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 ± 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.

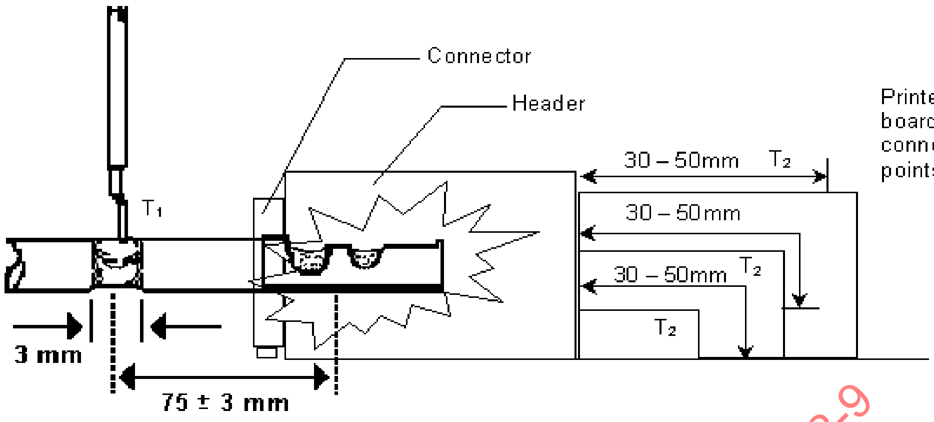


Figure 5.1.5 - Millivolt lead T1 and T2 attachment for headers (typical)

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.

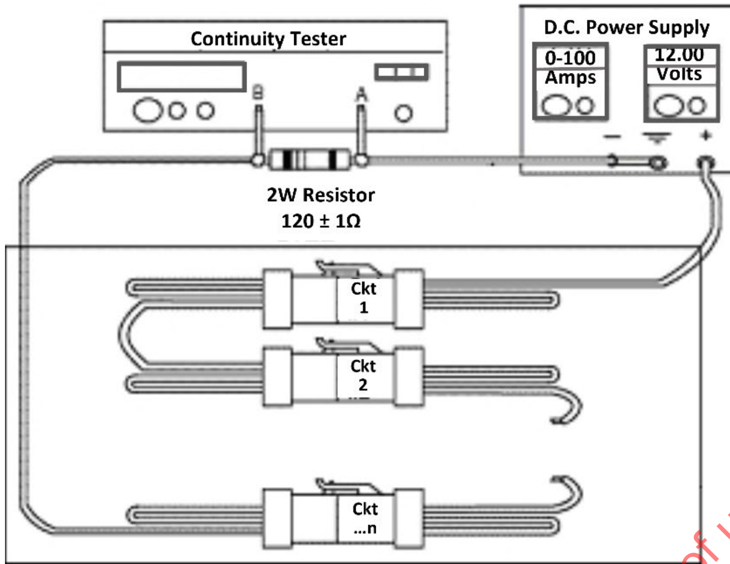


Figure 5.1.9.3 - Connector environmental test set-up

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 μs. 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 μs. Figure 5.1.9.4 illustrates the acceptance criteria graphically.

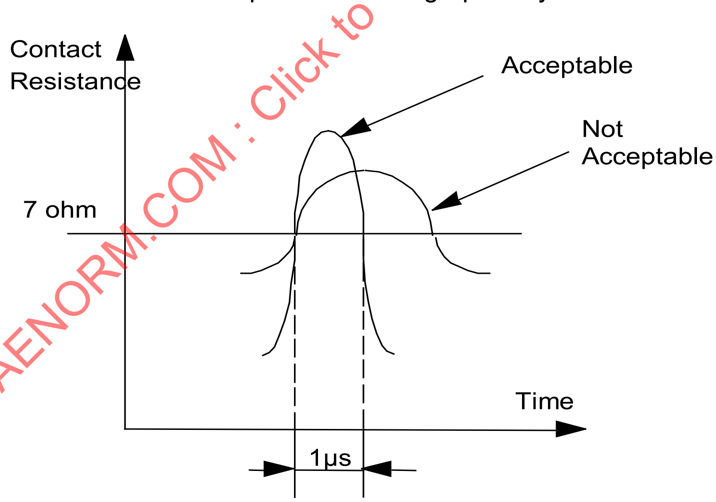


Figure 5.1.9.4 - Intermittency measurement

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.

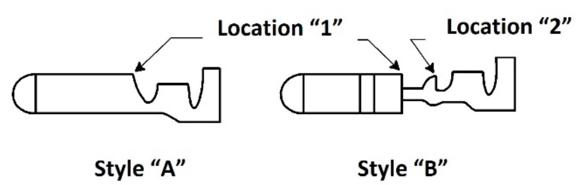


Figure 5.2.2.3-1 - Terminal design style

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.

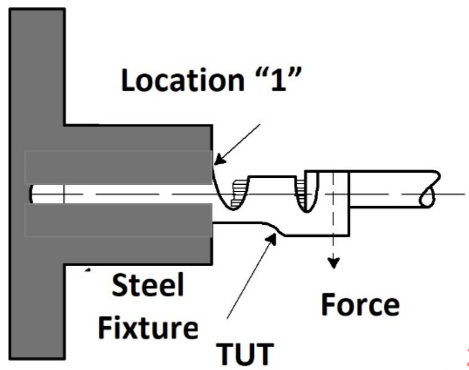


Figure 5.2.2.3-2 - Terminal bend test

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 mm^2. 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.

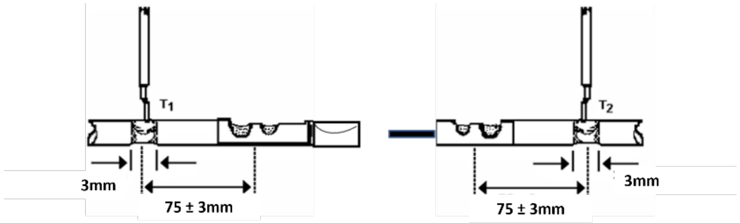


Figure 5.3.1.3 - Typical millivolt lead locations

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.

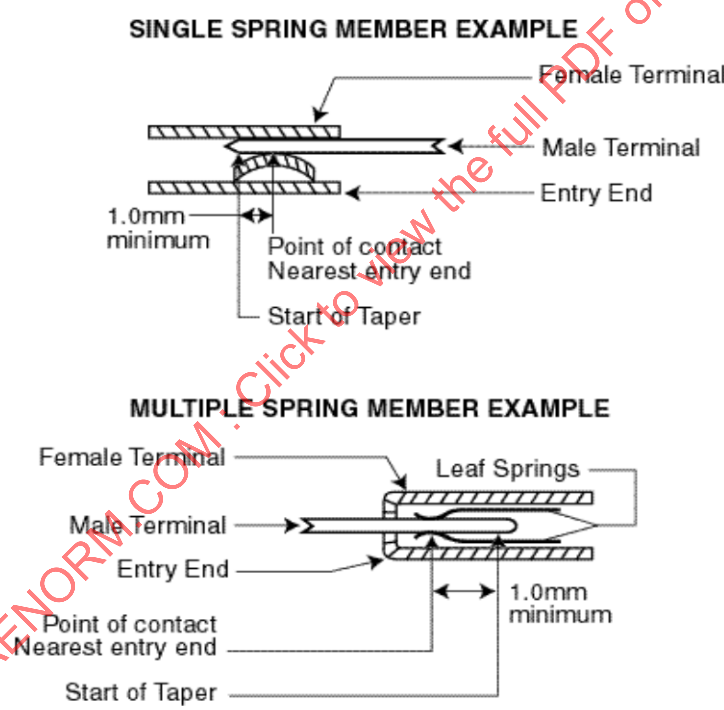


Figure 5.3.1.4 - Terminal insertion

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 mΩ. 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.

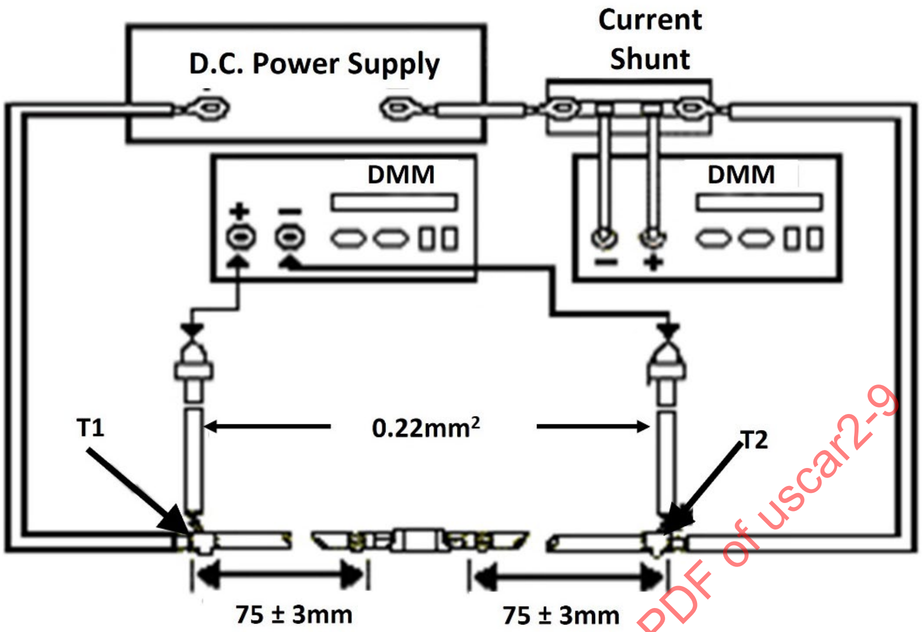


Figure 5.3.2.3 - Typical current resistance test set-up

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/mm^2 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 T_1 (see Figure 5.3.1.3) must be soldered for all stranded cable. For header type connectors, T_2 is attached to the header terminal per 5.1.5. All millivolt leads must be no larger than 0.22 mm^2.

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)		
	Terminals with Tin Plating	Terminals with Precious Metal Plating[1]	Voltage Drop (mV)[3]
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, ±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

2. 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.

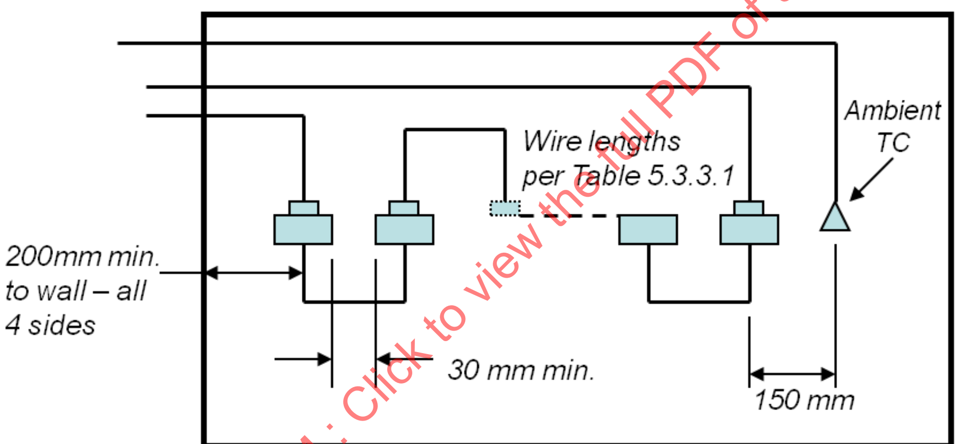


Figure 5.3.3.3-1 - Top view of draft-free enclosure for terminal testing

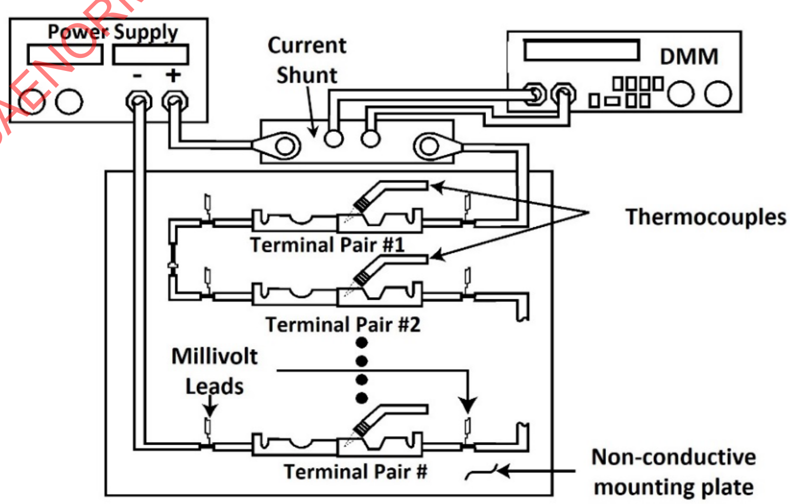


Figure 5.3.3.3-2 - Set-up for maximum test current

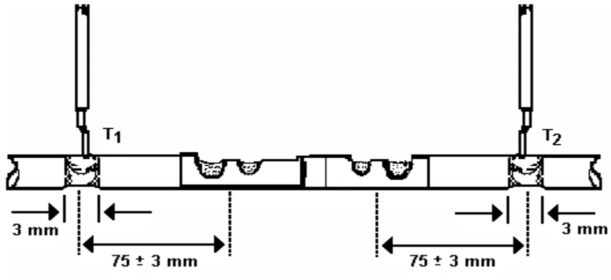


Figure 5.3.3.3-3 - Detail of millivolt lead locations for Figure 5.3.3.3-2

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 °C ± 5 °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 °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, ±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 mm^2.

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 ± 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.

Table 5.4.1.3.1 - Sample sizes and cavity requirements

# of Terminal Cavity Locations	Minimum # of CUTs	Minimum # of Terminal Samples	Cavity Locations Tested	Minimum # of Data Points
10 or more	3	= # of Terminal Cavity Locations	Each location at least once	= # of Terminal Cavity Locations
4 to 9	3	= # of Terminal Cavity Locations Times # of CUTs	Each location 3X or same num CUTs or each location the same number of times	= # of Terminal Cavity Locations X # of CUTs
3	4	= # of Terminal Cavity Locations Times # of CUTs	Each location an equal number of times	12
2	5	10	Each location an equal number of times	10
1	10	10	Each location an equal number of times	10

2. If more than one wire size is applicable to the CUT and terminal, create additional samples per step 1 but use the smallest conductor size and insulation type applicable to the design.

3. Number each connector terminal cavity and, if applicable, each connector.

4. Secure the connector shell in an appropriate fixture.

5. Secure the terminal sample in the force tester by gripping the conductor a minimum of 20 mm behind the insulation grip.

6. Adjust the force tester to insert the terminal straight into the connector at a uniform rate not to exceed 50 mm/min. Note peak insertion force. Continue to test using a fresh terminal sample for each insertion and test each terminal cavity location until all terminal samples prepared in step 1 have been used. Continue applying force until failure point of the forward stop is reached. Where wire buckling and operator sensitivity cause problems in obtaining test repeatability, one of two alternatives are acceptable. (A) Terminals may be crimped to a gage pin, solid core wire or other metal dowel material, or (B) Terminals may be pushed by cutting the wire off the CUT near the insulation grip and use a rod with a diameter similar to the cut-off wire and then push on the wire stub. Samples prepared using Option B cannot be used for terminal-to-connector retention tests.

7. Repeat step 6 using samples prepared in step 2 (smallest conductor size) until peak insertion force is measured (forward-stop test is not required). Repeat until all terminal samples prepared in step 2 have been used.

