



SURFACE VEHICLE STANDARD

J2863™**FEB2023**Issued 2010-04
Revised 2023-02

Superseding J2863 JUL2016

Automotive Trailer Tow Connector

RATIONALE

Updated an incorrect section reference and an incorrect datum callout in Figure B1. Other editorial changes have also been made.

1. SCOPE

This SAE Standard provides the minimum requirements for automotive or RV, seven position, self-draining trailer tow connector interface. The procedures included within this specification are intended to cover the test methods, design, and performance requirements of the electrical interface of the seven-position trailer tow connector in low voltage (0 to 20) road vehicle applications.

1.1 Connector Labeling Identification

A connector and/or vehicle inlet manufactured to this Recommended Practice may optionally visibly display the following identification on its outer surface in Arial font: "SAE J2863™." Any party providing such identification warrants that the connector and/or vehicle inlet complies with all mandatory requirements of this SAE Standard and agrees to indemnify and hold SAE harmless from any and all liability arising out of any failure to comply and any resulting injury or damage arising from such failure.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J1128 Low Voltage Primary Cable

SAE/USCAR-2 Performance Specification for Automotive Electrical Connector Systems

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SAE WEB ADDRESS:

For more information on this standard, visit

https://www.sae.org/standards/content/J2863_202302/

2.1.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM B117-94 Standard Method of Salt Spray (Fog) Testing

ASTM G153 Standard Practice for Operating Enclosed Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials

ASTM G154 Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials

2.1.3 AIAG Publications

Available from Automotive Industry Action Group, Box 77000, Detroit, MI 48277-0839, Tel: 248-358-3570, www.aiag.org.

Measurement Systems Analysis Reference Manual

3. DEFINITIONS

3.1 ACCEPTANCE CRITERIA

Generally, the final section in each test description. It specifies the requirements that all test samples must meet during or at the conclusion of that test.

3.2 AIAG

Abbreviation for Automotive Industry Action Group.

3.3 AUTHORIZED PERSON

One person will be responsible as the final authority for releasing a given part for production and/or for testing that part. Such person may delegate authority for testing that part or may retain the authority. The authorized person, as used in the specification, is the person with authority for making the final decision as to any question arising during testing to this specification or for any deviations from any requirement of this specification. Such authorized person is responsible for documenting any deviation they authorize from this specification. This documentation must be included in the final test report.

3.4 BENCHMARK

Performance measurements of a specific design which serve as a standard by which the performance of other connector systems and terminals can be compared.

3.5 BULK RESISTANCE

That part of total connection resistance attributed to the terminal body. Bulk resistance does not include crimp resistance or interface resistance.

3.6 CT

Abbreviation for continuity tester. A made-up test device composed of a data analyzer and a continuity monitor.

3.7 CUT

Abbreviation for component under test.

3.8 CRITICAL DIMENSION

Any dimension noted on the part drawing or otherwise specified that can adversely affect the performance or function of the part or assembly if it exceeds the applicable tolerance.

3.9 CROSS AXIS RESONANCE

Resonance measured on a vibration set up at right angles to the intentionally induced axis of motion. Example: X or Y measured resonance when shaker is operating in the Z axis.

3.10 DEVICE CONNECTOR

An electrical connector that mates with the electrical interface of a device (e.g., headlamp, switch, horn, etc.).

3.11 DIRECT CONNECT TYPE CONNECTION

A connector that is fixed to a module or panel that a cable plug or wired connector is mated with to provide an electrical interface. Typically, direct connect type connectors will contain the male terminals.

3.12 DMM

Abbreviation for digital multimeter.

3.13 DUE CARE

The proper use of sound engineering judgment to assure a part is fit for its intended use and meets all applicable FMVSS requirements. The assurance that design specifications and test plans satisfy all applicable FMVSS requirements. Use of sound, accepted engineering and laboratory practice to safeguard the integrity of all data and to ensure that no degradation of any sample occurs in any fashion except as specified in actual testing.

3.14 ENGAGING FORCE

The force required to mate a separate pair of contacts (terminals) or a contact and mating test gage. Note that engaging force is not used in this document.

3.15 EXTRACTION FORCE

The force required to completely remove an individual contact (terminal) from its cavity in a connector. Note that extraction force is not used in this document.

3.16 FEMALE CONNECTOR

The connector that houses the female terminal(s). Also referred to in this document as a cable plug connector.

3.17 FEMALE TERMINAL

The electrical receptacle that receives the male blade or pin.

3.18 FMVSS

Abbreviation for Federal Motor Vehicle Safety Standard.

3.19 FS

Abbreviation for full scale.

3.20 GD&T

Abbreviation for geometric dimensioning and tolerancing. A method required by the USCAR companies for representing dimensions and their tolerances on all part drawings

3.21 IACS

Abbreviation for International Annealed Copper Standard.

3.22 ISOLATION RESISTANCE

Isolation resistance, expressed in ohms (Ω), measures the electrical resistance between circuits in a connection system. This test is conducted to verify that there is sufficient spacing to prevent detrimental electrical conductivity between any circuits, terminals, shield, or housing in that connector for its intended application.

3.23 MALE CONNECTOR

The connector that houses the male terminal(s). Also referred to in this document as a receptacle connector.

3.24 MALE TERMINAL

The metal blade or pin that inserts into the female terminal.

3.25 MATING FORCE

The force required to mate male and female connector halves or to completely seat a connector in a receptacle when fully populated with applicable terminals.

3.26 MAXIMUM CURRENT CAPABILITY

The maximum current carrying capability at room temperature of the specific combination of terminal size, conductor gage, insulation type, etc., as determined in 5.2.2. This value must be de-rated for actual conditions in the expected application.

3.27 NOMINAL CURRENT

The current causing a 30 °C temperature rise over ambient based on given wire size.

3.28 PANEL MOUNT CONNECTOR

This type of connection system serves to pass a circuit or group of circuits through a panel, bracket, or other obstruction. It can be configured with connectors plugged into both ends or can be attached directly to a harness or circuit board on one end with a separable connector on the other end.

3.29 POWER CIRCUIT

Any electrical circuit expected to carry in excess of 5 A continuously for more than 1 minute.

3.30 RETENTION FORCE

The maximum force that can be exerted on an individual contact (terminal) without dislodging it from its proper position in its connector cavity. This force may have two different values; one with the associated wedge (TPA, PLK, etc.) installed and a second value without such assistance.

3.31 RH

Abbreviation for relative humidity.

3.32 ROA

Abbreviation for rise over ambient (temperature).

3.33 ROOM TEMPERATURE

23 °C ± 5 °C.

3.34 SEPARATING FORCE

The force required to disengage a mated pair of contacts (terminals) or a contact and a mating test gage.

3.35 SIGNAL CIRCUIT

Any electrical circuit expected to carry 5 A or less at all times.

3.36 SOAK

Refers to a time period during which the device under test is exposed to stated environmental conditions, such as temperature, humidity, current flow, etc. This exposure may be for the purpose of conditioning the sample prior to another test or may itself form part of a given test.

