



SURFACE VEHICLE RECOMMENDED PRACTICE

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High Voltage Shielded and Jacketed Cable

RATIONALE

The document has been updated with the following changes:

Updated 2.2.3 to the latest ISO documents.

Definitions have been reviewed and updated.

Table 1 has been reformatted and updated.

Updated 4.14 and added 4.15.

Added Figure 2 .

Updated Table 2.

Added Tables 2A and 2B to list temperature class ratings and SAE cable types.

Updated 4.19 to clarify test.

Updated Tables 4 and 5 to remove the diameter tolerances.

Updated figure to table references in all sections as needed.

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1. SCOPE

This document covers cable, shielded and jacketed, intended for use at a nominal system voltage up to 1000 V (AC rms or DC). It is intended for use in surface vehicle electrical systems.

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 J1127 Low Voltage Battery Cable

SAE J1128 Low Voltage Primary Cable

SAE J1654 Unshielded High Voltage Primary Cable

SAE J1678 Low Voltage Ultra Thin Wall Primary Cable

SAE Dictionary of Materials and Testing

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 B354 Standard Terminology Relating to Un-insulated Metallic Electrical Conductors

ASTM D883 Standard Terminology Relating to Plastics

2.1.3 IEC Publications

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

IEC, Electricity, Electronics and Telecommunications, Multilingual Dictionary

IEC 62153-4 Surface transfer Impedance and Shield Effectiveness

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 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 J1673 High Voltage Automotive Wiring Assembly Design

SAE J2501 Round, Screened and Unscreened, 60 V and 600 V Multi-Core Sheathed Cables

2.2.2 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 B1	Standard Specification for Hard-Drawn Copper Wire
ASTM B3	Standard Specification for Soft or Annealed Copper Wire
ASTM B8	Standard Specification for Concentric-Lay-Stranded Copper conductors, Hard, Medium-Hard, or Soft
ASTM B174	Standard Specification for Bunch-Stranded Copper Conductors for Electrical Conductors
ASTM B787	Standard Specification for 19 Wire Combination Unilay-Stranded Copper Conductors for Subsequent Insulation

2.2.3 ISO Publications

Copies of these documents are available online at <http://webstore.ansi.org/>.

ISO 19642 Road Vehicles - Automotive Cables - Parts 1, 2, and 9

3. DEFINITIONS

3.1 ADDITIONAL MASS

The mass is applied to the support rod. The combination of the forces exerted by the additional mass and the 0.63 N exerted by the remaining apparatus (bracket, support rod, and pivoting arm) is applied to the cable. See resistance to sandpaper abrasion test.

3.2 COATED WIRE

Wire comprised of a given metal covered with a relatively thin application of a different metal. (ASTM B354)

3.3 CABLE

An assembly of one or more insulated primary cables within an enveloping protective jacket (sheath), with such an arrangement that will permit their use separately or in groups. (Data Communications Dictionary, 1976)

3.4 CABLE FAMILY

A group with multiple conductor sizes having the same conductor strand coating, insulation formulation, and wall thickness type.

3.5 CONDUCTOR

A wire or combination of wires not insulated from one another, suitable for carrying an electrical current. (ASTM B354)

3.6 CONDUCTOR SIZE

See SAE conductor size.

3.7 CORE

One of the components in an assembly. A component may be an uninsulated conductor, an insulated conductor, a twisted pair, a shielded assembly, a coaxial cable, or any finished cable.

3.8 JACKET

A protective insulating sheath enveloping a cable assembly.

3.9 PLASTICS

A material that contains as an essential ingredient one or more organic polymeric substances of large molecular weight, is solid in its finished state, and, at some stage in its manufacture or processing into finished articles, can be shaped by flow. (ASTM D883)

3.10 PRIMARY CABLE

The single or multi-stranded, single conductor, insulated cable used to carry electric current.

3.11 SAE CONDUCTOR SIZE

A system that indicates the cross sectional area of the conductor. The SAE conductor size is the approximate area of the conductor.