8. Record the force required to insert the terminal into the connector for each terminal sample. For samples prepared in step 1 only, record the force at failure of the forward stop. Assess conformance to the acceptance criteria of 5.4.1.4.

Alternate Instructions for Connectors with Multi-Cavity (Mat) Seals

1. Prepare two sets of samples per unsealed connectors and sealed connectors with individual cable seals per step1 above and one set of samples per unsealed connectors and sealed connectors with individual cable seals per step 2 above.

2. Complete steps 3, 4, and 5 above.

3. Insert one set of terminals made in step 1 per step 6 above and in step 2 per step 7 above. For mat seals, each test sample lead may be removed after its cavity is tested. This is to prevent possible seal distortion or compression that might affect test results if neighboring seal holes remain filled. For connectors with fewer than ten cavities, use a new connector after each terminal cavity in the first connector has been tested and continue until at least ten terminal samples have been used.

4. With the extra set of samples prepared in step 1 above, use the force tester as in step 3 above, load each terminal into a separate cavity without removing samples previously inserted. Perform the test in such a sequence that the last cavity to be tested is as centrally located as possible. In addition to the data required in step 5 below, record the cavity number, the insertion force and the order in which the cavities were tested.

5. Record the force required to insert the terminal into the connector for each terminal sample tested and verify conformance to the acceptance criteria of 5.4.1.4.

6. Repeat steps 4 to 5 using the samples with the smallest conductor/insulation type appropriate to the design.

B. RETENTION FORCE

Retention testing is required to ensure that the terminal is retained in its housing with sufficient strength to withstand the rigors of the wiring harness and vehicle assembly processes.

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.

   NOTE: Solder may be added to terminal crimps to ensure accurate retention readings. Connectors are to be tested in "dry as molded" condition and should be protected from high humidity and heat levels between the time they are molded and the time they are tested.

2. Number each connector terminal cavity in each connector housing so there are no duplicate cavity numbers among the housings used.

3. Install a terminal sample into each cavity in the connector being tested. For connectors with less than ten cavities, use a new connector after each terminal cavity has been tested and continue until all ten terminal samples have been used. Do not install the terminal lock (PLR, TPA, wedge, etc.).

4. Secure the connector shell in an appropriate fixture.

5. Secure the terminal sample in the force tester by gripping the wire behind the back edge of the terminal.

6. Adjust the force tester to pull the terminal straight back from the connector. An aligned force is critical to avoid side loads and binding which can affect force measurements. Pull at a uniform rate not to exceed 50 mm/min until pullout occurs.

7. Record the force required to pull the terminal out of each terminal cavity along with the cavity number and the connector number. If the conductor breaks or pulls out of the terminal grip before the terminal is pulled from the connector, record this force together with a note as to what happened.

8. Repeat steps 1 to 3 and, if applicable, install the terminal secondary lock (PLR, TPA, wedge, etc.). Subject the samples to moisture conditioning (bring to the practical limit of moisture content by exposing “dry as molded parts” to 95 to 98% relative humidity at 40 °C for 6 hours followed by 1 hour at room ambient temperature and humidity. Repeat steps 1 to 7 above. Complete the retention test of all samples within 8 hours.

   NOTE: Samples may be sealed in non-moisture transferable plastic (Ziploc-type food storage) bags after moisture conditioning if the testing cannot be completed within 8 hours. In any case testing must be completed within 24 hours of moisture conditioning.)

5.4.1.4 Acceptance Criteria

1. Insertion force for terminals shall comply with Table 5.4.1.4A, or per customer requirement. (Since terminal insertion force is not related to part performance, a different requirement is typically permitted without requiring management review.)

2. Force to move past the forward stop (as tested in 5.4.1.3 A6) shall comply with the applicable column of Table 5.4.1.4A.

3. Retention strength for terminals shall comply with the applicable column of Table 5.4.1.4B.

Table 5.4.1.4A - Insertion force for terminals

Terminal Size (mm)	Terminal Insertion (N)	Forward stop (N)
≤0.5	≤15	≥35
≤1.2	≤15	≥50
1.2 < Term. ≤ 2.8	≤20	
2.8 < Term. ≤ 9.5	≤30	
9.5 < Term. ≤ 14.5	≤75	≥150

Table 5.4.1.4B - Terminal-connector retention force

Max. Nominal Blade Width (mm)	Criteria (N)[6]		
	Primary Lock Retention[3]	Retention after Moisture Conditioning[4]	Retention after Damage, Humidity and THE[5]
0.50	≥20	≥40	≥40
0.64	≥30	≥60	≥50
1.2	≥40	≥70	≥50
1.5	≥45	≥70	≥50
2.8	≥60	≥100	≥70
6.3	≥80	≥130	≥90
9.5	≥100	≥150	≥140
14.5 (cables >12 mm^2) 14.5 (cables ≤12 mm^2)	≥150	≥450 ≥180	≥450 ≥180
Mini coax[7]	≥60[2]	≥110[1][2]	≥80[1][2]
Traditional coax[7]	≥70[2]	≥110[1][2]	≥80[1][2]
Twisted pair[8]	≥60	≥110	≥80

NOTES:

(1) If the coax wire breaks or releases from terminal at less than the requirement and the terminal is still located in the cavity, retest using a terminal push-out test. The same requirement applies.

(2) Any free spinning terminals that are nonuniform about the axis (i.e., has a weld or seam, must be tested in all possible conditions). This includes any unique areas that will support the locking if the terminal Is aligned to the connector.

(3) See 5.4.1.3.B6

(4) Primary + secondary lock after moisture conditioning (see 5.4.1.3.B8)

(5) Primary + secondary lock retention after cavity damage, temp/humidity and HTE (see 5.4.9, 5.6.2, 5.6.3)

(6) For connectors not designed with a secondary lock, use the criteria in “primary + secondary lock” columns

(7) Mini coax has outer diameter <3.6 mm. Traditional coax is ≥3.6 mm.

(8) Jacketed twisted pair (JTP) is used for “single pair ethernet.” Full test requirements for JTP has not been written yet.

5.4.2 Connector - Connector Mating/Unmating/Retention/Lock Deflection Forces (Non-Assist)

5.4.2.1 Purpose

This test determines the mating/unmating forces associated with manual mating and unmating of connector assemblies. mating forces are an important consideration in determining the suitability of a given connector design for use in production. unmating and retention forces are important in determining serviceability of the design and ensuring the connection will stay mated for the service life of the vehicle.

5.4.2.2 Equipment

Insertion/retention force tester

5.4.2.3 Procedure

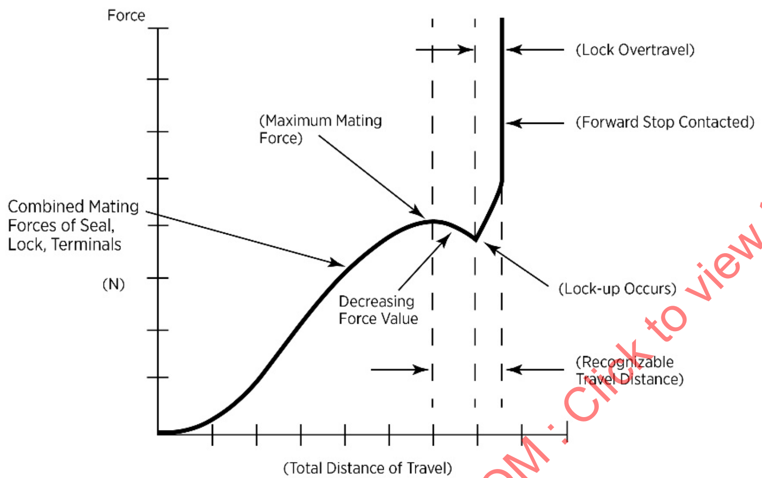
A. MATING FORCE

1. Using any applicable conductor size and insulation type, prepare enough samples of male and female terminals to fully populate a minimum of 15 connector assemblies per 5.1.6, terminal sample preparation (at least 15 male and 15 female halves).

2. Completely assemble (but do not mate) all connector halves (both male and female) using all applicable components such as terminals, wedges, and seals.

3. Number each connector assembly.

4. Secure the connector halves (one male and one female) in the appropriate fixtures of the force tester. Adjust the force tester to insert the male connector straight into the female connector. Straight-in engagement is critical to avoid side loads and binding which can affect force measurements.



If appropriate equipment is available, a continuous graph of applied mating force versus insertion distance is highly recommended. A properly designed connector (and sealing system where applicable) should produce a graph showing a smooth rise to a single peak force then a fall-off until the connector is fully mated. If the graph shows more than one force peak, the potential for a false lock condition exists.

Figure 5.4.2.3 - Typical connector mating force curve and explanation

5. Increase the mating force at a uniform rate of 50 mm/min ± 10 mm/min until complete mating occurs. Test all samples.

6. Record the force required to completely mate each set of connector halves into their locked position and use these values to verify conformance of each connector pair to the acceptance criteria of 5.4.2.4.

B. UNMATING/RETENTION FORCE

1. Prepare a total of 15 mated pair samples into two groups: For group 1, take ten connector pairs without their terminals/wires. Mate all connector pairs but do not engage the CPA. For group 2, take five connectors that have a full set of terminals/wires locked in place. Completely disable the primary connector locking mechanism(s). Mate all connector pairs but do not engage the CPA.

   NOTE: It is permissible to re-use applicable samples from section A for group 1, provided that the samples have remained in the mated state and have not had other conditioning.

2. Fixture a group 1 sample in a force tester that can completely unmate the connector halves by applying a force parallel to the centerline of the mated connector halves. The force tester must be configured to apply the unmating force directly to the connector halves. Straight-out unmating is critical to avoid side loads and binding which can affect force measurements.

   NOTE: For connectors with lock arms that protrude above the protective ribs, run this test with the lock arm deflected to make the highest point of the arm level with the protective ribs.

*** CAUTION ***

The following step will result in sample breakage. Adequate shielding and personnel safeguards must be employed to ensure the safety of persons and property in the vicinity of the test.

3. Start the tester at a uniform rate not to exceed 50 mm/min until complete connector separation occurs.

4. Stop the tester. Record the force required to separate the connector halves and verify conformance to the acceptance criteria of 5.4.2.4.

5. Repeat steps 2, 3, and 4 for all samples in group 1 and group 2.

C. LOCK DEFLECTION FORCE

1. Prepare five connector pairs without terminals or wires but include any auxiliary pieces that attach to the lever such as CPAs. Completely mate all connector pairs. Gradually apply a force to the lock release button. Stop the force at 6 N and verify the lock mechanism remains locked using an applicable evaluation method. Continue force application up to 51 N, or until the lock mechanism has clearly moved far enough to avoid contact with the lock feature on the mating part if unmating is attempted. If practical, record force when the lock just barely clears the mating part's lock feature. (Apply this force at an appropriate point so that the mated connector parts can be unmated in the intended manner with no damage to any component.) Record whether the connection can be successfully unmated at 6 N and 51 N.

2. If applicable, fully engage the CPA into the final lock position. Gradually apply a force of 70 N to the lock release button. Look to see if the lock mechanism clears the lock feature. Pull on connector to see if connector disengages.

3. Record results and verify conformance to the appropriate acceptance criteria of 5.4.2.4.

5.4.2.4 Acceptance Criteria

Table 5.4.2.4 - Connector-connector mating/unmating/retention/lock deflection forces

Test	No. of Connectors	Terminals Installed?	Acceptance Criteria
Connector mating	15	Yes	Per SAE/USCAR-25[a, c]
Connector unmating	5	Yes	≤75 N
Connector retention	10	No	≥110 N ≥170 N for large cables[b]
Lock deflection (no CPA)	5	No	<6 N - Unmating not possible >51 N - Unmating possible
Lock deflection w/CPA with force applied	5	No	Latch does not move above the locking feature [d]

NOTES:

[a] The maximum mating effort is meant to simulate assembly in a vehicle when the assembler's body position and access to the connector being mated is not physically restricted. This specification will cover most operations, but not all conditions of vehicle assembly and connector location can be anticipated. Refer to SAE/USCAR-25 for guidance.

[b] Applies to cavities that can accept a cable size >12 mm^2. The forces specified in the acceptance criteria shall be met regardless of the moisture content of the connector housing material. Consult the test request/order to determine if any conditioning of the test samples is required prior to testing.

[c] The acceptance criteria for connector mating forces vary with the available push surface area of the connector being tested. Refer to SAE/USCAR-25 "Electrical Connector Assembly Ergonomic Design Criteria" for specific acceptance criteria.

[d] In connector designs where it is difficult to apply pressure to the latch while unmating the connector, it is permissible to visually confirm the latch does not clear the locking feature with 70 N applied to the locking provision.

5.4.3 Connector to Connector Mate/Unmate Forces (Mechanical Assist)

5.4.3.1 Purpose

This test covers mating and unmating forces for mechanical assist connectors such as lever and slide lock. USCAR-25 ergonomic guidelines should be used as a further reference.

5.4.3.2 Equipment

- Force tester
- Fixtures for holding connectors as required

5.4.3.3 Procedure

Sample preparation:

Tests A, B, and C: Minimum ten connector samples each. Using any applicable conductor size and insulation type, prepare enough samples of male and female terminals to fully populate connector assemblies per 5.1.6, terminal sample preparation. Prepare connector samples with the full complement of wires, terminals, and secondary pieces as specified in the design and intended for the production application.

Test D: Prepare six connector pairs by mating male to female housings without terminals or wires.

Test E: Prepare five connector pairs without terminals or wires

A. FORCE TO ENGAGE/UNSEAT TO/FROM PRE-LOCK POSITION

Using the force tester, at a rate of 50 mm/min ± 10 mm/min, engage each connector fully to its pre-lock position. The pre-lock position is defined as the point where the connector is positioned on the mating part and the mechanical assist is ready to be activated. Connectors are normally held in the pre-lock position by detents.

1. Reverse the direction and measure the force required to unseat the connector from the pre-lock position.

2. Verify conformance to the acceptance criteria of 5.4.3.4-1 and 5.4.3.4-2.

B. FORCE TO RELEASE LATCH FROM PRE-STAGE POSITION

NOTE: Connectors may be required to be shipped as part of a wiring assembly with levers or mechanical slides locked in the “open” or “pre-stage” position. This eliminates un-necessary operations at the vehicle assembly plant. This part of the test procedure measures the ability of the connector mechanical assist to remain open during shipping and handling.

1. Using the unmated connector, place lever or slide in its shipping (open) position.

2. Using the force tester, apply the force to the lever slide at a rate not to exceed 50 mm/min to move the lever/slide toward the lock position.

3. Stop the test when the lever releases from the shipping position. Record peak force.

4. Manually reset the lever into the shipping position.

5. Re-insert the connector into the fixture (if needed)

6. Restart the test in the opposite direction, with the lever being pushed away from the “mated” position.

7. Stop the test when the when the lever releases. Record peak force.

8. Reset to the shipping position.

9. Verify conformance to the acceptance criteria of 5.4.3.4-3.

C. LEVER ACTUATION/REMOVAL FORCE

1. With the connector in its pre-stage condition, measure the force required to fully actuate and close the lever at a rate not to exceed 50 mm/min. Force shall be applied perpendicular with the contact surface of the lever or slide as nearly as possible.

2. For designs with a secondary release mechanism, without disabling or releasing this feature, apply a force of 60 N at a rate not to exceed 50 mm/min to the lever in the release direction.

3. Disable or release any existing release mechanism (if applicable). Move lever of CUT from locked to open position using a test speed not to exceed 50 mm/min. Record the force required to move the lever from the locked position to the open position.

