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(R) Heavy-Duty Wiring Systems for On-Highway Trucks**1. Scope**

This SAE Recommended Practice is intended to describe the application of the primary wiring distribution system of less than 50 V and includes cable sizes 0.5 to 19 mm² on heavy-duty on-highway trucks. The document identifies appropriate operating performances requirements. This document excludes the male to female connection of the SAE J560 and ISO 3731 connectors.

2. References**2.1 Applicable Publications**

The following publications form a part of this specification to the extent specified herein. Unless otherwise specified, the latest issue 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 J378—Marine Wiring
SAE J553—Circuit Breakers
SAE J560—Seven-Conductor Electrical Connector for Truck-Trailer Jumper Cable
SAE J561—Electrical Terminals Eyelets and Spades
SAE J1067—Seven Conductor Jacketed Cable for Truck Trailer Connections
SAE J1127—Battery Cable
SAE J1128—Low Tension Primary Cable
SAE J1284—Blade Type Electric Fuse
SAE J1455—Joint SAE/TMC Recommended Environmental Practices for Electronic Equipment Design
SAE J1493—Shielding of Starter System Energization
SAE J1614—Wiring Distribution for Construction, Agriculture and Off Road Work Machines
SAE J1678—Low Voltage Ultra-Thin Wall Primary Cable
SAE J1811—Power Cable Terminals
SAE J1888—High Current Electric Fuse
SAE J1908—Electrical Grounding Practice

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SAE J1939/11/13/15—Physical Layer 250K Bits/Sec, Twisted Shielded
SAE J2030—Heavy Duty Electrical Connector Performance Standard
SAE J2191—Identification of Standardized Truck and Tractor Electrical Circuits
SAE J2222—Coiled Electrical Cable
SAE J2223/1—Connections for On-Board Vehicle Electrical Wiring Harness—Part 1: Single-Pole Connectors—Flat Blade Terminals—Dimensional Characteristics and Specific Requirements
SAE J2223/2—Connections for On-Board Vehicle Electrical Wiring Harness—Part 2: Tests and General Performance Requirements
SAE J2223/3—Connections for On-Board Vehicle Electrical Wiring Harness—Part 3: Multiple Connectors—Flat Blade Terminals—Dimensional Characteristics and Specific Requirements
SAE J2247—Truck Tractor Power Output for Trailer ABS
SAE J2394—Seven Conductor Cable for ABS Power (Supercedes SAE J1067)
SAE J2497—Power Line Carrier Communications for Commercial Vehicles
SAE J2549—Low Tension Primary Cable

2.2 Related Publications

2.2.1 ASTM PUBLICATIONS

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

ASTM B 117—Standard Method of Salt Spray (Fog) Testing
ASTM D 471—Standard Test Method for Rubber Property-Effect of Liquids

2.2.2 FEDERAL PUBLICATION

Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

Federal Motor Carrier Safety Regulations 393.27
Military Standard—MIL Standard 1344A Method 3002/Low Voltage Dry Circuit
ISO Document—ISO 3731 Trailer Connector
Requirements and acceptance for cable and wire harness assemblies—IPC/WHMA-A-620 available from IPC-2215 Sanders Road-Northbrook, Illinois 60062-6135.

3. Definitions

3.1.1 ELECTRICAL CIRCUITS

An electrical circuit includes all of the components and connecting cables, starting from the electrical energy source, going to the functional component(s) and the return route through the energy source.

3.1.2 ELECTRICAL COMPONENT

An electrical component is normally a combination of parts, subassemblies, or assemblies creating a self-contained element intended to store, generate, distribute, alter, or consume electrical energy or affect an electrical junction.

3.1.3 CONDUCTOR

The current carrying element of an electrical cable.

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3.1.4 ELECTRICAL CABLE

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

3.1.5 HARNESS

A group of two or more cables bundled together.

3.1.6 TERMINAL

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

3.1.7 CONNECTION

An electrical and/or mechanical junction between two connectors, cables or between a cable(s) and an electrical component.

3.1.8 WIRING

The cables, terminations, and supporting accessories collectively used in the electrical distribution system.

3.1.9 CONNECTOR

A separable coupling device which contains the electrical interface and mechanical interface components.

3.1.10 POINT OF ELECTRICAL CONNECTION

The point where the conductor and terminal are crimped or joined together.

