Performance Specification for Automotive Electrical Connector Systems

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PERFORMANCE SPECIFICATION FOR AUTOMOTIVE
ELECTRICAL CONNECTOR SYSTEMS

TABLE OF CONTENTS

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TO PLACE A DOCUMENT ORDER: (724) 776-4970 FAX (724) 776-0790

1. SCOPE

Procedures included within this specification are intended to cover performance testing at all phases of development, production, and field analysis of electrical terminals, connectors, and components that constitute the electrical connection systems in low voltage (0 - 20 VDC) road vehicle applications. 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, > 20 VAC or DC, or to eyelet-type terminals.

No electrical connector, terminal, or related component may be represented as having met USCAR/EWCAP 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 section 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

Diagrams are provided where necessary to clarify the details of the various test procedures. The tests in each section must be performed in the order given unless otherwise specified in the test request/order. Construction details for selected test fixtures and equipment are provided in 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. For the purposes of this specification there are only two types of electrical connectors: sealed and unsealed.

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 OEM's are listed below for reference only:

1st - Applicable FMVSS or other state and federal requirements

2nd - OEM-released Applicable part drawing(s)

3rd – 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 (per section 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-21: Performance Specification for Cable-to-Terminal Electrical Crimps
- SAE/USCAR-25: Electrical Connector Assembly Ergonomic Design Criteria
- AIAG: Measurement Systems Analysis Reference Manual
- ISO TS16949: 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 ISO TS16949 and the AIAG PPAP.

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 Default Test Tolerances

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

Temperature = ± 3 ^{o} C
Voltage = ± 5%
Current = ± 5%
Resistance = ± 5%
Length = ± 5%
Time = ± 5%
Force = ± 5%
Frequency = ± 5%
Flow Rate = ± 5%
Relative Humidity = ± 5% (When controlled)
Sound = ± 5%
Speed = ± 5%
Pressure = ± 5%
Vacuum = ± 5%

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

Room Temperature	=	23 ± 5^{o} C
Relative Humidity	=	Ambient (Uncontrolled as in lab ambient conditions)
Voltage	=	14.0 ± 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.

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 limits the current applied 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 Volts DC ⇒ 0-10 Megohms
4	Current Shunts	100 mA or as required with accuracy of ± 1% of nominal
5	Millivolt Meter	Capable of measuring 0-100 mVDC 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°C to +175°C or as required by Temperature Class ⇒ 0% to 95% RH
10	Vibration Controller	As Required
11	Vibration Table	2640N (600 Lbs.) Sine, 2200N (500 Lbs.) RMS Force (Certification to V4 level may require larger capacity)
12	Vacuum	As Required
13	Megohmeter	Accuracy <5% of full scale
14	High Pressure Spray Equipment	See Section 5.6.7.2
15	Decibel Meter	+/- 1.5 dB “A” scale
16	Seal retention test	Variable Speed Motor with rotating table. See section 5.4.13.2

TABLE 4.5: EQUIPMENT

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 & Calibration

All equipment used for test sample evaluation shall be calibrated and maintained according to the applicable standards and requirements set forth by ISO TS16949 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 Section 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 a premature non-conformance 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 200,000 miles.

5. TEST AND ACCEPTANCE REQUIREMENTS

5.1 General

The tests detailed in this specification are qualitative in nature and are not expected to stress any part beyond its anticipated application limit, except where tests to failure are specified. The test procedures that follow were written as stand-alone tests and may be used as such. However, they are intended to be performed in sequence as specified in 5.9.3 – 5.9.9 via appendix C and D. Common sense is required to overcome any redundancies in sample preparation or in procedures. For example, if samples have already been prepared for the preceding test in a sequence, it should be obvious that the sample preparation step for that individual test (included so that test can be used as a stand-alone test) should be skipped. Should any conflicts or questions arise concerning procedures and/or requirements, contact the Authorized Person.

5.1.1 Performance Requirements

Connection systems must meet all performance test requirements for the appropriate Class as listed in Section 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 for 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 the table below according to the expected environment in their intended vehicle application. Include the classifications to used in the Test Request/Order and the report of results.

5.1.4.1 Temperature Classification

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

Class	Ambient Temperature Range	Typical Application
T1	-40° C to + 85° C	T1 is not recommended for new applications
T2	-40° C to +100° C	Typically suitable for use in passenger compartment
T3	-40° C to +125° C	Typically suitable for use in engine compartment
T4	-40° C to +150° C	Needed for some on-engine applications near hot components
T5	-40° C to +175° C	For use as needed

TABLE 5.1.4.1: COMPONENT TEMPERATURE CLASSES

5.1.4.2 Sealing Classification

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

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 (meets requirements of 5.9.7) is for exposed locations
S3	Sealed (with High Pressure Spray)	S3 is for exposed locations. S3 meets Sections 5.9.7 plus 5.6.7; it is applicable when robustness to direct splash is needed

TABLE 5.1.4.2: COMPONENT SEALING CLASSES

5.1.4.3 Vibration Classification

Components to be tested must be assigned a class from the table below according to their intended vehicle applications. See Table 5.4.6.3A, B, and C for Vibration Schedules and Figure 5.4.6.3D for Vibration graphs.

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 => pass also for V1
V3	Severe On-Engine	Components subject to severe vibration	Pass on V3 => pass also for V1 and V2
V4	Extreme Vibration	Used as needed to correlate to extreme vibration areas	Pass on V4 => pass also for V1 and V2 and V3
V5	Unsprung Component	Wheel-mounted components	None

TABLE5.1.4.3: COMPONENT VIBRATION CLASSES

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 & 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. Refer to Figure 5.1.5.

Note: 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+/-3mm 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.

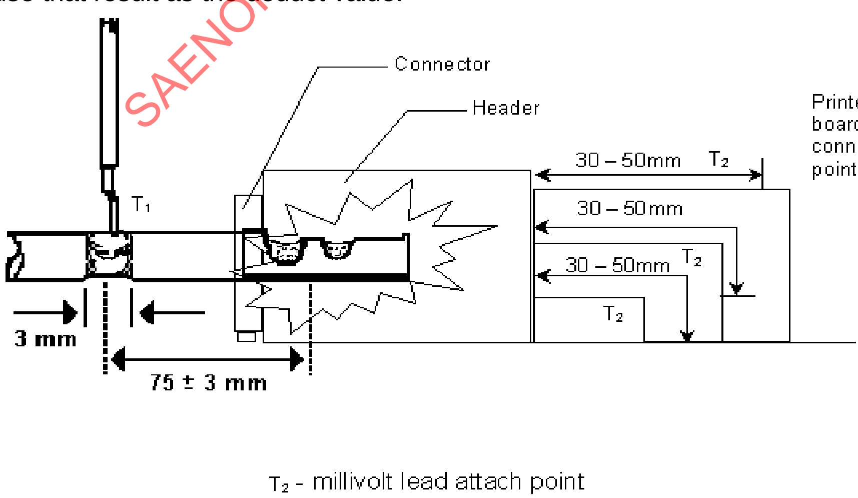


FIGURE 5.1.5: MILLIVOLT LEAD ATTACHMENT (TYPICAL)

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, “Performance Specification for Cable to Terminal Electrical Crimps” Crimp dimension physical characteristics and mechanical pull strength shall be within tolerance as it applies to the respective terminal and wire gage. 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 (ref. Section 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 Performance Specification for Cable-to-Terminal Electrical Crimps 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 series of test as in section 5.9.

5.1.7.2 Equipment

None

5.1.7.3 Procedure

1. Completely mate and un-mate each connector or terminal pair 10 times.

    a. When working with terminals only, use caution to assure that mating and un-mating 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 un-mated) per section 5.3.1. Record the number for later use in calculating the resistance change as part of the Dry Circuit Test procedure.

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.

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 cool white fluorescent lighting. Photographs and/or videos are encouraged as a more complete means of documentation. An appropriately identified untested sample from each test group must be retained for post-test physical comparisons.

5.1.8.2 Equipment

- ⇨ Camera
- ⇨ Video Recorder
- ⇨ Magnification apparatus (as required)

5.1.8.3 Procedure

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.

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. For CUTs subjected to Test Sequence Q (Section 5.9.7), swelling of cable and seals is permissible within the limits of that specific material specification.

5.1.8.3.1 Contact Surface Examination

At the conclusion of the Test Sequence M (Section 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 (photographs):

- Inspect all male terminals
- Inspect all female terminals with resistance over 75% of resistance criteria
- Inspect no fewer than 5 female terminals.

5.1.8.3.2 Sealing/Environmental Protection [Solution Intrusion]

At the conclusion of the appropriate Test Sequence, 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 device under test must not show, any evidence of deterioration, cracks, deformities, etc. that could affect their 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 non-conductive 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 100mA DC

5.1.9.3 Procedure

At least 10 individual terminal and 5 connector pairs must be monitored. On connectors with up to 10 cavities, all cavities shall be monitored on the 5 samples. On connectors with more than 10 cavities, all terminal cavities must be represented in the 5 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 20mvolts. 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 watt, 120 ± 1.2 ohm 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.

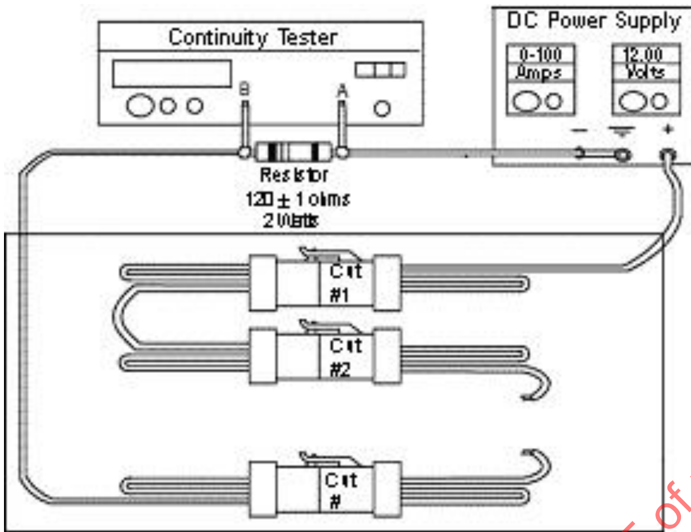


FIGURE 5.1.9.3: CONNECTOR ENVIRONMENTAL TEST SET-UP

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

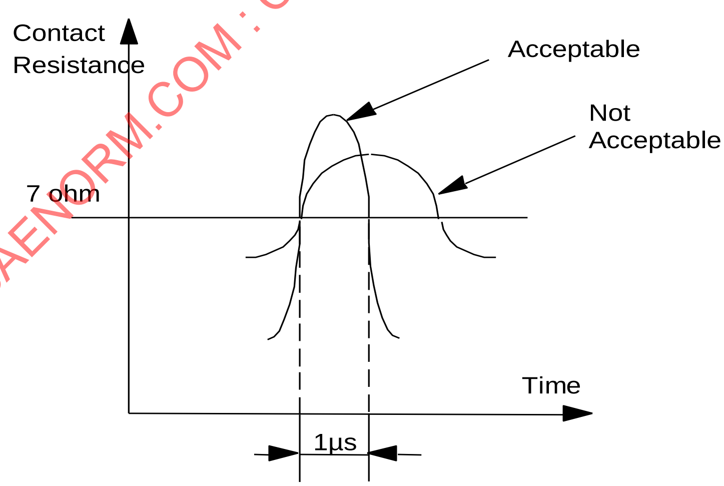


FIGURE 5.1.9.4: INTERMITTENCY MEASUREMENT

5.1.10 Multi-cavity (mat) Conductor Seals Sample Preparation

5.1.10.1 Purpose

This procedure preconditions a multi-cavity (mat) conductor 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 (2) sets of 10 CUT samples. Number each connector pair.