3.12 SEPARATOR

A thin layer used as a barrier to prevent mutually detrimental effects between different components of a cable such as between the conductor and insulation or between the insulation and the sheath. (IEC, Electricity, Electronics and Telecommunications, Multilingual Dictionary)

3.13 SHIELD

Conductive material intended to reduce the penetration and/or radiation of a varying electromagnetic field into an assigned region. Not intended as a current carrying member.

3.14 STRAND

One of the wires of any stranded conductor. (ASTM B354)

3.15 THERMOPLASTIC

A plastic capable of being softened by heating and hardened by cooling through a temperature range characteristic of the plastic and, in the softened state, capable of being repeatedly shaped by flow into articles by molding, extrusion, or forming. (IEC, Electricity, Electronics and Telecommunications, Multilingual Dictionary)

3.16 THERMOSET

A polymeric material which, when cured by heat or other means, changes into a substantially infusible and insoluble product.

NOTE: Thermosets are often called thermosetting before curing and thermoset after cure. (IEC, Electricity, Electronics and Telecommunications, Multilingual Dictionary)

3.17 UNSHIELDED

Absence of a shield.

3.18 WIRE (STRAND)

A rod or filament of drawn or rolled metal whose length is great in comparison with the major axis of its cross section. (ASTM B354)

4. TECHNICAL REQUIREMENTS

4.1 General Test Conditions

Test samples shall be preconditioned for at least 16 hours at a room temperature of $23^{\circ}\text{C} \pm 3^{\circ}\text{C}$. Unless otherwise specified, all tests shall be conducted at this same temperature.

4.2 Tolerances

Unless otherwise specified, all values are considered to be approximate.

4.3 Representative Conductor Sizes for Testing

When a test is required, all combinations of conductor size, wall thickness, and insulation formulation shall meet the appropriate requirements. However, if testing representative conductor sizes is permitted, compliance for a cable family may be demonstrated by testing examples of large and small conductor sizes only. Permission to show compliance for a cable family by testing representative conductor sizes will be established by agreement between customer and supplier.

4.4 General Specifications

The finished cable shall meet the requirements for all tests specified in Table 1 for each cable type.

Table 1 - General specifications

Clause	Description	Initial Qualification Tests	Periodic Qualification Tests ³
4.4	General Specifications		
4.5	Insulated Conductor Requirements	x	x
4.6	Shield Requirements	x ⁽²⁾	x ⁽²⁾
4.7.1	Outside Cable Diameter	x	x
4.7.2	Jacket Wall Thickness	x	x
4.8	Dielectric Test	x	x
4.9	Jacket Faults	In-Process Test	In-Process Test
4.10	Abrasion Resistance	x	x
4.11	Pinch Resistance	x	x
4.12	Resistance to Flame Propagation	x ⁽¹⁾	x ⁽¹⁾
4.13	Winding Test	x	x
4.14	Heat Aging	x ⁽¹⁾	x ⁽¹⁾
4.15	Long-Term Heat Aging	x ⁽¹⁾	
4.16	Cold Bend	x	x
4.17	Fluid Compatability	x ⁽¹⁾	x ⁽¹⁾
4.18	Resistance to Ozone	x ⁽¹⁾⁽²⁾	
4.19	Temperature and Humidity Cycling Test	x ⁽¹⁾⁽²⁾	
4.20	Strip Force	x ⁽²⁾	x ⁽²⁾
4.21	Shrinkage of Jacket	x	x

NOTES:

(1) Compliance for a cable family may be demonstrated by using representative conductor sizes for testing; see 4.3.

(2) The usage will be established by agreement between customer and supplier.

(3) All tests listed under periodic qualification shall be repeated within a frequency determined by agreement between the supplier and the customer.

4.5 Insulated Conductor Requirements

The cable shall meet all of the requirements of SAE J1654 for the applicable cable type.

4.6 Shield Requirements

The cable shall be tested per Method 1, Section 5, of IEC 62153-4 for surface transfer impedance and shield effectiveness. The requirements shall be established by agreement between the customer and supplier.