3.1.11 SEALED

A condition which provides a nonleaking union between two mechanical components or any place within an electrical distribution system. A sealed union is defined as one which does not allow the ingress of moisture.

3.1.12 SIGNAL LEVEL CIRCUIT

A circuit in which open circuit voltages are low and the currents are low (100 milliamps and 20 millivolts open circuit) and at the levels where the current is not able to break through the film of oxides, sulfides, or other films or contaminants which may build up on the contact surfaces.

4. Tests

4.1 Test Procedures

The testing shall validate the appropriate design and performance characteristics of the primary wiring distribution system including the connector interfaces of mating devices but not the mating device itself. Conformance to the requirements of this document shall be determined by subjecting each component to

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the test procedure listed in this document. Unless otherwise stated, the tests are to be performed at $25^{\circ}\text{C} \pm 5^{\circ}\text{C}$ and at 12.5 V DC \pm 0.1 V DC or per the manufacturers recommendations. The tests shall be conducted as defined in the following test procedures. Minimum sample size to be 6 parts unless otherwise specified by customer requirements.

- 4.1.1 Voltage Drop
- 4.1.2 Low Voltage Resistance (Dry Circuit)
- 4.1.3 Oil Absorption
- 4.1.4 Thermal
 - 4.1.4.1 Thermal Cycle
 - 4.1.4.2 Thermal Shock
- 4.1.5 Humidity
- 4.1.6 Salt Fog *
- 4.1.7 Salt Water Immersion *
- 4.1.8 Spray Wash *
- 4.1.9 Vibration
- 4.1.10 Insulation Resistance – Multiconductor Assemblies
- 4.1.11 Tensile Strength – Wire to Terminal
- 4.1.12 Tensile Strength – Wire to Wire
- 4.1.13 Connector Pull Force
- 4.1.14 Connector Misengagement Force
- 4.1.15 Connector Terminal Retention Force
- 4.1.16 Chemical Exposure
- 4.1.17 Circuit Identification (Stand Alone Test)

* Tests conducted on sealed connector systems

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.

4.1.1 VOLTAGE DROP

The measurement of connection voltage drop shall be per SAE J163 and Figures 1 and 2. The voltage drop of the cables shall be subtracted from the measured values.

4.1.2 LOW-VOLTAGE DRY CIRCUIT RESISTANCE

“Signal Level Circuit” (Reference MIL-STD-1344A; Method 3002.1) – Test with applied voltage not exceeding 20 m V open circuit and the test current shall be limited to 100 mA. Utilizing Figure 1 record connection resistance.

4.1.3 OIL ABSORPTION

Connectors shall be capped prior to testing to prevent entry of oil into the connector cavities during the test. The wiring assembly shall be immersed in ASTM D 471, IRM-902 engine oil at $50^{\circ}\text{C} \pm 3^{\circ}\text{C}$ for a period of 20 h. After removal from the engine oil, remove excess oil from the surface and allow sufficient time for excess oil trapped in the assembly to drain completely.

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4.1.4 THERMAL SHOCK

The cable to cable or cable to component connector assemblies shall be subjected to 10 cycles of thermal shock. One cycle shall consist of 30 min. at a temperature of $-40\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ followed by 30 min. at a temperature of $80\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ with a transfer time of 2 min. maximum.

4.1.4.1 Thermal Cycle

Connector and cable assemblies shall be connected to their mating parts. The assemblies shall be exposed to 25 cycles of the thermal cycle. The assemblies shall be energized with test voltage commencing at $20\text{ }^{\circ}\text{C}$ and transferring to $-40\text{ }^{\circ}\text{C}$ for 1 h and then transfer to $+70\text{ }^{\circ}\text{C}$ within 10 min. Hold $+70\text{ }^{\circ}\text{C}$ for 1 h and then transfer to $+20\text{ }^{\circ}\text{C}$ within 30 min. This completes the cycle. The current shall be limited to 1.0 amp.

