SAE International™ SURFACE VEHICLE STANDARD

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(R) Heavy-Duty Electrical Connector Performance Standard

Foreword

NOTICE—Some test procedures are potentially dangerous. SAE Technical Reports do not purport to address all of the safety problems, if any, associated with their use. It is the responsibility of the user of an SAE Technical Report to establish and employ appropriate safety practices. Tests should only be conducted by individuals who have been properly trained in the test procedure and who are aware of any hazards which may be present. Appropriate safety and health precautions must be employed when conducting any test.

1. ***Scope—***This SAE Standard encompasses connectors between two cables or between a cable and an electrical component and focuses on the connectors external to the electrical component. This document provides environmental test requirements and acceptance criteria for the application of connectors for direct current electrical systems of 50 V or less in the majority of heavy-duty applications typically used in off-highway machinery. Severe applications may require higher test levels, or field-testing on the intended application.

2. References

2.1 Applicable Publications—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated, the latest revision of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J163—Low Tension Wiring and Cable Terminals and Splice Clips
SAE J726—Air Cleaner Test Code Standard
SAE J1455—Joint SAE/TMC Recommended Environmental Practices for Electronic Equipment Design (Heavy-Duty Trucks)
SAE J1614—Wiring Distribution Systems for Construction, Agricultural, and Off-Road Work Machines

2.1.2 ASAE PUBLICATION—Available from the American Society of Agricultural Engineers, 2950 Niles Road, St. Joseph, MI 49085-9659.

ASAEEP455—Environmental Considerations in Development of Mobile Agricultural Electrical/Electronic Components

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2.1.3 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 471—Standard Test Method for Rubber Property—Effect of Liquids
ASTM G 153—Standard Practice for Operating Enclosed Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials
ASTM G 154—Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials

2.1.4 MIL SPECIFICATION—Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-1344A—Method 3002.1 Low-Signal Level Contact Resistance

2.2 Related Publications—The following publication is provided for information purposes only and is not a required part of this document.

2.2.1 API PUBLICATION—Available from American Petroleum Institute, 1220 L Street, Northwest, Washington, DC 20005.

API 1560—Lubricant Service Designation for Automotive Manual Transmissions and Axles

2.2.2 ISO PUBLICATION—Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002.

ISO 8090—Road vehicles—Connections for on-board electrical harnesses

3. Definitions

3.1 Connector—A coupling device, which provides an electrical and/or mechanical junction between two cables or between a cable(s) and an electrical component. It can also provide for mechanical stability and geometric arrangement.

3.2 Terminal—An electrically conductive device attached to a cable to facilitate connection to an electrical component, cable, or termination.

3.3 Sealed—A system that creates a nonleaking union between mechanical elements when submerged in a water solution as defined in the tests within this document.

3.4 Signal Level Circuit—A circuit in which open circuit voltage is typically less than 5 V and current is typically less than 0.05 A. Circuits of this energy level typically are not able to break through oxides, sulfides, or other contaminants, which may build up on the contact surfaces and prevent continuity.

3.5 Power Circuit—A system using two or more cables where current flows from the source to one or more electronic/electrical devices and back again to the source. The electrical energy is supplied at high levels of current and typical system voltage (system battery voltage).

3.6 Cable—Insulated stranded electrical conductor used to establish a single current path.

3.7 Wiring—Collectively, the cables, harnesses, connectors, terminations, and supporting components used in the electrical wiring distribution system.

4. Sample Preparation—Samples shall be made on the connector manufacturer's recommended tooling and checked for conformance to the connector manufacturer's standards.

4.1 Assembly—All connector cavities shall be wired with manufacturer's minimum approved cable outside diameter size except for test groups 'A' and 'E' which will be wired with manufacturer's maximum approved conductor size in lengths sufficient to accommodate testing. Cable diameter shall be checked and be within the connector's manufacturing specification. Crimp characteristics (i.e., height, width, etc.) shall be checked. To prevent capillary action on sealed connectors, all loose wire ends and test points (i.e., millivolt test connection) shall be sealed with alcohol-base RTV silicone or equivalent.

5. Test Sequence—For qualification testing, test samples shall be subjected to the tests in the order shown in Table 1 with a quantity of 6 for each group. The tests are to be carried out in the numerical sequence as described in each group's column.