4.7 Jacket Requirements

4.7.1 Outside Cable Diameter

The outside cable diameter shall be measured at five separate cross sections spaced 50 mm apart with an optical device accurate to at least 0.01 mm. Other devices may be used; however, in case of dispute, the referee shall be the optical device. A minimum of two readings shall be taken at each cross section. The sample should be rotated 90 degrees between readings. The mean of the diameter readings shall determine the outside cable diameter and shall be in accordance with Table 4 for thin wall cables or Table 5 for thick wall cables. Figure 5 provides the references for the various dimensions.

4.7.2 Jacket Wall Thickness

The minimum wall thickness shall be measured at five separate cross sections spaced 400 mm apart using the equipment described in 4.7.1. The minimum wall thickness shall meet the requirements specified in Tables 4 or 5, whichever is applicable.

4.8 Dielectric Test

The test shall be conducted according to 6.4 of SAE J1128. The voltage is to be applied between the shield and the water.

4.9 Jacket Faults

This is an in-process test intended for mass production of all cable covered in this document. The test electrode shall be of the link or bead-chain type and shall make intimate contact with the cable surface under test. The speed of the cable and the length of the electrode field shall ensure that each point of the cable is loaded with at least nine complete voltage cycles. The test voltage is 2 kV.

4.10 Abrasion Resistance

The test shall be conducted in accordance to the procedure outlined in 6.11 of SAE J1128 with the difference that the sandpaper shall be pulled until a conductive strip contacts the metallic shield instead of the conductor. The applied mass during the test shall follow the TWP/TXL column for sizes up to AWG 8 as shown in SAE J1128. For sizes >AWG 8, the applied weight shall be 0.45 kg. The minimum abrasion resistance of the jacket shall be 300 mm of tape (jacket to shield only). The test may run to failure or 450 mm to conserve tape.

4.11 Pinch Resistance

The test shall be conducted in accordance to the procedure outlined in 6.10 of SAE J1128 with the difference that the test shall stop when the jacket is pinched through and the 3 mm diameter rod makes contact with the metallic shield in place of the conductor. The minimum pinch resistance of the jacket shall be 2.0 kg (jacket to shield only) for all types and sizes of this standard.

4.12 Resistance to Flame Propagation

A 600 mm sample of finished cable shall be suspended taut at 45 degrees to a horizontal plane within a partial enclosure which allows a flow of sufficient air for complete combustion but is free from drafts. A gas burner shall be used having a 13 mm inlet, a nominal core of 10 mm, and a length of 100 mm above the primary inlets. The gas burner shall be adjusted to produce a 100 mm gas flame with an inner cone 1/2 of its height. The gas burner shall be positioned beneath the test sample and perpendicular to the axis of the test sample. The top of the inner cone of the flame shall be applied as shown in Figure 1. The time of application of the flame shall be 15 seconds. However, the exposure time shall not be longer than the time at which the shield becomes visible. After removal of the gas burner flame, the test sample shall not continue to burn for more than 30 seconds and a minimum of 50 mm of jacket at the top of the test sample shall remain unburned. Test five specimens.