4.1.5 HUMIDITY – SAE 1455

Temperature/Humidity-Test samples to be placed in a temperature/humidity chamber and shall be subjected to 42 cycles described as follows:

- a. Chamber temperature raised to $55\text{ }^{\circ}\text{C}$ at $3\text{ }^{\circ}\text{C}/\text{min} \pm 1\text{ }^{\circ}\text{C}/\text{min}$.
- b. Chamber temperature held for 16 h at a relative humidity of $95\% \pm 5\%$
- c. Chamber temperature lowered to $-55\text{ }^{\circ}\text{C}$ at $3\text{ }^{\circ}\text{C}/\text{min} \pm 1\text{ }^{\circ}\text{C}/\text{min}$.
- d. Chamber temperature held for 2 h.
- e. Chamber temperature raised to $125\text{ }^{\circ}\text{C}$ at $3\text{ }^{\circ}\text{C}/\text{min} \pm 1\text{ }^{\circ}\text{C}/\text{min}$.
- f. Chamber temperature held for 2 h.
- g. Chamber temperature lowered to $25\text{ }^{\circ}\text{C}$ at $3\text{ }^{\circ}\text{C}/\text{min} \pm 1\text{ }^{\circ}\text{C}/\text{min}$.
- h. Chamber temperature held for remainder of 24 h cycle.

4.1.6 SALT FOG

Testing shall be performed per ASTM B 117-73 test method for 96 h. During the test, each circuit shall be operating at the test currents specified in Table 2. (Voltage Drop)

4.1.7 SALT WATER IMMERSION

The wired mated connectors shall be placed in an oven at $125\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$ 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 $23\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$. Non terminated ends of the test cable are not to be immersed in salt water bath.

4.1.7.1 Cable to Cable Assembly

- a. Immerse the assembly at a minimum depth of 300 mm in a 5% solution of salt (sodium chloride) water
- b. Extend the cable ends out of the solution.
- c. Connect the assembly to a source with 1 amp minimum current flowing.
- d. Energize the assembly for 30 min. each hour.
- e. Terminate test after 60 h.

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4.1.7.2 Component Assembly

- a. Immerse the assembly at a minimum depth of 300 mm in a 5% solution of salt (sodium chloride) water.
- b. Extend the ends of the cable assembly out of the solution.
- c. Connect the assembly to a source set at component rated voltage or test voltage. The current flowing shall be at the rated current.
- d. Energize the assembly for 30 min. each hour.
- e. Terminate test after 60 h.

4.1.8 SPRAY WASH

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/in² gage) with a flow rate of approximately 9460 cm³/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 (para. 4.1.10) shall be conducted after this test.

4.1.9 VIBRATION

Connectors under test are 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. Sine sweep rate from 10 to 2000 Hz and back to 10 Hz completed in 15 min
- b. Initial displacement 1.78 mm DA
- c. Maximum acceleration 20 g
- d. Duration of test to be 24 h
- e. X, Y, and Z-axis to be tested 8 h each
- f. Apply current as specified in Table 2 for the first 3 h in each axis

4.1.10 INSULATION RESISTANCE

Multi conductor assemblies using a 500 volt megohmmeter or 500 volt DC hipotential tester check each terminal to all other terminals and any conducting shell or conduits.

4.1.11 TENSILE STRENGTH-CABLE TO TERMINAL

If insulation crimps are present, the crimp wings shall be opened before testing. The terminal and wire assembly shall be placed in a wire terminal pull tester. Sufficient force shall be applied to pull the wire out of the terminal or break the wire. All testing is to be conducted at a uniform rate of speed not to exceed 305 mm/min.

4.1.12 TENSILE STRENGTH-CABLE TO CABLE

The wire to wire splice shall be place in a pull tester. Sufficient force shall be applied to break the wire or break the wire to wire splice. All testing is to be conducted at a uniform rate of speed not to exceed 305 mm/min.

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4.1.13 CONNECTOR PULL FORCE

All mated connectors that may be subjected to disconnection forces during use shall have a force of 100 N applied in the axis of engagement of the connector pair in the direction of disengagement. The force shall be applied at a rate not to exceed 5 N/s.

4.1.14 CONNECTOR MISENGAGEMENT FORCE

Unmated multicavity connector pairs shall have a force of 178 N applied in the axis of and in the direction of engagement. The connectors shall be oriented to test the mechanical strength of the connector system's polarization features.

4.1.15 TERMINAL RETENTION TENSILE FORCE

The terminal retention force within the connector cavity shall be determined by applying the minimum tensile load specified in Table 4 for the size of the specified cable. The harness designer shall be responsible for determining the application of standard or heavy duty rating. The load shall be applied along the axis of the terminal.