3.37 SPRUNG

Describes any portion or component of a motor vehicle that is supported by the suspension system. Sprung components do not include tires, wheels, hubs, or outboard disc or drum brake assemblies.

3.38 STEADY STATE

A condition of environment or current flow that remains stable for 1 minute or more.

3.39 TOTAL CONNECTION RESISTANCE

Electrical resistance of one terminal to terminal interface plus the resistance of the conductor to terminal grip for each terminal. For direct connect type connections, only the resistance of the one conductor to terminal grip is included. Included is the "bulk resistance" of the terminal material itself.

3.40 TUT

Abbreviation for terminal under test.

3.41 UNMATING FORCE

The force required to un-mate male and female connector halves (including terminals), or a connector from a direct connect or panel mount connector or receptacle.

3.42 UN-SPRUNG

Describes any component of a motor vehicle that is not supported by the suspension system.

3.43 USCAR

Abbreviation for United States Council for Automotive Research. A consortium of representatives from Ford, General Motors, and Stellantis to promote joint research in noncompetitive areas that can strengthen the U.S. automotive industry.

3.44 VOLTAGE DROP (VD)

The difference in potential between two points in an electrical circuit caused by resistance at nominal current. Voltage drop may be used to calculate resistance when the current value is known.

4. GENERAL REQUIREMENT

4.1 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.

4.2 Default Test Tolerances

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

Temperature = ± 3 °C

Voltage = $\pm 5\%$

Current = $\pm 5\%$

Resistance = $\pm 5\%$

Length = $\pm 5\%$

Time = $\pm 5\%$

Force = $\pm 5\%$

Frequency = $\pm 5\%$

Flow Rate = $\pm 5\%$

Relative humidity = $\pm 5\%$ (when controlled)

Speed = $\pm 5\%$

Sound = $\pm 5\%$

Pressure = $\pm 5\%$

Vacuum = $\pm 5\%$

4.2.1 Test Default Conditions

When specific test conditions are not given either in the product design specification, the test request/order or elsewhere in this specification, the following basic conditions shall apply:

Room temperature = 23 °C ± 5 °C

Relative humidity = Ambient (uncontrolled as in lab ambient conditions)

4.3 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. Many other items of customary laboratory equipment and supplies will also be required.

NOTE: On requirements, Use of equipment with a lesser range is acceptable for specific tests where the required range for that test can be met. The equipment range specified does not preclude use of equipment with a larger range, but the accuracy must remain within the specified tolerance. For example, a DMM with a range of 0 to 100 V could be substituted for one specified as 0 to 50 V, with the provision that the accuracy could be maintained as $\pm 0.5\%$ of the 50 V full scale, or 0.25 V, not 0.5% of the 100 V full scale of the substituted equipment.

Table 1 - Equipment

Item	Description	Requirements
1	DC power supply (regulated)	⇒0-20 V Current as necessary
3	Digital multimeter (DMM)	Capable of measuring the following at an accuracy of ≤0.5% of full scale: ⇒0-50 VDC ⇒0-10 MΩ
4	Current shunts	As required with accuracy of ±1% of nominal
5	Millivolt meter	Capable of measuring 0-100 m VDC at 0.5% full scale
6	Item removed	
7	Insertion/extraction force tester	Capable of 1.0% accuracy, full scale
8	Data logger	As required
9	Temperature chamber	⇒-40 to +85 °C ⇒0 to 95% RH
10	Vibration controller	As Required
11	Vibration table	⇒2640 N (600 pounds) sine force ⇒2200 N (500 pounds) RMS force
13	Megohmmeter	Accuracy <5% of full scale

4.4 Measurement Resolution

Unless otherwise specified, meters and gages used in measurements of the test sample(s) shall be capable of measuring with a resolution one decimal place better than the specified value. For example, even though a wire diameter specified as 0.1 mm might actually be the same as one specified as 0.10 mm, calipers capable of 0.01 mm resolution may be used to measure the first wire but a micrometer with 0.001 mm resolution is required to measure the second wire.

4.5 Test Repeatability and Calibration

All equipment used for test sample evaluation shall be calibrated and maintained according to the applicable standards and requirements set forth by ISO TS16949 and the AIAG publication Measurement Systems Analysis Reference Manual. Copies of this manual can be obtained from the AIAG. Refer to www.aiag.org for further information.

4.6 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, except where a test to failure is specified.

4.7 Part Endurance

Successful completion of all 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.

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.

5.1.1 Performance Requirements

Trailer tow connection systems must meet all performance test requirements.

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 Temperature, Sealing, and Vibration

5.1.4.1 Temperature Performance Requirements

The trailer tow interface is intended to operate in -40 to +85 °C environmental conditions. This includes ambient plus temperature rise due to electrical loading. Care must be taken to ensure that the conductor and insulation materials selected for the application, or any test will withstand the stated temperature range.

5.1.4.2 Sealing Performance Requirements

The sealing performance of the A~B interface (see Appendix A) is determined separately from this specification. SAE/USCAR-2 Sealing level 2, 2.5 are commonly used. The C~D interface defined in this specification is unsealed.

NOTE: The B and C connector interfaces must be environmentally sealed from each other to prevent contaminants from passing from the unsealed (C~D) section into the sealed (A~B) section of the interface. The sealing ability of the interface is determined in testing of the A~B interface, that is separate from tests described in this specification.

5.1.4.3 Vibration Requirements

These trailer tow connection components are intended for use on sprung portions of the vehicle (not coupled to the engine). They shall be tested to and meet the acceptance requirements of 5.4.3 (USCAR-2 Vibration Level 1).

5.1.5 Testing Panel Mount or Direct Connect Type Components

The trailer tow interface described in this specification is a direct connect type component. In order to completely test the electrical connection, access must be gained to both the terminals in the plug as well as those in the receptacle. This is accomplished by measuring the total resistance between T_1 and T_2 . The bulk resistance of the wire is measured and subtracted from the $T_1 \sim T_2$ value to obtain the total connection resistance value.