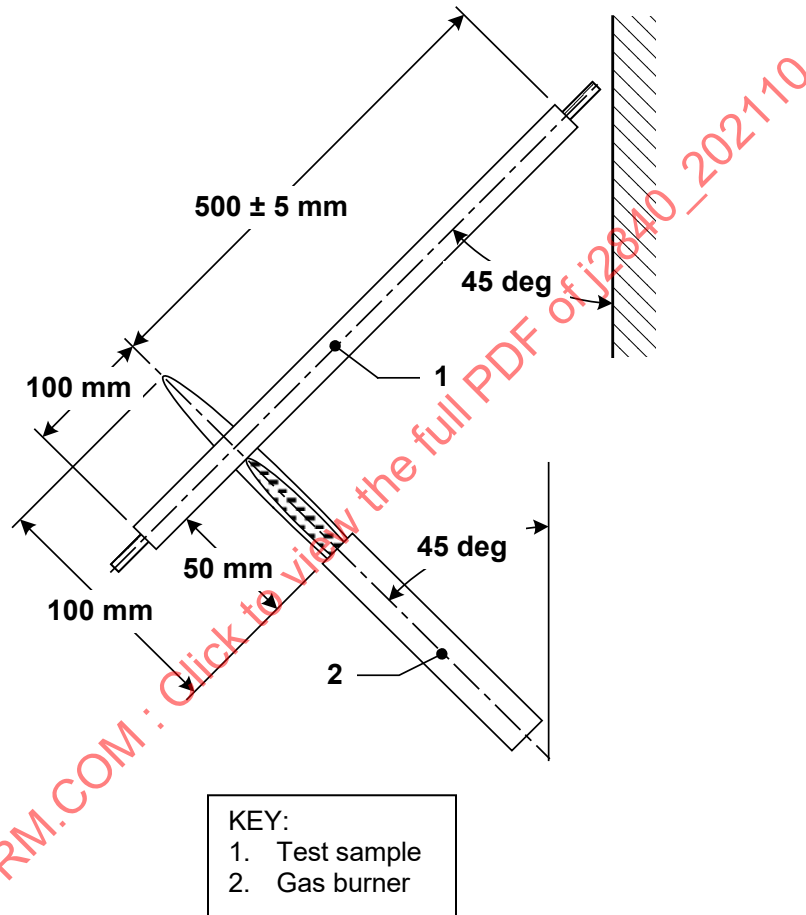


Figure 1 - Apparatus for "flame resistance" test

4.13 Winding Test

Wind the test specimen around a mandrel 5X the maximum diameter of Tables 4 or 5 as applicable for a given conductor size. The specimen shall be wrapped a minimum of three complete turns for cables up to 10 mm and 0.5 times for cables with outer diameters >10 mm. The winding speed shall be 0.2 turns per second. Either a revolving or stationary mandrel may be used. If the mandrel is revolving, the mass shall be large enough to ensure continuous contact between the cable and the mandrel during winding. A mass is not required for stationary mandrels. In either case, revolving or stationary, the cable must maintain contact with the mandrel. A visual inspection shall reveal no cracks or splits. If there are no visible cracks that expose the shield conduct the dielectric test described in 4.8.

4.14 Heat Aging

An accelerated aging test shall be conducted in accordance with ASTM D412 and ASTM D573, except using samples of insulation removed from finished cable. The sample shall be stretched at a rate of 50 mm/min. 500 mm/min may be used as the strain rate; however, in case of a dispute, the referee method will be a 50 mm/min strain rate. The original and conditioned samples must both be elongated at the same strain rate. The original properties shall conform to the values shown in Table 2. Samples of insulation shall be aged 168 hours in an oven at the test temperature shown in Table 2. After aging, the tensile strength shall not be less than 80% of the original test value and the elongation shall not be less than 50% of the original test value.

Table 2 - Heat aging test and temperature and humidity cycling test conditions

SAE Cable Type	Tensile Strength MPa Minimum	Elongation % Minimum	Test Temperature °C (See 6.3)	Temperature Class Rating °C (See 6.16)
TWP1 GPT1 HDT1 STT1 SGT1	11	125	110 ± 2	80
HTS1 STR1 SGR1	7	150	110 ± 2	80
TWP2 GPT2 HDT2 STT2 SGT2	11	125	130 ± 3	100
HTS2 STR2 SGR2	7	150	130 ± 3	100
HTS3 STR3 SGR3	7	150	155 ± 3	125
TXL3 GXL3 SXL3 STX3 SGX3	10	150	155 ± 3	125
HTS4 STR4 SGR4	7	150	180 ± 3	150
TXL4 GXL4 SXL4 STX4 SGX4	10	150	180 ± 3	150

NOTE: The above accelerated aging temperatures are appropriate for insulating materials currently specified in this document. Different test conditions may be necessary for other materials.