1. 10 samples prepared with the number of terminal samples per Section 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. 10 samples prepared with the number of terminal samples per Section 5.1.6 so that all but one randomly selected cavity in each connector half is populated with a terminal crimped to the largest conductor size. Then fill the remaining cavity in each connector half with the appropriate terminals crimped to the smallest conductor size.

5.1.10.4 Procedure

Select 10 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 a given 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 (10^{th}) 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 (10 male and 10 female) are required. If the optional Step 8 is to be used, at least an additional 10 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 and use this value to verify conformance to the Acceptance Criteria of Figure 5.2.1.4.

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 & 5 nine (9) more times at a rate not to exceed 100mm/min (no readings are taken) Record the 10th disengage force reading taken at a rate not to exceed 50mm/min. Use this value to verify conformance to the Acceptance Criteria of Section 5.2.1.4.

7. Repeat Steps 2-6 for each pair (one male and one female) of sample terminals.

8. (Optional gage test) Repeat Steps 2-7 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 .01 mm of nominal. Surface finish must be 0.076-0.305 micro meters (3-12 micro inches). Polish direction must be parallel to the blade/pin length. Test the additional 10 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 section 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° 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 terminal under test (TUT).

2. For Style "A" terminals, prepare a total of at least 15 samples. For Style "B" terminals, prepare a minimum of 30 terminals, in order to test both bend locations.

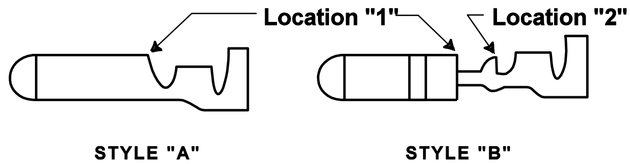


FIGURE 5.2.2.3-1: TERMINAL DESIGN STYLE

3. Number each terminal. (Use at least 5 new samples for each test sequence, Steps 6 - 9).

4. Mount the TUT in a fixture taking care that location "1" is positioned as shown in Figure 5.2.2.3-2.

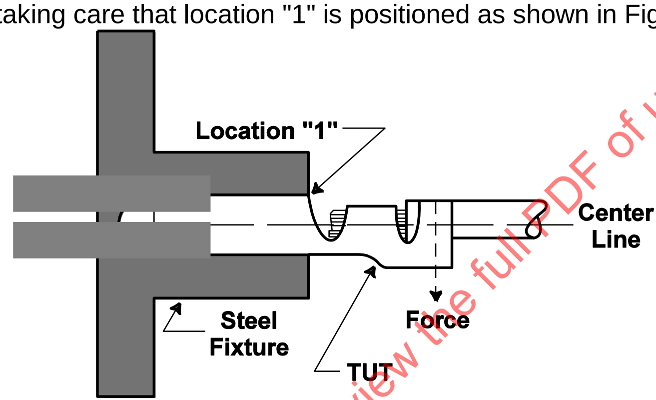


FIGURE 5.2.2.3-2: TERMINAL BEND TEST

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.

Nominal Blade Size (mm)	Applied Force (N)
0.5	3.0
0.64 - < 1.5	4.0
1.5 - < 2.8	7.0
2.8 - < 6.3	10.0
6.3 - < 9.5	15.0
9.5	20.0

TABLE 5.2.2.4: APPLIED BENDING FORCE BY TERMINAL SIZE

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.

7. Select a new batch of at least 5 samples and mount them in the test fixture with the terminal rotated 180^{o} from the position shown in Figure 5.2.2.3-2. Repeat Steps –5-7.

8. Select a new batch of at least 5 samples and mount them in the test fixture with the terminal rotated 90^{o} from the position shown in Figure 5.2.2.3-2. Repeat Steps –5-7. 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 (Figure 5.2.2.3-1), repeat Steps 5 - 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 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. For terminals in mated connector housings, omit Steps 1 and 5 - 7.

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 20 (at least 10 male and 10 female) terminal samples per section 5.1.6, Terminal Sample Preparation, using the cable size per the appropriate table Test Sequence (5.9) applicable to the design of the terminal to be tested.

2. Do NOT mate the terminal pairs until after the millivolt leads have been attached, as directed in Step 5. 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 150mm of the conductor to be used for the test. For tests using a Header terminal as one half of the test connection, refer to Section 5.1.5 and measure only 75 mm (recommended length for most applications) of the conductor

4. For attachment points exceeding 75mm 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. In either case, the sense point T_1 (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 Section 5.1.5. Millivolt leads must be no larger than 0.22 mm^2.

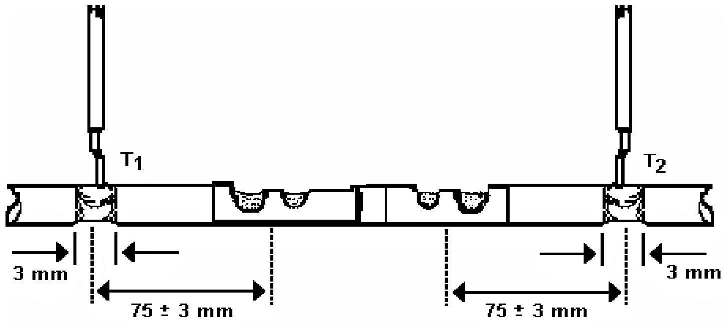
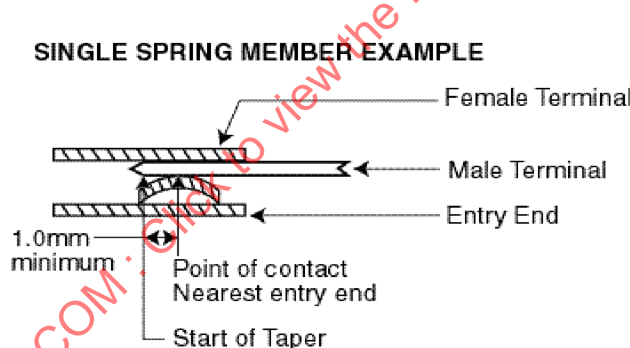


FIGURE 5.3.1.3: TYPICAL CONNECTION RESISTANCE MILLIVOLT LEAD LOCATIONS

6. 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 1mm 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.



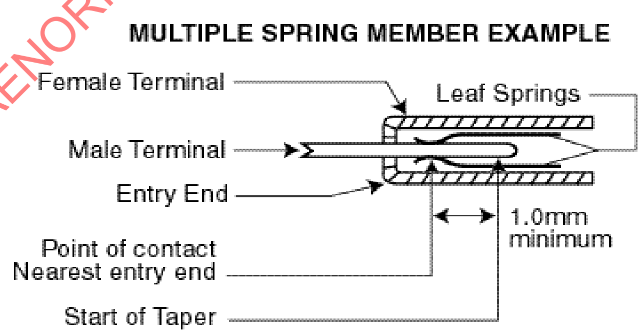


FIGURE 5.3.1.4: TERMINAL INSERTION

7. Prior to mating the test terminal pairs, provision must be made for mounting them on an electrically non-conductive surface in such a manner that the mechanical stability of the male to female interface can be maintained.

8. Carefully mate the test terminal pair to the appropriate depth, as specified in Step 5 above. Use caution to assure 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 Section 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 8 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 <40mΩ. 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.

5.3.2.2 Equipment

- ⇨ Digital Multi-meter (DMM)
- ⇨ DC Power Supply (0-20 VDC @ 0-150 A)
- ⇨ Current shunts

5.3.2.3 Procedure

1. Prepare 20 (at least 10 male and 10 female) terminal samples per section 5.1.6, Terminal Sample Preparation, using the cable size per the appropriate table Test Sequence (5.9) applicable to the design of the terminal to be tested.

2. For purposes of this test, 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 1mm 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. Do not use the connector housings, even unsealed, to control terminal insertion since the housings will alter heat dissipation during testing. This will compromise test repeatability and will invalidate comparisons of data collected for various terminals.

3. Prior to mating the test terminal pairs, provision must be made for mounting them on an electrically non-conductive surface in such a manner that the mechanical stability of the male to female interface can be maintained.

4. Carefully mate the test terminal pair to the appropriate depth, as specified in Step 2 above. Use caution to assure 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, Current Resistance Test Set-Up. Adjust the power supply to provide the required test current of 5A per square millimeter of conductor cross section for the conductor selected in Step 1. Refer to ISO 6722-1, SAE J1127 or SAE J1128 for the cross sectional area of the conductor selected. More than one terminal pair may be tested in series. Refer to Figure 5.3.1.3 for Connection Resistance Millivolt Lead Locations, for placement of the millivolt test leads. Record the test current used.