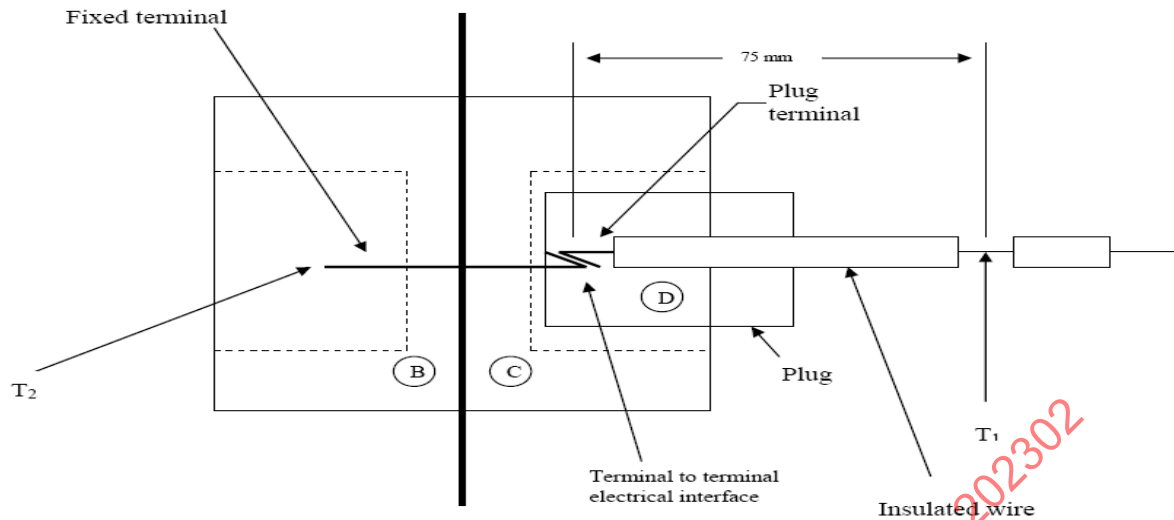


Figure 1 - Panel mount or direct connect type connector

NOTE: Ballooned letters are to be used for nomenclature only. Example: The C/D interface describes the trailer to tow vehicle connection.

5.1.6 Terminal Sample Preparation

Terminals used for testing, if crimped, need to conform to the requirements as defined in SAE/USCAR-21 crimp dimension physical characteristics and mechanical pull strength shall be within tolerance as it applies to the respective terminal and wire gage. Crimp both the conductor and insulation grips unless otherwise specified in the individual test procedures. Use the appropriate cable seal as applicable. Assemble samples requiring other termination methods per their manufacturer's requirements. When testing panel mount or direct connect type connectors with mating connectors, prepare samples for both the mating trailer side connector) and the vehicle side connector (see connectors in Appendixes A, C, and D). Record the crimp height and width (if applicable) of a representative group of samples of each terminal. Number all samples for tracking and later identification as appropriate.

NOTE: The T₂ test lead can be connected directly to the terminal on the "B" side of the panel mount or direct connect type connector under test.

5.1.7 Connector Cycling

5.1.7.1 Purpose

This procedure preconditions a connection system with terminals prior to a test sequence. Connectors may be subjected to a repeated cycling due to in-plant and/or service repair prior to and during the life of the connector.

5.1.7.2 Procedure

Completely mate and un-mate each connector ten times. After the cycling re-mate connectors for one last time in preparation for future test sequence.

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

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, etc. Compare the tested and/or conditioned samples to the control samples, the videos, and/or the photographs, recording any differences in the test report. The authorized person will need to provide an additional sample for this purpose.

Return test samples to requestor after all tests are completed and all necessary data have been obtained.

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 criteria (if any are) 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)

5.1.9.3 Procedure

Prepare six (at least six male and six female) connector samples per 5.1.6 using 3 mm² (12 gauge) wire. Three sets-center pin position #7 and three sets-blade positions #1, #3, and #5 will be monitored during this test. Solder the conductors from each terminal in the CUT in series to form one continuous current path with only two free ends. Solder one of the free conductor ends to a 2 W, 120 $\Omega \pm 1.2 \Omega$ 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 (CT) 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 m ADC 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 2. Other suitable continuity monitoring equipment may be used.

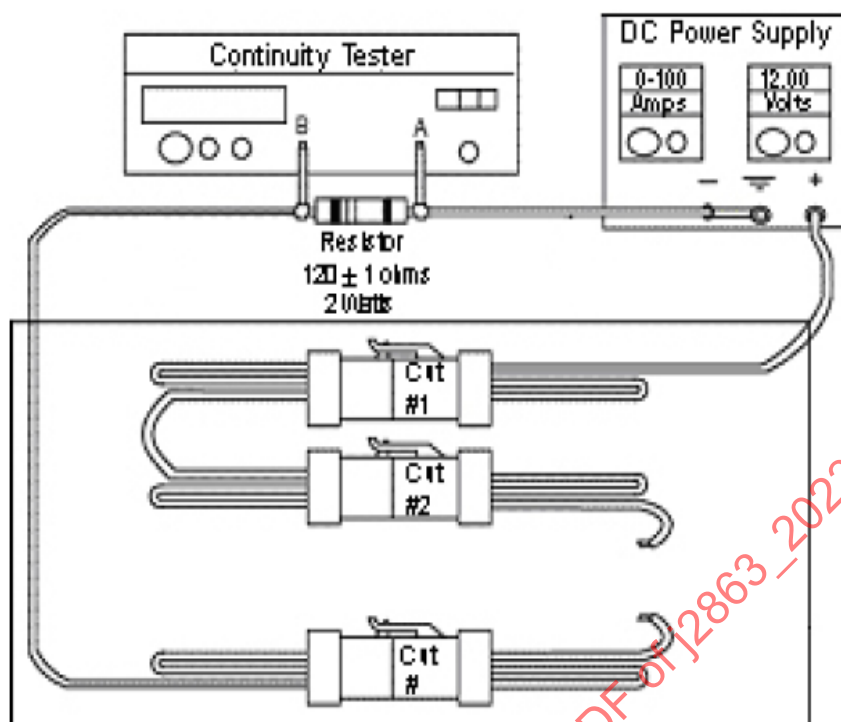


Figure 2 - Circuit continuity monitoring test set-up

5.1.9.4 Acceptance Criteria

Where continuity monitoring is required during any conditioning procedure, there must be no loss of electrical continuity (any instance of the resistor current dropping below 95 mA), for more than 1 μ s. If one or more terminal pairs are monitored, rather than the series resistor, there must be no instance in which the resistance of any terminal pair exceeds 7.0 Ω for more than 1 μ s. Figure 3 illustrates the acceptance criteria graphically.

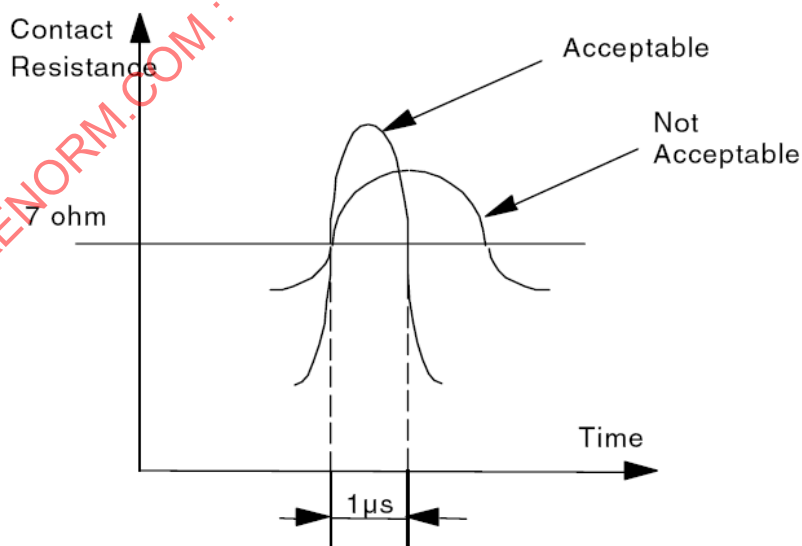


Figure 3 - Intermittency measurement

5.2 Terminal - Electrical Tests

5.2.1 Voltage Drop

5.2.1.1 Purpose

This test determines the voltage drop associated with the electrical resistance of the contact interface at nominal current conditions. The voltage drop is then used to calculate the Connection Resistance.