4. Verify conformance to the acceptance criteria of 5.4.3.4-4 and 5.4.3.4-5.

D. CONNECTOR TO DEVICE OR CONNECTOR TO CONNECTOR LATCH RETENTION FORCE

Mount the mated connectors in a fixture so as not to distort the housings or any of their associated parts. With connector to connector locking feature enabled, pull the connectors apart at a rate not to exceed 50 mm/min using a suitable force tester and measure the peak force required to separate the connectors. CPAs and or secondary locks shall be disabled for this test. Repeat on four additional samples. (Test five samples.) Verify conformance to 5.4.3.4-6.

E. LEVER RELEASE LATCH ACTUATION FORCE

1. With the samples completely mated, gradually apply a force of up to 51 N to the lock release button until the lock mechanism clears the lock feature (allowing the lever/slide to move toward the disengaged -open- position. This force is applied at the appropriate point such that the lever/slide can be moved in the intended manner with no damage to any component. Note whether the lever/slide can be moved to the open position.

2. Record results and verify conformance to the appropriate acceptance criteria of 5.4.3.4-8.

3. If applicable, fully engage the CPA into the final lock position. Gradually apply a force up to 70 N to the lock release button and hold. See if the lock mechanism clears the lock feature. Pull on connector to see if connector disengages.

4. Record results and verify conformance to the appropriate acceptance criteria of 5.4.3.4-9.

5.4.3.4 Acceptance Criteria

Note that the acceptance criteria of this section vary with the available contact (grip) area of the connector being tested. Refer to SAE/USCAR-25 Electrical Connector Assembly Ergonomic Design Criteria for details of the acceptance criteria.

1. The force to engage the connector to its pre-lock position shall meet the requirements of SAE/USCAR-25.

2. The force required to release the connector from its pre-lock position shall be between 15 N and 75 N.

3. The force to move the lever/slide from its shipping position while the connector is not in its pre-stage position shall be 60 N min for class 1 and 2 connectors and 90 N min for class 3 connectors (both defined in USCAR-25, Section 4.1). When the lever is reset to the shipping position, there shall be no damage to the lever or housing that impairs reuse of the connector.

4. The force required to move the lever to and from the locked (engaged) position shall meet the requirements of SAE/USCAR-25.

5. The minimum force to release the assist feature without depressing the release mechanism (if applicable) shall be ≥60 N for a fully mated connector.

6. Unmating force shall be ≥110 N with the primary connector lock fully engaged. A CPA device, if provided for, must NOT be engaged during this test.

7. Unmating force from the “unlatched/open” lever position to full separation shall be ≤75 N.

8. The force to completely disengage the connector lock shall be between 6 N and 51 N, inclusive, in its fully seated position (without the CPA engaged).

9. The primary connector lock must not deflect enough to clear the mating locking (shark fin) feature or be easily separated when pulled on when subjected to 70 N force with CPA engaged (see 5.4.3.3.E3).

5.4.4 Polarization Feature Effectiveness

5.4.4.1 Purpose

This test ensures that the polarization feature(s) is adequate to meet its purpose of (a) preventing incorrect mating of a connector housing, (b) preventing mating of a connector housing with any unintended mate, and (c) test the adequacy of the polarization feature(s) in preventing terminal damage during incorrect assembly attempts.

5.4.4.2 Equipment

- Insertion/retention force tester with peak reading feature
- 9 VDC continuity meter ranging from 50 to 500 Ω with audible alarm

5.4.4.3 Procedure

1. Two factors must be considered: attempting to incorrectly mate two connector halves, or a connector half and a header that are supposed to mate if properly oriented and attempting to mate a connector with an incorrect mate.

2. Sample size varies depending on the number of incorrect orientations tested. Test at least one sample set for each selected mis-orientation or mis-index.

3. Connectors are to be loaded with a complete compliment of male and female terminals. In place of terminals a suitable mechanical or electrical means may be devised to detect penetration of one half of the CUT into the other to a depth sufficient to contact any male terminal in any position if that male terminal was installed.

4. Orient the CUT with any possible mate in the same family in one or more incorrect orientations chosen by the authorized person as most likely to defeat the polarization. The parts should be tested as follows, using a fresh sample of each half for each orientation:

   a. The correct orientation, but with the wrong index

   b. The incorrect orientation

5. Secure the connector halves (or connector and header) (one male and one female) in the appropriate fixtures of the force tester. Adjust the force tester to attempt insertion of the male connector into the female connector in the orientation selected in step 3.

6. Attempt to engage the connector halves at a rate not to exceed 50 mm/min until a force of 3X the maximum value of a properly mated connector (with force being ≥60 N and ≤150 N) is applied (see 5.4.2 or 5.4.3.3-A). For connectors with mechanical assist, use 3X the maximum measured force to engage to pre-lock position (but not to be less than 60 N or greater than 150 N) per 5.4.3.3-A. Hold force for 3 seconds. Note the indication of the penetration detection device installed in step 3 if present.

7. Complete an expert evaluation. This evaluation shall be conducted among knowledgeable individuals trying “hands-on” mis-mating to evaluate the effectiveness of the polarization features.

5.4.4.4 Acceptance Criteria

1. The connection system must withstand a mis-mating force as specified in step 6 without damage to the connector and no electrical contact shall be made between the male/female terminals. If sufficient mis-mating is achieved to allow contact with any properly installed male terminal in any position in its connector housing, the polarizing feature(s) is considered to be inadequate

2. After an expert evaluation has been conducted, the design must be considered effective in “hands-on” mis-mating attempts.

NOTE: There may be cases where all polarizations for a given design are not available (i.e., not tooled) and therefore cannot be tested. In such cases, state these exceptions in the DVP&R.

5.4.5 Miscellaneous Component Engage/Disengage Force

5.4.5.1 Locator Clips, Wire Dress Features, and Loose Piece TPA/PLR/ISL

5.4.5.1.1 Purpose

This test is done to ensure that connector assembly components such as locator clips, wire dress features, etc., will be sufficiently retained yet allow easy and consistent assembly and removal for service.

5.4.5.1.2 Equipment

- Insertion/retention force tester with peak reading feature

5.4.5.1.3 Procedure

A. ENGAGEMENT FORCE

1. Completely identify and number each component to be tested. A minimum of ten samples is required to be tested for each of the applicable conditions found in the acceptance criteria. The same samples may be used for various phases of testing.

2. All components to be tested and their mating parts must be fixtured so that proper alignment is maintained during testing. Straight-in engagement and extraction are critical to avoid side loads and binding which can affect force measurements.

3. Engage each component to be tested, with its retaining mechanism in place at a rate not to exceed 50 mm/min. Test each applicable condition per Table 5.4.5.1.4.

4. Record the force required to completely engage the component with its mating part and use this value to verify conformance to the acceptance criteria of 5.4.5.1.4.

B. DISENGAGING FORCE

*** CAUTION ***

The following step may result in sample breakage. Adequate shielding and personnel safeguards must be employed to ensure the safety of persons and property in the vicinity of the test.

1. With the component fully installed and properly fixtured, disengage the component at a rate not to exceed 50 mm/min. The force must be applied parallel to the centerline of the component being tested to avoid side loads and binding which can affect force measurements. The direction must be opposite to the direction of normal insertion of the component part. Test each applicable condition per Table 5.4.5.1.4.

2. Record the force required to disengage the component from its mating part without releasing any latch feature if it exists and use this value to verify conformance to the acceptance criteria of 5.4.5.1.4.

3. For locator clips only, repeat step 1 above in each of the three directions 90 degrees, 180 degrees, and 270 degrees from the initial insertion direction. Repeat step 1 in a direction orthogonal to the plane of the first four tests. Do not exceed a force of 110 N for any of these subsequent tests. Use fixture identified in Figure 5.4.6.3A.

4. For wire dress covers only

    a. Obtain new dress cover samples. Subject the samples to moisture conditioning to bring the sample to the practical limit of moisture content. Do this by exposing test parts to 95 to 98% relative humidity at 40 °C for 6 hours, followed by 1 hour at room ambient temperature and humidity. Complete the test of all samples within 8 hours (or samples may be sealed in Ziploc-type food storage bags after moisture conditioning if the testing cannot be completed within 8 hours). In any case testing must be completed within 24 hours of moisture conditioning.

    b. Apply an offset force as shown in Figure 5.4.5.1.3 B (simulating a push on the dress cover until it comes off its connector). Offset test is to be performed with cover assembled to connector and no wires attached. Push as shown by the arrow in the figure. Place force "probe" as close to dress cover's end as possible while keeping the probe in full contact with the cover. Push until the cover separates from the connector housing.

    c. Record the length of the dress cover as shown in Figure 5.4.5.1.3 B.

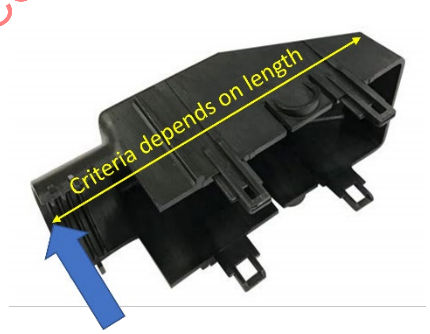


Figure 5.4.5.1.3B - Offset dress cover force set-up

5.4.5.1.4 Acceptance Criteria

Insertion/retention forces shall meet the values shown in Table 5.4.5.1.4.

Table 5.4.5.1.4 - Miscellaneous component and loose piece TPA/PLR/OR ISL assembly forces

Test	Insert to Lock Force (N)	Straight Removal Force (N)	Removal Force with Offset/Angle (N)
Clip removal from slot - Clip width ≤11 mm - Clip width >11 mm	≤60 ≤60	≥110 ≥165	N/A (tested in 5.4.11)
Loose piece TPA/PLR or ISL	≤60 (w/terminals in all cavities)	≥25	No requirement
Wire dress covers - Small (covers ≤45 mm) - Large (covers ≥45 mm)	≤60	≥110	≥45 ≥75
Other component	≤60	≥110	As directed

5.4.5.2 Pre-Staged CPA/TPA/PLR/ISL Engage/Disengage Force

5.4.5.2.1 Purpose

This test is completed to ensure that connector secondary locking features will be sufficiently retained in shipping and will remain in their intended position until intentionally activated to close or remove for service.

5.4.5.2.2 Equipment

- Insertion/retention force tester with peak reading feature

5.4.5.2.3 Procedure

A. ENGAGE FORCE - Pre-Staged CPA/TPA/PLR/ISL

1. Identify and number each component. A minimum of ten samples is required to be tested for each of the applicable conditions found in the acceptance criteria. The same samples may be used for various phases of testing.

2. All components to be tested and their mating parts must be fixtured so that proper alignment is maintained during testing. Straight-in engagement and extraction are critical to avoid side loads and binding which can affect force measurements.

3. Engage each component to be tested with its retaining mechanism(s) in place at a rate not to exceed 50 mm/min. Test TPA, PLR, and ISL forces with terminals installed in all available cavities and test for two mate/unmate cycles.

4. Record the force required to completely engage the component with its mating part and use this value to verify conformance to the acceptance criteria of 5.4.5.2.4.

B. DISENGAGE FORCE

*** CAUTION ***

The following step may result in sample breakage. Adequate shielding and personnel safeguards must be employed to ensure the safety of persons and property in the vicinity of the test.

1. With the component fully installed and properly fixtured, disengage the component at a rate not to exceed 50 mm/min. The force must be applied parallel to the centerline of the component being tested to avoid side loads and binding which can affect force measurements. The direction must be opposite to the direction of normal insertion of the component part. Test each applicable condition per Table 5.4.5.2.4.

2. Record the force required to disengage the component from its mating part and use this value to verify conformance to the acceptance criteria of 5.4.5.2.4.

3. For TPAs/PLRs/ISLs, with due care engage the component into the fully locked position and repeat steps 1 and 2.

5.4.5.2.4 Acceptance Criteria

Insertion/Retention forces shall conform to Table 5.4.5.2.4.

Table 5.4.5.2.4 - Pre-staged CPA/TPA/PLR and ISL assembly/disassembly forces

	Engage	Removal (N)	
Device	Pre-set to lock (N)	Lock to pre-set	Pre-set to Removed
CPA (Unmated Connector)	≥60 ≥100 for airbag connectors[1]	N/A	≥30
CPA (Mated Connector)	Min. ≥5 Max. per USCAR-25 Table 7.1	10 ~ 30	N/A
TPA/PLR/ISL (terminals installed in cavities)	≤60 1st mate N/A 2nd mate	1st removal: ≤60 2nd removal: ≥18	≥25
TPA/PLR/ISL (without terminals installed)	≥15	N/A	N/A

NOTES:

[1] Pre-set to lock is ≥100 N for air bag initiators mating to USCAR dwg. 999-U-002-1-Z03 or 999-U-002-1-Z04. This is needed to compensate for the exposed CPA in that design style.

5.4.5.3 Pin Protection Plate (PPP) Blocking/Removal Force

5.4.5.3.1 Purpose

This test is designed to assess whether a pin protection plate (PPP) is able to withstand expected mechanical stresses and still remain in its intended position. A PPP is shipped in a pre-set position that protects the blades and the first test in this section evaluates whether the force needed to unintentionally activate the PPP (the blocking force) is great enough to withstand forces that may be unintentionally applied. The reset force test determines the force to reset a seated PPP to its initial position and ensures the force required is ergonomically appropriate (this test is applicable only to designs that require manual PPP reset). The force for complete removal from pre-set position on an unmated connector ensures the PPP will not separate from the connector housing in shipping.

5.4.5.3.2 Equipment

- Insertion/retention force tester with peak and hold feature

5.4.5.3.3 Procedure

A. PPP BLOCKING FORCE

1. Identify and number each component to be tested. A minimum of ten samples is required to be tested for each of the applicable conditions found in the acceptance criteria. Samples are to be tested without terminals. This applies to in-line connectors; header connectors are expected to have blades present. If blade tips interfere with the force probe, blades may need to be removed. The same samples may be used for phases A and B of the testing.

2. All components to be tested and their mating parts must be fixtured so that proper alignment is maintained during testing. Recording forces perpendicular to the connector surface is critical to avoid side loads and binding which can affect force measurement data.

3. Engage each component to be tested, at a rate not to exceed 50 mm/min. Force to be applied in a centrally distributed area of the component. Pushing probe size and shape can be customized to ensure the PPP has force applied to it directly. If ribs are present on the PPP (for help in scoop-proofing the design), pushing on the ribs is acceptable. The TPA from the mating connector may be used if it provides access to a push surface.

4. When the applicable force per the criteria is reached, hold that force for 5 seconds.

5. Record whether the PPP moved from its starting position or stayed in the original position.

B. PPP RESET AND REMOVAL FORCE

*** CAUTION ***

The following step may result in sample breakage. Adequate shielding and personnel safeguards must be employed to ensure the safety of persons and property in the vicinity of the test.

1. Skip this step and step 2 if PPP has a self-resetting feature. With the PPP in the seated position and test sample properly fixtured, move the PPP to the pre-staged (shipping) position at a rate not to exceed 50 mm/min. Apply force perpendicular to the mating surface of the component to avoid side loads and binding which can affect force measurement data. The direction of force should be opposite the direction of normal seating of the PPP.

2. Record force to reset the PPP. Leave connector in fixture.

3. With the PPP in the pre-set position and test sample properly fixtured, disengage and completely remove the PPP at a rate not to exceed 50 mm/min. Apply force perpendicular to the mating surface of the component to avoid side loads and binding.