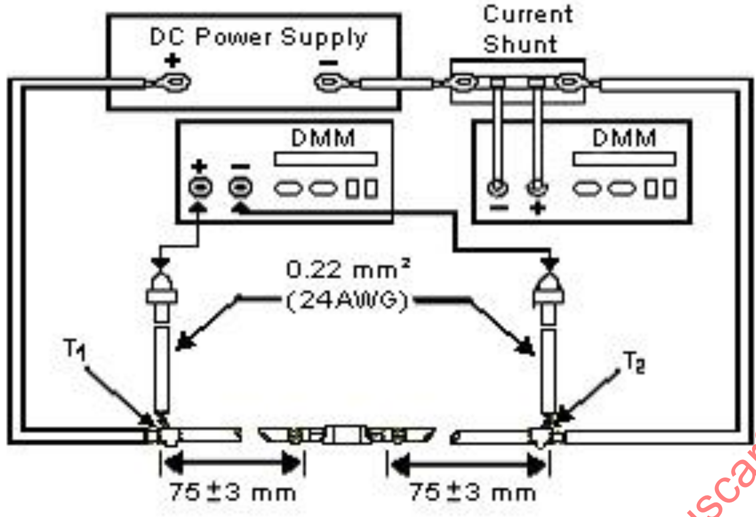


FIGURE 5.3.2.3: TYPICAL CURRENT RESISTANCE TEST SET-UP

6. Measure and record the millivolt drop across 150mm of the conductor size and insulation type to be used during the test, using the test current determined in Step 5. For testing Header type connectors, refer to Section 5.1.5 and measure the millivolt drop across only 75 mm of the conductor used. For attachment points exceeding 75+/-3mm 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 >75mm 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 (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 Section 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 the equation below 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 Section 5.1.5.

mVD of Entire Connection = mVD (T_1 - T_2) - [mVD Conductor (Step 6)]

Total Connection Resistance = (mVD Entire Connection/Test Current)

Use these results to verify conformance to the Acceptance Criteria of Section 5.3.2.4. Values for terminal sizes between 0.50mm and 9.5mm but not in the table are calculated by interpolation. These values apply both before and after any environmental or mechanical conditioning and to field samples.

5.3.2.4 Acceptance Criteria

For inline connectors, the values in Table 5.3.2.4 are for "crimp - to - crimp" measurements (T_1 to T_2 in Figure 5.3.2.3 less the appropriate conductor resistance). For headers, the values are the "crimp – to – tail" (T_1 to T_2 in Figure 5.1.5) less the appropriate conductor resistance).

Nominal Male Terminal Size	Total Connection Resistance (mΩ)Maximum	Precious Metal [1] Total Connection Resistance (mΩ) Maximum	Maximum Voltage Drop (mV) [1mΩ = 1mV/A]
0.50mm	25.0	25.0	50
0.64mm	20.0	10.0	50
1.2mm	15.0	10.0	50
1.5mm	10.0	10.0	50
2.8mm	5.0	5.0	50
6.35mm	1.5	1.5	50
9.5mm	1.0	1.0	50

(1) Silver or gold top plating

TABLE 5.3.2.4: MAXIMUM RESISTANCE VALUES

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) vs. Current (X axis) shall be plotted for each applicable conductor size. These graphs are NOT to be used for actual terminal application in a vehicle (see Appendix F). This test is conducted on terminals alone, thus eliminating the variation that may be introduced by variations in the heat dissipating characteristics of differing connector housing designs and sizes.

5.3.3.2 Equipment

- ⇨ Digital Multimeter (DMM)
- ⇨ DC Power Supply (0-20 VDC @ 0-150 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 150mm (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 200mm. Minimum spacing between samples is 30mm 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 $\leq$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.

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

TABLE 5.3.3.3: MINIMUM WIRE LENGTH

2. Measure and record the Voltage Drop across 150mm 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, refer to Section 5.1.5 and measure the millivolt drop across only 75mm of the conductor used.

3. Assemble the circuit shown in Figures 5.3.3.3-2 in a draft free enclosure as described in section 5.3.3.3 and Figure 5.3.3.3-1. Use at least 10 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 (Figure 5.3.1.3) 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.

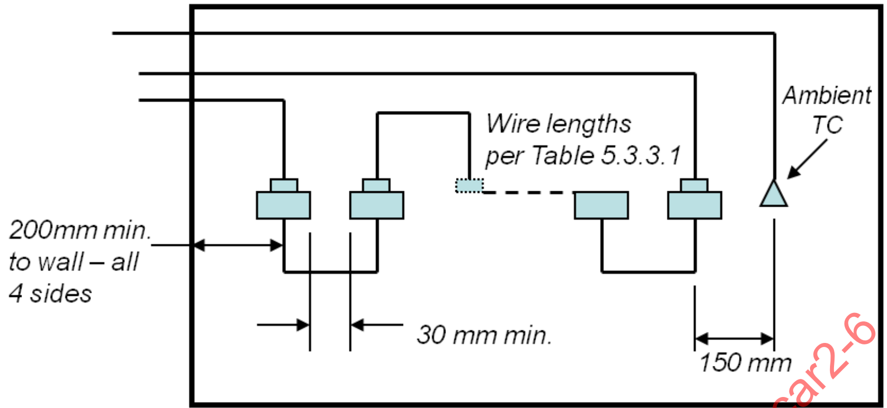


FIGURE 5.3.3.3-1: TOP VIEW OF DRAFT-FREE ENCLOSURE

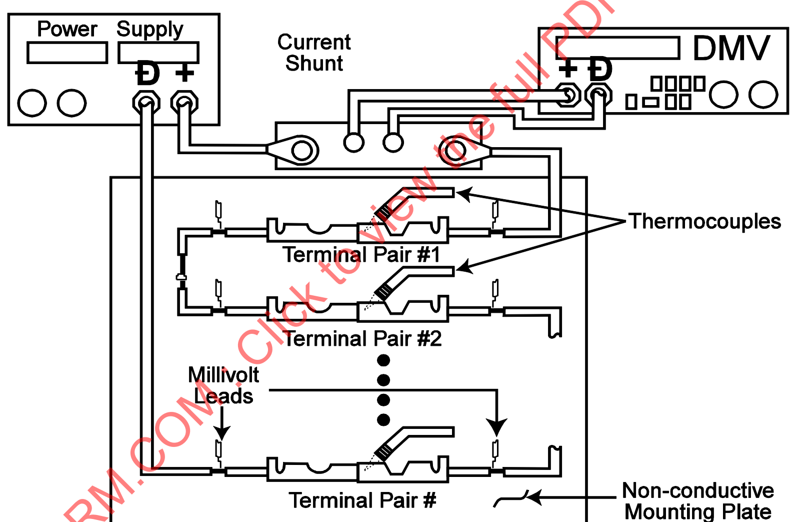


FIGURE 5.3.3.3-2: SET-UP FOR MAXIMUM TEST CURRENT

4. Test the sample terminal pairs at 23 ± 5 °C (Room Temperature).

5. Adjust the power supply to zero Amps output and then turn on the supply and the DMM's.

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. 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 5.3.1.3, 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 oC rise over ambient (ROA).

    b. The Total Connection Resistance of any terminal interface exceeds the "After Test" Acceptance Criteria listed in Section 5.3.2.4.

    c. Any TUT does not meet the Visual Acceptance Criteria listed in Section 5.1.8.4.

10. [Optional, as 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 F.

5.3.3.4 Acceptance Criteria

No pass/fail criteria applies; value is used to establish "Maximum Test Current" for the TUT in Section 5.3.4. The maximum test current of the specific combination of the terminal and the wire conductor gage 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.

5.3.4.2 Equipment

- ⇨ Digital Multimeter (DMM)
- ⇨ DC Power Supply (0-20 VDC @ 0-150 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 Section 5.1.5. Millivolt leads must be no larger than 0.22 mm^2.

2. Measure and record the Voltage Drop across 150mm of the conductor to be used for the test, using the maximum test current previously determined (Section 5.3.3.4) for the combination of that conductor size, insulation type and the TUT. For testing Header type connectors, refer to Section 5.1.5 and measure the millivolt drop across only 75mm of the conductor used. For attachment points exceeding 75 mm per side, 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 section 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 (Section 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°+/- 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, DMM's, and data logger.

6. After 30 minutes into the first on 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 on cycle, and at the conclusion of the test, 30 minutes into the final "on" cycle. mV 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 8) 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 (5.9).

2. The temperature of any terminal interface must not exceed a 55 °C ROA at any time during the test.

5.4 Connector - Mechanical Tests

5.4.1 Terminal - Connector Insertion/Retention and Forward Stop Force

5.4.1.1 Purpose

This test is required to in order to measure the Insertion Force of a terminal into its connector cavity. 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.

5.4.1.2 Equipment

⇨ Insertion/Retention Force Tester with Peak Reading Feature
⇨ Temperature/Humidity Chamber capable of 95 to 98% RH at 40ºC

5.4.1.3 Procedure

A. INSERTION FORCE:

Un-sealed Connectors and Sealed Connectors with Individual Cable Seals

1. Prepare terminal samples per section 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 10 or more terminal cavity locations, use a minimum of 3 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 4 ~9 terminal cavity locations, use a minimum of 3 connector housings and prepare enough terminal samples to test each cavity location in each CUT. For connectors with 3 terminal cavity locations use a minimum of 4 connector housings and prepare enough terminal samples to test each cavity location in each CUT. For connectors with 1 or 2 cavity locations use enough connector housings to obtain at least 10 data points and test all cavity locations an equal number of times. See table 5.4.1.3.1

NOTE: Use these sample sizes and cavity requirements for insertion, retention, forward stop and after conditioning force measurements.

# 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 an same num. 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

TABLE 5.4.1.3.1: SAMPLE SIZES AND CAVITY REQUIREMENTS

2. Repeat Step 1 using 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 20mm 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 per minute. Upon reaching the forward stop, continue applying force until failure point of the forward stop is reached (plastic failure or terminal damage) . Use a fresh terminal sample for each insertion and test each terminal cavity location until all terminal samples prepared in step 1 have been used. (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 and used to measure terminal insertion or forward stop push through 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. Push directly on the wire stub. Samples prepared in this manner require additional connector samples and cannot be used for terminal to connector retention tests.

7. Record the force required to insert the terminal into the connector for each terminal sample to be tested and verify conformance to the Acceptance Criteria of Section 5.4.1.4.

Connectors with Multi-Cavity (Mat) Seals

1. Complete steps 1 – 3 above, except prepare at least one additional set of samples.

2. Complete steps 4 and 5 above.

3. Adjust the force tester to insert the terminal straight into the connector at a uniform rate not to exceed 50 mm per minute. Use a fresh terminal sample for each insertion and test each terminal cavity in the connector at least once. Upon reaching the forward stop, continue applying force until a minimum 50N of force is exerted. 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 less than 10 cavities, use a new connector after each terminal cavity in the first connector has been tested and continue until at least 10 terminal samples have been used.

4. Use the extra set of samples prepared in Step 1 above. Using 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 Section 5.4.1.4.