5.2.1.2 Equipment

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

5.2.1.3 Procedure

1. Prepare six (at least six male and six female) connector samples per 5.1.6 using 3 mm² (12 gauge) wire. The voltage drop on three sets-center pin position #7 and three sets-blade positions #1, #3, and #5 will be monitored during this test.
2. Complete the connector and/or terminal cycling procedure per 5.1.7 if not already performed on the sample set.
3. Carefully mate the test connector pair.
4. Assemble the test circuit shown in Figure 4.
5. Adjust the power supply to provide the required test current of 5 A per square millimeter of the wire core cross section used for the sample preparation in step 1.

NOTE: The circuits in the samples under test may be wired in series and the test current applied to the CUTs as a group. The millivolt test leads shall be connected as shown in Figure 4.

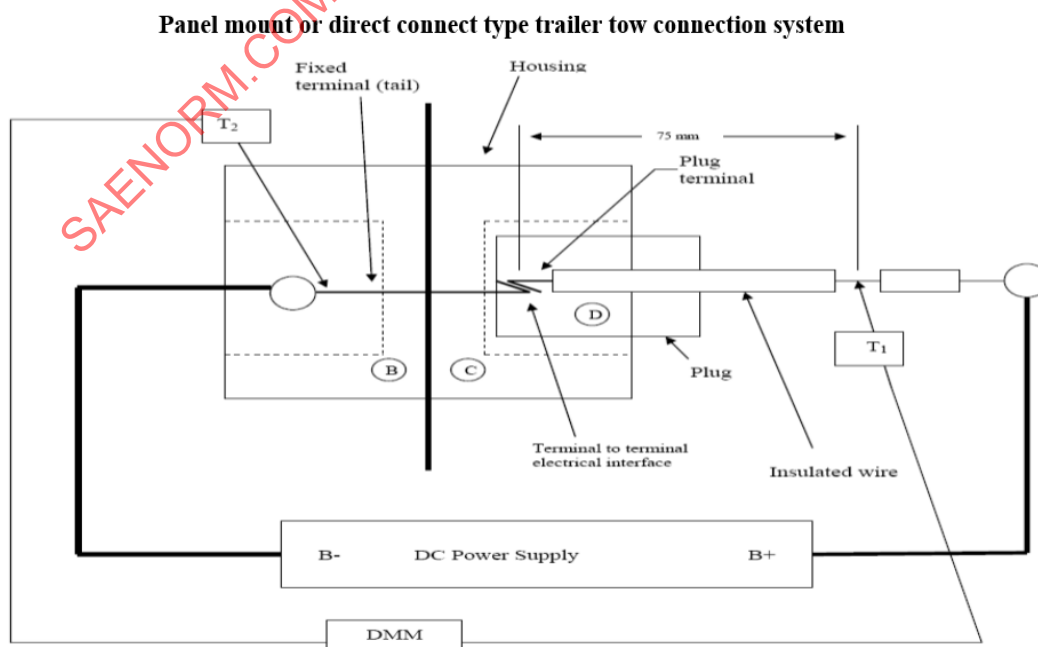


Figure 4 - Voltage drop and maximum current, test set-up

6. Using the test current determined in step 5, measure and record the millivolt drop through 75 mm of the same wire type and size used in step 1. This measured value will be used as the “deduct” value and subtracted from the measured test value to establish the interface mVD (see step 9)

NOTE: For attachment points exceeding 75 mm ± 3 mm, the resistance of the alternate wire length shall be measured and used as the deduct value per step 6.

7. Choose the preferred method of taking measurements (soldered sense lead or probe) and document the method chosen. In either case, the sense point T₁ (Figure 4) must be soldered for all stranded cable. For direct connect type connectors, T₂ is attached to the direct connect terminal per 5.1.5. All millivolt leads must be no larger than 0.22 mm² (24 AWG).
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 T₁ and T₂. Use these values in the equation below to calculate the voltage drop across the entire connection. In the case of direct connect type connectors, T₂ is attached to the “tail” of the direct connect terminal (see 5.1.5).

$$\text{mVD Entire Connection} = \text{mVD (T}_1 - \text{T}_2) - [\text{mVD Deduct Value (see step 6)}]$$

$$\text{Total Connection Resistance}^1 = \text{mVD Entire Connection} \div \text{Test Current}$$

Use these results to verify conformance to the acceptance criteria of 5.2.1.4.

NOTE: These values apply to both before and after environmental conditioning such as thermal shock, temperature/humidity cycling, etc., or on field samples.

5.2.1.4 Acceptance Criteria (Values Apply Before and After Testing)

Male blade terminal: Maximum total connection voltage drop is 1.5 mV/A

Pin terminal: Maximum total connection voltage drop is 1 mV/A

(Exception: see 5.4.8.4 for after coupling cycle test acceptance criteria)

NOTE: The “after test” values for direct connect type interfaces are the “wire attachment to tail” (T₁ to T₂ in Figure 1) minus the measured wire resistance

5.2.2 Maximum Test Current Capability

5.2.2.1 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 interface resistance begins to occur. This test is conducted with the terminals in the housing.

NOTE: A draft free environment is necessary to get accurate measurements.

¹ 1 mV/A = 1 mΩ.

5.2.2.2 Equipment

- Digital multimeter (DMM)
- DC power supply (0 to 20 VDC at 0 to 150 A)
- Current shunts (size as required, $\pm 1\%$)
- Ambient temperature sensor
- Data logger (as required)

5.2.2.3 Procedure

1. Prepare six (at least six male and six female) connector samples per 5.1.6 using 3 mm² (12 gauge) wire. Three sets-center pin position #7 and three sets-blade positions #1, #3, and #5 will be monitored during this test.
2. Complete the connector and/or terminal cycling procedure per 5.1.7 if not already performed on the sample set.
3. Measure and record the voltage drop, at the expected maximum current capability of the CUT, through 75 mm of the wire used to prepare the samples. This will be the “deduct” value subtracted from the measured value to establish the total connection resistance. For testing direct connect type connectors, see 5.1.5.

NOTE: For attachment points exceeding 75 mm $\pm$ 3 mm per, the extra wire resistance shall be measured and subtracted per step 3.