4. Record the force required to completely remove the PPP from the pre-set position. Note that flexing of the PPP is expected due to the nature of these components.

5.4.5.3.4 Acceptance Criteria

Blocking, reset, and removal forces shall meet the values shown in Table 5.4.5.3.4.

Table 5.4.5.3.4 - Pre-set, blocking, and removal forces for PPP

Connector Size	Blocking Force Pre-Set to Lock[1] (N)	Reset Force Lock to Pre-Set (N)	Complete Removal from Pre-Set (N)
LARGE (Female connector face has a diagonal dimension >35 mm)	≥50[3]	15 ~ 60 Manual reset only[2]	≥25
SMALL (Female connector face has a diagonal dimension ≤35 mm)	≥25[3]	10 ~ 60 Manual reset only[2]	≥25

NOTES:

(1) Specific limit for engagement force is not defined, will be determined by allowable mating force/ergonomic requirements.

(2) Requirement applies to connectors with a manual reset only. If part is an “automatic” reset type (where female connector pulls PPP back to pre-set position), ensure PPP does not pull out of connector completely during unmating in 5.1.7 (connector cycling). There is no “lock to pre-set” requirement for automatically resetting connectors.

(3) Customer may specify other tests and criteria with force applied at corners or select points.

5.4.6 Vibration/Mechanical Shock

5.4.6.1 Purpose

This test subjects a connector system to vibration, simulating accelerated exposure to actual vehicle conditions. Vibration and shock can cause wear of the terminal interfaces, intermittent electrical contact and failure of mechanical components of the connector system.

Since unsealed connectors are not suitable for use outside the passenger and luggage compartments, they would normally be tested only to the non-engine/transmission profile (V1). Sealed connectors may be used in applications requiring direct attachment to the engine/transmission, so they should normally be qualified to the harsher vibration profiles (V2 to V5).

5.4.6.2 Equipment and Set-up

- Vibration table (with environmental chamber for levels V3 and V4)
- Vibration controller
- Accelerometers

Map each table, cube, or head expander combination. For typical mapping procedure set-up, placement of the control accelerometer will be determined as follows. Other mapping procedures and control locations are acceptable but must be documented in the test report and must be approved by the authorized person.

Step 1 With the table, cube and or head expander to be used in this test in place, create a map of the vibration equipment by measuring the equipment resonance in at least five places as far apart as practical (see Figure 5.4.6.2). No additional mounting features or brackets will be on the equipment for this step.

Step 2 Determine the point of lowest resonance. This is defined as the midpoint between the points of lowest measured resonance.

Step 3 The control accelerometer shall be mounted at the point of lowest resonance.

Set-up requirements:

1. Use tri-axis accelerometer or sequentially rotate single axis accelerometers for the mapping process.

2. The cross-axis resonance must be no greater than 30% of the control resonance. (The on-axis resonance measured in step 1 must not vary more than 30%.)

3. The mapping procedure used shall be documented in the test report and will include frequency, acceleration, profile (random or sine sweep), and accelerometer locations.

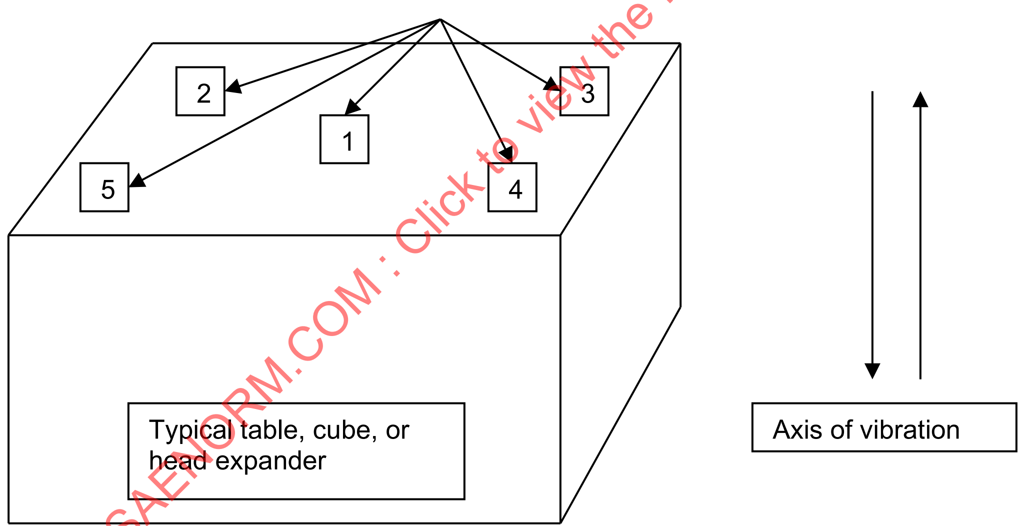


Figure 5.4.6.2 - Typical mapping accelerometer locations

5.4.6.3 Procedure

1. CUT must include all applicable wedges (TPAs, PLRs, etc.), seals, etc. Number each mated connector pair. Prepare each sample by assembling all applicable parts and bundling (with tape, convolute, scroll, etc.) the conductors. Consult the authorized person for details on intended bundling.

2. Construct a suitable mounting apparatus using the following design criteria:

   a. The mounting apparatus must be constructed and secured to minimize added effects (harmonics, dampening, resonance, etc.).

   b. For in-line connectors, mount the mated connector pair directly to the mounting bracket using the connector feature provided for mounting. See Figure 5.4.6.3A.

   c. For device connectors, mount the device directly to the mounting bracket. See Figure 5.4.6.3B. Use the normal device mounting feature(s) used to secure the device in its intended vehicle location.

   d. For all connectors, provide wire retention at 100 mm ± 10 mm from the rear of the connector body. This is illustrated in Figure 5.4.6.3C. The figure also shows three allowable attachment methods for the wires at the 100 mm distance. These are examples. Other wire attachment configurations not shown in the figure are allowed.

3. Should an application arise that does not lend itself to either situation described above, consult the authorized person. It is his or her responsibility to devise a suitable method for attaching the CUT as directly and firmly as possible to the mounting bracket consistent with the intended vehicle mounting.

4. Securely attach the conductor bundle ends to the mounting fixture so there is no stress on the cable.

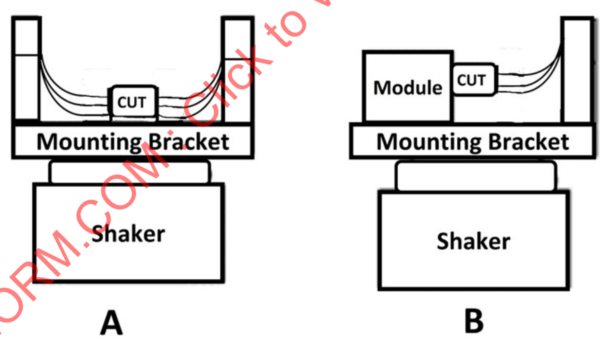
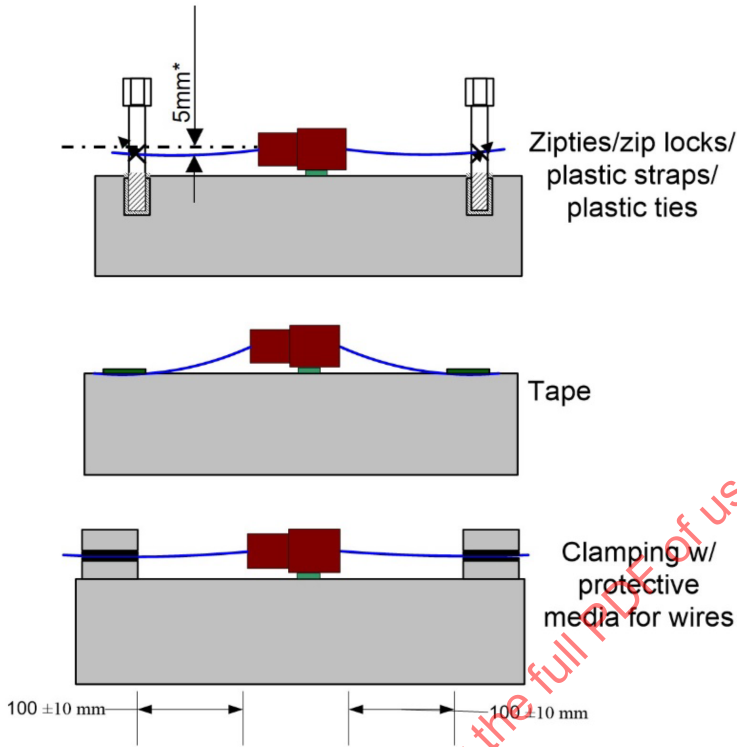


Figure 5.4.6.3A and 5.4.6.3B - Vibration mounting positions



* The 5 mm dimension is a suggestion only. For low voltage wire, most set-ups will have a 10 mm ± 5 mm sag relative to the attachment point. For most high voltage wires and large low voltage wires, there will be less than 5mm sag. The only requirement is to not intentionally stress the wire when placing the wire.

Figure 5.4.6.3C - Wire attachment examples for vibration

5. Subject the CUT to mechanical shock per Table 5.4.6.3A in each of the three mutually perpendicular axes. Mechanical shock and vibration testing may be completed in sequence for each axis before proceeding to the next axis.

6. Subject the CUT to the appropriate vibration class schedule per Table 5.4.6.3B in each of the three mutually perpendicular axes. When identified in Table 5.4.6.3B, thermal cycling shall be performed during the entire vibration cycle. Related to the temperature/vibration profile that the temperature profile in ISO 16750-3 Section 4.1.1 is an acceptable alternate to the temperature cycle shown in Table 5.4.6.3B. Sine and random profiles shall be run separately (not concurrently as sine + random profile). Sine frequency sweep is 1 octave/minute for all sine profiles.

7. Repeat the schedule for vibration duration (Table 5.4.6.3B) until the test is complete.

8. Age the samples for 48 hours at ambient conditions.

9. At the conclusion of the test, measure the CUT/TUT as required per appropriate test sequencing table.

Table 5.4.6.3A - Schedule for shock testing

Vibration Class	Shocks per Axis		Wave Shape	Direction (±)	Duration (ms)	Acceleration (g)
V1	10		Half Sine Wave	Positive	5 to 10	35
V2	10		Half Sine Wave	Positive	5 to 10	35
For V3, V4, V5 only: Perform Tests 1 and 2	1	132 x 6 = 792	Half Sine Wave	Positive/Negative	15	25
	2	3 x 6 = 18	Half Sine Wave	Positive/Negative	11	100

Table 5.4.6.3B - Schedule for vibration duration and temperature

Vibration Class	Sine Duration (hours/axis)	Random Duration (hours/axis)	Total Vibration Time for each CUT (reference)	Chamber Temperature for Thermal Cycling
V1	N/A	8	24	N/A
V2	N/A	8	24	N/A
V3	22	22	132	T_{min} per Table 5.1.4.1 with dwell time of 2 hours then transition to T_{max} per Table 5.1.4.1 with dwell time of 2 hours
V4	32	50	246	T_{min} per Table 5.1.4.1 with dwell time of 2 hours then transition to T_{max} per Table 5.1.4.1 with dwell time of 2 hours
V5	N/A	22	66	N/A

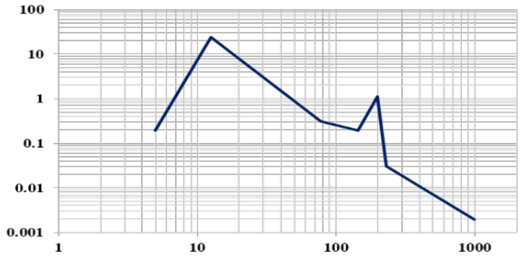
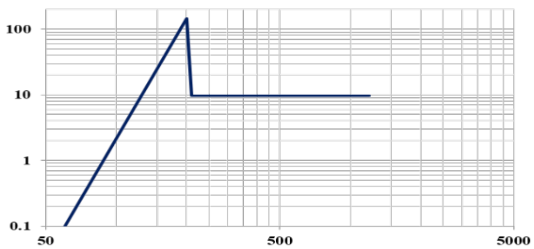
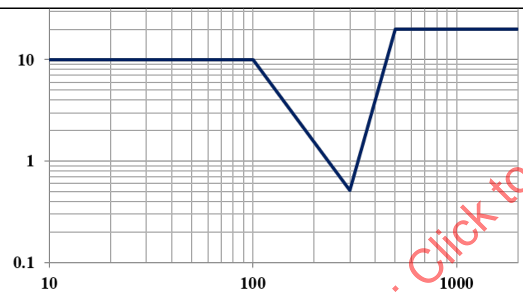
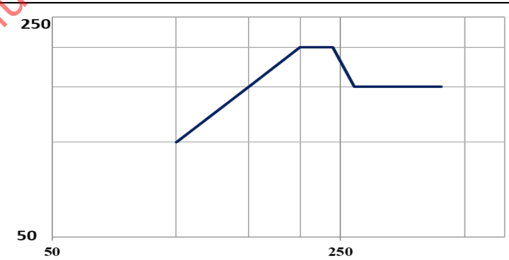
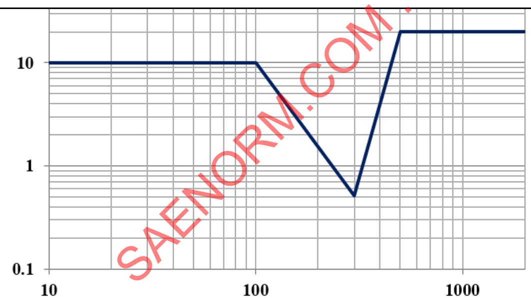
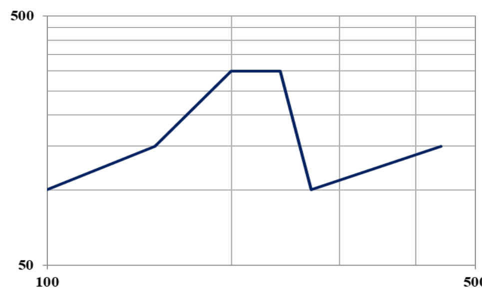
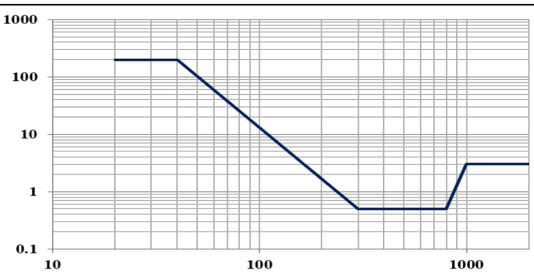
NOTES:

1. Prior note deleted.
2. Prior note deleted.
3. One thermal cycle is approx. 360 minutes.
4. Humidity is not controlled for vibration testing.
5. The temperature transition rate in the chamber is to be between 3 to 5 °C/min.