6. Repeat Steps 4 - 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 Section 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 10 or more terminal cavity locations, use a minimum of 3 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 4 ~9 terminal cavity locations, use a minimum of 3 connector housings and prepare enough terminal samples to test each cavity location in each CUT. For connectors with 3 terminal cavity locations use a minimum of 4 connector housings and prepare enough terminal samples to test each cavity location in each CUT. For connectors with 1 or 2 cavity locations use enough connector housings to obtain at least 10 data points and test all cavity locations an equal number of times. See table 5.4.1.3.1 Solder may be added to terminal crimps to assure 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 10 cavities, use a new connector after each terminal cavity has been tested and continue until all 10 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. Straight back force is critical to avoid side loads and binding which can affect force measurements. Increase the pullout force at a uniform rate not to exceed 50mm/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. Using an additional set of new connectors, moisture condition (bring to the practical limit of moisture content by exposing "dry as molded parts" to 95-98% Relative Humidity at 40ºC for 6 hours followed by one hour at room ambient temperature and humidity.) connectors, repeat Steps 1-8 above and install the terminal lock (PLR, TPA, Wedge, etc.). Begin the retention test after one hour at ambient condition. Complete the test within eight hours of beginning the retention testing. (Samples may be sealed in non-moisture transferable plastic (Zip-lock 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

Insertion:

1. The maximum Insertion Force for a terminal is 30 Newtons. (see note under procedure – Para. 5.4.1.3 A6).

2. The forward stop (tested in Para. 5.4.1.3 A6) push-through force must be $\geq$ 35N for 0.50mm terminals and $\geq$50N for >0.50mm terminals.

3. With the TPA removed, the terminal must remain in its cavity location (i.e. not dependent on the TPA to hold terminals in place. This is to be evaluated by removing the TPA and performing visual inspection.

Retention:

The minimum Retention Force of a terminal from its cavity shall meet the values shown in the table 5.4.1.4.

Max. Nominal Blade Width (mm)	Primary Lock Retention (ref. 5.4.1.3.-B6) (N)	Primary + Secondary Lock[1] after Moisture Conditioning (ref. 5.4.1.3- B8) (N)	Primary + Secondary Lock[1] after Temp/ Humidity and HTE (ref. 5.6.2, 5.6.3) (N)
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

TABLE 5.4.1.4: TERMINAL-CONNECTOR MINIMUM RETENTION FORCE
[1] Includes connectors not designed with a secondary lock.

APPLICATION NOTES:

- Primary lock retention is a harness manufacturing requirement.
- Primary and secondary lock is a vehicle assembly requirement.
- After temperature humidity cycling is a service/performance requirement to end of life.

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

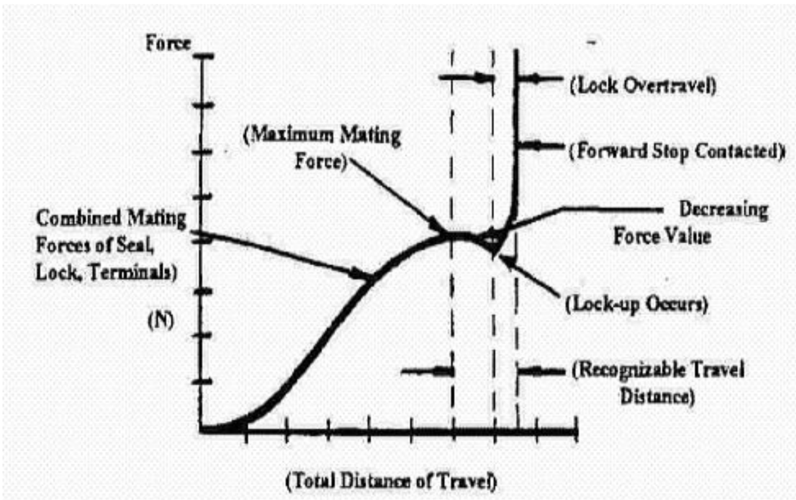
A. MATING FORCE

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 section 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 vs. 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+/- 10mm/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 Section 5.4.2.4.

B. UNMATING/RETENTION FORCE

1. Prepare an additional 15 connector pairs by mating the male and female connectors. This test will be conducted without terminals or wires on 10 of the 15 samples. The remaining 5 samples will be loaded with the appropriate wires and terminals and used in step 5.

2. Five samples are to be tested with the connector primary locking mechanism (without CPA) fully engaged. For this group, completely un-mate the connector halves by applying a uniform force parallel to the centerlines of the fully mated connector halves. The force tester must be configured to apply the Un-mating Force directly to the connector halves. Straight-out un-mating is critical to avoid side loads and binding which can affect force measurements. 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. Increase the Retention Force at a uniform rate not to exceed 50mm/min. until complete separation occurs. Test all samples in the first group.

4. Record the force required to completely separate the connector halves and verify conformance to the Acceptance Criteria of Section 5.4.2.4.

5. Repeat Steps 2, 3 and 4 above with the primary connector locking mechanism(s) completely disabled using the 5 mating connector samples loaded with terminals.

C. LOCK DEFLECTION FORCE

1. For the remaining 5 samples, gradually apply a force of up to 51N to the lock mechanism until the lock mechanism clears the lock feature on the mating part and attempt to unmate the connection. This force is applied at the appropriate point such that the mated connector halves (or a connector mated to a device) could be unmated in the intended manner with no damage to any component and shall be the furthest from the fulcrum on the latch mechanism where persons could reasonably be expected to depress the latch mechanism. It shall also include any auxiliary pieces attached to the lever such as CPAs, and shall take into account the possibility of any accidental or inadvertent actuation. Note whether the connection can be successfully unmated.

2. Record results and verify conformance to the appropriate Acceptance Criteria of Section 5.4.2.4.

5.4.2.4 Acceptance Criteria

NOTE: 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.

NOTE: The forces specified in the Acceptance Criteria must 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.

NOTE: The acceptance criteria of this section varies with the available finger contact area of the connector being tested. Reference SAE/USCAR-25 Electrical Connector Assembly Ergonomic Design Criteria for details of the acceptance criteria.

1. Mating (engage) force shall meet the requirements of SAE/USCAR-25.

2. Retention Force must be ≥ 110 Newtons with the primary connector lock fully engaged. A CPA device, if provided for, must NOT be engaged during this test.

3. Unmating Force must be ≤ 75 Newtons with the primary connector lock completely disengaged/disabled.

4. The force to completely disengage the primary connector lock must be ≥6N and ≤ 51N in its fully seated position (without the CPA engaged).

NOTE: Connector designs where it is difficult to apply pressure to the latch while un-mating the connectors it is permissible to visually confirm the latch will clear the locking feature with ≥6N and ≤51N 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 un-mating 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 10 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 section 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 6 connector pairs by mating male to female housings without terminals or wires.

Test E: Prepare 5 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+/-10mm/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 un-seat the connector from the pre-lock position.

2. Verify conformance to the acceptance criteria of Section 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. Determine the force class of the connector from USCAR-25. Using the force tester apply the appropriate force to the lever slide at a rate not to exceed 50mm/min. to move the lever/slide toward the lock position.

    1. Class 1 connectors (15mm^2 push area per USCAR-25, Table 5.1)

    2. Class 2 connectors (115mm^2 push area per USCAR-25, Table 5.1)

    3. Class 3 connectors (230mm^2 push area per USCAR-25, Table 5.1)

1. Verify conformance to the acceptance criteria of section 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 50mm/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 60N at a rate not to exceed 50mm/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 50mm/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 section 5.4.3.4-4 and 5.

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

1. 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 50mm/minute 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 4 additional samples. (Test 5 samples) Verify conformance to 5.4.3.4-6

2. Mount one mated connector in a fixture so as not to distort the housings or any of their associated parts. With primary connector to connector locking feature **disabled** (lever or slide open), pull the connectors apart at a rate not to exceed 50mm/minute 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. Verify conformance to 5.4.3.4-7

E. LEVER RELEASE LATCH ACTUATION FORCE

For the remaining 5 samples, gradually apply a force of up to 45N to the secondary lock mechanism 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. Record results and verify conformance to the appropriate Acceptance Criteria of Section 5.4.3.4-8

5.4.3.4 Acceptance Criteria

Note that the acceptance criteria of this section varies with the available contact (grip) area of the connector being tested. Reference 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 un-seat the connector from its pre-lock position shall be $\geq$15 and $\leq$75.

3. The force required to move the lever or slide from its shipping position while the connector is not in its pre-stage position shall be:

   - Class 1 and 2 connectors (defined in USCAR-25, Section 4.1) – 60N min.

   - Class 3 connectors (defined in USCAR-25, Section 4.1) – 90N min.

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 $\geq$60N for a fully mated connector

6. Un-mating Force must be ≥ 110 Newtons with the primary connector lock fully engaged. A CPA device, if provided for, must NOT be engaged during this test.

7. Un-mating Force must be ≤ 75N with the primary connector lock completely disengaged/disabled.

8. The force to completely disengage the secondary connector lock, F, is 6N< F ≤ 51N.

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
- ⇨ 9VDC Continuity meter ranging from 50 to 500ohms 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 50mm/min. until a force of 3X the maximum value of a properly mated connector (with force being $\geq$60N and $\leq$150N) is applied (ref. Section 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 60N or greater than 150N) per section 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/or 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 10 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 is 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 50mm/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 Section 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 50mm/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 Section 5.4.5.1.4.

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

5.4.5.1.4 Acceptance Criteria

Insertion/Retention Forces shall meet the shown in Table 5.4.5.1.4.

Device	Force (N)	
	Insert to lock	Remove
Component with positive retaining feature such as locator clip, wire dress, etc.*	60 max	110 Minimum. (Also see section 5.4.11), Connector Mounting Feature Mechanical Strength.)
Loose piece TPA/PLR/ or ISL	60 Max (w/terminals installed in all available cavities)	25 Min

* For connectors with integral locator clip features, the Connector Mounting Feature Mechanical Strength test (Section 5.4.11) must also be completed.

TABLE 5.4.5.1.4: MISC. COMPONENT & LOOSE PIECE TPA/PLR/OR ISL ASSEMBLY FORCES

5.4.5.2 Pre-Staged CPA/TPA/PLR 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. ENGAGEMENT FORCE – Loose Piece CPA's/TPA's/PLR's

1. Completely identify and number each component to be tested. A minimum of 10 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 is 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 50mm/min.

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 Section 5.4.5.2.4 and Table 5.4.5.2.4.

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 50mm/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 Section 5.4.5.2.4.

5.4.5.2.4 Acceptance Criteria

Insertion/Retention Forces shall meet the values shown in Table 5.4.5.2.4.

	Engagement	Removal	
Device	Pre-set to lock (N)	Lock to pre-set (N)	Complete Removal from Pre-stage on Unmated Connector (N)
CPA	- 60 Min Unmated (for airbag connectors, see *) - 22 Max w/connectors mated	10 Min. 30 Max.	30 min.
TPA/PLR/or ISL	- 60 Max (w/terminals installed in all available cavities) - 15 Min(w/o terminals)	- 60 Max (w/terminals installed in all available cavities) - 18 Min after two cycles	25 Min
* Pre-set to lock is 100N Min for air bag initiators mating to USCAR dwg. 999-U-002-1-Z03. (This is needed to compensate for the exposed CPA in that design style.)			

