SAE The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

# SURFACE VEHICLE RECOMMENDED PRACTICE

SAE J2202

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## 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 wire sizes 0.5 to 19 $mm^2$ on heavy-duty on-highway trucks. The document identifies appropriate operating performances and durability.

**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 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 J1067—Seven Conductor Jacketed Cable for Truck Trailer Connections
SAE J1127 JUN88—Battery Cable
SAE J1128 JUN88—Low Tension Primary Cable
SAE J1455—Joint SAE/TMC Recommended Environmental Practices for Electronic Equipment Design
SAE J2222—Coiled Electrical Cable

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

Federal Motor Carrier Safety Regulations 393.27

**3.** ***Definitions***

**3.1** **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.

**3.2 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.

**3.3 Conductor—**The current carrying element.

**3.4 Electrical Cable—**Insulated stranded electrical conductor used to establish a single path.

**3.5 Harness—**A group of two or more cables bundled together.

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

**3.7 Connection—**A coupling device which provides an electrical and/or mechanical junction between two cables or between a cable(s) and an electrical component.

**3.8 Wiring—**The cables, terminations, and supporting accessories collectively used in the electrical distribution system.

**3.9 Low-Voltage Circuit—**Any circuit that has an open circuit potential of less than or equal to 5 V.

**3.10 Point of Electrical Connection—**The point where the conductor and terminal are crimped or joined together.

## *4. Wiring Design*

**4.1 Cable Selection—**The cable insulation selected shall meet the performance requirements of SAE J1127 JUN88 and SAE J1128 JUN88. Additionally, the cable type shall be selected to be in conformance to applicable Federal Regulations FMCSR 393.27. Alternate cable designs may be used to meet specific requirements.

4.1.1 CABLE TYPE—The cable type selection should include consideration of the following factors:

a. Ambient operating temperature and temperature rise potential
b. Overload of the circuit (reference 4.7 of SAE J1128)
c. Short circuit test (reference 4.8 of SAE J1128)
d. Fuels, lubricants, and other chemicals and fluids to which the cable may be exposed
e. Thermal shock to the cable
f. Expected service life (pinch and abrasion) (reference 4.9 and 4.10 of SAE J1128)

**4.2 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.

4.2.1 PROCEDURE—As a guide, the following procedure may be used to select cable size. Appropriate sizes to be verified by load testing.

4.2.1.1 *Voltage Drop*—Determine cable size by the voltage drop method using Equations 1 and 2.

For frame ground:

$$R = \frac{VD}{2LI} \times 10^{-6} \qquad \text{(Eq. 1)}$$

NOTE—In Equation 1, the factor of two doubles the actual cable resistance to allow for contact, terminal, and frame return path resistance. When the component is not frame grounded, the lead length to and from the component should be used.

For nonframe grounded:

$$R = \frac{VD}{LI} \times 10^{-6} \qquad \text{(Eq. 2)}$$

Maximum allowable voltage drop VD(volts)
Length of cable L(mm)
Maximum steady-state current in circuit I(amps)

Calculate cable resistance (R) in micro ohms/mm as shown in Equations 1 and 2.

After determining the resistance, select the cable size from Table 1.



**TABLE 1—CABLE SIZE**

| 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 | 1.1 |

EXAMPLE—The maximum voltage drop allowable is 0.5 V. The circuit length is 6000 mm. The maximum steady-state current in the circuit is 5 A.

$$R = \frac{0.5}{2 \times 6000 \times 5} \times 10^{-6} = 8.3\mu\Omega/mm \qquad \text{(Eq. 3)}$$

Since 8.3 is between cable size 3 and 2, the larger (3) should be selected.

4.2.2 ADDITIONAL FACTORS FOR SELECTION

*4.2.2.1 Fault Conditions*—It is important that the cable and the protection device be sized in such a way that the protection device heats at a rate higher than the cable to protect the cable from damage. Refer to SAE J553 4.9.2.2 and 4.9.2.3. Also, it should be noted that fuses and circuit breakers react differently under the same fault conditions.

*4.2.2.2 Mechanical Strength*—In general, for mechanical strength the minimum cable size shall be 0.5 $mm^2$ (with 19/32 strands) in harnesses and/or protected areas. Cable size 0.8 $mm^2$ shall 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 and/or constant mechanical flexing.