Table 5.4.6.3C - Schedule for vibration intensity

Level	Random			Sine		
	F (Hz)	PSD $(m/s^2)^2/Hz$	PSD g^2/Hz	F (Hz)	Accel. (m/s^2)	Accel. g
V1	5.0	0.192	0.00200	Vibration schedule at this level does not have a sine component.		
	12.5	23.8	0.24800			
	77.5	0.307	0.00320			
	145.0	0.192	0.00200			
	200.0	1.13	0.01180			
	230.0	0.031	0.00032			
	1000.0	0.002	0.00002			
	g (rms)	17.74	1.81 g			
V2	60.0	0.096	0.00100	Vibration schedule at this level does not have a sine component.		
	200.0	144	1.50000			
	210.0	9.60	0.10000			
	1200.0	9.60	0.10000			
	g (rms)	119	12.1 g			
V3	10	10	0.104	100	100	10.2
	100	10	0.104	150	150	15.3
	300	0.51	0.0051	200	200	20.4
	500	20	0.208	240	200	20.4
	2000	20	0.208	255	150	15.3
	g (rms)	181	18.5 g	440	150	15.3
V4	10	10	0.104	100	100	10.2
	100	10	0.104	150	150	15.3
	300	0.51	0.0051	200	300	30.6
	500	20	0.208	240	300	30.6
	2000	20	0.208	270	100	10.2
	g (rms)	181	18.5 g	440	150	15.3
V5	20	200	2.08	Vibration schedule at this level does not have a sine component.		
	40	200	2.08			
	300	0.5	0.005			
	800	0.5	0.005			
	1000	3	0.031			
	2000	3	0.031			
	g (rms)	107.3	10.9 g			

Table 5.4.6.3D - Vibration intensity - Graphic

<table>
<tr><th>Level</th><th>Random
(PSD in (m/s²)²/Hz versus Frequency in Hz)</th><th>Sine
(Acceleration in m/s² versus Frequency in Hz)</th></tr>
<tr><td>V1</td><td>
</td><td>Vibration schedule at this level does not have a sine component.</td></tr>
<tr><td>V2</td><td>
</td><td>Vibration schedule at this level does not have a sine component.</td></tr>
<tr><td>V3</td><td>
</td><td>
</td></tr>
<tr><td>V4</td><td>
</td><td>
</td></tr>
<tr><td>V5</td><td>
</td><td>Vibration schedule at this level does not have a sine component.</td></tr>
</table>

NOTES:

(1) Sine and random profiles shall be run separately (not concurrently as sine + random profile).

(2) Sine frequency sweep is 1 octave/minute for all sine profiles.

5.4.6.4 Acceptance Criteria

Verify conformance of CUT/TUT per corresponding measurement section as identified in test sequence.

5.4.7 Connector-to-Connector Audible Click

5.4.7.1 Purpose

Studies show that assembly plant technicians depend on audible and coincident tactile feedback that indicate full seating of electrical connectors regardless of background noise. This test measures the level of noise generated when two connectors are mated. Connectors are mated by hand for this test rather than being clamped into a fixture which could dampen or amplify the sound.

The values shown in this test procedure and acceptance criteria are taken from actual plant experience.

5.4.7.2 Equipment

- dB meter

5.4.7.3 Procedure

16 sample pairs are required (two groups of eight). Samples are to be production-intent. The connector cavities shall not be populated with terminals. Include all TPAs, seals, stuffers and auxiliary pieces as applicable.

1. Measure and record the dB (A) level of the ambient sound within the test environment. The ambient noise level must be between 30 and 50 dB (A).

2. Locate the sound measuring device or microphone 600 mm ± 50 mm from the connector.

3. Mate the connectors in group 1 by hand and measure the dB (A) level of the sound generated as the lock engages. Do not bias the connectors toward or away from the latch as they are engaged.

4. Repeat steps 1 through 3 using the group 2 connectors, post moisture conditioning. Parts are brought to their practical limit of moisture content by exposing “dry as molded parts” to 95 to 98% relative humidity at 40 °C for 6 hours (minimum), then completing the test within 30 minutes.

5.4.7.4 Acceptance Criteria

The values measured in this test shall be documented in the test report. These values should be considered for information only and are used to compare connector designs or to assist in the connector selection/wire harness design process.

5.4.8 Connector Drop Test

5.4.8.1 Purpose

This test evaluates the ability of the connection to withstand impact due to dropping on a hard surface.

5.4.8.2 Equipment

- Ruler
- Concrete surface

5.4.8.3 Procedure

1. Prepare connector assemblies with all components to be used in the intended application (CPA, TPA, PLR, lever/slide, etc.). Lock components as applicable in their design intended pre-staged (shipping) position. For harness type connectors, do not insert leads or terminals.

2. Divide samples into six groups.

3. For each group, drop one sample at a time once and only once onto a horizontal concrete surface from a height of at least 1 m, orienting the samples in six groups corresponding to the six connector “faces” of a rectangular connector. Use one group for each orientation.

4. Record any damage or movement/separation of components.

5. Verify conformance of each sample connector assembly to the acceptance criteria of 5.4.8.4.

5.4.8.4 Acceptance Criteria

1. Samples shall meet 5.1.8.

2. Components shall not be displaced from their intended shipping position.

5.4.9 Cavity Damage Susceptibility

5.4.9.1 Purpose

This test is intended to demonstrate resistance to damage when the connector TPA (or PLR or ISL as applicable) is forcefully inserted on a connector with one or more terminals in an incomplete (unseated) position. The cavity and other plastic and metal parts must subsequently be able to be assembled correctly and retain full function following such an event. This procedure does not apply to connectors where the TPA is designed to push the terminal into its seated and locked position or to TPAs that are designed such that their mating direction interferes or is perpendicular with a terminal that is unseated.

5.4.9.2 Equipment

- Force tester

5.4.9.3 Procedure

1. Obtain samples. Samples consist of five connectors with terminal secondary locks in the un-seated position and five terminated leads for each terminal size in the connector.

2. Randomly select one cavity of each terminal size from each connector sample. Note that testing is done for each of the terminal sizes used when testing hybrid connectors.

3. Determine the applicable test force to be applied to the secondary lock using this procedure: Add 40 N to the maximum force measured to seat the TPA/PLR device (with all terminals located properly) per 5.4.5.2.3 A4. The test force shall be the determined force or 80 N for ≥1.5 nominal size terminals and 60 N for <1.5 terminals whichever is greater. Note that the force will increase quickly and an automated stop on the machine applying the force will be needed.

4. Partially insert a terminated lead into the selected cavity. The terminal should be inserted until it is just short of locking into position. While holding the terminal in this position, apply the force determined in step 3 at a rate not to exceed 50 mm/min to the terminal secondary lock in the direction of normal seating. Record whether the TPA traveled to its normal seated and locked position.

5. Remove the force, remove the terminal from the cavity, and seat the terminal in its normal position. Inspect for damage. Seat the secondary lock.

6. Perform a terminal retention test on each terminated lead per 5.4.1.3 B.

5.4.9.4 Acceptance Criteria

1. When the force in step 4 is fully applied, the TPA shall not seat in its final position.

2. Terminal retention must meet the force listed in the far-right (post humidity) column of Table 5.4.1.4.

NOTE: Moisture conditioning is not required for this group, the heading of the table applies to a different test.

3. No damage shall be seen in the inspection from step 5.

5.4.10 Terminal/Cavity Polarization Test

5.4.10.1 Purpose

This test is conducted to ensure that the design of the cavity and terminal polarization features will prevent insertion of the terminal in any incorrect orientation. This procedure is not required for multi-directional (round) or other designs where the terminal is meant to plug and lock in any (360 degrees) orientation.

NOTE: Mechanical equipment may not simulate the action of an operator to finesse terminals and connectors during assembly. Therefore, in addition to this procedure, an expert evaluation shall be conducted and documented to show that it is not reasonably possible to incorrectly assemble terminals to connectors. A summary of the results shall be included in the test report.

NOTE: Surrogate data may be used to fulfill the requirements of this test. If surrogate data is used, the design of the cavity, terminal, cable, and all materials (except terminal plating) shall be identical. Other factors such as connector wall thickness double or single row, etc., may also influence the test outcome. The responsible engineer shall determine the need for individual testing in such cases.

5.4.10.2 Equipment

- Insertion force tester with peak reading feature and fixtures or jigs as necessary

5.4.10.3 Procedure

1. By analyzing the cavity and terminal design, choose the incorrect terminal orientations to be tested. At a minimum, each incorrect orientation in increments of 90 degrees must be tested. Rectangular designs where improper insertion at 90 degrees from horizontal is clearly not possible do not need to be tested at these positions. It is permissible to test these designs in 180 degree increments. The responsible engineer is the final authority for determining the positions to be tested.

2. Prepare enough terminated leads to test each orientation selected in step 1 at least ten times. Prepare leads per 5.1.6 using the largest gage size conductor and insulation thickness applicable to the design.

3. Procure connectors sufficient to test each incorrect orientation determined in step one at least ten times using a fresh cavity for each test. Use no less than three connectors. Number each connector and each cavity.

4. Secure the connector shell in an appropriate fixture. The fixture shall not distort the natural state, shape, or geometry of the connector or the terminal cavities

5. Secure the terminal sample in the force tester by gripping the conductor a minimum of 20 mm behind the insulation grip.

6. Adjust the connector holder and force tester to insert the terminal in one of the “incorrect” orientations chosen in step 1. Adjust the force tester to insert the terminal straight into the connector.

7. At a rate not to exceed 50 mm/min, apply a force equaling 1.5 times the maximum force recorded in 5.4.1.3-7 (terminal-connector insertion force) or 15 N, whichever is greater.

8. Insert the terminal into the cavity until the force determined in step 7 is reached.

9. Record results (terminal seated in cavity, terminal inserted but did not seat and to what approximate depth, terminal did not enter cavity, etc.).

10. Repeat steps 4 through 9 using fresh terminals and cavities/connectors until all combinations determined in step 2 have been tested.

11. Complete the visual examination of the terminals and connectors per 5.1.8.

5.4.10.4 Acceptance Criteria

1. Terminals inserted at a force 1.5 times the normal insertion force or 15 N (whichever is greater) in any incorrect orientation shall not fit or lock into a connector cavity beyond the insulation wings (grips) or cable seal (see Figure 5.4.10.4).

2. There shall be no visible damage to either the terminal or connector that would prevent subsequent correct insertion and function following any attempt at incorrect insertion per this procedure.

3. The expert evaluation shall be completed and documented.

NOTE: Where wire buckling and operator sensitivity cause problems in obtaining test repeatability, terminals may be crimped to a gage pin, solid core wire, or other metal dowel material and used to obtain measurements. Samples prepared in this manner require additional connector samples.

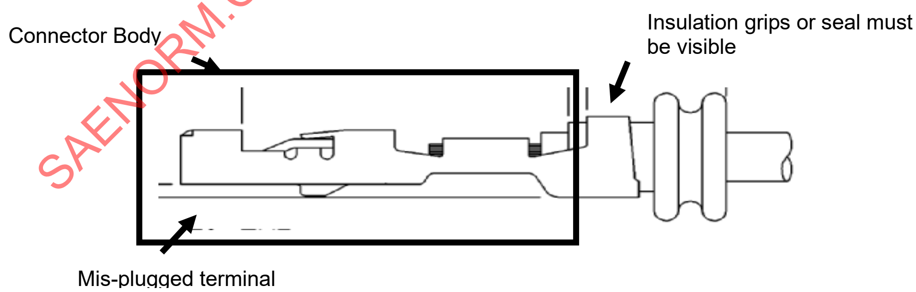


Figure 5.4.10.4 - Maximum allowable insertion of incorrectly plugged terminal

5.4.11 Connector Mounting Feature Mechanical Strength

5.4.11.1 Purpose

This test is designed to test the mechanical strength of clip slots and other designed-in mounting features for electrical connectors. Such features must withstand mechanical stresses (pulling, pushing, etc.) expected in the vehicle including vehicle assembly, service and repair without functional damage to the housing.

5.4.11.2 Equipment

- Force tester

- Metal attachment fixture tooled to the dimensions of a typical mating clip slot (see Figure 5.4.11.3A for an example using the standard 11 mm clip slot)

- Mating connector for the CUT; one non-mounting (mating) connector may be used to test all connectors if not damaged

5.4.11.3 Procedure

1. Ensure the correct number of samples are available. Six directions/locations are tested (F1 through F6). A minimum of 30 connectors (five in each direction) must be tested. Use of a new sample for each test is recommended; however, the same samples may be used for testing various force directions if not damaged. If clip is tested on the connector under test and passes per 5.4.5.1.4, testing in direction F5 does not need to be performed. If a retainer clip is available, it typically will be used to reduce sample size and avoid making a custom fixture with a locking feature.

2. Mate connector under test to its mating connector. Secure the mated connector pair to the attachment bracket in the way intended for use. No additional reinforcement of the connector slot is permitted.

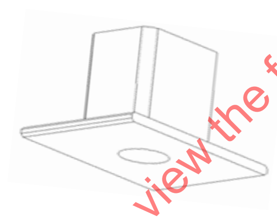


Figure 5.4.11.3A - Mounting fixture example (non-locking)

3. Apply a force to the connector at a rate not to exceed 50 mm/min to the non-mounted mating connector in direction F1 until breakage of the mounting feature, release from fixture, or the force specified in the acceptance criteria of 5.4.11.4 is reached. Apply the force 5 mm from the edge (rear or side as applicable). Figures 5.4.11.3B and 5.4.11.3C provide illustrations for typical connectors.

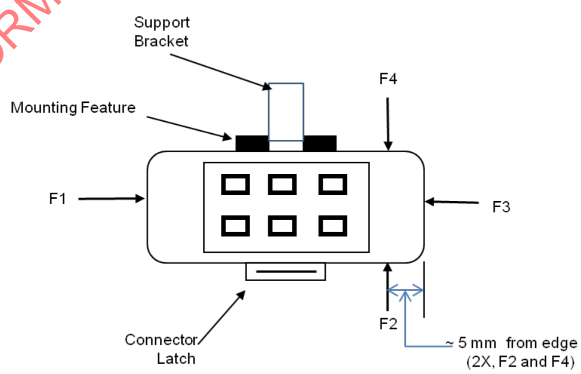


Figure 5.4.11.3B - Test set-up (end view)

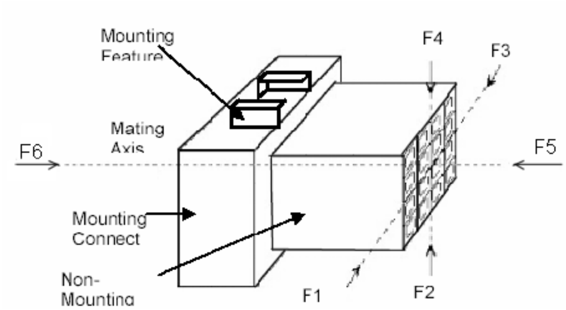


Figure 5.4.11.3C - Test set-up (3D view)

4. Remove the connector from the fixture.

5. Repeat steps 2 to 4 with four additional connectors.

6. Repeat steps 2 to 5 in the other directions, F2, F3, F4, F5 (if needed), and F6. Each force is designed to be applied 90 degrees apart. (As noted before, if clip is tested on the connector under test and passes per 5.4.5.1.4, testing in direction F5 does not need to be performed.)

5.4.11.4 Acceptance Criteria

Table 5.4.11.4 - Clip slot acceptance criteria

Direction of Force Per Figure 5.4.11.3 B/C	Clip Slot Width ≤11 mm (N)	Clip Slot Width >11 mm (N)
F1	50	50
F2	50	50
F3	50	50
F4	50	50
F5*	110	165
F6	50	50

* Typically not tested if there is a pass of 5.4.5.1.

5.4.12 Mechanical Assist Integrity (Connectors with Mechanical Assist Only)

5.4.12.1 Purpose

This test is used to ensure that lever or slide assist features as part of a connector assembly will remain in place and undamaged during the wiring harness and vehicle assembly process.