4.1.16 CHEMICAL RESISTANCE

Subject each connector to one fluid only (Table 1) in the wired and mated condition. Entirely submerge the mated connector in fluid 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 1—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
Gear oil 90 wt	100%	85 °C	ASTM STP 512, API GL-5

4.1.17 CIRCUIT IDENTIFICATION TEST METHOD (ONLY REQUIRED WITH CABLES WHICH CONTAIN CIRCUIT ID)

4.1.17.1 Abrasion Resistance

Place the cable on a firm surface with the circuit identification markings facing up. Secure the cable in place. With a force of 31 N, applied perpendicular to the markings, wipe a new, never used, eraser, example pink pearl, across the cable and markings parallel to the axial centerline ten times.

4.1.17.2 Fluid Resistance

Immerse a 200 mm length of cable in the fluids defined in Table 1 for 10 min. Remove and wipe the insulation two times with slight pressure using a paper towel.

5. Requirements

5.1 The following define the required performance for each test sequence.

5.1.1 VOLTAGE DROP

The voltage drop shall not exceed the values tabulated in Table 2

TABLE 2—VOLTAGE DROP

SAE Cable Size Test Current Maximum		
(mm ²) Cable Size	(Amperes) Test Current	Millivolt Drop (cable to device) (cable to cable)
0.5	5	100
0.8	10	100
1.0	15	100
2.0	20	100
3.0	30	100
5.0	40	100
8.0	50	100
13.0	60	100
19.0	70	100

5.1.2 LOW VOLTAGE DRY CIRCUIT RESISTANCE

The maximum contact resistance shall not exceed the values shown in Table 2A

TABLE 2A—CONTACT RESISTANCE

Cable Size mm ²	Maximum Resistance mΩ
0.8	10
1	10

5.1.3 OIL ABSORPTION

Upon completion of the oil absorption tests, the connectors must remain serviceable. A serviceable part is one that can be removed with reasonable force and reinstalled without visible damage. A visual inspection shall reveal no cracks, splits, or other damage to the items used in the construction of the assembly. The increase of the cable OD may not be greater than 15% increase.

5.1.4 THERMAL SHOCK

There shall be no evidence of damage detrimental to the normal operation of the assembly. Dry circuit resistance is to be measured before starting and at the end of the test.

5.1.4.1 Thermal Cycle

Upon completion of the thermal cycle exposure, there shall be no cracking, warping, or rupture of any of the components. The connectors shall remain serviceable. Dry circuit resistance is to be measured before starting and at the end of the test.

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5.1.5 HUMIDITY

At the completion of the test, there shall no be visual evidence of corrosion residue on any of the electrical terminals and the terminals shall be intact in their original condition.

Allow the assembly to dry for 4 h after test and check each circuit for shorting between circuits and grounding to any conducting shell or conduit.

5.1.6 SALT FOG

At the completion of the test, there shall no be visual evidence of corrosion residue on any of the electrical terminals and the terminals shall be intact in their original condition.

Allow the assembly to dry for 4 h after test and check each circuit for shorting between circuits and grounding to any conducting shell or conduit.

5.1.7 SALT WATER IMMERSION – CABLE TO CABLE AND COMPONENT

At the completion of the test, there shall be no visual evidence of corrosion residue on any of the electrical terminals and the terminals shall be intact in their original condition.

5.1.8 SPRAY WASH – IMMEDIATELY AFTER TEST, CONNECTOR MUST MEET REQUIREMENTS OF 5.1.10

Upon visual examination at the conclusion of the test, there shall be no evidence of water ingress into any sealed connector cavities and sealed cables.

5.1.9 VIBRATION

The millivolt drop shall not exceed the values listed in Table 2 for the wire size under consideration. There shall be no apparent loosening of terminals within a connector. There shall have been no electrical discontinuities greater than 95 ma for greater than 1 microseconds for the entire test. There shall be no signs of mechanical or electrical damage or defects upon visual examination. Dry circuit resistance is to be measured before starting and at the end of the test.

5.1.10 INSULATION RESISTANCE

The insulation resistance shall be in excess of 1 MΩ The leakage current shall be less than 50 mA.

5.1.11 TENSILE STRENGTH-CABLE TO TERMINAL

The tensile strength shall exceed the values listed in Table 3 for an effective electrical and mechanical connection.