Table 2A - Temperature class ratings for legacy types

Insulation	Legacy SAE Legacy Cable Types ⁽¹⁾				Temperature Class Rating ⁽¹⁾
	Thin Wall	General Purpose	Special Purpose	Heavy Wall	
Thermoplastic	TWP STT	GPT SGT		HDT	1
Thermoset Elastomer	STR	SGR		HTS	1
Crosslinked Polyolefin	TXL STX	GXL SGX	SXL		3

NOTE:

⁽¹⁾ Temperature class rating is defined as 1 = 80 °C, 3 = 125 °C. Existing three character cable type will default to these temperature classes.

Table 2B - Temperature class ratings for SAE cable types

Insulation	SAE Cable Types ⁽²⁾				Temperature Class Rating ⁽¹⁾
	Thin Wall	General Purpose	Special Purpose	Heavy Wall	
Thermoplastic	TWP1	GPT1		HDT1	1
	STT1	SGT1			1
	TWP2	GPT2		HDT2	2
	STT2	SGT2			2
Thermoset Elastomer	STR1	SGR1		HTS1	1
	STR2	SGR2		HTS2	2
	STR3	SGR3		HTS3	3
	STR4	SGR4		HTS4	4
Crosslinked Polyolefin	TXL3	GXL3	SXL3		3
	STX3	SGX3			3
	TXL4	GXL4	SXL4		4
	STX4	SGX4			4

NOTES:

⁽¹⁾ Temperature class rating is defined as 1 = 80 °C, 2 = 100 °C, 3 = 125 °C, 4 = 150 °C.

⁽²⁾ TWP1, GPT1, HDT1, HTS1, STT1, SGT1, STR1, SGR1, TXL3, GXL3, SXL3, STX3, and SGX3 are new four character cable types equivalent to legacy types in Table 2A.

4.15 Long-Term Heat Aging Test (1500 hours at the Temperature Class Rating)

This test is intended to verify the upper value of the temperature class rating as shown in Tables 2A and 2B.

Prepare three test specimens, each of a minimum length of 350 mm, and remove 25 mm of insulation from each end. A specimen of at least 600 mm may be needed for the winding tests after heat aging.

Place the test specimens in the oven for 1500 hours. Fix the specimens by the conductor to avoid contact between the insulation and the supports. The test specimens shall be separated by at least 20 mm from each other and from the inner surfaces of the oven. Cable insulations and jackets made of different materials shall not be tested at the same time. After aging, remove the samples from the oven and allow them to condition at room temperature for at least 16 hours. Then perform the winding test according to 4.13 using a mandrel size of less than or equal to five times the outer diameter. If no shield is visible, proceed with the voltage test.

4.15.1 Voltage Test

Partially fill a non-conductive vessel with a 3% by weight solution of water and NaCl. Immerse a test specimen in the water-NaCl solution for at least 10 minutes. Leave at least 25 mm of insulation exposed at each end as shown in Figure 2. Connect a 50 Hz or 60 Hz AC voltage source to the shield and the solution and apply a potential of 1 kV (AC) for 1 minute.

Cracks in the jacket or voltage breakdown shall not occur.

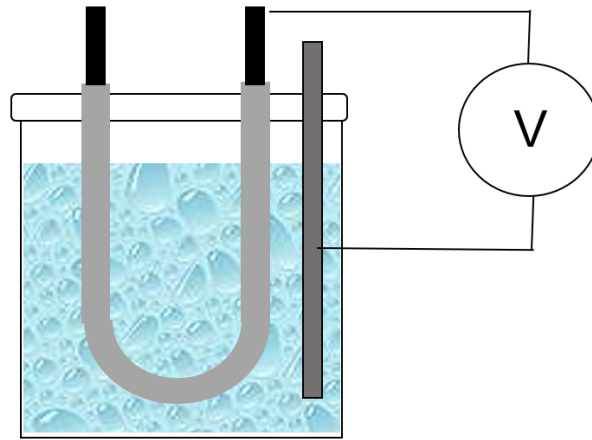


Figure 2 - Voltage test set-up

4.16 Cold Bend Test

25 mm of insulation shall be removed from each end of a 1000 mm sample of finished cable. The sample shall be placed in a cold chamber at $-40\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ for a period of 3 hours. While the sample is still at this low temperature, perform the winding test in 4.13. A visual inspection shall reveal no cracks or splits. The sample is to be returned to room temperature and then subjected to the dielectric test specified in 4.8. Test three specimens.