5.4.12.2 Equipment

- Force tester

5.4.12.3 Procedure

1. Prepare a minimum of five sample connectors with levers/slides in their open position. Wires, terminals, TPAs, and seals are not required.

2. Complete the visual examination per 5.1.8.

3. Make a fixture that will secure the connectors to be tested without distorting any of the parts. Mating parts may be used as part of the test fixture.

4. Mount the samples in the fixture.

5. Apply a 100 N force in direction "F," as shown in Figure 5.4.12.2, at the rate of 50 mm/min ± 10 mm/min with the lever or slide in both the open and closed positions. The point of the force application is determined by the authorized person to be that which is most likely to cause failure.

6. Apply a 100 N force in the direction opposite to direction "F" at the rate of 50 mm/min ± 10 mm/min with the lever or slide in the open and closed positions.

7. Position the slide or lever in a position approximately halfway between the open and closed positions. Apply a 60 N force in direction "F," as shown in Figure 5.4.12.2, at the rate of 50 mm/min ± 10 mm/min.

8. Position the slide or lever in a position approximately halfway between the open and closed positions. Apply a 60 N force in the direction opposite to direction "F," as shown in Figure 5.4.12.2, at the rate of 50 mm/min ± 10 mm/min

9. Complete the visual examination per 5.1.8.

Figure 5.4.12.2 - Side force strength

5.4.12.4 Acceptance Criteria

1. The lever/slide must withstand a 100 N force in the open and closed positions without separation or damage.

2. The lever/slide must withstand a 60 N force in the midpoint position (lever half -way closed) without separation or damage.

5.4.13 Connector Seal Retention - Unmated Connector

5.4.13.1 Purpose

This test is done to ensure that connector seals will be sufficiently retained during shipping and handling prior to being mated or assembled.

5.4.13.2 Equipment

- Variable speed motor with rotating table

5.4.13.3 Procedure

NOTE: If the design uses a pre-staged secondary component that interacts or aids in the retention of the connector seal, then conduct the test with this component in both its pre-staged and final position. If the design uses a loose-piece secondary component, then conduct the test with and without this component.

1. Prepare ten fully assembled connector samples. Terminals and wires are not required.

2. Properly secure the sample under test per Figure 5.4.13.3 and ensure that only the connector seal is free to move.

3. Rotate the table at a speed [rpm] to generate a minimum acceleration of 1960 m/s^2 [≈200g] for a minimum of 10 seconds. Direction is optional. Using the equation below, calculate the required RPM.

$$N = [(\mathrm{sqrt}\ (a/R)) \times 60]/(2 \times \pi)$$

where:

a = acceleration in m/s^2

R = distance [meters] from the center of rotation to the nearest edge of the connector seal

Example:

a = 1960 m/s^2 and R = 0.2 m → N = [(sqrt (1960 m/s^2/0.2 m)) x 60s]/(2 x π)→ N = 945.33 rpm

4. Record and document [photograph] the position of the connector seal.

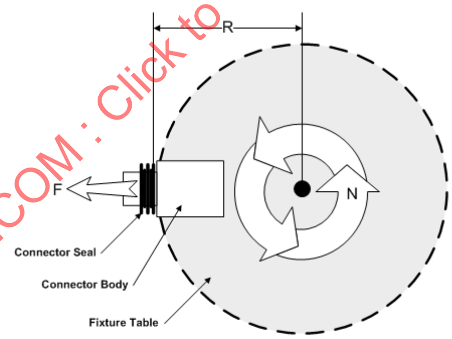


Figure 5.4.13.3 - Unmated connector seal retention test configuration

5.4.13.4 Acceptance Criteria

The connector seal shall be sufficiently retained in design position such that both mating of the connector and the function of the seal are not diminished.

5.4.14 Connector Seal Retention - Mated Connector

5.4.14.1 Purpose

This test is used to determine that the connector seal will retain during mating and unmating of the connector assembly.

5.4.14.2 Procedure

1. Prepare ten female housings with radial seals and ten complimentary male connectors or mating parts along with terminals, wires and seals as appropriate for the design.

2. Mate connector to device or mating male connector.

3. Remove connector from the device or mating connector by using the wires when possible or by grasping the connector housing. Connector shall be fully separated within 1 second.

5.4.14.3 Acceptance Criteria

Seal shall remain on the connector and in its intended position.

5.4.15 Airbag Inflator Connector Self-Rejection Assessment

5.4.15.1 Purpose

This test determines the self-ejection performance of airbag connectors designed to self-reject if not properly mated. The self-ejection performance is important in determining if an incompletely mated connector can be detected by monitoring for electrical disconnection. The test procedures apply to 90 degrees (right angle) and 180 degrees (straight) versions. This specification applies to versions with and without shorting bars.

5.4.15.2 Equipment

- Force tester with rectangular probe (size between 8 mm and 9 mm, round, rectangular, or square). Customer and supplier may agree on a smaller size only if the available push surface cannot fit the called-for sizes. Any variance must be noted in the test report.

- Continuity tester (CT)

- Power supply capable of 100 mA DC

- Inert igniter pocket with applicable coding ring, as applicable (typically per EWCAP 999-U-002-1-Z02) with 2 Ω bridge resistor. Reuse of this part is allowed so only one device is required for the test.

- Retainer as applicable to design (for example, per EWCAP 999-U-002-1-Z03 or EWCAP 999-U-002-1-Z04)

- Shim with thickness matched to connector under test so the connector is just prevented from locking

5.4.15.3 Procedure

1. Prepare a sample group with a minimum of ten samples for each of four probe positions (40 samples min) with complete assembled squib connectors. Any conductor size and insulation type applicable to the connector can be used. These details must be documented in the test report. Number each connector assembly.

2. Determine an applicable shim thickness as shown in Figure 5.4.15.3E so when placed between connector and top surface of igniter, the shim prevents the connector from locking but comes as close as possible to allowing the connector to lock. No friction between shim and connector is allowed. Place the shim on the inert inflator as shown in Figure 5.4.15.3E.

3. Attach continuity test leads to the connector as shown in Figure 5.4.15.3A. The electrical measurement is done through the inert igniter.

4. Secure the inert inflator in an appropriate fixture. Place, but do not secure, the female connector on the male connector in the correct mating orientation. Adjust the probe to insert the female connector axially to the male counterpart. (Straight-in engagement is important to avoid torque loads and torsion, which may affect the force results.)

5. Test per this sequence:

   a. Set stop force on force tester to 80 N to avoid damage or compression of sample.

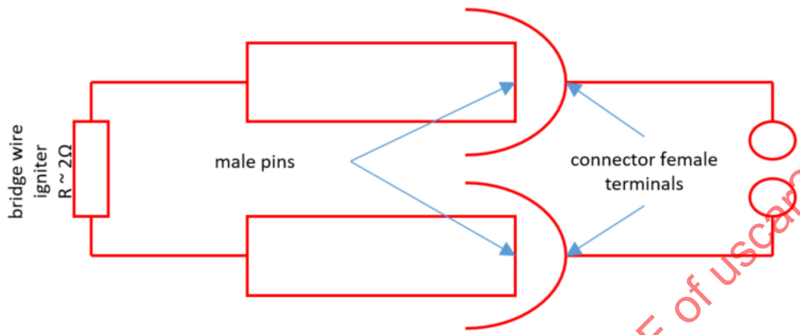


Figure 5.4.15.3A - Circuit for monitoring continuity

   b. Mate the connector at a uniform rate of 50 mm/min ± 10 mm/min in position 1, 2, 3, or 4 as applicable per step e (see Figure 5.4.15.3B for locations). Continue until the female connector is blocked by male counterpart and shim.

   c. Reverse test direction to unmating direction at a rate of ≥300 mm/min until movement of connector stops. Ensure that force probe is not in contact with connector after this step.

   d. Record whether the electrical signal indicates disconnected (resistance infinite) or connected (resistance is not infinite and approximates the value of the bridge resistor). The resistance value itself will be different depending on shorting clip version and actuation method and does not need to be recorded.

   e. Repeat test with probe in positions 2, 3, and 4 per Figure 5.4.15.3B using new samples. Note that additional test locations have the force applied off-center with ~1 mm of probe contacting the connector body.

   f. Repeat above steps for all samples of group.

Area to apply the probe for testing is marked as 1 through 4, where #1 probe location is centered on the axis of the interface as close as possible without disturbing wires or motion of connector components (spring, CPA, etc.).

For locations 2, 3, and 4, the probe overhangs, contacting only 1 mm of the connector.

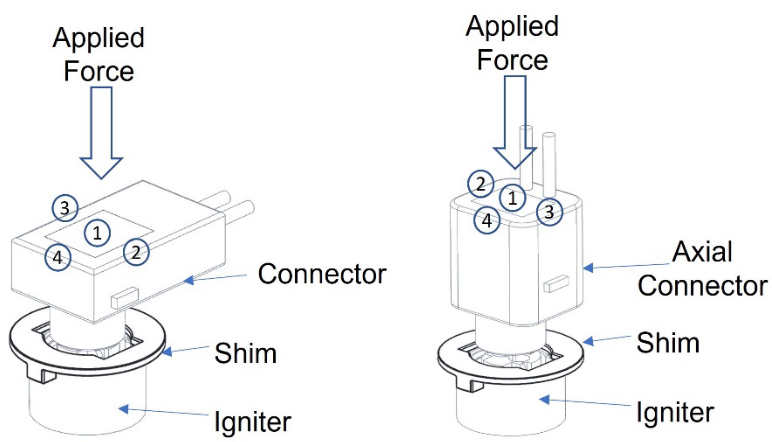


Figure 5.4.15.3B - Self rejection set-up (90 degrees and 180 degrees)

5.4.15.4 Acceptance Criteria

Connector shall be disconnected at end of movement by having an infinite resistance reading and visual confirmation

NOTE: The acceptance criteria of this section is not linked with mating force. Forces are measured by the separate relevant paragraphs. The result of this section is not a resistance value; it is an electrical condition (connect/disconnect).

5.4.16 Bolted Connector Function

5.4.16.1 Purpose

This test determines whether a bolt-mated connector will remain operational for the life of a vehicle.

5.4.16.2 Equipment and sample prep

Equipment: Force tester (6 kN capacity, minimum) with applicable test fixtures and probes to push and pull connector's bolt head.

- Samples: When used for "bolt-mated connector (stand alone)" per test sequence AK (see Table 5.9.5), divided samples into two equal groups:
- Group A, fully populated
- Group B, at least 75% of the wires removed leaving wires in the furthest corner from the bolt (or a location that would induce the largest offset mating force).

For all other test sequences, use three samples (randomly selected) for the test.

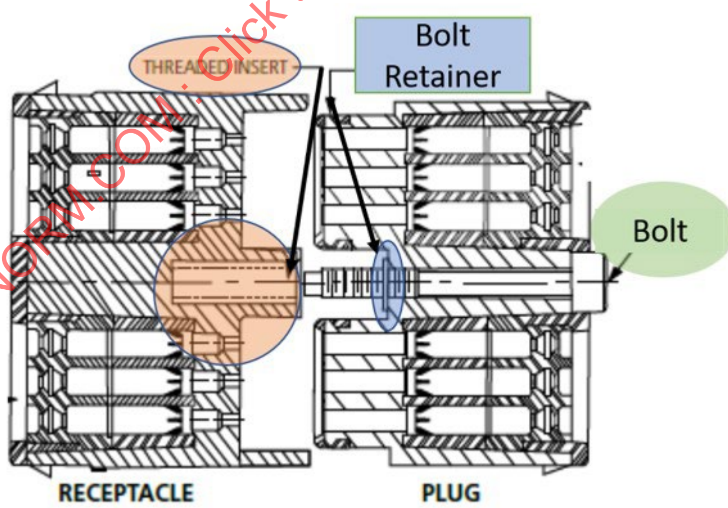


Figure 5.4.16.2 - Parts of a bolted connector

5.4.16.3 Procedure

1. If connector is mated from prior operations, inspect the permanent line mark placed on the bolt and nearby connector structure in USCAR-2 step 5.1.7.3. Record whether the initial bolt head position has changed, and by how much. Unmate connector. Record the torque required to unmate.

2. Place a mark either vertically or horizontally across the threaded insert and accompanying support walls. This will be the “zero-point of insert” marking.

3. Mate connector under test (CUT) using the recommended installation torque. (This is referred to as the first mating.) Omit this step if connector was mated in prior operations.

   NOTE: The recommended installation torque is provided by the connector engineer based on the design. Using a torque tied to standardized manufacturing practices for air guns will generate too much torque for this test method.

4. Unmate CUT. Record the torque required to unmate.

5. Inspect and record any displacement from the zero-point marking of the insert.

6. Mate CUT again, applying 200% of the recommended installation torque (second mating).

   NOTE: The 200% requirement is based on having a “recommended installation torque” based on the torque needed to mate the connector. If the torque requirement is directed by an OEM in order to standardize power tools, the requirement may not be applicable. If the recommended installation torque is not based on the force to mate the connector plus an acceptable design margin, this requirement needs to be assessed between supplier and customer.

7. Unmate. Note any difficulties in disassembly.

8. Inspect for damage related to the bolt-assisted mating. Record any displacement from the zero-point of insert marking.

9. Using three samples (from group A, when performing the stand-alone test), continue testing using the following steps. For all other samples, if CUT passes, proceed to the next step in the test sequence.

10. Mate the connector (third mating) until the bolt is hand tight.

    NOTE: At the discretion of the lab manager, a separate bolt can be used rather than mating the entire connector.

11. Mount connector on a force tester with the bolt facing the tester’s movable probe. Align the probe’s center to the bolt’s center.

12. Slowly apply force in direction A per Figure 5.4.16 until 3 kN is reached and hold for at least 30 seconds. NOTE: Stop the test if failure occurs before test force is reached or test hold time elapses.

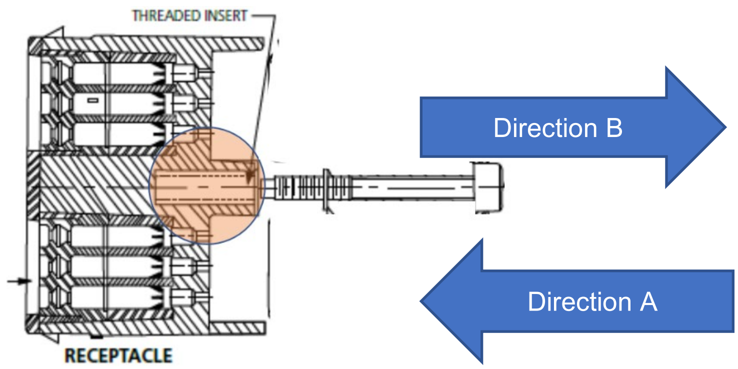


Figure 5.16.3 - Direction of force for bolt connector insert strength test

13. Release the force. Remove CUT from force tester and visually inspect for defects related to bolt function. If CUT passes, proceed to the next step.

14. Disassemble and measure the displacement of threaded insert relative to the connector housing. Calculate how much the insert moved from its initial position.

15. Re-assemble the connector (fourth mating). Attach a test fixture that allows the bolt to be pulled in direction B per Figure 5.4.16.3.

    NOTE: At the discretion of the lab manager, a separate bolt can be used rather than mating the entire connector. The lab manager may also insert the bolt into the back of the connector to allow a push force to be used instead of a pull force.

16. Mount CUT on a force tester and slowly apply a force on the centerline of the bolt in direction B per Figure 5.4.16 until 6 kN is reached and hold for at least 30 seconds. NOTE: Stop testing if failure occurs before test force is reached or test hold time elapses.