4. Assemble the CUT circuits in a draft free enclosure as shown in Figure 4. Use at least six mated connector pairs (three sets-center pin position #7 and three sets-blade positions #1, #3, and #5, connected in series). Choose the preferred method of taking measurements (soldered sense lead or probe) and document the method chosen. In either case, the sense point T₁ (Figure 4) must be soldered for all stranded cable. Attach conductor ends of the terminal pairs to form one continuous series circuit. Attach the CUT to a non-conductive surface, such as wood or high temperature plastic, leaving a minimum of 50 mm between test samples.
5. Test the sample terminal pairs at 23 °C $\pm$ 5 °C (room temperature). The ambient temperature sensor must be placed on the same plane as the test samples, 30 to 60 cm from the any sample under test.
6. Adjust the power supply to zero amps output and then turn on the supply and the DMMs.
7. Slowly (taking a minimum of 20 seconds) increase the power supply output until it is providing no greater than 50% of the expected maximum current capability of the CUT.
8. Wait at least 15 minutes for the circuit temperature to reach steady state. Then record the ambient temperature and the millivolt drop across each terminal pair (T₁ to T₂ in Figure 4, less the millivolt drop of the wire as determined in step 3). Then calculate the total resistance of the terminal pair interface per step 9 of 5.2.1.3.
9. Increase the current by no more than 10% of the expected maximum current capability of the CUT and repeat step 8.
10. Repeat step 9 until 80% of the expected maximum current capability of the CUT is met.
11. Continue to increase the current in increments of 5% of the expected maximum current capability of the CUT, repeating step 8 after each incremental increase.
12. For samples to be used in subsequent tests, repeat step 11 until the following condition occurs: The total connection resistance of any terminal interface exceeds the “after test” acceptance criteria listed in 5.2.1.4.

5.2.2.4 Acceptance Criteria

The maximum test current = The current at which any sample exceeds the “after test” acceptance criteria of 5.2.1.4 minus 10% of that current.

5.2.3 1008-hour Current Cycling

5.2.3.1 Purpose

This test simulates the main function of the terminal over the expected life of the vehicle. Current cycling is an accelerated aging test which electrically heats terminal interfaces and core conductor crimps, and then allows them to cool under no current conditions, causing expansion and contraction that may affect connection resistance due to wear, oxidation, inter-metallic growth, and stress relaxation.

5.2.3.2 Equipment

- Digital multimeter (DMM)
- DC power supply (0 to 20 VDC at 0 to 150 A, timer controlled)
- Current shunts (size as required, $\pm 1\%$)
- Data logger (as required)

5.2.3.3 Procedure

1. Prepare six (at least six male and six female) connector samples per 5.1.6 using 3 mm² (12 gauge) wire. Three sets-center pin position #7 and three sets-blade positions #1, #3, and #5 will be monitored during this test.
2. Attach the millivolt leads in positions T₁ and T₂ as shown in Figure 4. For direct connect type connectors, T₂ is attached to the direct connect terminal (see 5.1.5). All millivolt leads must be no larger than 0.22 mm² (24 AWG).
3. Complete the connector and/or terminal cycling procedure per 5.1.7 if not already performed on the sample set.
4. At the maximum test current determined in 5.2.2, measure and record the voltage drop through 75 mm of the wire used for the sample preparation in step 1. This measured value will be used as the “deduct value” to calculate the total resistance value in step 10.

NOTE: For attachment points exceeding 75 mm per side, the extra wire resistance shall be measured and subtracted per step 10.

5. Assemble the circuit shown in Figure 4 in a draft free enclosure. Set the power supply to provide 45 minutes “ON” and 15 minutes “OFF” at the maximum test current previously determined (see 5.2.2). Connect a data logger to the voltage drop leads.
6. Test the set of sample terminal pairs at 23 °C $\pm$ 5 °C (room temperature). An ambient temperature sensor must be placed on the same plane as the test samples, 30 to 60 cm from any sample under test.
7. Turn “ON” the power supply, DMMs, and data logger.
8. After 30 minutes into the first “ON” cycle, record the interface millivolt drop readings (T₁ to T₂ in Figure 4) for each terminal pair.
9. Cycle for 1008 hours taking readings at least once daily or as specified by the test request/order, 30 minutes into the “ON” cycle, and at the conclusion of the test, 30 minutes into the final “ON” cycle. mV drop readings must be taken at maximum test current.
10. For each set of data, calculate and record the total connection resistance by subtracting the deduct value (step 4) from the T₁ to T₂ millivolt drop reading (step 8) and dividing the result by the test current (step 5).
11. Allow the samples to cool to ambient, and then complete the voltage drop test in 5.2.1.

5.2.3.4 Acceptance Criteria

The Voltage drop must not exceed the “after test” acceptance criteria in 5.2.1.4 for any data set.

5.3 Connector - Electrical Tests

5.3.1 Isolation Resistance

5.3.1.1 Purpose

This test verifies that the electrical resistance between any two cavities in a connector system will be sufficient to prevent detrimental electrical conductivity 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.

5.3.1.2 Equipment

- Megohmmeter

5.3.1.3 Procedure

NOTE: The test samples shall rest in ambient environment for ≥ 3 hours prior to measuring isolation resistance after any prior environmental conditioning.

1. Prepare three connector samples per 5.1.6 fully populated with wires and terminals using 3 mm² (12 gauge) wire and mated with the panel mount or direct connect receptacle
2. Connect one lead of the megohmmeter, set to 500 VDC, to the bared conductor end of any circuit in the CUT. Connect the other megohmmeter lead to an adjacent circuit.
3. Use the megohmmeter to measure the resistance between the adjacent circuits: Apply the test voltage, allow for meter to stabilize. Move to the next circuit and repeat this process until all circuits in the CUT have been tested for isolation from all other circuits in the CUT. A minimum of 10 seconds stabilization time is recommended.
4. Record the minimum resistance measured and verify conformance to the acceptance criteria of 5.3.1.4.

5.3.1.4 Acceptance Criteria

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

5.4 Connector - Mechanical/Durability Tests

5.4.1 Terminal Retention Force

5.4.1.1 Purpose

This test determines the retention effectiveness of mating cable plug and the trailer tow connector receptacle terminals to their respective housings.

5.4.1.2 Equipment

- Insertion/extraction force tester with peak reading feature

5.4.1.3 Procedure

Both the receptacle and/or cable plug terminals shall be subjected to a direct push in the direction of the mating interface to a force of 175 N for 1 minute. The force is to be exerted on each terminal without sudden or jerking forces during the test. All terminals in three samples shall be tested.

NOTE: Secondary lock devices should be utilized if part of the design.

5.4.1.4 Acceptance Criteria

Terminals shall maintain their original position in the connector after testing.

5.4.2 Polarization Feature Effectiveness

5.4.2.1 Purpose

This test ensures that the polarization feature is adequate to meet its intended purpose of preventing incorrect mating of a connector housing with its intended mate, it also tests the adequacy of the polarization feature in preventing terminal damage during incorrect assembly attempts.

5.4.2.2 Equipment

- Insertion force tester with peak reading feature

5.4.2.3 Procedure

1. Test at least one sample set for each selected mis-orientation. Test at 90, 180, and 270 degrees from its intended orientation.
2. A suitable mechanical or electrical means must be devised to detect penetration of one half of the CUT into the other to a depth sufficient to contact any male terminal.
3. Secure the connector halves (or connector and direct connect type interface) (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 1.
4. Engage the connector halves at a uniform rate not to exceed 50 mm/min until the maximum force specified in the part drawing is applied. If no value is specified, apply a maximum force of 3X the average value of properly mated connectors. Note the indication of the penetration detection device installed in step 3.