4.17 Fluid Compatibility Test

Compliance for a cable family may be demonstrated by using 4.3. 25 mm of insulation shall be removed from each end of 1000 mm samples of finished cable. A separate sample shall be used for each fluid. The original outside cable diameter shall be measured using the procedure described in 4.7.1. The area of the sample to be subjected to the winding test shall be immersed in the fluid shown in Table 3 for a period of 20 (+1, -0) hours. After removal from the fluid, remove excess fluid from the sample and then condition the sample for 4 hours at room temperature. After conditioning, the diameter shall again be measured using the procedure in 4.7.1. The mean of the diameter readings taken after conditioning shall be compared to the mean of the original diameter readings. The outside cable diameter, maximum change shall be in accordance with Table 3. After conditioning at room temperature, perform the winding test in 4.13. A visual inspection shall reveal no cracks or splits. If no exposed shield is visible, subject the sample to the dielectric test specified in 4.8. Test three specimens.

Table 3 - Fluid compatibility

Test Fluid		Test Temperature °C	Outside Cable Diameter Maximum Change %
Name	Fluid		
Engine Oil	ASTM D471, IRM-902	50 ± 3	15
Gasoline	ASTM D471, Ref Fuel C	23 ± 5	15
Ethanol	85% Ethanol + 15% ASTM D471, Ref Fuel C	23 ± 5	15
Diesel Fuel	90% ASTM D471, IRM 903 + 10% p-xylene	23 ± 5	15
Power Steering	ASTM D471, IRM-903	50 ± 3	30
Auto Trans	Dexron VI, SAE J311	50 ± 3	25
Engine Coolant	50% Distilled Water + 50% Ethylene Glycol	50 ± 3	15
Battery Acid	H ₂ SO ₄ , Specific Gravity = 1.260 ± 0.005	23 ± 5	5

NOTE: Solutions are determined as % by volume.

4.18 Resistance to Ozone

Attention is drawn to the highly toxic nature of ozone. Efforts should be made to minimize the exposure of workers at all times.

This test is for initial qualification only. The usage of this test will be established by agreement between customer and supplier. Compliance for a cable family may be demonstrated by using 4.3. Prepare a 300 mm test sample of finished cable, perform the winding test in 4.13, and secure the ends. The assembly shall then be conditioned for 192 (+1, -0) hours at 65 °C ± 3 °C in an atmosphere containing 100 pphm ± 5 pphm (parts per hundred million) of ozone. A visual inspection shall reveal no cracks or splits. Test three specimens.

4.19 Temperature and Humidity Cycling Test

This test is for initial qualification only. The usage of this test will be established by agreement between customer and supplier. Compliance for a cable family may be demonstrated by using 4.3. 25 mm of insulation shall be removed from each end of two 600 mm samples of finished cable. Wind the test sample around the mandrel according to 4.13 and secure the ends, except that the mandrel size is a maximum of 1.5X the outer diameter of the wire. Condition the sample according to the temperature and relative humidity shown in Figure 3. The temperature class rating is shown in Table 2. 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 ± 2 °C and uncontrolled relative humidity. Completion of the schedule shown in Figure 3 will constitute one cycle. Repeat the cycle for a total of 40 cycles. While still on the mandrel, remove the test sample from the chamber, allow it to stabilize at room temperature for 30 minutes, and unwind it from the mandrel. Make a visual inspection of the insulation. Ignore any damage caused by the ties, which secure the ends. If no exposed shield is visible, perform the dielectric test per 4.8, except the voltage will be applied after immersion in the salt solution for a minimum of 10 minutes. Test two specimens.