17. Measure displacement of threaded insert relative to the connector housing (in mating directions A/B). Calculate how much the insert moved from its initial position.

18. Inspect for damage.

19. Re-assemble connector (fifth time) and apply torque until there is a failure. Note failure mode (whether the bolt breaks first or insert spins or strips first).

20. If CUT passes, proceed to the next step in the test sequence.

5.4.16.4 Requirements

1. If CUT is part of a larger test sequence and a mark was placed on the CUT per USCAR-2 step 5.1.7.3, the bolt head shall be in the same position as it was initially, as indicated by the mark.

2. Inspection of CUT shall show no damage related to the mating and unmating operations on first, and second mates.

3. Threaded insert shall not move more than 0.5 mm because of the applied force in direction A after third mating or direction B after fourth mating.

4. Bolt must break during fifth mate (over-torque-to-failure test). Bolt shall break at a torque higher than 200% of the recommended application torque. No other part of CUT shall break other than the bolt.

5. Threaded insert shall remain at the zero point of the insert after all connector mates, including when applying torque-to-failure during fifth mate.

6. Threaded insert shall not have stripped threads or spin in the connector housing after any test, including the fifth mating (to connector failure).

7. For samples put through environmental testing, connector unmating process shall not be changed in any way because of the exposure to the environmental stresses (i.e., part operates as easily after environmental stress as before).

5.5 Connector - Electrical Tests

5.5.1 Insulation Resistance

5.5.1.1 Purpose

This test verifies that the electrical resistance between any two cavities in a connector system will be sufficient to prevent detrimental electrical conductivity (current leakage) between the various circuits passing through that connector system. This test is typically done after other environmental stress tests to ensure that any contaminants that may have entered the connector during testing are not sufficient to create an unintended electrical path. This test shall be performed on all connector types both sealed and unsealed.

5.5.1.2 Equipment

- Megohmmeter

5.5.1.3 Procedure

NOTE: This test is typically used only in conjunction with another test that subjects the connector to the chance of some form of moisture or other contaminant intrusion. Test the same samples used for the related test. For unsealed connector pairs, test samples must rest in ambient environment for ≥3 hours prior to measuring insulation resistance after any prior environmental conditioning. When sealed connectors are to be tested following exposure to moisture or other contaminants (except in fluid resistance test) it is important that this insulation resistance test be performed on each sample within 1 hour of concluding the associated test (otherwise, any contaminant that might invade the samples may dry to the point of being undetectable by this insulation resistance test).

1. Prepare cut leads as specified in 5.1.6, if not done already.

2. Connect the megohmmeter, with the power off during set-up, to the bared conductor ends, as illustrated in Figure 5.5.1.3 so that adjacent cavities have opposite polarization. For special applications, the test voltage may be reduced or increased with the approval of the authorized person. Keep power off while the CUT may be touched. Test coaxial cables with voltage on the center conductor and the ground on the shield wire.

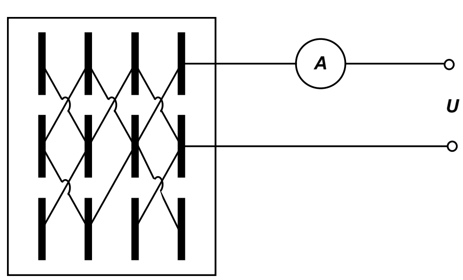


Figure 5.5.1.3 - Method of connecting leads for insulation resistance test

3. Use the megohmmeter to measure the resistance between adjacent terminals: Apply a test voltage of 500 VDC and allow the meter to stabilize. Test the mated connector assembly for those samples that have been subjected to prior stress testing. Test both halves of the connector system if applicable.

4. Record the minimum resistance measured and verify conformance to the acceptance criteria of 5.5.1.4.

5. For connectors with shorting bars, take the insulation resistance measurement between the two terminals designed to be shorted together by the shorting bars (shorting bars “open”).

5.5.1.4 Acceptance Criteria

The resistance between every combination of two adjacent terminals in the CUT must exceed 100 MΩ at 500 VDC. This includes terminals that may be separated by one or more vacant terminal cavities.

5.6 Connector Environmental Tests

5.6.1 Thermal Shock

5.6.1.1 Purpose

This test subjects the connector assembly to extreme temperature cycles that cause expansion and contraction of the various materials used in the connector system. This is intended to produce accelerated wear at the terminal interface.

5.6.1.2 Equipment

- Two temperature chambers: Cold soak chamber capable of -40 °C and hot soak chamber capable of meeting maximum temperature of the temperature class selected from Table 5.1.4.1

5.6.1.3 Procedure

1. Number each mated connector pair.

2. Determine the temperature class for the intended application of the connector system from Table 5.1.4.1. Set the cold soak chamber temperature to the minimum ambient temperature for that class. Set the hot soak chamber to the maximum ambient temperature for the temperature class selected. Allow the chambers to stabilize.

3. Place the samples in the cold soak chamber so that there is no substantial obstruction to air flow across and around the samples and the samples are not touching each other.

4. Allow the samples to cold soak for 30 minutes.

5. Transfer samples from the cold to hot chamber in less than 30 seconds. (Automated equipment that moves CUT from cold to hot chambers is acceptable.)

6. Allow the samples to heat soak for 30 minutes.

7. Transfer the samples from the hot soak chamber to the cold soak chamber.

8. Repeat steps 4, 5, 6, and 7 99 more times.

5.6.1.4 Acceptance Criteria

Verify conformance of CUT/TUT per corresponding measurement section as identified in 5.9.

5.6.2 Temperature/Humidity Cycling

5.6.2.1 Purpose

This test simulates actual operating conditions using temperature and humidity variations as aging mechanisms for evaluation of a connector system's electrical durability. High humidity and temperature can promote galvanic and electrolytic corrosion of the terminals which may cause electrical and mechanical degradation. Temperature cycling promotes relative movement of the contact surfaces that can cause wear and fretting corrosion. Certain plastic materials may also degrade.

5.6.2.2 Equipment

- Temperature chamber(s) capable of -40 °C to temperature class selected from Table 5.1.4.1 and RH of 0 to 95%

5.6.2.3 Procedure

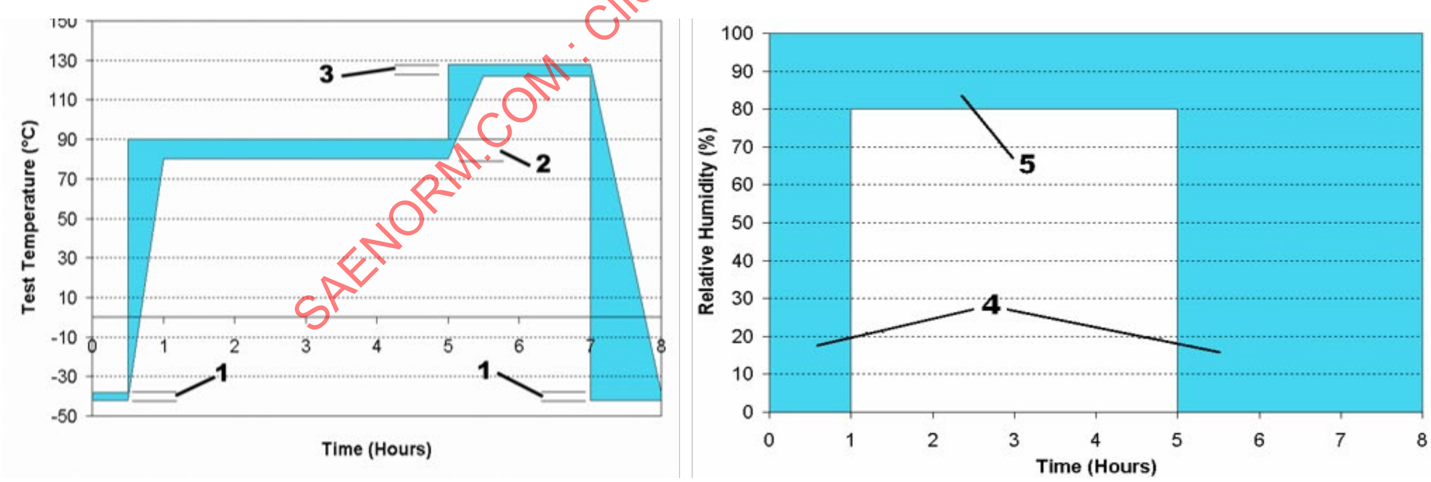
1. CUT must include all applicable wedges (TPAs, PLRs, etc.), seals, etc. Number each mated connector pair.

2. Place the samples in the chamber so that there is no substantial obstruction to air flow across and around the samples, and the samples are not touching each other.

3. Determine the temperature class for the intended application of the connector system from Table 5.1.4.1. Then set the temperature chamber to the temperature for that class. Allow the chamber to stabilize before proceeding.

4. Subject samples to 40 times per the blue-shaded cycling schedule shown in Figure 5.6.2.3. Extended transition times may be used as long as the dwell times at temperature are maintained. The cycle begins with the sample at -40 °C and un-controlled relative humidity. Completion of the schedule shown in Figure 5.6.2.3 constitutes one cycle. Use the maximum ambient temperature for hours 5 through 7, as determined from Table 5.1.4.1 in step 6 above.

5. At the conclusion of the test, measure the CUT/TUT as required per appropriate test sequencing table.



Key:
1. -40 °C
2. 80 to 90 °C
3. Test temperature per Table 5.1.4.1 (class 3 shown for illustration)
4. Relative humidity is uncontrolled. Do not vent chamber at hour 5.
5. Use 80 to 100% relative humidity

Figure 5.6.2.3 - Temperature/humidity cycling schedule

5.6.2.4 Acceptance Criteria

Verify conformance of each CUT/TUT per corresponding measurement section as identified in 5.9.

5.6.3 High Temperature Exposure

5.6.3.1 Purpose

This test evaluates the effects of long-term exposure to elevated temperature on connector assembly components. Thermal aging may cause changes in metal and plastic materials, including stress relaxation in important flexing members of the terminal or its connector. These changes may be detrimental to electrical and physical performance.

5.6.3.2 Equipment

- Temperature chamber(s) -40 °C to + temperature class selected from Table 5.1.4.1.

5.6.3.3 Procedure

1. CUT must include all applicable wedges (TPAs, PLRs, etc.), seals, etc. Number each mated connector pair.
2. Determine the temperature class for the intended application of the connector system from Table 5.1.4.1. Then set the temperature chamber to the maximum ambient temperature for that class. Allow the chamber to stabilize before proceeding.
3. Place the samples in the chamber, set to the maximum ambient temperature, so that there is no substantial obstruction to air flow across and around the samples, and the samples are not touching each other. Leave the samples in the chamber for 1008 hours.
4. At the conclusion of the test, measure the CUT/TUT as required per appropriate test sequencing table.

5.6.3.4 Acceptance Criteria

Verify conformance of CUT/TUT per corresponding section identified in 5.9.

5.6.4 Fluid Resistance

5.6.4.1 Purpose

This test evaluates the sealing capability and material compatibility of a sealed connector system when immersed in various fluids commonly found in and around road vehicles.

This test is for sealed (S2, S2.5, and S3) connector systems only. Since the same materials are commonly used for numerous connection systems, the use of surrogate data is acceptable for this test. If surrogate data is used, all references to the original test(s) shall be included in the test report.

5.6.4.2 Equipment

- Laboratory fume hood
- Stainless steel tanks or glass beakers
- Explosion-proof heat chamber

5.6.4.3 Procedure

1. CUT must include all applicable wedges (TPAs, PLRs, etc.), seals, etc. Number each mated connector pair.

2. Completely submerge sample for 30 minutes in fluids, stabilized at the temperatures shown in Table 5.6.4.3. A fresh sample is to be used for each fluid.

Table 5.6.4.3 - Fluid test schedule

Fluid	Specification	Test Temp (°C)
Gasoline	Any grade, locally obtained	23 ± 5
Diesel fuel	Any grade, locally obtained	23 ± 5
Engine oil	API certified, any grade, locally obtained	50 ± 3
Ethanol	≥85% Ethanol, locally obtained	23 ± 5
Power steering fluid	Any grade, locally obtained	50 ± 3
Automatic transmission fluid	Dexron VI, locally obtained	50 ± 3
Engine coolant	50% ethylene glycol + 50% distilled water by volume, locally obtained	50 ± 3
Brake fluid	DOT 4 or 5 (or latest available fluid), locally obtained	50 ± 3
Diesel exhaust fluid (DEF)	API certified, locally obtained	23 ± 5

3. At the conclusion of the submersion period, remove the sample from the fluid. Do NOT shake off any excess fluid. Use care not to splash any fluid on unintended surfaces. Leave the samples “wet” and store them in a suitable container or area at lab ambient temperature for 7 days. Do not allow samples submersed in different fluids to touch each other and do not allow any dissimilar fluid drippings to intermingle.

4. At the conclusion of the storage period, samples may be dried sufficiently to allow inspection and to avoid contamination of test apparatus.

5. At the conclusion of the test, measure the CUT/TUT as required per appropriate test sequencing table.

5.6.4.4 Acceptance Criteria

Verify conformance of CUT/TUT per corresponding measurement section as identified in 5.9.

5.6.5 Submersion

This test is to be used for sealed (S2, S2.5, and S3 sealing classification) connector systems.

5.6.5.1 Purpose

This test is an accelerated simulation of the “breathing” that may occur in a sealed connector system when it is heated and suddenly cooled by submersion in a cooler liquid. Salt water is used as the liquid to facilitate detection of any leakage into the connector. As a further aid to detecting any leakage, it is recommended that a suitable ultraviolet dye be added to the saltwater solution.

5.6.5.2 Equipment

- Stainless steel tanks or glass beakers
- Megohmmeter
- Temperature chamber (-40 °C to + temperature class selected from Table 5.1.4.1)

5.6.5.3 Procedure

This test is intended for test sequences S, RSAA, T, and TUAB (see 5.9.7) for full validations. For submersion-standalone use test sequence AC (see 5.9.9).

1. Prepare CUT. Seal all loose conductor ends to eliminate possible leakage through the conductor strands. Install all applicable wedges (TPAs, PLRs, seals, etc.). Number each mated connector pair.

2. Prepare enough saltwater solution to completely submerse the samples. Use tap water and 15 to 16 g of table salt and 10 mL of liquid dish washing soap per liter. Mix well before adding to the test apparatus. It is recommended that an appropriate ultraviolet dye be added to assist in visual inspection for any ingress of solution into the test samples. Cool the solution to 0 °C.

3. Place the samples in the chamber such that there is no substantial obstruction to air flow across and around the samples, and the samples are not touching each other.

4. Determine the temperature class of the connector system from Table 5.1.4.1 and set the chamber to the maximum ambient temperature for that class. Allow the chamber to stabilize before proceeding. Heat soak the samples at the elevated temperature of the chamber for 2 hours. If the internal temperature of a representative sample of the parts to be tested can be shown to stabilize at oven temperature in less than 2 hours, the shorter time may be used. The demonstration sample may not be used as an actual test sample.

5. Remove the samples from the chamber. Within 30 seconds, submerse them in the 0 °C temperature saltwater solution to a depth of 30 to 40 cm. The samples shall remain submersed at this depth for a period of 30 minutes.

6. At the end of the 30-minute submersion, remove the samples from the saltwater solution, shake off the excess solution, and then carefully dry the exterior surfaces of the samples. Immediately perform the insulation resistance test of 5.5.1 on each sample.