TABLE 5.4.5.2.4: PRE-STAGED CPA/TPA/PLR AND ISL ASSEMBLY/DISASSEMBLY FORCES

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 through 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 5 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.

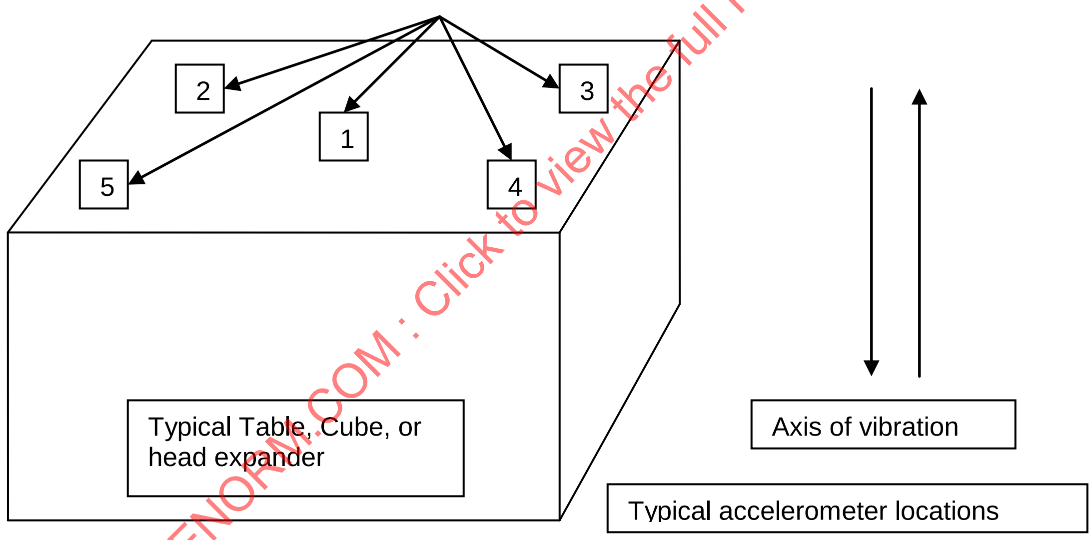


FIGURE 5.4.6.2 TYPICAL MAPPING ACCELEROMETER LOCATIONS

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. Refer to Fig. 5.4.6.3 for examples of test mounting arrangements. Mounting position A is for in-line type connectors. Position B is for connectors that will mate to an electrical device.

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. Refer to Figure 5.4.6.3-A. Do not use a "Christmas Tree" or any other type of mounting device. Instead, the Mounting Bracket itself must be constructed so as to include a direct mounting feature to mate with the mounting feature (Dovetail) on the mated connector pair.

    c. For Device Connectors, mount the device directly to the Mounting Bracket. Refer to Figure 5.4.6.3-B. Use the normal device mounting feature(s) used to secure the device in its intended vehicle location. Do not use any intervening bracket or mounting device. Instead, the Mounting Bracket must be fabricated to include any cooperating features necessary to mount the device directly to it.

    d. The conductor attachment must be 100±10mm from the rear of the connector body per Fig. 5.4.6.3-C.

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 such that there is a 10 ± 5 mm sag relative to the bisecting plane of the attachment points. See Figure 5.4.6.3-C. NOTE: It is vital to secure the conductors to their respective connector housings. Terminals "float" in their cavities and will wear rapidly if the associated conductors are allowed unrestrained movement relative to the connector housing. See 5.4.6.3-C.

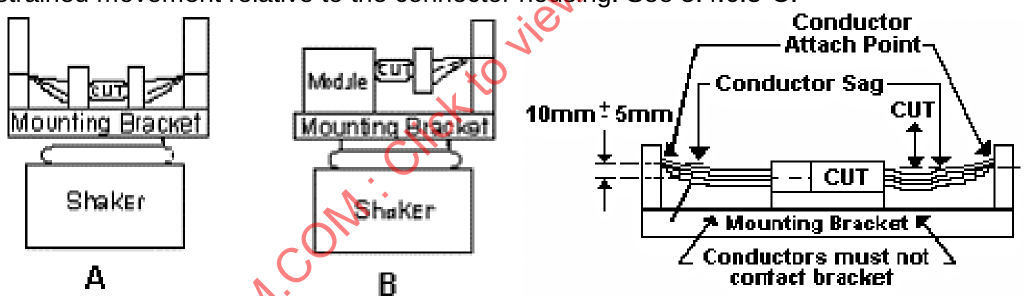


FIGURE 5.4.6.3-A AND 5.4.6.3-B: VIBRATION MOUNTING POSITIONS

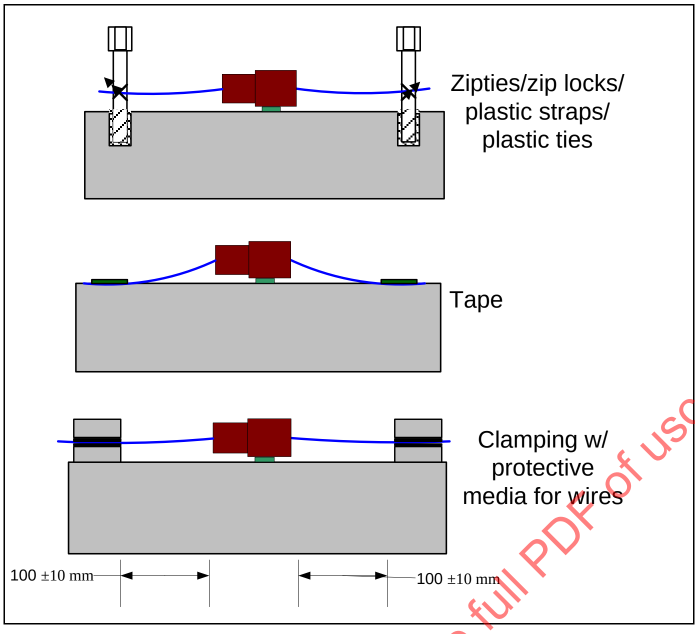


FIGURE 5.4.6.3-C: TYPICAL WIRE ATTACHMENT TEST SET-UP FOR VIBRATION

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. NOTE: When identified, Thermal Cycling shall be performed during the vibration schedules with temperatures per this schedule:

- Temperature Range is T_{min} to T_{max}
- Dwell time for T_{min} equals 2 hours.
- Dwell time for T_{max} equals 2 hours.
- Temperature Transistion rate shall range between 3 to 5°C /minute.
- One thermal cycle is approx. 360 minutes.

NOTE: Use of the profile in ISO 16750-3 Section 4.1.1 is an acceptable alternate profile.

7. Table 5.4.6.3E repeated until the test is complete. Humidity is not controlled for the vibration testing.

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

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

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

Class Schedule for Shock

<table>
<tr><th>Vibration Class</th><th colspan="2">Shocks per Axis</th><th>Wave Shape</th><th>Direction (+/-)</th><th>Duration (ms)</th><th>Acceleration (g)</th></tr>
<tr><td>V1</td><td colspan="2">10</td><td>Half Sine Wave</td><td>Positive</td><td>5 ~ 10</td><td>35</td></tr>
<tr><td>V2</td><td colspan="2">10</td><td>Half Sine Wave</td><td>Positive</td><td>5 ~ 10</td><td>35</td></tr>
<tr><td rowspan="2">V3
V4
V5
(Perform Both Tests</td><td>1</td><td>132 x 6 =792</td><td>Half Sine Wave</td><td>Positive/Negative</td><td>15</td><td>25</td></tr>
<tr><td>2</td><td>3 x 6 =18</td><td>Half Sine Wave</td><td>Positive/Negative</td><td>11</td><td>100</td></tr>
</table>

TABLE 5.4.6.3A: CLASS SCHEDULE FOR SHOCK

Vibration Duration by Vibration Class

Vibration Class	Sine Duration (Hrs./axis)	Random Duration (Hrs./axis)	Thermal Cycling
V1	n/a	8	n/a
V2	n/a	8	n/a
V3	22	22	Per 5.4.6.3 #6
V4	32	50	Per 5.4.6.3 #6
V5	n/a	22	n/a

NOTE: Sine and random profiles shall be run separately (not concurrently).

TABLE 5.4.6.3B: CLASS SCHEDULE FOR VIBRATION DURATION

V1 - Random

F (Hz)	PSD[1]	PSD g^2/Hz
5.0	0.192	0.00200
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**

V4 – Sinusoidal[2]

F (Hz)	Accel. (m/s2)	Accel. g
100	100	10.2
150	150	15.3
200	300	30.6
240	300	30.6
270	100	10.2
440	150	15.3

V2 - Random

F (Hz)	PSD[1]	PSD g^2/Hz
60.0	0.096	0.00100
200.0	144	1.50000
210.0	9.60	0.10000
1200.0	9.60	0.10000
g_{rms}	**119**	**12.1 g**

V4 - Random

F (Hz)	PSD[1]	PSD g^2/Hz
10	10	0.104
100	10	0.104
300	0.51	0.0051
500	20	0.208
2000	20	0.208
g_{rms}	**181**	**18.5 g**

V3 – Sinusoidal[2]

F (Hz)	Accel. (m/s^2)	Accel. g
100	100	10.2
150	150	15.3
200	200	20.4
240	200	20.4
255	150	15.3
440	150	15.3

V5 - Random

F (Hz)	PSD[1]	PSD g^2/Hz
20	200	2.08
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**

V3 - Random

F (Hz)	PSD[1]	PSD g^2/Hz
10	10	0.104
100	10	0.104
300	0.51	0.0051
500	20	0.208
2000	20	0.208
g_{rms}	**181**	**18.5 g**

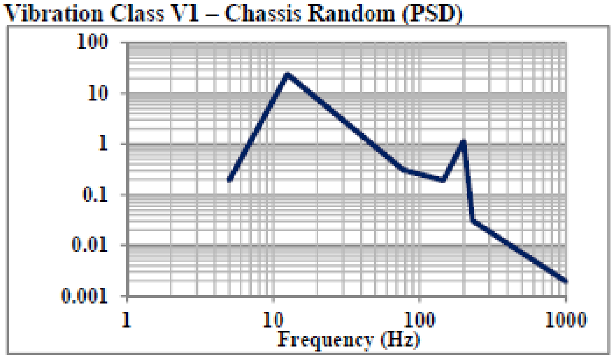
NOTES:

