.5) less the appropriate conductor resistance.

Table 5.3.2.4 - Maximum values for dry circuit (see 5.3.1) and voltage drop for (see 5.3.2)

Nominal Male Terminal Size	Maximum Total Connection Resistance (mΩ)		Voltage Drop (mV) ⁽³⁾
	Terminals with Tin Plating	Terminals with Precious Metal Plating ⁽¹⁾	
0.50 mm	25.0	25.0	50
0.64 mm	20.0	10.0	50
1.2 mm	15.0	10.0	50
1.5 mm	10.0	10.0	50
2.8 mm	5.0	5.0	50
6.35 mm	1.8 ⁽²⁾	1.8 ⁽²⁾	50
9.5 mm	1.0	1.0	50
14.5 mm	0.7	0.7	50
Coax (center pin dia. >0.4 mm)	24 - Center 6 - Shield	24 - Center 6 - Shield	N/A ⁽⁴⁾
“Mini” Coax (center pin dia. ≤0.4 mm)	24 - Center 10 - Shield	24 - Center 10 - Shield	N/A ⁽⁴⁾
Twisted Pair	25 ⁽⁵⁾	25 ⁽⁵⁾	N/A ⁽⁴⁾

NOTES:

- (1) Silver or gold top plating.
- (2) High-performance 6.35 mm terminals may require a tighter value. It is the connector maker’s responsibility to identify high-performance terminals and define the alternate criteria.
- (3) For reference: 1 mΩ = 1 mV/A.
- (4) Maximum voltage drop test may be desired for “power” applications such as “power over coax” (PoC). Methods and limits for these special cases are customer-specified.
- (5) Criteria apply to both circuits in the pair. Only limited tests for twisted pair are in USCAR-2.

5.3.3 Maximum Test Current Capability

5.3.3.1 Purpose

This test is used to determine the maximum test current at which a terminal system can operate in a room temperature environment before excessive thermal degradation and/or resistance begins to occur. Temperature rise (Y axis) versus current (X axis) is plotted for each applicable conductor size, but these graphs are not used for applications in a vehicle (see Appendix E). This test is conducted on terminals alone, thus eliminating the variation that may be introduced by the heat dissipating characteristics of connector housing designs and sizes. Current rating is not applicable to coax cable test.

5.3.3.2 Equipment

- Digital multimeter (DMM)
- DC power supply (0 to 20 VDC at 0 to 150 A)
- Current shunts (size as required, $\pm 1\%$)
- Thermocouples (Type "J" or "T")
- Data logger (as required)

5.3.3.3 Procedure

1. Draft-free enclosure construction: A draft free environment is necessary to get accurate measurements. The samples shall be mounted in an enclosure which protects the immediate environment from external movement of air. A "draft free" environment is indicated by an undisturbed vertical smoke plume of 150 mm (6 inches). A description follows:

Draft-Free Enclosure Description:

- Construction: Made from a non-thermally conductive and non-heat reflective material. The sides of the enclosure may be moveable to accommodate different specimen sizes. Access panels or doors are acceptable provided they do not allow external air movement to enter the enclosure when closed.
- Top and bottom: The enclosure may have a lid. Any such lid shall have sufficient openings or be of an open mesh or screen or be raised above the sides to minimize any rise in ambient temperature caused by the heating effect of the samples under test. The bottom of the enclosure shall be solid.
- Spacing of samples: Minimum spacing from the sides of the enclosure to the edges of the samples is 200 mm. Minimum spacing between samples is 30 mm and should be sufficient so as to negate the effects of heating due to proximity of samples.
- Sample orientation: Orient samples "horizontally" as best is possible and evenly distributed over the area of the enclosure. As far as possible, the specimens shall be in free suspension. If this is not possible due to the need to maintain specified contact insertion distance, a thermal insulating material with a thermal conductivity ≤ 0.2 W/mK may be used, provided that not more than 20% of the surface of the specimen is in contact with the insulating material.
- Ambient temperature sensor: The measuring point for measuring the ambient temperature shall be located in a horizontal plane passing through the axis of the specimens. It shall be located a minimum of 150 mm from any energized sample. Care shall be taken to protect the probe against radiant heat.