**4.3 Terminals**

4.3.1 Terminals shall be used and applied according to manufacturer's specification.

4.3.2 A conductive plating on the terminals is recommended to retard corrosion.

4.3.3 Low-energy circuits may require terminal materials and/or platings which do not degrade due to vibration, fretting, corrosion, and oxidation.

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

4.3.5 All power terminations (those conducting greater than 1 A) shall conform to the physical and electrical performance requirements of SAE J163 except Voltage Drop Test for Preinsulated Terminals. Measure the connection resistance per Figures 1 and 2 and per Profile A, B, and C. Measurements shall be taken after thermal equilibrium at current levels shown in Table 2. The resistance of the cables shall be subtracted from the measured values.

Profile:

a. 200 off/on cycles at 125 °C ± 3 °C (each cycle to consist of 20 min on, 20 min off)
b. 50 cycles: 20 min on at 125 °C ± 3 °C
   60 min off at 21 °C ± 1 °C
c. Transition between temperature states shall occur at a rate equaling or exceeding 3 +3/–0 °C per minute with the power off during transition



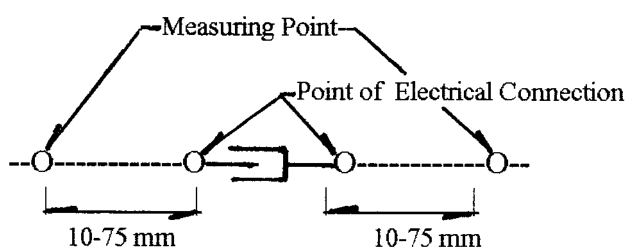


FIGURE 1—CONNECTION RESISTANCE CABLE TO CABLE

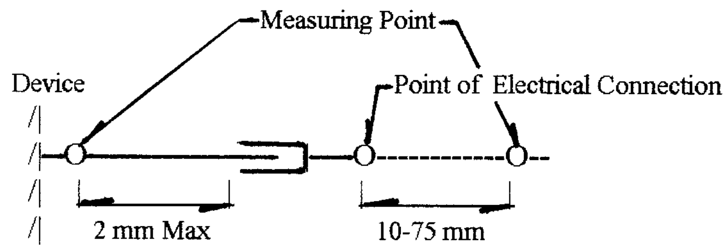


FIGURE 2—CONNECTION RESISTANCE CABLE TO DEVICE

**TABLE 2—CURRENT LEVELS**
**(Reference SAE J163)**

| Cable Size ($mm^2$) | Test Current | Voltage Drop millivolts |
|---|---|---|
| 0.8 | 10 | 5 |
| 1 | 15 | 8 |
| 2 | 20 | 10 |
| 3 | 30 | 15 |
| 5 | 40 | 20 |
| 8 | 50 | 25 |
| 13 | 60 | 15 |
| 19 | 70 | 18 |

4.3.6 Terminals should have cable insulation support or the connector body/device should provide support for the cable.

**4.4 Connector Selection**

4.4.1 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.

4.4.2 Cable-to-cable connectors must have locking devices. The locking device on multipole connectors shall withstand a minimum pulling force of 100 N. Test shall be conducted with both halves of the connector secured in fixtures. No distortion of the connector bodies is allowed. The locking device shall be engaged. The pulling force shall be applied along the same axis as the connector. The force shall be applied at a rate not to exceed 5 N per second up to the specified load which shall be applied for a minimum of 30 s.

4.4.3 Multicavity connectors must be polarized in a manner that prevents electrical contact and does not allow the connectors to be mismated partly or fully in any false position when a force of 170 N minimum is applied.

4.4.4 Minimum terminal retention within the connector shall be as per Table 3. Note the retention force includes secondary locking devices if available. The harness designer shall be responsible for determining if the axial pull force required in the application should be Standard or Heavy-Duty rating.

TABLE 3—MINIMUM TERMINAL RETENTION

| Cable Size mm² | Minimum Pull Force N Standard | Minimum Pull Force N Heavy-Duty |
|---|---|---|
| 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 |

4.4.5 Connectors designed to use secondary locks are recommended.

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

**4.5 Splicing**

4.5.1 When splices are required, avoid locating 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

4.5.2 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

4.5.3 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 4 (extracted from SAE J378). Value to be based upon smallest cable in the splice. Method per SAE J378.