TABLE 3—MINIMUM TENSILE STRENGTH

SAE Cable Size (mm ²)	Force (N)
	(Cable to Terminal) (Wire to Wire)
0.5	70
0.8	80
1	124
2	155
3	177
5	200
8	222
13	355
19	400

5.1.12 TENSILE STRENGTH-CABLE TO CABLE

The tensile strength shall exceed the values listed in Table 3 for an effective electrical and mechanical connection.

5.1.13 CONNECTOR PULL FORCE

The mated connectors shall withstand the specified load without any damage or disengagement. Includes CPPA (Connector Position Assurance, if appropriate)

5.1.14 CONNECTOR MISENGAGEMENT FORCE

The connectors shall withstand the specified load without any damage, without connector engagement, and without electrical connection to any terminal position.

5.1.15 TERMINAL RETENTION TENSILE FORCE (IN CONNECTOR CAVITY)

The connector and terminal shall withstand the specified load without any damage or terminal disengagement. (Per Table 4) (Includes Secondary Lock if appropriate)

TABLE 4—MINIMUM TERMINAL RETENTION IN CONNECTOR CAVITY

Cable Size (mm ²)	Minimum Pull Force (N)	
	Standard	Heavy Duty
0.5	53	89
0.8	53	89
1	53	111
2	53	111
3	53	133
5	53	133
8	53	155
13	100	155
19	100	155

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5.1.16 CHEMICAL RESISTANCE

Upon completion of chemical exposure tests, the connectors must remain serviceable. A serviceable part is one that can be removed with reasonable force and reinstalled without visible damage. A visual inspection shall reveal no cracks, splits, or other damage to the items used in the construction of the assembly. The increase of the cable OD may not be greater than 15% increase.

5.1.17 CIRCUIT IDENTIFICATION

5.1.17.1 Abrasion Resistance

Acceptance Criteria-The characters on the cable insulation shall be legible after each test when viewed using a 60 watt work lamp held at a distance of 450 mm from the cable.

5.1.17.2 Fluid Resistance

Acceptance Criteria-The characters on the cable insulation shall be legible after each test when viewed using a 60 watt work lamp held at a distance of 450 mm from the cable.

6. Design Requirements

6.1 Where applicable, single conductor primary wire shall conform to the requirements of SAE J1128, SAE J1127, SAE J2549 or SAE J1678 and multiconductor cables shall conform to the performance requirements for SAE J2394, SAE J1067 or SAE J1939 physical layer. Since there are a large diversity of local environments within the vehicle, additional consideration should be given to cold bend requirements, locations where flexing occurs, unique chemical requirements, and high ambient temperature requirements. Alternative conductor stranding or conductor insulation may be required in these instances.

6.1.1 Wherever possible, all conductors shall be grouped together in a suitable conduit or jacket to protect them from detrimental environmental conditions.

6.2 Wire sizes for the main and all branch circuits shall be sufficient to provide all electrical components with component design voltage or component manufacturer's recommended voltage. Particular attention should be paid to any components with safety related functions such as ABS, lighting, etc.

6.2.1 CABLE SIZE DETERMINATION

Cable size selection is determined by consideration of the following factors:

- a. Maximum temperature rise above ambient with steady-state currents
- b. Temperature rise with respect to continuous-duty temperature rating of the cable insulation
- c. Maximum temperature rise in a fault condition
- d. Maximum temperature rise above ambient with intermittent load cycles
- e. Allowed system voltage drops with given loads
- f. Cable mechanical strength
- g. Temperature rise with respect to enclosure, bundling, multiple cables, etc.

6.2.2 FAULT CONDITIONS

It is important that the cable and the protection device be sized in such a way that the protection device interrupts the circuit and protects the cable from damage. Refer to SAE J553. Also, it should be noted that fuses and circuit breakers react differently under the same fault conditions. Derating curves of components should be reviewed in extreme temperatures.

6.2.3 MECHANICAL STRENGTH

In general, for mechanical strength the minimum cable size shall be 0.5mm² in harnesses and/or protected areas. Cable size 0.8 mm² is recommended to be the minimum cable size in exposed areas or where one or two cables are extended from the harness. Extra care must be used when selecting cables to be used in areas of high vibration.

6.2.3.1 Mechanical Flex

Flex life is a condition where the harness is subjected to constant flexing as in a door or brake sensor. Every effort in harness routing should be made to avoid applications in which high cycles of wire flex occur. If cable flex cannot be avoided the following cable stranding and insulation items should be reviewed for a particular design.