(1) PSD in $(m/s^2)^2/Hz$

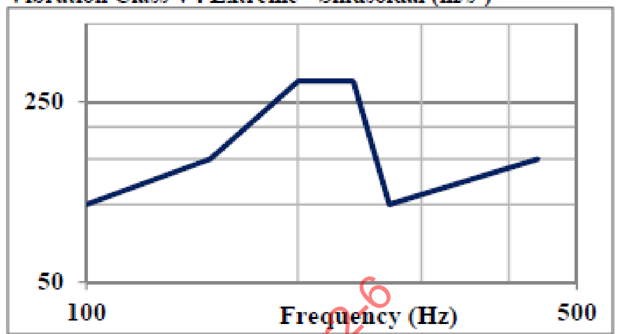
(2) Sine Frequency sweep is:
1 octave/minute for all sine profiles

TABLE 5.4.6.3C: VIBRATION CLASS SCHEDULES

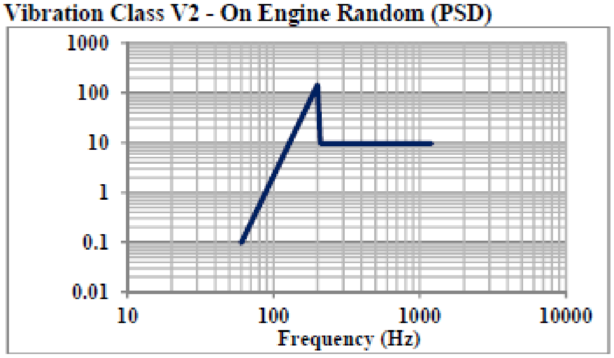
Vibration Class V1 – Chassis Random (PSD)



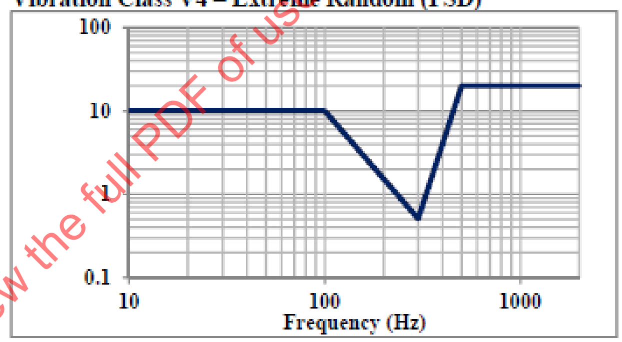
Vibration Class V4 Extreme - Sinusoidal (m/s^2)



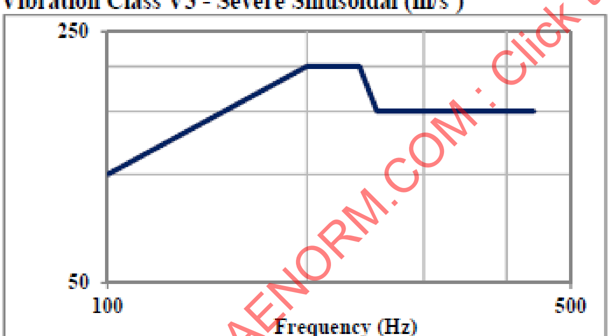
Vibration Class V2 - On Engine Random (PSD)



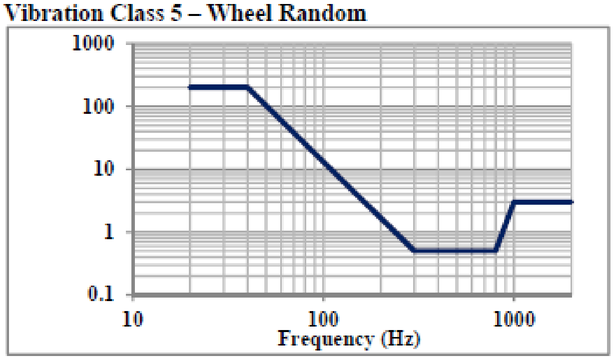
Vibration Class V4 – Extreme Random (PSD)



Vibration Class V3 - Severe Sinusoidal (m/s^2)



Vibration Class 5 – Wheel Random



Vibration Class V3 - Severe Random (PSD)

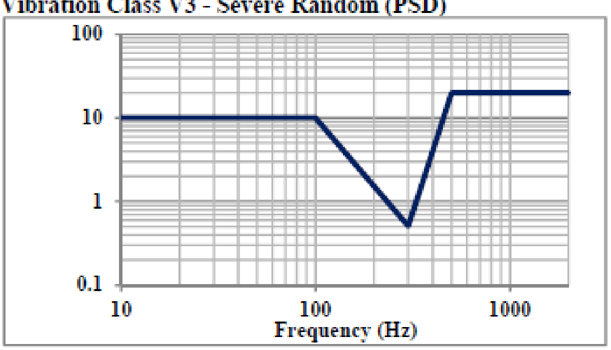


TABLE 5.4.6.3D: VIBRATION CLASS GRAPHS

5.4.6.4 Acceptance Criteria

Verify conformance of CUT/TUT per corresponding measurement section as identified in Section 5.9 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. (2 groups of 8) 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+/-50mm 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 95-98% Relative Humidity at 40ºC 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 18 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 6 groups of 3 samples each for testing X, Y, and Z axis orientation.

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 meter, orienting the samples in six groups corresponding to the six connector "faces" of a rectangular connector. Use one group for each orientation shown.

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

5. Verify conformance of each sample connector assembly to the Acceptance Criteria of section 5.4.8.4

5.4.8.4 Acceptance Criteria

1. Samples shall meet the Acceptance Criteria of section 5.1.8, Visual Inspection.

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/PLR is forcefully inserted on a connector with one or more terminals in an incomplete (un-seated) 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. Samples consist of five connectors with terminal secondary locks in the un-seated position and five leads terminated with each terminal size in the connector.

2. Randomly select one cavity of each terminal type from each sample for testing.

3. Determine the force to be applied to the secondary lock by adding 40N to the maximum force required to seat the TPA/PLR device when all terminals are located properly (section 5.4.5.2.3 A4). The minimum force is 80N for ≥1.5 nominal size terminals and 60N for <1.5 terminals. (Actual measured TPA seating forces are to be used in the calculation, not the criteria from the Table.)

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 a force as determined in step 3 at a rate not to exceed 50mm/min to the terminal secondary lock in the direction of normal seating. Record whether the TPA seated and locked.

5. Remove the force and seat the terminal in its normal position. Seat the secondary lock.

5.4.9.4 Acceptance Criteria

When the force in Step 4 is fully applied, the TPA must not seat in its final position and terminal retention must meet the forces in table 5.4.1.4. Use the after moisture conditioning values in Table 5.4.1.4. (Note: moisture conditioning is not required for this group of samples, the heading of the Table applies to a different test.

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°) 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° must be tested. Rectangular designs where improper insertion at 90° from horizontal is clearly not possible do not need to be tested at these positions. It is permissible to test these designs in 180° 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 10 times. Prepare leads per section 5.1.6, Terminal Sample Preparation, 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 10 times using a fresh cavity for each test. Use no less than 3 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 20mm 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 50mm/min, apply a force equaling 1.5 times the maximum force recorded in step 5.4.1.3-7 (Terminal-Connector Insertion Force) or 15N, 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 section 5.1.8.

5.4.10.4 Acceptance Criteria

1. Terminals inserted at a force 1.5 times the normal insertion force or 15N (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 5.4.10.5).

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.

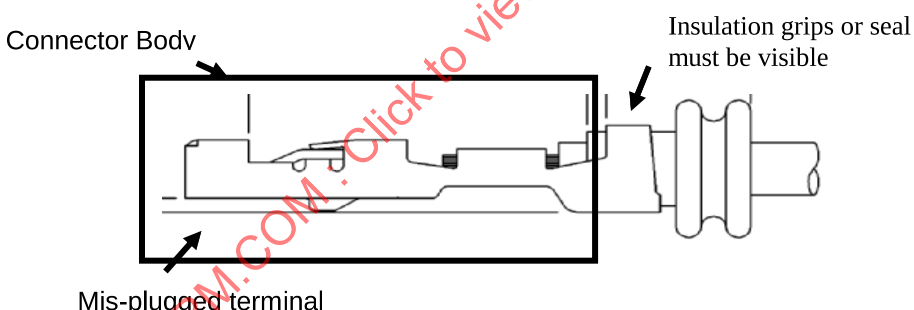


FIGURE 5.4.10.5: MAXIMUM ALLOWABLE INSERTION OF INCORRECTLY PLUGGED TERMINAL

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

FIGURES 5.4.11.3 A-D: MOUNTING FIXTURES

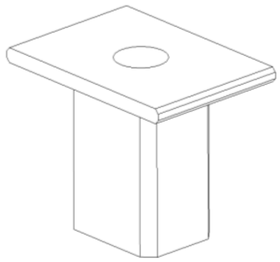


FIGURE 5.4.11.3-A: MOUNTING FIXTURE EXAMPLE

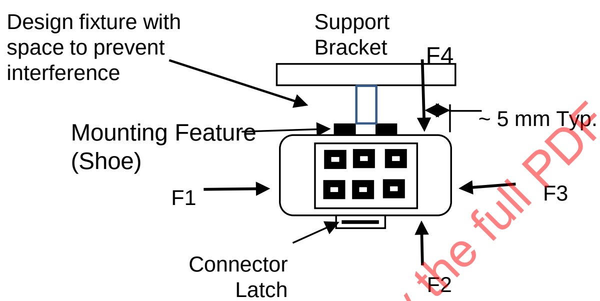
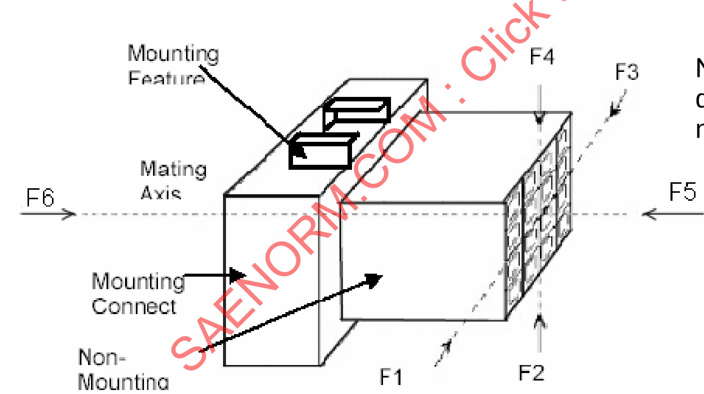
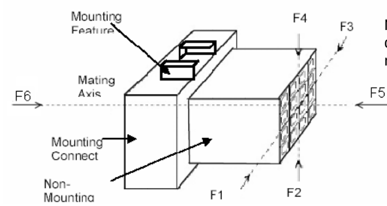


FIGURE 5.4.11.3-B: TEST SET-UP (END VIEW)



NOTE: "F" Arrows indicate direction of applied force, not location of probe

FIGURE 5.4.11.3-C: 3D VIEW



NOTE: "F" Arrows indicate direction of applied force, not location of probe

FIGURE 5.4.11.3-D TEST SET-UP (END VIEW)

5.4.11.3 Procedure

1. Test a minimum of 30 connectors (five in each direction).

2. One non-mounting (mating) connector may be used to test all connectors.

3. Secure a virgin connector with the designed-in mounting feature to a bracket with a fixture simulating the coordinating mounting feature (see Figure 5.4.11.3-A). No additional reinforcement of the connector slot is permitted.