Group 'A' emphasizes mechanical, fluid, and thermal performance for sealed signal connectors
Group 'B' emphasizes mechanical and thermal performance for signal connectors
Group 'C' emphasizes thermal performance for all connectors
Group 'D' emphasizes mechanical performance for all connectors
Group 'E' emphasizes mechanical, fluid, and thermal performance for sealed power connectors
Group 'F' emphasizes mechanical and thermal performance for power connectors

TABLE 1—TEST SEQUENCES

Test Description	Test Para.	Group A Sequence Sealed Signal Connector Test	Group B Sequence Signal Connector Test	Group C Sequence Connector Test	Group D Sequence Connector Test	Group E Sequence Sealed Power Connector Test	Group F Sequence Power Connector Test
Examination of Product	6.1	1	1	1	1	1	1
Low-Voltage Resistance	6.2	2,15,21	2,14,19				
Insulation Resistance	6.3	3	3	2		2	2
Connection Resistance	6.4	4	4	3		3	3
Pressure Washing	6.5	5				4	
Maintenance Aging	6.6				2		
Temperature Life	6.7		5	4			4
Ultraviolet Effects	6.8				4		
Mating Forces	6.9		7		6		6
Unmating Forces	6.10		8		7		7
Durability	6.11		9		8		8
Salt Fog	6.12	7				6	
Thermal Shock	6.13	9	11	6		8	10
Fluid Immersion	6.14	11				10	
Vibration	6.15	13	13			12	12
Shock	6.16	14	15			13	13
Drop Test	6.17	16		7		14	
Terminal Retention in Connector	6.18				10		
Water Immersion	6.19	18				16	
Connector Retention	6.20			9	11		
Mismating	6.21				12		
Current Test	6.22					18	15
Dust Test	6.23		17				16
Temperature/Humidity	6.24	20	18			19	17
Current Cycling	6.25					21	19
Terminal Crimp Strength	6.26				14		
Visual Examination	6.27	6, 8, 10, 12, 17, 19, 22	6, 10, 12, 16, 20	5, 8, 10	3, 5, 9, 13, 15	5, 7, 9, 11, 15, 17, 20, 22	5, 9, 11, 14, 18, 20

5.1 Test Groups A, B, C, and D are for sealed signal level connectors.

5.2 Test Groups C, D, E, and F are for sealed power level connectors.

5.3 Test Groups B, C, and D are for unsealed signal level connectors.

5.4 Test Groups C, D, and F are for unsealed power level connectors

Test Sequence Example using Test Group C as follows:

a. Examination of Product per 6.1.
b. Insulation Resistance per 6.3.
c. Connection Resistance per 6.4.
d. Temperature Life per 6.7.
e. Visual Examination per 6.27.
f. Thermal Shock per 6.13.
g. Drop Test per 6.17.
h. Visual Examination per 6.27.
i. Connector Retention per 6.20.
j. Visual Examination per 6.27.

***6. Test Methods*—**All tests shall be carried out at an ambient temperature of 23 °C ± 3 °C and a relative humidity between 20% and 90% unless otherwise stated. Not all test descriptions contained herein describe acceptance criteria. Tests may be conducted for conditioning purposes only.

6.1 Examination of Product—Conduct a visual examination only for identification of product, torn seals, cracked plastic, etc.

6.2 Low-Voltage Resistance (Reference MIL-STD-1344A; Method 3002.1)—Test with applied voltage not exceeding 20 mV open circuit and the test current shall be limited to 100 mA. Utilizing Figure 1, record connection resistance per 6.4. Acceptance criteria are shown in Table 2.