7. For sequences AC and AF (5.9.9), repeat steps 3, 4, 5, and 6 four more times. For sequences R, RSAA, U, and TUAB (see 5.9.7), proceed to next test step.

8. At the conclusion of the test, measure the CUT/TUT as required per appropriate test sequencing table.

5.6.5.4 Acceptance Criteria

Verify conformance of CUT/TUT per corresponding measurement section as identified in 5.9.

5.6.6 Pressure/Vacuum Leak

5.6.6.1 Purpose

This test evaluates the sealing capability of connector systems by applying a pressure differential between the inside and outside of the sealed area. It is applicable to sealed connectors being tested to S2, S2.5, and S3 sealing classifications.

5.6.6.2 Equipment

- Pressure/vacuum source (regulated)
- Pressure/vacuum gage - 48 kPa (7 psig) minimum
- Container (for sample immersion)
- Temperature chamber (from -40 °C to applicable temperature per the temperature class selected from Table 5.1.4.1)

5.6.6.3 Procedure

This test is intended for test sequences S, RSAA, U, and TUAB (see 5.9.7) for full validations. For pressure vacuum leak standalone, use test sequence W (see 5.9.9).

1. Ensure CUT consists of a mated connector pair that includes all applicable parts. Number each CUT. Seal all loose conductor ends to eliminate possible leakage through the conductor strands, if not already done.

2. Replace two terminated cables in the connector with two tubes of sufficient diameter and wall strength to ensure that there is no possible leak path between the outer tube surface and the conductor seal into the open cavities in each connector pair. Use of the actual wire leads instead of using tubes is acceptable if the cable composition is such that sufficient air can pass in a reasonable time to complete the test.

   NOTE: It may take several tries to create a system that allows sufficient airflow. The length and inner diameter of the pressure/vacuum supply tubing (or stranded cable if used) as well as the volume within a mated connector has an effect on the time required to reach the pressure/vacuum values within the CUT. Alternative methods of adding pressure/vacuum ports are acceptable as long as the integrity of the part is not compromised.

3. Prepare enough saltwater solution to completely submerse the samples. Use tap water and 15 to 16 g of table salt and 10 mL of liquid dish washing soap per liter. Mix well before adding to test apparatus. It is recommended that an appropriate ultraviolet dye be added to assist in visual inspection for any ingress of solution into the test samples.

4. Bend, do not apply a load, and secure all conductors in the same direction, 90 degrees to the back of each sample connector half and secure them in this position using actual conductor dress shields if available. This is to simulate dressing of the conductors as they exit the connector and is intended to stress the conductor seal(s) as in actual applications. If actual production dress shields are not available, simulate allowable worst-case production application intent as closely as possible. Ensure that the tube is not kinked, squeezed shut or otherwise obstructed. The tube should be left out of the 90-degree bend if feasible.

5. Connect the free end of one of the tubes (or wires, if using) to a regulated pressure source and the other to the pressure/vacuum gage. Completely submerse all samples into a container of the room temperature bath prepared in step 3.

6. Slowly increase the air pressure of the regulated pressure source supplying the tube (wire) in each sample until the monitored pressure within the CUT reads 48 kPa (7 psig). Upon the CUT reaching the specified pressure, observe samples for a minimum of 15 seconds and verify that there are no air bubbles. Note the monitoring requirements outlined in step 2.

7. Switch the regulated source from pressure to vacuum. Decrease the air pressure until the monitored pressure within the CUT reads negative 48 kPa (7 psig) and hold for a minimum of 15 seconds. Note the monitoring requirements outlined in step 2.

8. Remove the samples from the water, shake off excess fluid and then carefully dry all exterior surfaces of the sample. Immediately perform insulation resistance per 5.5.1.

9. For test sequences S, RSAA, T, or TUAB (see 5.9.7), see sequence for appropriate conditioning then proceed to step 11. For sequence W (see 5.9.9), proceed to next step.

10. Place the samples in a temperature chamber stabilized at the maximum ambient temperature for the temperature class selected from Table 5.1.4.1 for the CUT. Heat soak all samples for 70 hours. After the heat soak, remove the samples from the chamber and allow the samples to cool to room temperature.

11. Repeat steps 4 to 9 except limit pressure in step 6 and the vacuum in step 7 to 28 kPa (4 psig).

12. At the conclusion of the test, measure the CUT/TUT as required per appropriate test sequencing table.

5.6.6.4 Acceptance Criteria

1. Upon reaching the specified positive internal pressure and holding for 15 seconds, there shall be no bubbles visible exiting any test sample.

2. Verify conformance of CUT/TUT per corresponding measurement section as identified in 5.9.

5.6.7 High Pressure Spray

5.6.7.1 Purpose

Assess the ability of sealed connection systems to withstand high pressure spray that may be encountered where there is direct road splash or where high-pressure washing is performed. Perform this test for sealed class S2.5 and S3 connectors (see 5.1.4.2). This test is used for test sequences AA, RSAA, AB, and TUAB (see 5.9.7) for full validations and for high pressure spray standalone test sequence AD (see 5.9.9). The high-pressure spray test, when performed at level S3, aligns to ISO 20653 with an IPX9K degree of protection.

5.6.7.2 Equipment

- High pressure sprayer capable of Figure 5.6.7.3-1 configuration and Table 5.6.7.3-1 specifications
- Heated water 80 °C ± 5 °C
- Fan jet nozzle per Figure 5.6.7.3-2
- Device holder
- Rotating table

5.6.7.3 Procedure

NOTE: The procedure that follows tests to level S2.5 first and then to level S3. Omit steps 4 and 5 if the customer does not want an S2.5 evaluation to be performed. Omit steps 6, 7, and 8 if the customer does not want an S3 evaluation to be performed.

1. Ensure CUT includes all applicable wedges (TPAs, PLRs, seals, etc.). Number each mated connector pair.

2. Use samples from prior PV testing, if available. If standalone testing, prepare samples per 5.6.6.3-4. Mount the CUT onto the device holder such that the connector lays flush against the turntable with wires parallel to the table. See Figure 5.6.7.3-1 for mounting position details. See Figure 5.6.7.3-2 for details on how to mount large connectors. See Figure 5.6.7.3-3 for spray nozzle details.

3. Position the sprayer at position 1 and initiate turntable rotation.

4. With the table rotating, spray the CUT as specified in Table 5.6.7.3-1 for level “S2.5.”

5. Remove samples from the chamber, shake off excess fluid and then carefully dry all exterior surfaces of the sample. Immediately perform the insulation resistance test of 5.5.1.

6. Position the sprayer at a 0 degrees and initiate turntable rotation (if not already in place on turntable).

7. With the table rotating, spray the CUT as specified in Table 5.6.7.3-1 for level “S3.”

8. Remove samples from the chamber, shake off excess fluid and then carefully dry all exterior surfaces of the sample. Immediately perform the insulation resistance test of 5.5.1.

9. At the conclusion of the test, measure the CUT/TUT as required per appropriate test sequencing table.

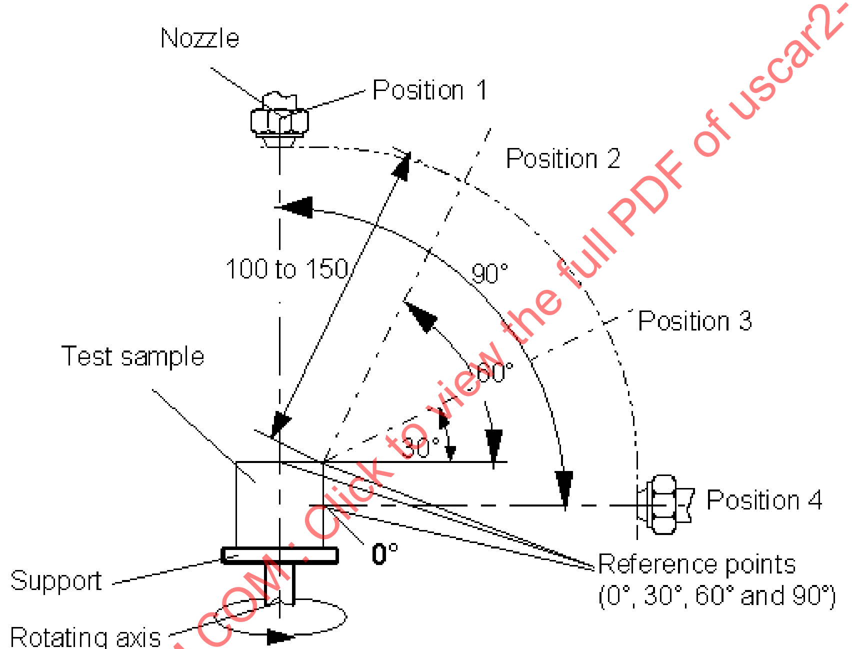


Figure 5.6.7.3-1 - Spray nozzle and table arrangement

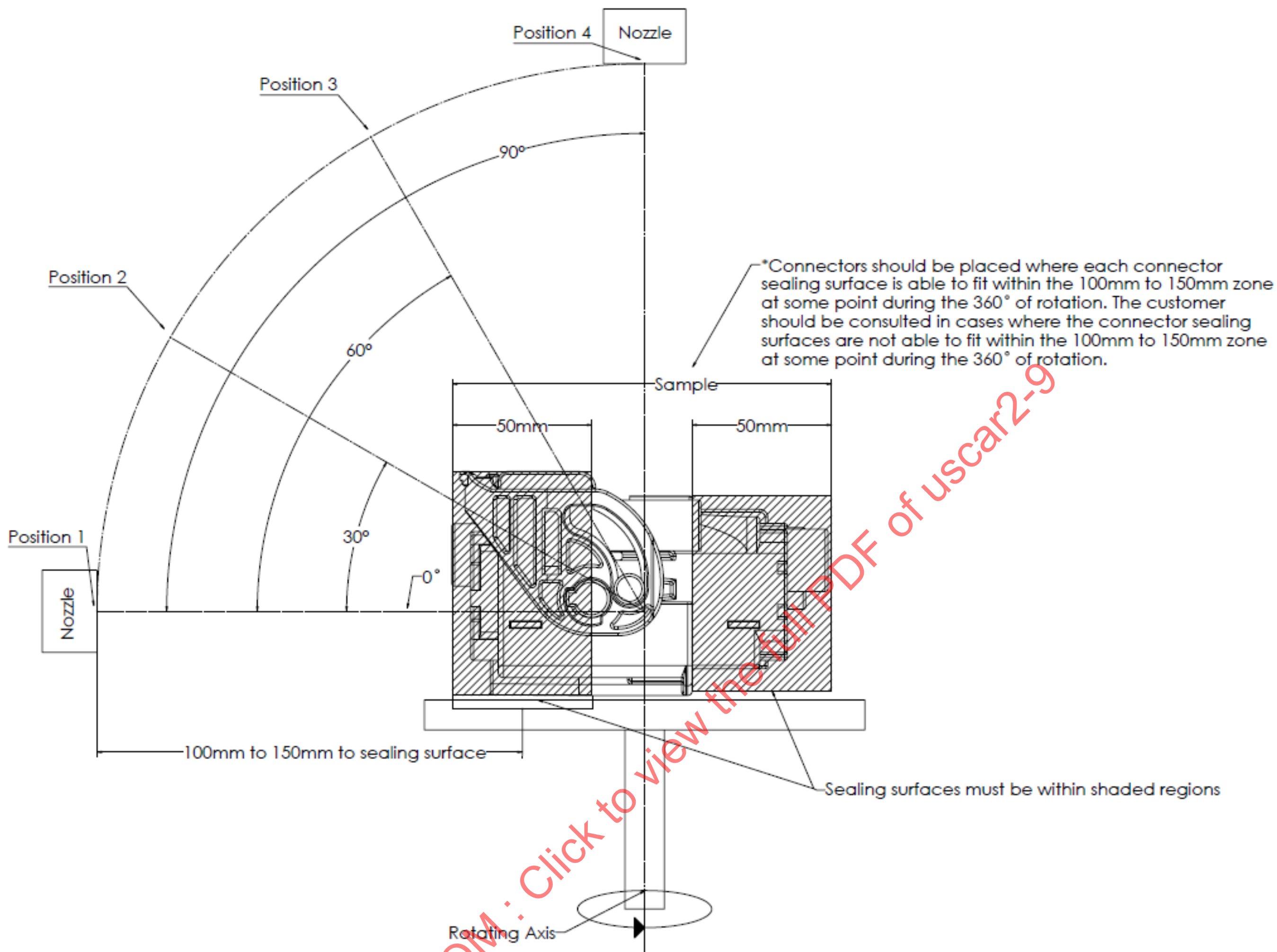


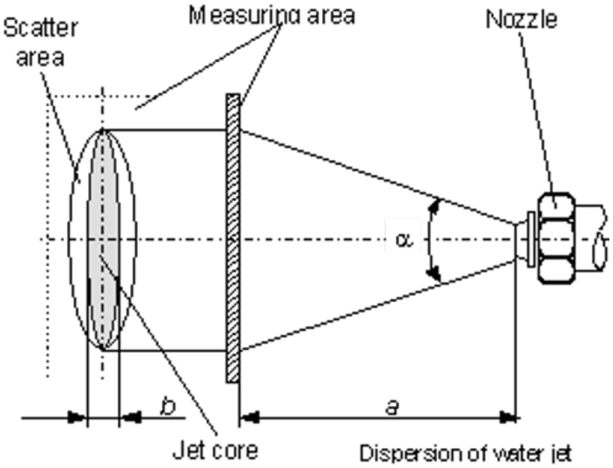
Figure 5.6.7.3-2 - Detail on spray nozzle placement for large connectors

Table 5.6.7.3-1 - Specification for high pressure spray testing

Sealing Level[(1)]	Spray Requirements	Water Pressure and Temp	Exposure Time
S2.5	Turntable Speed = 5 rpm ± 1 rpm Water flow: 14 to 16 L/min	1900 to 2400 kPa, 80 °C ± 5 °C	30 sec. each at positions 1, 2, 3, and 4 per Figure 5.6.7.3-1 (±5 °C)
S3	Turntable Speed = 5 rpm ± 1 rpm Water flow: 14 to 16 L/min	8000 to 10000 kPa, 80 °C ± 5 °C	30 sec. each at positions 1, 2, 3, and 4 per Figure 5.6.7.3-1 (±5 °C)

NOTES:

[(1)] Per Table 5.1.4.2.



α	a	b
30±10	100	8±2
30±10	150	10±2

Figure 5.6.7.3-3 - High pressure nozzle spray range and distance

5.6.7.4 Acceptance Criteria

1. Level “S3” requires passing IR test after spray level “S3 is performed.”

2. Level “S2.5” requires passing IR test after spray level “S2.5” is performed.

3. Verify conformance of CUT/TUT per corresponding measurement section as identified in 5.9.

5.7 Tests for Headers

5.7.1 Header Pin Retention

5.7.1.1 Purpose

The header pin retention test is used to determine the retention of the male terminal in stitched or insert molded header connectors. It may also be used to test the attachment of male pins when staked or soldered directly to circuit boards. Proper pin retention ensures that the terminal will not be displaced by forces associated with normal engagement and disengagement of the mating connector. These requirements apply to finished devices only and not to “in-process” products such as pin blocks or other sub-assemblies. The module and/or connector suppliers need to determine at what stage of the process these requirements will be tested and verified.

5.7.1.2 Equipment

- Insertion/retention force tester with peak reading feature
- Appropriate fixtures to hold the connector
- Collets, mandrels, or jaws to grip the terminal or pin in a longitudinal direction as needed