**TABLE 4—SPLICE PULL TEST**

| Cable Size ($mm^2$) | 1 s Pull Value (N) |
|---|---|
| 0.8 | 80 |
| 1 | 124 |
| 2 | 155 |
| 3 | 177 |
| 5 | 200 |
| 8 | 222 |
| 13 | 355 |
| 19 | 400 |

4.5.4 Splices in protected areas shall be covered and insulated with a material typically equivalent to the cable used.

4.5.5 Splices in unprotected areas (exposed to an exterior to corrosive environment) shall be environmentally protected and shall meet or exceed the dielectric test as specified in SAE J1128.

**4.6 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 5.

**TABLE 5—TWISTED CABLES**

| Number of Cables | Twists Per 305 mm | Cable Sizes |
|---|---|---|
| 2 | 12 | 1 to 0.5 $mm^2$ |
| 3 | 9 | 1 to 0.5 $mm^2$ |
| 2 | 8 | 2 $mm^2$ |

**4.7 Harness Assembly Construction**

4.7.1 Cables should be grouped, where practical, in jacketed cable or harness form.

4.7.2 Examples of some suitable harness bundling materials such as: thermoplastic tape, straps, jackets, conduit, or braid may be used to form the harness assembly.

**4.8 Circuit Identification**

4.8.1 Circuits shall be identified with either color, numbers, letters, symbols, or a combination thereof.

4.8.2 Circuit identification test method.

*4.8.2.1* *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, “Pink Pearl” eraser across the cable and markings parallel to the centerline ten times.

4.8.2.2 *Fluid Resistance*—Immerse a 200 mm length of cable in 25 °C ± 5 °C fluid for 10 min. Remove and wipe the insulation two times with slight pressure using a paper towel. The fluids required for this test are: diesel fuel, gear and engine oil, antifreeze fluid, hydraulic fluid, and gasoline.

4.8.2.3 *Acceptance Criteria*—The characters on the cable insulation shall be legible after each test.

**4.9 Harness Routing and Protection**

4.9.1 Harness design should prevent misconnection during assembly or service.

4.9.2 Whenever possible, the routing of the harness shall provide maximum protection via routing through the sheet metal and structure.

4.9.3 Grommets, insulated clamps, and shields are required to provide protection from sharp edges, vibration, and wear.

4.9.4 Wiring shall be located to afford protection from splash, stone, abrasion, grease, oil, and fuel. Excessive heat areas must be avoided. The wiring shall not contact or be directly attached to lines carrying: fuel, starting fluid, hot fluids, or brake lines. If a design or assembly process requires routing cable adjacent to these lines, a protective barrier shall be provided to maintain integrity of the installation.

4.9.5 Strain relief may be necessary for some connector applications and can be addressed by connector design or by clamping, routing, and harness support.

4.9.6 Wiring harness covering shall be adequate to protect the harness in the expected environment and furnish protection during all phases of assembly and operation. Based on the environmental description listed in SAE J1455, harness covering should be selected based on the general characteristics described in Table 6.



**TABLE 6—GENERAL CHARACTERISTICS**

| Harness Covering | General Application |
|---|---|
| Thermoplastic Tape | Primarily used for grouping cables into harnesses, where wiring is not subjected to damage from scuffing or scrubbing on rough metal edges. |
| Extruded Plastic (PVC) | Improved scuff and abrasion resistance. Difficult in harness fabrication. Can trap fluids. |
| Flexible Thermoplastic Conduit Typically Slit Lengthwise | Maximum-abrasion resistance. Can trap fluids. Easy to install and service. Good appearance. |
| Woven Braid: Vinyl/Nylon or Vinyl/Polypropylene or Vinyl/Hytrel, etc. | High-abrasion resistance. Does not trap fluids. Long-life covering. Difficult to service. |

4.9.7 Protection (i.e., insulating boots, shields, covers, etc.) of exposed terminals which always have voltages present is recommended to prevent accidental short circuits. Protection is required when a 12 mm round rigid metal bar, 250 mm long, can short from a terminal to ground or to another terminal thus causing a condition which is unacceptable.