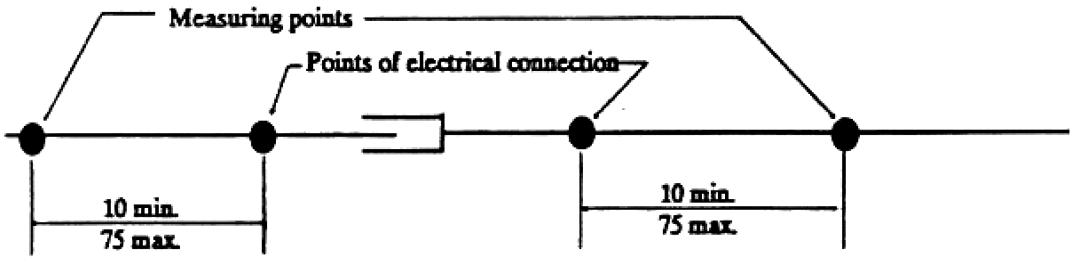
TABLE 2—CONTACT RESISTANCE

Cable Size mm^2	Maximum Resistance mΩ
0.8	10.0
1	6.7

6.3 Insulation Resistance—Using a 1000 VDC insulation resistance test measurement device or equivalent, check insulation resistance between each contact to each adjacent contact or housing edge. If the housing edge is plastic, then a metal foil may be applied around it, to create a grounding surface for the tester return. The insulation resistance shall be greater than 20 megohms.

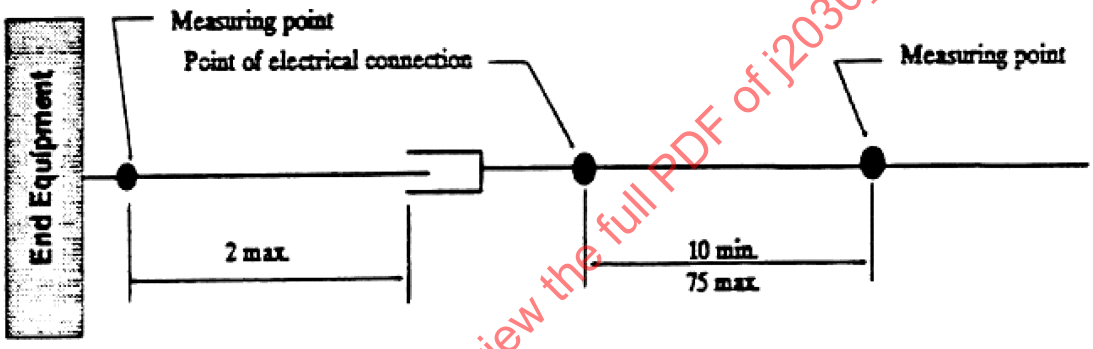
CAUTION—A shock hazard exists with the voltages available from the insulation resistance test measurement device; always use insulation resistance test measurement device procedures when testing.

6.4 Connection Resistance—The measurement of connection resistance shall be per Figures 1 and 2. The resistance of a cable equal in length to that of the two measuring points shall be subtracted from the measured values. The cable used shall be from the same batch of cable as used for the connector wiring.



Note: — All dimensions are in millimeters.
Measuring points are on the cable.
Points of electrical connection are typically the joint of the cable to the terminal.

FIGURE 1—CONNECTION RESISTANCE, CABLE TO CABLE



Note: — All dimensions are in millimeters.
Measuring points are on the cable.
Points of electrical connection are typically the joint of the cable to the terminal.

FIGURE 2—CONNECTION RESISTANCE, CABLE TO DEVICE

6.4.1 MEASUREMENTS AT SPECIFIED TEST CURRENT—Measurements shall be taken after thermal equilibrium at current levels as shown in Table 3. Voltage drops shall not exceed the levels of Table 3.

(Reference SAE J163):

TABLE 3—MEASUREMENTS AT SPECIFIED TEST CURRENT

Cable Size mm^2	Test Current Amps	Maximum Millivolt Drop (cable to device) (cable to cable)
0.8	10	100
1	15	100
2	20	100
3	30	100
5	40	100
8	55	100
13	70	100
19	90	100

COMMENT—There is a direct relationship between conductor temperature rise and the current flowing through the conductor. The effect of this temperature rise is additive to the ambient temperature conditions. The system working temperature shall not exceed the maximum applicable temperature rating of any component in the current carrying system. Consult the connector manufacturer for these material thermal limitations.

NOTE— Design application currents should be obtained from SAE J1614.

6.5 Pressure Washing—Test Method (Reference SAE J1455)—The mated and cabled connectors under test shall be mounted in its normal operating position with drain holes, if used, open. The test apparatus should be designed to provide 100% coverage of the exposed surface of the mated and cabled connectors using flat fan spray nozzles located 20 cm to 30 cm (7.9 in to 11.8 in) away. This apparatus should provide a source pressure of approximately 7000 kPa gage (1020 lbf/in^2 gage) with a flow rate of approximately 9460 cm^3 /min (150 gal/h). The test item should be exposed to the spray for 3 s of a 6 s period for a total of 375 cycles. The test should be run at 40 °C (104 °F) with water/detergent. An Insulation Resistance test (see 6.3) shall be conducted after this test.