5.4.2.4 Acceptance Criteria

The connection system must withstand a minimum mis-mating force of 200 N or three times the average value measured on a fully loaded, properly mated connector without damage to the connector that would prevent subsequent proper mating.

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.

5.4.3 Vibration/Mechanical Shock

5.4.3.1 Purpose

This test subjects a connector system to variable 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.

5.4.3.2 Equipment

- Vibration table
- Vibration controller
- Accelerometers

5.4.3.3 Procedure

1. Prepare six (at least six male and six female) connector samples per 5.1.6 using 3 mm² (12 gauge) wire. Three sets-center pin position #7 and three sets-blade positions #1, #3, and #5 will be monitored during this test.
2. Prepare each assembly with all applicable parts and bundling and wire covering. See Figure 5 for example of test mounting arrangement. At least six samples are required unless otherwise specified in the test request/order.
3. Complete the connector and/or terminal cycling procedure per 5.1.7 if not already performed on the sample set.
4. Measure the voltage drop of at least six (three sets of the center pin position #7 and three sets of blade positions #1, #3, and #5 connected in series).
5. Verify conformance of each sample connector assembly to the acceptance criteria of the voltage drop (5.2.1.4).
6. Construct a suitable mounting fixture using the following design criteria:
 - a. The mounting fixture must be constructed and secured to minimize added effects (harmonics, dampening, resonance, etc.).
 - b. Secure the panel mount connector directly to the mounting fixture. See Figure 5. 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. The mounting fixture must be fabricated to include any cooperating features necessary to mount the device directly to it.
 - c. The conductor attachment points must be 900 mm ± 10 mm from the rear of the connector body. See Figure 5.
7. Should an application arise that does not lend itself to either situation described 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 fixture consistent with the intended vehicle mounting.
8. Securely attach the conductor bundle ends to the mounting fixture such that there is a 300 mm ± 5 mm sag relative to the bisecting plane of the attachment points. See Figure 5.
9. The sample group shall be set up and monitored continuously for discontinuity per 5.1.9.

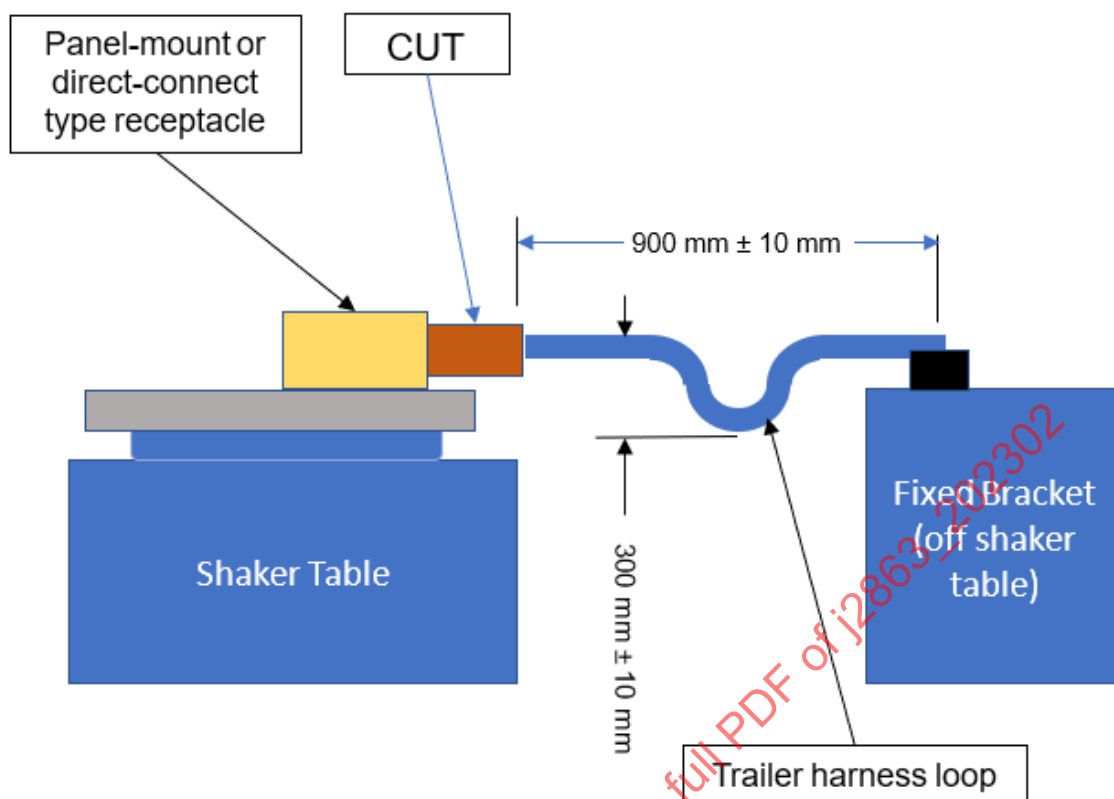


Figure 5

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.

10. The test fixtures, system layout, and test set-up must be approved by the authorized person prior to testing.
11. Subject the CUT to ten positive half-sine wave pulses (5 to 10 ms duration at 35 G force) 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.
12. CUTs mounted anywhere on the sprung portions of the vehicle. Vibration shall be 8 hours in each of the three mutually perpendicular axes (X, Y, Z) unless otherwise specified in the test request/order.
13. Record the results of the continuity monitoring, inspect the CUT, and verify conformance to the acceptance criteria of 5.4.3.4.

Table 2 - Vibration class 1 (PSD)

Frequency (Hz)	Power Spectral Density (g ² /he)
5.0	0.00200
12.5	0.24800
77.5	0.00320
145.0	0.00200
200.0	0.01180
230.0	0.00032
1000.0	0.00002
Grms = 1.81	

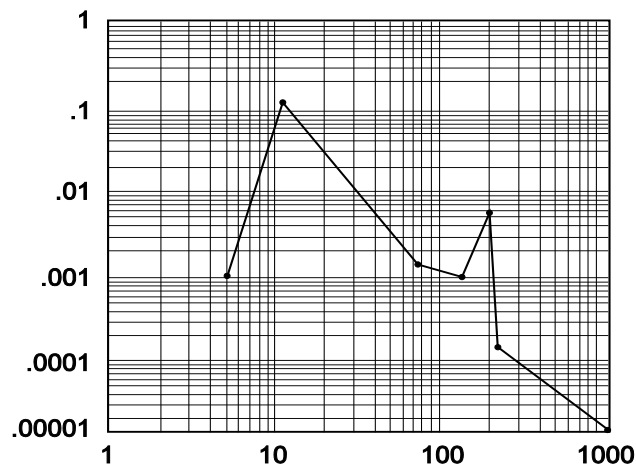


Figure 6 - Vibration class 1 (profile)

5.4.3.4 Acceptance Criteria

At the conclusion of the test, verify conformance of each terminal pair and each sample connector assembly, as appropriate, to the acceptance criteria of 5.1.9.4 (continuity monitoring) and to the following tests:

1. Terminals must meet the acceptance criteria of the voltage drop test (5.2.1.4). Check the same terminal pairs as in step 4 above.
2. The connector assembly must not show, with the aid of 10X magnification, any evidence of deterioration, cracks, deformities, etc., that could affect its functionality or severely degrade its appearance.
3. The terminals must not show, with the aid of 10X magnification, any evidence of deterioration, cracks, deformities, excessive plating wear, etc., that could affect their functionality.