- Wiring the circuit: The specimens shall be connected with wires of suitable cross-section for the maximum current to be expected or according to the size of the termination. In order to reduce external heat dissipation to a minimum, at least the length of the connecting wires given in Table 5.3.3.3 shall be within the measuring enclosure: This table is based on heat conduction criteria and is designed to ensure that the wires are long compared with their cross-section.

Table 5.3.3.3 - Minimum wire length

Wire Size (mm ²)	Minimum Wire Length (mm)
<0.5	200
0.5 to 5.0	500
>5.0	500

- Measure and record the voltage drop across 150 mm of the conductor to be used for the test, using the expected maximum current capability of the TUT in combination with that conductor size and insulation type. For testing header type connectors, see 5.1.5 and measure the millivolt drop across only 75 mm of the conductor used.

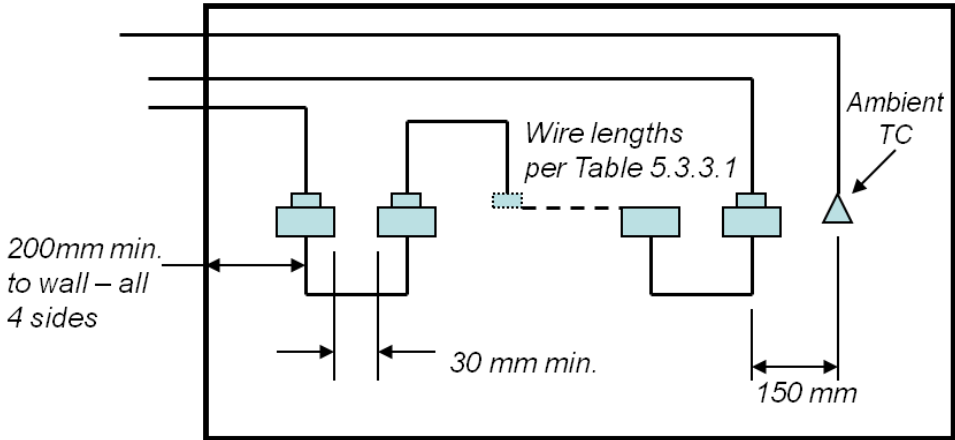


Figure 5.3.3.3-1 - Top view of draft-free enclosure for terminal testing

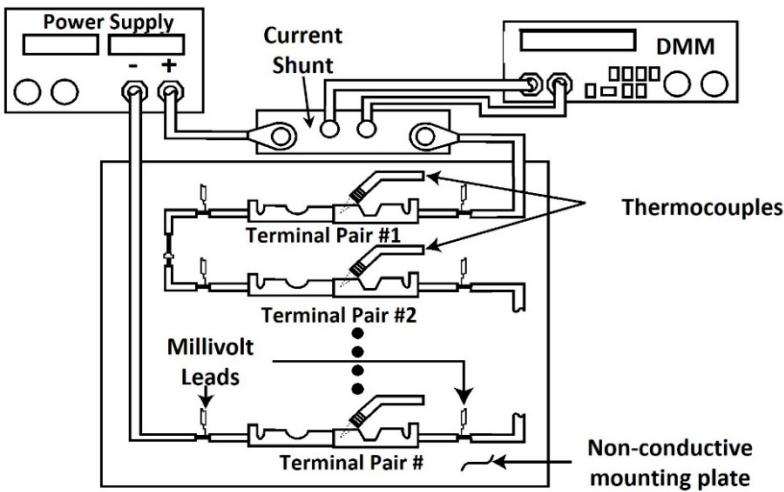


Figure 5.3.3.3-2 - Set-up for maximum test current

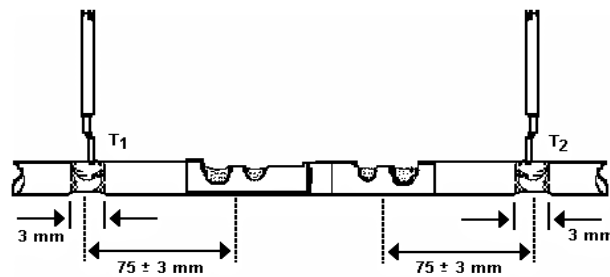


Figure 5.3.3.3-3 - Detail of millivolt lead locations for Figure 5.3.3.3-2

3. Assemble the circuit shown in Figure 5.3.3.3-2 in a draft free enclosure as described in 5.3.3.3 and Figure 5.3.3.3-1. Use at least ten terminal pairs. Choose the preferred method of taking measurements (soldered sense lead or probe) and document the method chosen. In either case, the sense point T_1 (see Figure 5.3.3.3-3) must be soldered for all stranded cable. Attach conductor ends of the terminal pairs to form one continuous series circuit and attach the thermocouples to each mated pair as shown in Figure 5.3.3.3-2. Mount the circuit in the draft-free enclosure.
4. Test the sample terminal pairs at $23\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ (room temperature).
5. Adjust the power supply to 0 A output and then turn on the supply and the DMMs.
6. Slowly increase the power supply output until it is providing no greater than 50% of the expected maximum current capability of the TUT.
7. Wait at least 15 minutes for the circuit temperature to reach steady state (as defined in Appendix A). Then record the ambient temperature, the temperature of each terminal pair interface and the millivolt drop across each terminal pair (T_1 to T_2 in Figure 5.3.3.3-3 for in-lines and 5.3.1.3 for headers, less the millivolt drop of the conductor as determined in step 2). Then calculate the resistance of the terminal pair interface.