A sample test device is illustrated in Figure 3.

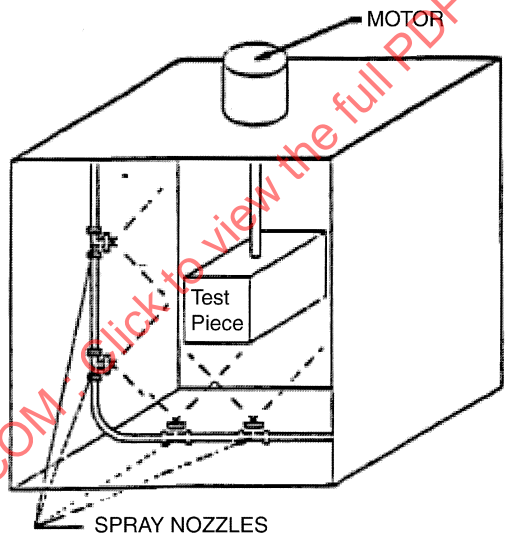


FIGURE 3—PRESSURE WASH CHAMBER

6.6 Maintenance Aging—Subject at least 10% of the cavities to ten cycles of inserting and removing its respective contact. The ten cycles shall also include any disassembly required to remove the contacts. The connectors shall be mated and unmated during each cycle. Insertion and removal shall be performed using manufacturer's recommended practice.

6.7 Temperature Life—The cabled-mated connectors shall be subject to 1000 h at 125 °C ± 3 °C without current flowing. There shall be no evidence of cracking, distortion, or detrimental damage.

6.8 Ultraviolet Effects—Test the mated connectors for 1000 h per ASTM G 154 or ASTM G 153 with 20 h UV and 4 h of condensation for each cycle.

6.9 Mating Forces—Test the maximum required force to mate the plug and receptacle pair and engage the latching mechanism. The force is not to exceed 135 N.

6.10 Un-mating Forces—Test the maximum force required to separate the plug and receptacle with the latch mechanism fully disengaged. The force is not to exceed 135 N.

6.11 Durability—The connector shall be mated and unmated for a total of 50 complete cycles. No visual defects shall be apparent.

6.12 Salt Fog—The connector shall be fully mated then submerged in a fine mist of 5% by weight salt solution for 96h at 35 °C ± 3 °C. Allow the connector to dry for 4 h after test. There shall be no detrimental evidence of corrosion on the connector or contacts after the connector is removed from the test.

6.13 Thermal Shock—The cabled-mated connector shall be subjected to 10 cycles of thermal shock with no evidence of cracking, chipping, or other damage detrimental to the normal operation of the connector. One cycle shall consist of a soak time at –55 °C ambient, then a transition within 2 min to an ambient of 125 °C, with a soak time there and then a transition back to–55 °C ambient within 2 min. The soak times shall be established as the time necessary to bring the internal connector temperature on test to within 5 °C of each of the ambient temperatures. The connectors shall be mounted, as they would be in practice — in plate steel or sheet steel surfaces.

6.14 Fluid Immersion—Subject each connector to one fluid only in the cabled and mated condition. Submerge the mated connector in fluid from Table 4 at the specified temperature ±3 °C for 5 min, then remove and allow to air dry for 24 h. This completes one cycle. Each connector is to be subjected to a total of five cycles. Inspect for damage after the test.

TABLE 4—FLUIDS

Fluid	Concentration	Temperature	Classification
Motor oil 30 wt	100%	85 °C	ASTM D471, IRM-902
Brake fluid (disc type 1)	100%	85 °C	SAE RM66-04
Diesel fuel #2	90/10%	60 °C	IRM-903/T-Xylene
50/50 antifreeze mixture	50/50	85 °C	ASTM Service Fluid 104
Roundup Original	7.5%(48 oz to 592 oz)	23 °C	EPA Reg. No. 524-445
Gear oil 90 wt	100%	85 °C	ASTM STP 512, API GL-5

6.15 Vibration

a. Sine sweep 10 to 2000 Hz
b. Initial displacement 1.78 mm DA
c. Maximum acceleration 20 g (the transition from displacement to acceleration occurs at 75 Hz)

Connectors under test are to be fixed to the vibrating plane with the wire harness fixed to non-vibrating objects no closer than 100 mm and not farther than 300 mm from the rear of the connector.

a. Duration of test to be 24 h
b. X, Y, and Z-axis to be tested 8 h each
c. Apply current as specified in Table 2 for the first 3 h in each axis

Monitor each circuit for discontinuity greater than 10Ω in excess of 1 microsecond at 100 mA during last hour of vibration in each axis.