6.2.3.1.1 Stranding

1. Increased strand count
2. Increased strand count with Rope Stranding
3. Reinforced conductors with stainless steel support members
4. Annealed copper or clad steel *
5. High conductive alloys – High tensile high flex

* 30 to 40% conductivity compared to copper

* Flex life 10x increase compared to annealed copper

6.2.3.1.2 Insulation

1. Cold temperatures can result in insulation embrittlement and cracks. Ex. PVC will not perform very well when flexed at cold temps.
2. Softer insulation may provide more flex life but a stiffer insulation may spread the effects of flexing over a greater area, increasing flex life. The design must consider all these issues when selecting the proper insulation.

6.3 Conductor Sizing

6.3.1 Conductor sizes for the main and all branch circuits shall be determined by the voltage drop method using the following equation:

$$R = [(VD) \times 10^{+6}] \div (L \times I) \quad (\text{Eq. 1})$$

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Where

VD = Maximum allowable voltage drop (volts)

L = Length of cable (mm).

I = Maximum steady-state current in circuit (A)

Calculate cable resistance [R] in micro ohms/mm and locate the cable size in Table 5. If the resistance falls between two conductor sizes, specify the larger conductor.

TABLE 5—CONDUCTOR SIZING

Cable Size (mm ²)	Resistance at 20°C Micro Ohms/mm
0.5	35.2
0.8	22.2
1	15.1
2	9.18
3	5.85
5	3.7
8	2.37
13	1.48
19	1.10

6.4 Terminals

6.4.1 Terminals should be applied to the cable according to terminal manufacturer's recommended application specification.

Terminals designed for fully automated assembly operations are preferred over manually assembled parts to assure consistent high quality terminations.

6.4.2 A conductive plating on the terminals is recommended for enhanced electrical conductivity performance.

6.4.3 Low-energy circuits may require terminal materials with noble plating which will enhance performance in areas subjected to vibration, fretting, corrosion, and oxidation.

6.4.4 Terminal materials and/or platings shall be chosen to prevent galvanic corrosion when mated.

6.4.5 All power terminations (those conducting greater than 1 A) shall conform to the physical and electrical performance requirements of SAE J163, SAE J561 and SAE J1811. Measure the connection resistance per Figures 1 and 2 and per Profile A, B, and C. Measurements shall be taken after thermal equilibrium (3 consecutive readings within a 5 minute interval with no greater than a 2 °C variation) at current levels shown in Table 1. The resistance of the cables shall be subtracted from the measured values.

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Profile:

- a. 200 off/on cycles at $125\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$ (each cycle to consist of 20 min on, 20 min off)
- b. 50 cycles: 20 min on at $125\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$
60 min off at $21\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$
- c. Transition between temperature states shall occur at a rate equaling or exceeding $3\text{ }^{\circ}\text{C} +3/-0\text{ }^{\circ}\text{C}$ per minute with the power off during transition

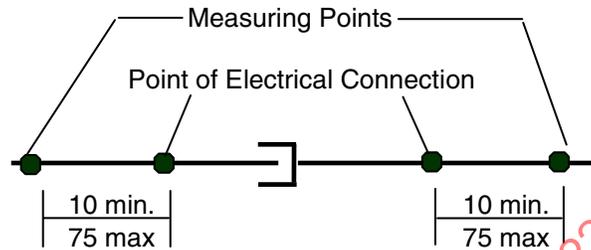


FIGURE 1—CONNECTION RESISTANCE CABLE TO CABLE

NOTE: All dimensions are in millimeters.
Measuring points are on the wire.
Points of electrical connection (back of the crimp) are typically the joint of the wire to the terminal.