8. Increase the current by no more than 10% of the expected maximum current capability of the TUT and repeat step 7.
9. Repeat steps 7 and 8 until one of the following conditions occurs:
 - a. The temperature of any terminal interface exceeds a $55\text{ }^{\circ}\text{C}$ rise over ambient (ROA).
 - b. The total connection resistance or maximum voltage drop of any terminal interface exceeds the acceptance criteria listed in 5.3.2.4.
 - c. Any TUT does not meet the visual acceptance criteria listed in 5.1.8.4.
10. Save test set-up for subsequent tests (see 5.3.4).
 - * This optional step can be performed at this point with excess samples, if requested: Using samples that will not be used in subsequent tests, continue to increase the current in steps of 5% of the maximum current capability of the TUT until the thermal stability of any one or more samples can no longer be achieved. Data from this “test to failure” step may be useful for statistical purposes or for estimating safety margins.
11. Graph the data with temperature on the Y-axis and current (in amps) on the X-axis for all conductor sizes and insulation types tested.

NOTE: That this data is NOT to be used as guidance for any actual application of the TUT; see Appendix E.

5.3.3.4 Acceptance Criteria

No pass/fail criteria apply; value is used to establish “maximum test current” for the TUT in 5.3.4. The maximum test current of the specific combination of the terminal and the wire conductor size and insulation type used is the current that produces an exact or interpolated value of 55 °C rise in the first increment in which either the condition described in 9.a. or 9.b. above was achieved, less 10% of that value.

5.3.4 Current Cycling

5.3.4.1 Purpose

This test simulates the main function of power terminals over the expected life of the vehicle. Current cycling is an accelerated aging test which electrically heats terminal interfaces and core conductor crimps, then allows them to cool under zero current conditions, causing expansion and contraction that may affect connection resistance due to wear, oxidation, inter-metallic growth and stress relaxation. Current cycling is not applicable to coax cable testing.