4. With the connector assembly attached to the bracket, apply a downward force with a probe (at a rate not to exceed 50 mm/min) to the non-mounted mating connector in direction F1 until breakage of the mounting feature or until the force specified in the Acceptance Criteria of section 5.4.11.4 is reached. The force shall be applied 5 mm from the rear and side of the connector to affect the greatest moment arm (see Figures 5.4.11.2-B, C & D).

5. Remove the connector from the fixture.

6. Repeat steps 2 – 5 with four additional connectors.

7. Repeat steps 2 – 6 in the other three directions (F2, F3, & F4 - 90 degrees apart, each perpendicular to the direction of mating of the mounting feature). The same samples may be used for testing various force directions if not damaged.

8. Secure a new connector with the designed-in mounting feature to a bracket with a fixture simulating the coordinating mounting feature (see Figure 5.4.11.3-A).

9. With the connector assembly attached to the bracket, apply a push force to the connector with a probe (at a rate not to exceed 50 mm/min) at the centerline of the connector in direction F5 until breakage of the mounting feature or until the force specified in the Acceptance Criteria of section 5.4.11.4 is reached (see Figure 5.4.11.3-C).

10. Remove the connector from the fixture.

11. Repeat steps 8 to 10 with four additional connectors.

12. Repeat steps 8 to 11 in the other direction (F6).

5.4.11.4 Acceptance Criteria

1. The minimum force required to break the mounting feature or separate the connector from the mounting feature in direction F1 to F5 shall be > 50 N.

2. The minimum force required to break the mounting feature or separate the connector from the mounting feature in direction F6 shall be >110 N.

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 5 sample connectors with levers/slides in their open position. Wires, terminals, TPA's, and seals are not required.

2. Complete the Visual Examination per paragraph 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 ± 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 ± 10 mm/min with the lever or slide in the open and closed positions.

7. Position the slide or lever in a position approximately half way 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 ± 10 mm/min.

8. Position the slide or lever in a position approximately half way 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 - Side Force Strength, at the rate of 50 ± 10 mm/min.

9. Complete the Visual Examination per paragraph 5.1.8

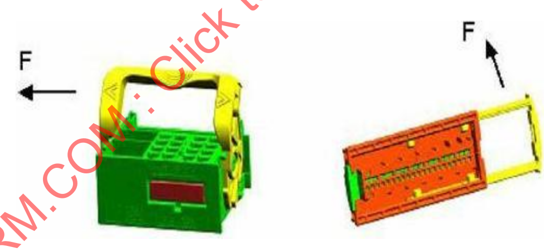


FIGURE 5.4.12.2 - SIDE FORCE STRENGTH

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 10 fully assembled connector samples. Terminals and wires are not required.

2. Properly secure the sample under test per Figure 5.4.13.3 – Unmated Connector Seal Test 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.

    a. Using Equation 1, calculate the required RPM.

    b. Where,

        a = acceleration in m/s^2
        R = the distance [meters] from the center of rotation to the nearest edge of the connector seal.
        EQ 1: N = [(sqrt (a / R)) x 60] / (2 x π)
        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.

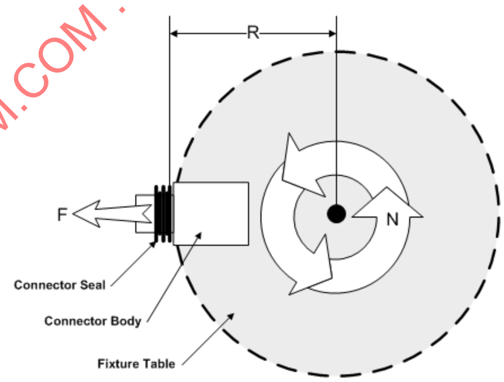


FIGURE 5.4.13.3 - UNMATED CONNECTOR SEAL TEST

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 10 female housings with radial seals and 10 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 one second.

5.4.14.3 Acceptance Criteria

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

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

⇨ Megohmeter

5.5.1.3 Procedure

NOTES: 1) 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. 2) For un-sealed connector pairs, the test samples shall rest in ambient environment for ≥3 hours prior to measuring insulation resistance after any prior environmental conditioning. 3) When Sealed Connector systems are to be tested following exposure to moisture or other contaminants (except fluid resistance test) it is important that this Insulation Resistance test be performed on each sample within one hour of concluding the associated test. Otherwise, particularly where samples are exposed to elevated temperatures in the preceding test, any contaminant that might invade the samples may dry to the point of being undetectable by this Insulation Resistance test.

1. If this test is to be performed to check insulation resistance of a new connector housing, prepare cut leads as specified in Section 5.1.6, Terminal Sample Preparation

2. Connect the Megohmeter, set to 500 VDC, 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.

3. Use the Megohmeter to measure the resistance between the adjacent terminals: Apply the test voltage, allow for meter to stabilize. Test both halves of the connector system (if applicable for new connector housings. Test the mated connector assembly for those samples that have been subjected to prior stress testing.

4. Record the minimum resistance measured and verify conformance to the Acceptance Criteria of Section 5.5.1.4

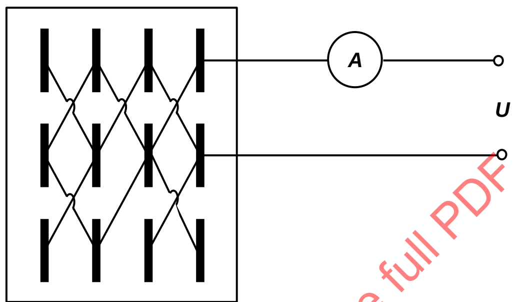


FIGURE 5.5.1.3: METHOD OF CONNECTING LEADS FOR INSULATION RESISTANCE TEST

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-to-terminal interface.

5.6.1.2 Equipment

- ⇨ Temp. Chamber(s) (-40^{o} C to +175^{o} C (as required by the Temperature Class selected from Table 5.1.4.1).
- ⇨ Continuity monitoring equipment per Section 5.1.9

5.6.1.3 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 minimum ambient temperature for that class. Allow the chamber to stabilize, then cold Soak the samples an additional 30 min.

4. Transfer the samples to another chamber set to the maximum ambient temperature for the Temperature Class selected in Step 6. It is important to complete the transfer of all samples from the cold to hot chamber (or, optionally, to transition one chamber from the coldest to the hottest extreme) in less than 30 seconds. Allow the samples to heat Soak for 30 minutes.

5. Transfer the samples to another chamber set to the minimum ambient temperature for the Temperature Class selected in Step 6. It is important to complete the transfer of all samples from the hot to cold chamber in less than 30 seconds. Allow the samples to cold Soak for 30 minutes.

6. Repeat Steps 7 and 8 ninety nine (99) more times.

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

5.6.1.4 Acceptance Criteria

1. Verify conformance of CUT/TUT per corresponding measurement section as identified in Section 5.9 Test Sequence.

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) (-40^{o} C to Temperature Class selected from Table 5.1.4.1, 0%-95% RH)

5.6.2.3 Procedure

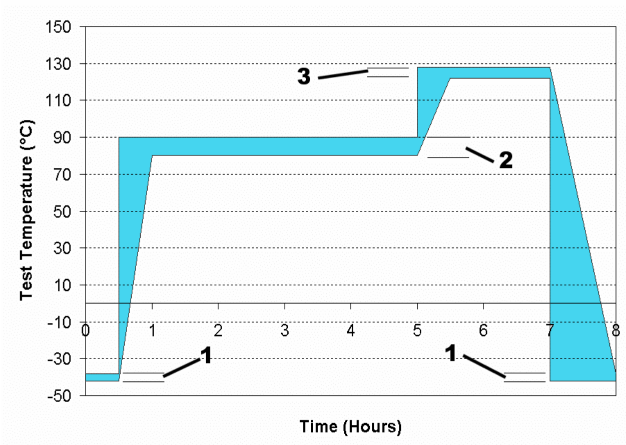
1. CUT must include all applicable Wedges (TPAs, PLRs, etc.), Seals, etc. Number each mated connector pair.

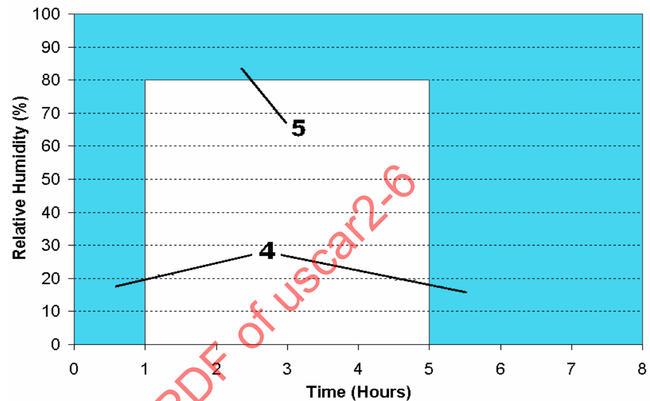
2. Place the samples in the chamber so that there is no substantial obstruction to air flow across and around the samples, and the samples are not touching each other.

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 minimum temperature for that class. Allow the chamber to stabilize before proceeding.

4. Cycle the test samples 40 times using the 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 uncontrolled relative humidity. Completion of the schedule shown in Figure 5.6.2.3 will constitute 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 – 90)°C 3 Test temperature per Table 5.1.4.1 (Class 3 shown for illustration only) 4 Relative Humidity, uncontrolled. Do not vent chamber at hour 5. 5 (80 – 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 Section 5.9 Test Sequence.

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

1. Verify conformance of CUT/TUT per corresponding section identified in Section 5.9 Test Sequence.

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 to be used for sealed (S2 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 submerse at least 1 test sample in each fluid listed in table 5.6.4.3 for 30 minutes. Fluids are to be stabilized at the temperatures indicated. A fresh sample is to be used for each fluid and each sample is to be submersed in one fluid only, unless otherwise requested by the Authorized Person.