6.16 Shock—10 cycles of 1/2 sine pulses, 50 g, 11 ms duration X, Y, and Z axis are to be tested. Monitor for discontinuity greater than 10Ω in excess of 1 microsecond at 100 mA. Connector under test to be fixed to the shock plane with the wire harness fixed to non-shocked objects no closer than 100 mm and not farther than 300 mm from the rear of the connector

6.17 Drop Test—The free end of the cord or cable, which shall be 1500 mm ± 25 mm long, shall be fixed to a wall at a height of 750 mm ± 25 mm above a concrete floor, as shown in Figure 4. The specimen shall be held so that the cord or cable is horizontal and allowed to fall to a concrete floor eight times. Rotate the specimens through approximately 45 degrees at its fixing each time. After the test, the specimens shall not become detached or loosened. Small chips and dents that do not adversely affect the product shall be disregarded.

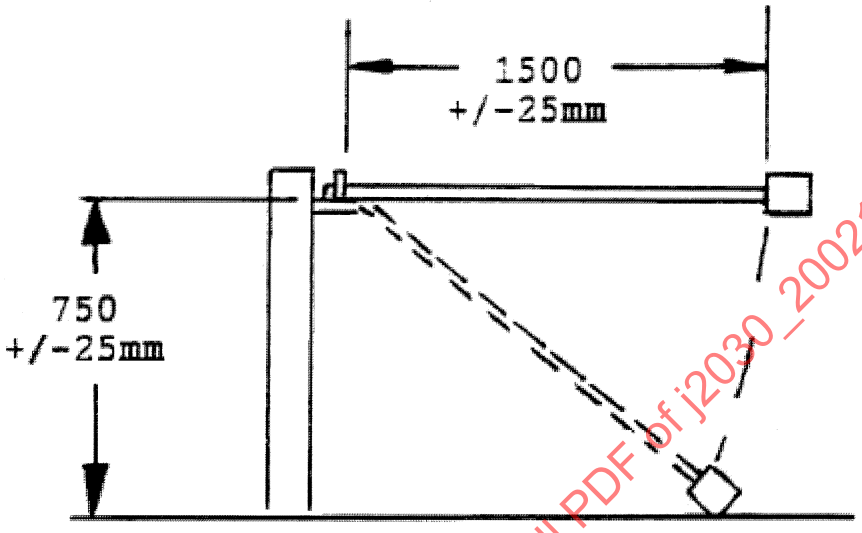


FIGURE 4—IMPACT TEST EQUIPMENT

6.18 Terminal Retention in Connector—The contacts shall be subjected to a direct pull. The minimum value specified in Table 5 shall be applied for 1 min. The pull is to be exerted on the conductor by means of a tension-testing machine or equivalent to prevent sudden or jerking force during test. The terminal shall maintain its original position in the connector throughout the test.

NOTE— Secondary-locking devices should be utilized if available.

TABLE 5—PULLOUT FORCES

Cable Size mm^2	Minimum Pull-Out Force N
0.8	110
1	110
2	110
3	110
5	175
8	175
13	220
19	220

6.19 Water Immersion—The wired mated connectors shall be placed in an oven at 125 °C ± 3 °C for 1 h then immediately be placed in water with a 5% salt in weight content and 0.1 g/L wetting agent, to a depth of 1 m for 4 h. Water temperature is to be 23 °C ± 3 °C. Test samples for insulation resistance per 6.3 and visually inspect for moisture inside the connector. The ends of the cable are to be sealed during this test.

6.20 Connector Retention—Apply a pulling force to the wire bundle of the mated connector at 111 N times the number of contacts or a maximum of 444 N. The load shall be applied for 30 s. Inspect the damage after test. If the connector is designed to uncouple under tension, the maximum force required shall be 222 N.