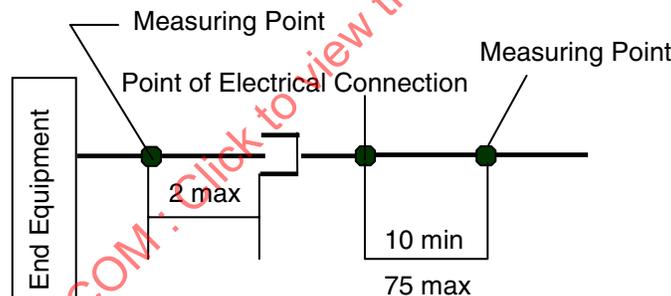


FIGURE 2—SPECIFIED RATED RESISTANCE, CABLE TO DEVICE

NOTE: All dimensions are in millimeters.
Measuring points are on the wire. Note: Subtract the wire resistance in Ohms.
Points of electrical connection are typically the joint of the wire to the terminal

- 6.4.6 Terminals should have cable insulation support or the connector body/device should provide support for the cable.
- 6.4.7 Oxides on the surface of non-noble terminal contact plating may affect voltage drop when operated at low voltages or currents. If circuits operate at less than 5 volts or less than 0.5 amps in the operation of a component, then the component manufacturer should be consulted to assure that adequate testing is performed to assure proper operation of the the device.

6.5 Connector Selection

6.5.1 Keyed/Polarized Connector bodies should be used at all points where two or more cables terminate and where there is a possibility of miss-connection in fabrication, assembly, or service. It is recommended that connectors meet the performance requirements described in SAE 2223/1/2/3, SAE 2030.

6.5.2 Cable-to-cable connectors must have locking devices.

6.5.3 Connectors designed to use terminal secondary locks are recommended.

6.5.4 Connectors located in unprotected areas shall incorporate environmental protection appropriate for the application.

6.5.5 CONNECTOR MATING AND UNMATING FORCE

6.5.5.1 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.

6.5.5.2 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.

6.6 Splicing

6.6.1 When splices are required, avoid locating splices, if design is agreeable, in the following areas:

- a. Where significant harness flexing occurs
- b. Within 50 mm of a branch/breakout of the harness
- c. Within 50 mm of any other splice
- d. Within 100 mm of any connector or termination
- e. Not in a drip loop

6.6.2 If possible, splices should be configured so that:

- a. Wires are not double back within the harness
- b. Splices are normally within the covered section of the harness
- c. Basically equal distribution of cables based upon circular mil cable sizing on both sides of the splice
- d. One-to-one splices should be avoided

6.6.3 SPLICE CONSTRUCTION

The cable conductors shall be joined in a manner which shall conform with the electrical specifications for splices per SAE J163. Additionally, the splice shall meet or exceed the minimum pull test as shown in Table 3 (extracted from SAE J378). Value to be based upon smallest cable in the splice. Method per SAE J378.

- 6.6.4 Splices in protected areas shall be covered and insulated with a material typically equivalent to the cable used.
- 6.6.5 Splices in unprotected areas (exposed to an exterior or corrosive environment) shall be environmentally protected and shall meet or exceed the dielectric test as specified in SAE J1128. (Electrical tape should not be used for sealing a splice exposed to elements which may cause corrosion or oxidation.)

6.7 Twisted Cables

The twists shall be distributed evenly over the length of the cable with a minimum of 360 degree twist. Twisted cables to be a minimum as shown in Table 6. (Twisting when required not otherwise specified)

TABLE 6—TWISTED CABLES

Number of Cables	Twists Per Meter	Cable Sizes
2	40	1 to 0.5 mm ²
3	30	1 to 0.5 mm ²
2	25	2 mm ²

Twisting should start 75 mm back of connector (Max.) and should not distort connector seals.

6.8 Solder

- 6.8.1 If solder is required on crimped terminals the following applies:
- 6.8.2 Noncorrosive flux must be used during any solder operation performed on any wire or cable assembly or component. Acid core solders or acid fluxes must not be used.
- 6.8.3 If terminals are soldered to the wires, solder shall not wick under the insulation beyond the end of the terminal insulation support.

6.9 Uninsulated Terminals

- 6.9.1 Wire and cable assemblies shall be designed such that all uninsulated terminals are on the ground side of each connection. This applies to terminals which may be insulated in their connected state but which are uninsulated should a disconnect occur.

7. Harness Assembly Construction

- 7.1 Cables should be grouped, where practical, in jacketed cable or harness form.
- 7.2 Examples of some suitable harness bundling materials such as: thermoplastic or fiber reinforced tape, straps, jackets, conduit, or braid may be used to form the harness assembly.
- 7.3 When exposed to water or condensation, connectors shall be sealed.
- 7.4 The harness assembly document IPC/WHMA-A-620 Class 2 can be used as a reference to aid in harness manufacturing techniques.