5.4.4 Connector Drop Test

5.4.4.1 Purpose

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

5.4.4.2 Equipment

No specific equipment is required.

5.4.4.3 Procedure

1. Ten samples are required. Assemble connectors with all parts to be used in the intended application.
2. Drop each sample three times (or as agreed upon by the supplier and user) onto a horizontal concrete surface from a height of 1 m, orienting the sample in different directions each time. The responsible engineer may direct specific orientations in order to expose areas of the design that may be vulnerable to damage.

5.4.4.4 Acceptance Criteria

Samples shall meet the visual inspection acceptance criteria of 5.1.8.4.

5.4.5 Coupling Force

5.4.5.1 Purpose

This test determines the engagement forces between the trailer tow connector receptacle and mating cable plug.

5.4.5.2 Equipment

- Insertion/extraction force tester with peak reading feature

5.4.5.3 Procedure

1. Prepare six fully populated (at least six male and six female) connector samples per 5.1.6 using 3 mm² (12 gauge) wire.
2. Mount the assembled cable plug and receptacle on a suitable fixture so the force is applied parallel to the axis of connector mating. Measure and record the peak force to fully mate the receptacle and cable plug at a uniform rate not to exceed 50 mm/min. The connector is considered fully mated when the receptacle's cover latch feature has engaged. Mate each connector pair only once.

NOTE: The mated samples under test may be used for the uncoupling force test (5.4.6).

5.4.5.4 Acceptance Criteria

The engagement force shall not exceed 150 N.

5.4.6 Uncoupling Force

5.4.6.1 Purpose

This test determines the disengagement forces between the trailer tow connector receptacle and mating cable plug.

5.4.6.2 Equipment

- Insertion/extraction force tester with peak reading feature

5.4.6.3 Procedure

1. Prepare six fully populated (at least six male and six female) connector samples per 5.1.6 using 3 mm² (12 gauge) wire.
2. Mount the assembled cable plug and receptacle on a suitable fixture. The force in the following tests shall be applied parallel to the axis of the connector at a uniform rate not to exceed 50 mm/min.
3. Measure and record the peak force required to disconnect the cable plug after manually disengaging the receptacle's cover latch feature.
4. Re-mate the sample under test. Measure and record the peak force required to disconnect the cable plug with the cover latch engaged.

5.4.6.4 Acceptance Criteria

The unlatched uncoupling force shall not be more than 100 N.

The latched uncoupling force shall not be less than 100 N and while latched must release without damage to the vehicle side.

5.4.7 Cycle Cover Spring

5.4.7.1 Purpose

This test determines the integrity of the spring which closes the trailer tow connector receptacle cover.

5.4.7.2 Equipment

- Any suitable cycling fixture

5.4.7.3 Procedure

Test 10 receptacle assemblies. Each cover shall be cycled to 2000 times open/closed to the full extent of its motion, not to exceed 1200 cycles per hour. The force to move the cover for the initial 10 degrees of motion shall be measured before and after test.

5.4.7.4 Acceptance Criteria

The force to move the cover for the initial 10 degrees of motion after 2000 cycles shall be within 10% of the initial measurement.

5.4.8 Coupling Cycle Test

5.4.8.1 Purpose

This test determines the electrical integrity of the trailer tow connector receptacle and mating cable plug during cycling.

5.4.8.2 Equipment

- Any suitable cycling fixture

5.4.8.3 Procedure

Prepare six (at least six male and six female) connector samples per 5.1.6 using 3 mm² (12 gauge) wire. The voltage drop on three sets-center pin position #7 and three sets-blade positions #1, #3, and #5 will be measured per 5.2.1 at the conclusion of the mating cycles. The SAE J2863 plug and receptacle shall be mated and unmated at a rate not to exceed 300 cycles per hour for 2000 cycles.

5.4.8.4 Acceptance Criteria

Voltage drop no greater than 5 mV/A on any terminal interface in the CUT after 2000 mating cycles.

5.5 Connector - Environmental Tests

5.5.1 Thermal Shock

5.5.1.1 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.

5.5.1.2 Equipment

- Temp chamber(s) (-40 to +85 °C)

5.5.1.3 Procedure

1. Prepare six (at least six male and six female) connector samples per 5.1.6 using 3 mm² (12 gauge) wire. The voltage drop on three sets-center pin position #7 and three sets-blade positions #1, #3, and #5 will be monitored during this test. Assemblies must include all applicable parts (covers, wedges, TPAs, PLRs, etc.). Number each mated connector pair.
2. Complete the Connector and/or terminal cycling procedure per 5.1.7 if not already performed on the sample set.
3. Verify conformance of each mated sample assembly under test to the voltage drop test acceptance criteria (5.2.1.4).
4. 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.
5. Set the temperature chamber to -40 °C. Allow the chamber to stabilize, and then cold soak the samples an additional 30 minutes.
6. At the conclusion of the 30 minute cold soak, transfer the samples to another environment set to +85 °C. 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.
7. At the conclusion of the 30 minute heat soak, transfer the samples to another environment set to the minimum -40 °C. 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.
8. Repeat steps 6 and 7 an additional 99 times.
9. Measure the voltage drop per 5.2.1. At least nine blade type and three pin type terminal pairs must be measured. At least three sets of the center pin position (#7) and three sets of blade positions #1, #3 and #5 (monitored previously).
10. Verify conformance to the acceptance criteria (5.5.1.4).

5.5.1.4 Acceptance Criteria

1. At the conclusion of the test, verify conformance of each terminal pair and each sample connector assembly, as appropriate, to the acceptance criteria of the voltage drop test (5.2.1.4).
2. The connector assemblies must not show, with the aid of 10X magnification, any evidence of deterioration, cracks, deformities, etc., that could affect their fit or function, or distort their appearance.