See appendix E for fluid source list

Automotive Fluids

Fluid	Specification	Test Temp. (°C)
Gasoline	ISO1817, liquid C	23 ± 5
Diesel fuel	90% ISO 1817, Oil No. 3 + 10% p-xylene*	23 ± 5
Engine oil	ISO 1817, Oil No. 2	50 ± 3
Ethanol	85% Ethanol + 15% ISO 1817 liquid C*	23 ± 5
Power steering fluid	ISO 1817, Oil No. 3	50 ± 3
Automatic transmission fluid	Dexron VI (North American specified material)	50 ± 3
Engine Coolant	50% ethylene glycol + 50% distilled water*	50 ± 3
Brake Fluid	SAE RM66xx (Use latest available fluid for xx)	50 ± 3
Diesel Exhaust Fluid (DEF)	API certified per ISO22241	23 ± 5

*Solutions are determined as percent by volume

TABLE 5.6.4.3: FLUID TEST

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 Section 5.9 Test Sequence

5.6.5 Submersion

This test is to be used for sealed (S2 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 salt water solution.

5.6.5.2 Equipment

- ⇨ Stainless steel tanks or glass beakers
- ⇨ Megohmeter
- ⇨ Temperature Chamber (-40^o 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 (Section 5.9.7) for full validations. For Submersion-Stand Alone use Test Sequence AC (Section 5.9.9).

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

2. Prepare enough salt water solution to completely submerse the samples. Use tap water and 15-16 grams 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. Cool the solution to 0^{o}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 two 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 zero degree (C) temperature salt water solution to a depth of 30 - 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 salt water solution, shake off the excess solution, and then carefully dry the exterior surfaces of the samples. Immediately perform the Insulation Resistance test of Section 5.5.1 on each sample.

7. For Test Sequence AC (Section 5.9.9), repeat Steps 3, 4, 5, and 6 four (4) more times. For Test Sequences R, RSAA, U, and TUAB (Section 5.9.7) refer to Test Sequence.

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

5.6.5.4 Acceptance Criteria

1. Verify conformance of CUT/TUT per corresponding measurement section as identified in Section 5.9 Test Sequence.

5.6.6 Pressure/Vacuum Leak

5.6.6.1 Purpose

This test evaluates the sealing capability of sealed (S2 and S3 sealing classification) connector systems when subjected to a specified pressure differential between the inside and outside of the sealed area.

5.6.6.2 Equipment

- ⇨ Pressure/Vacuum Source (Regulated)
- ⇨ Pressure/Vacuum gage - 48 kPa (7psig) minimum
- ⇨ Container (for sample immersion)
- ⇨ Temperature Chamber (-40^{o} C to required 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 (Section 5.9.7) for full validations. For Pressure Vacuum Leak Stand Alone use Test Sequence W (Section 5.9.9).

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

2. Insert 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 to replace the tubes is acceptable if the cable composition is such that sufficient air can pass in a reasonable time to complete the test. Be sure the tubes are inserted far enough to engage the full sealing capability of the conductor seal. Alternative methods of adding pressure/vacuum ports are acceptable as long as the integrity of the part is not compromised. 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 can have an effect on the time required to reach the pressure/vacuum values within the CUT. Two tubes are inserted so that the pressure/vacuum within the mated connector housing can be monitored to determine if and when the pressure/vacuum reaches the specified value.

3. Prepare enough salt water solution to completely submerse the samples. Use tap water and 15-16 grams 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 all conductors in the same direction, 90^o 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 90^0 bend if feasible. Seal all loose conductor ends to eliminate possible leakage through the conductor strands.

5. Connect the free end of one of the tubes (wires) 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 (7psig). 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 (7psig) 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 the Insulation Resistance test of Section 5.5.1.

9. For Test Sequences Test Sequences S, RSAA, T, or TUAB (Section 5.9.7) refer to Test Sequence for appropriate conditioning then proceed to Step 12. For Test Sequence W (Section 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 5 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 must be no bubbles visible exiting any test sample.

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

5.6.7 High Pressure Spray

This test and the associated equipment are intended to conform to ISO CD 20653, with a 9K degree of protection.

5.6.7.1 Purpose

The purpose of this test is to determine the ability of sealed (S3 sealing classifications) connection systems to withstand high pressure spray during use. Such conditions may be encountered where there is direct road splash or in cases where high-pressure washing may be expected. Perform this test for sealed class S3 connectors only (reference para. 5.1.4.2.

5.6.7.2 Equipment

- ⇨ High pressure sprayer with heated water
- ⇨ Fan jet nozzle
- ⇨ Device holder
- ⇨ Swiveling table

5.6.7.3 Procedure

This test is intended for Test Sequences AA, RSAA, AB, and TUAB (Section 5.9.7) for full validations. For High Pressure Spray Stand Alone use Test Sequence AD (Section 5.9.9).

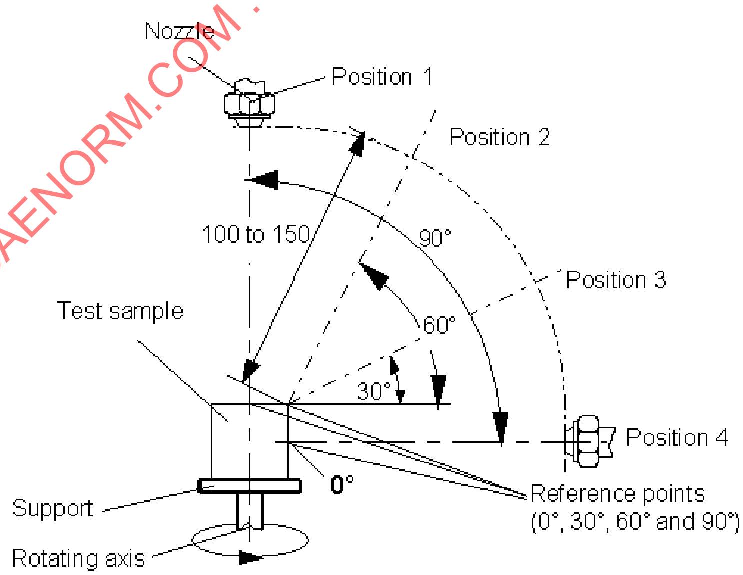
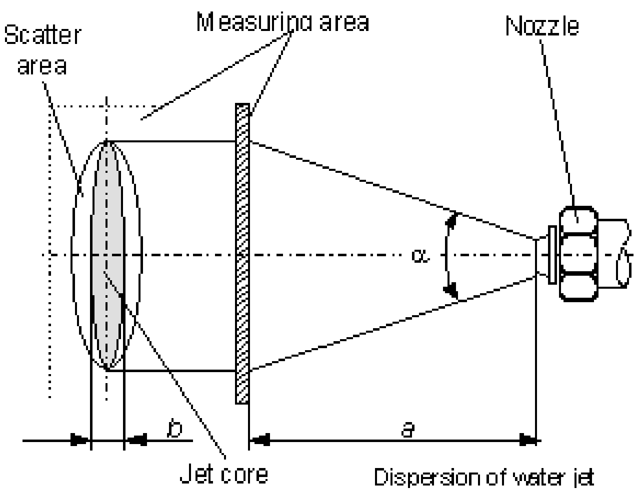


FIGURE 5.6.7.3-1: SPRAY NOZZLE AND TABLE ARRANGEMENT

Equipment	Spray Requirements	Water Flow	Water Pressure	Water temperature	Exposure Time
Fan jet nozzle ά=30°+/-10°	Turntable Speed = 5±1 rpm, Position Angle of (0°, 30°, 60°, 90°) ±5°, Distance of (100 to 150) mm	14 to 16 L/min	Approx. 8,000 to 10,000 KPa	80±5 °C	30sec / position of spray angle

TABLE 5.6.7.3-1 SPECIFICATION FOR HIGH PRESSURE SPRAY TESTING



Ά	a	b
30±5	100	8±2
30±5	150	10±2

FIGURE 5.6.7.3-2 AND TABLE 5.6.7.3-2: NOZZLE AND JET DIMENSIONS (MM)

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

2. Mount the connector under test onto the device holder such that the connector lays flush against the turntable.

3. Position the sprayer at a 0° and initiate spray and turntable rotation.

4. With the table rotating, spray the connector under test for 30s. Repeat at each of the spray angles specified in table 5.6.7.3-1

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 Section 5.5.1.

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

5.6.7.4 Acceptance Criteria

1. Verify conformance of CUT/TUT per corresponding measurement section as identified in Section 5.9 Test Sequence

5.7 Tests for Headers

5.7.1 Header Pin Retention

5.7.1.1 Purpose

The terminal push-out test is used to determine the retention of the Male Terminal in certain 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 assures 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

5.7.1.3 Procedure

Samples are to be production intent. For designs where pins are closely spaced, pins or terminals may need to be selectively removed or cut to allow space for attachment of jaws, collets or mandrels. Pins may be shortened if necessary to allow for gripping and fixturing. All pin locations for a given design shall be tested and in no case less than 10 pins.

1. Moisture condition samples by exposing “dry as molded parts” to 95-98% relative humidity at 40ºC for 6 hours, then immediately complete the retention test.

2. Measurements shall be taken in both directions if possible, i.e. force to push the pin longitudinally through the connector, and to pull it out as if removing a female plug from the header. Depending on individual design, “pushing” or “pulling” may be reversed in order to get the proper reading. It may also be appropriate to apply the loads from the back of the connector on certain designs. Pressure or tension must be applied parallel with the axis of the pin to achieve accurate results. In the case of headers with bent pins it may be necessary to cut the pins in the straight section near the header. If the pins need to be cut prior to taking the force measurement care should be used to avoid affecting the test result.

3. Secure the connector body to the appropriate fixture.

4. Using the force tester, apply a ramping pressure to the terminal pin. Note and record the maximum force required to displace the pin a maximum of 0.2mm, within the plastic housing or board attachment. Repeat for each pin location. Where resultant damage to the connector housing would affect readings on adjacent cavities, move to an undamaged pin or use a fresh connector.

5. Using fresh samples as needed, reverse force direction and repeat steps 3 and 4.

5.7.1.4 Acceptance Criteria

The minimum force required to displace the pin 0.2mm longitudinally in either direction shall meet the values specified in table 5.7.1.4.

Terminal Family	Minimum Displacement Force
<1.2	15N
≥1.2	50N

TABLE 5.7.1.4: MINIMUM HEADER PIN DISPLACEMENT FORCE