5.3.4.2 Equipment

- Digital multimeter (DMM)
- DC power supply (0 to 20 VDC at 0 to 150 A, timer controlled)
- Current shunts (size as required, $\pm 1\%$)
- Thermocouples (type “J” or “T” typically)
- Data logger (as required)

5.3.4.3 Procedure

1. Attach the millivolt leads in positions T_1 and T_2 as shown in Figure 5.3.1.3. For header type connectors, T_2 is attached to the header terminal per 5.1.5. Millivolt leads must be no larger than 0.22 mm².
2. Measure and record the voltage drop across 150 mm of the conductor to be used for the test, using the maximum test current previously determined (see 5.3.3.4) for the combination of that conductor size, insulation type and the TUT. For testing header type connectors, see 5.1.5 and measure the millivolt drop across only 75 mm of the conductor used. For attachment points exceeding 75 mm, the extra wire resistance shall be measured and subtracted.
3. Assemble the circuit shown in Figure 5.3.3.3-2 in a draft free enclosure as described in 5.3.3.3, except use a timer-controlled power supply. Set the power supply to provide 45 minutes on and 15 minutes off at the maximum test current previously determined (see 5.3.3.3, step 9) for the combination of that conductor size, insulation type, and the TUT. Connect a data logger to the voltage drop and thermocouple leads.
4. Test the set of sample terminal pairs at 23 °C $\pm$ 5 °C (room temperature). An ambient temperature sensor must be placed on the same plane as the test samples, 150 mm/min from the nearest sample.
5. Turn on the power supply, DMMs, and data logger.
6. After 30 minutes into the first cycle, record terminal crimp and interface millivolt drop readings (T_1 to T_2 in Figure 5.3.2.3) as well as thermocouple readings for each terminal pair.
7. Complete 1008 cycles taking readings at least once daily 30 minutes into the cycle, and at the conclusion of the test, 30 minutes into the final “on” cycle. Millivolt drop readings should be taken at maximum test current.

8. For each set of data, calculate and record the total connection resistance by subtracting the conductor millivolt drop reading (step 4) from the T_1 to T_2 millivolt drop reading (step 7) and dividing the result by the test current.
9. Allow the samples to cool to ambient, then measure CUT/TUT as required per appropriate test sequencing table.

5.3.4.4 Acceptance Criteria

1. At the conclusion of the test, verify conformance of CUT/TUT per corresponding measurement section as identified in test sequence (see 5.9).
2. The temperature of any terminal interface must not exceed a 55 °C ROA at any time during the test.
3. The total connection resistance or maximum voltage drop of any terminal interface reading shall not exceed the acceptance criteria listed in 5.3.2.4.

5.4 Connector - Mechanical Tests

5.4.1 Terminal - Connector Insertion/Retention and Forward Stop Force

5.4.1.1 Purpose

This test measures the insertion force of a terminal into its connector cavity. Retention testing measures how well the terminal is retained in its housing to withstand the rigors of the wiring harness and vehicle assembly processes.

5.4.1.2 Equipment

- Insertion/retention force tester with peak reading feature
- Temperature/humidity chamber capable of 95 to 98% RH at 40 °C

5.4.1.3 Procedure

A. INSERTION FORCE

Un-Sealed Connectors and Sealed Connectors with Individual Cable Seals

1. Prepare terminal samples per 5.1.6, using the largest gage size conductor and insulation thickness applicable to the design of the terminal to be tested. For connectors with ten or more terminal cavity locations, use a minimum of three connector housings and prepare at least one terminal for each cavity location. Test each terminal cavity location in the CUT at least once. For connectors with four to nine terminal cavity locations, use a minimum of three connector housings and prepare enough terminal samples to test each cavity location in each CUT. For connectors with three terminal cavity locations, use a minimum of four connector housings and prepare enough terminal samples to test each cavity location in each CUT. For connectors with one or two cavity locations use enough connector housings to obtain at least ten data points and test all cavity locations an equal number of times. See Table 5.4.1.3.1. Use sample sizes and cavity requirements from the table for insertion, retention, forward stop and after conditioning force measurements. If CUT has a mat seal, jump to the mat seal section for sample requirements and process steps.