5.5.2 Temperature/Humidity Cycling

5.5.2.1 Purpose

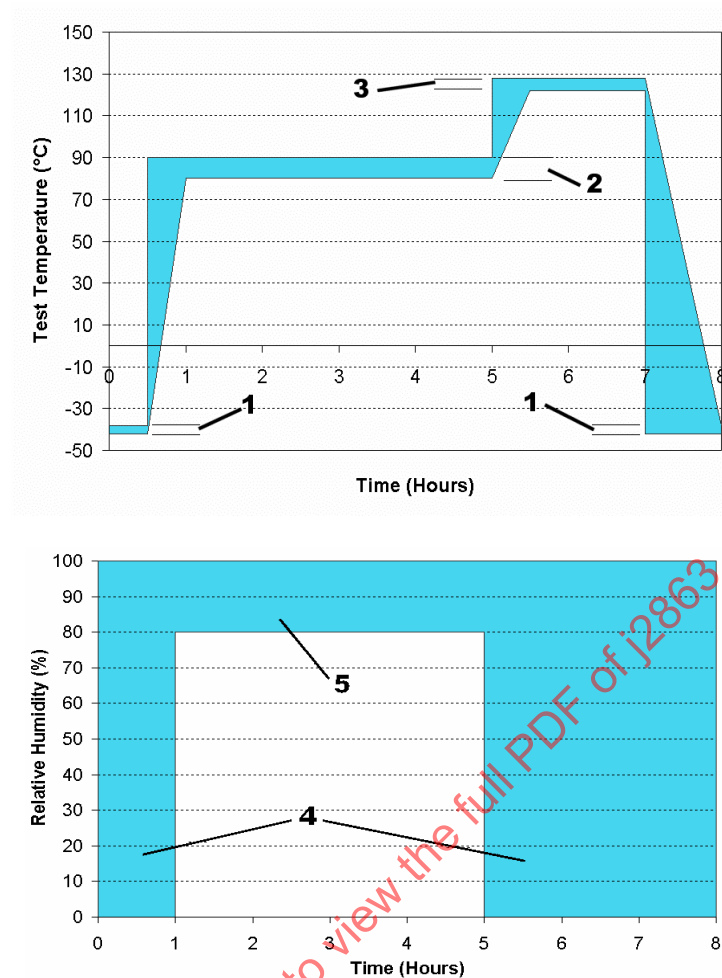
This test simulates actual operating conditions using temperature and humidity variations as aging mechanisms for evaluation of a connector system's electrical durability. High humidity and temperature can promote galvanic and electrolytic corrosion of the terminals which may cause electrical and mechanical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

5.5.2.2 Equipment

- Data logger
- Temperature chamber(s) (-40 to +85 °C, 0 to 95% relative humidity)

5.5.2.3 Procedure

1. Prepare six (at least six male and six female) connector samples per 5.1.6 using 3 mm² (12 gauge) wire. The voltage drop on three sets-center pin position #7 and three sets-blade positions #1, #3, and #5 will be monitored during this test. Assemblies must include all applicable parts (covers, wedges, TPAs, PLRs, etc.). Number each mated connector pair. Prepare three additional samples to be used as described in step 7.
2. Complete the connector and/or terminal cycling procedure per 5.1.7 if not already performed on the sample set.
3. Verify conformance of each mated sample assembly under test to the voltage drop test acceptance criteria (5.2.1.4).
4. 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.
5. Set the temperature chamber to -40 °C. Allow the chamber to stabilize before proceeding.
6. Cycle the test samples 40 times using the cycling schedule shown in Figure 7. Extended transition times may be used as long as the dwell times at temperature are maintained. The cycle begins with the sample at -40 °C and un-controlled relative humidity. Completion of the schedule shown in Figure 7 will constitute one cycle. Use 85 °C as the maximum ambient temperature for hours 5 through 7.
7. Using the three additional samples mentioned in step 1 designated for that purpose, complete the connector/terminal retention force test (5.4.1.3), steps 4 through 6, but do not increase the force above 90 N. Test three samples (minimum) to complete the terminal extraction test. Each cavity location must be tested at least once but not all cavities in all housings need to be tested.
8. Verify conformance to the acceptance criteria of 5.5.2.4.



Key:

1 -40 °C

2 80 to 90 °C

3 Test temperature (Class 3 shown for illustration only)

4 Relative humidity, uncontrolled (do not vent chamber at hour 5)

5 80 to 100% relative humidity

Figure 7 - Temperature/humidity cycling schedule

5.5.2.4 Acceptance Criteria

NOTE: If samples are to be subjected to further testing, the following steps may be deferred until that additional testing is complete.

1. At the conclusion of the test, verify conformance of each terminal pair and each sample connector assembly, as appropriate, to the acceptance criteria of the following tests:
 - a. voltage Drop test (5.2.1.4). Measure all terminal pairs under test.
 - b. Isolation resistance test (5.3.1.4).
2. The connector assemblies must not show, with the aid of 10X magnification, any evidence of deterioration, cracks, deformities, etc., that could affect their functionality or distort their appearance.

5.5.3 High Temperature Exposure

5.5.3.1 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.

5.5.3.2 Equipment

- Temperature chamber(s) (+85 °C)

5.5.3.3 Procedure

1. Prepare six (at least six male and six female) connector samples per 5.1.6 using 3 mm² (12 gauge) wire. The voltage drop on three sets-center pin position #7 and three sets-blade positions #1, #3, and #5 will be monitored during this test. Assemblies must include all applicable parts (covers, wedges, TPAs, PLRs, etc.). Number each mated connector pair.
2. Complete the connector and/or terminal cycling procedure per 5.1.7 if not already performed on the sample set.
3. Verify conformance of each mated sample assembly under test to the voltage drop test acceptance criteria (5.2.1.4).
4. Set the temperature chamber to +85 °C. Allow the chamber to stabilize before proceeding.
5. 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. Leave the samples in the chamber for 1008 hours.
6. Sample evaluation is required only end of the test.

5.5.3.4 Acceptance Criteria

At the conclusion of the test, verify conformance of each terminal pair and each sample connector assembly to the following:

- a. The voltage drop test (5.2.1). Measure all terminal pairs under test.
- b. The visual inspection (5.1.8).

5.5.4 Fluid Resistance

5.5.4.1 Purpose

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

5.5.4.2 Equipment

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

5.5.4.3 Procedure

1. Prepare six (at least six male and six female) fully populated connector samples per 5.1.6 using 3 mm² (12 gauge) wire. Assemblies must include all applicable parts (covers, wedges, TPAs, PLRs, etc.). Number each mated connector pair.
2. Completely submerge at least one test sample in each fluid listed in Table 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 submerged in one fluid only, unless otherwise requested by the authorized person.
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 submerged 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. Verify conformance of each test sample to the acceptance criteria of 5.5.4.4.

CAUTION: Follow all Federal, state, and local safety regulations, standards, and procedures when performing this test.

Table 3 - Fluid test

Fluid	Specification*	Test Temp
Gasoline	ISO 1817, liquid C	23 °C ± 5 °C
Diesel fuel	90% ISO 1817, Oil No. 3 + 10% p-xylene	23 °C ± 5 °C
Engine oil	ISO 1817, Oil No. 2	50 °C ± 3 °C
Ethanol	85% Ethanol + 15% ISO 1817 liquid C	23 °C ± 5 °C
Washer fluid	Commercially available	23 °C ± 5 °C

* Solutions are determined as percent by volume.

5.5.4.4 Acceptance Criteria

There must be no visible degradation², cracking, or loss of mechanical function evident on any test sample, examined with the aid of a 10X magnifying glass.

² Swelling of cable and seals is permissible, within the limits of that specific material specification.