



SURFACE VEHICLE STANDARD

J1678™**JUN2023**

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Superseding J1678 FEB2020

(R) Low Voltage Ultra-Thin Wall Primary Cable

RATIONALE

SAE J1678 has been revised to: (1) remove the reference to an ignition coil in 3.14 and redefine use as an insulated small conductor for signal, low current or power applications, (2) clarify cable types in Figure 1 as “not all types are commercially available,” (3) add a cross-linking test as shown in Figure 2 and 6.17, (4) reformat Figure 5, (5) insert Figure 13 to clarify the temperature and humidity cycles and transition zones, (5) remove Figure C1 from the document, (6) all figures, appendix, and equation references were reviewed and added as required in the text.

SAE J1678 has been reaffirmed to comply with the SAE Five-Year Review policy.

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1. SCOPE

This standard covers ultra-thin wall low voltage primary cable intended for use at a nominal system voltage of 60 VDC (60 VAC rms) or less in surface vehicle electrical systems. The tests are intended to qualify cables for normal applications with limited exposure to fluids and physical abuse. This standard covers SAE conductor sizes which usually differ from ISO conductor sizes.

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 EA-1128 Wire Color Charts

SAE J311 Fluid for Passenger Car Type Automatic Transmissions

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 B33 Standard Specification for Tinned Soft or Annealed Copper Wire

ASTM B193 Standard Test Method for Resistivity of Electrical Conductor Materials

ASTM B263 Method for Determination of Cross-Sectional Area of Standard Conductors

ASTM B298 Standard Specification for Silver-Coated Soft or Annealed Copper Wire

ASTM B354 Definitions of Terms Relating to Uninsulated metallic Electrical Conductors

ASTM B355 Standard Specification for Nickel-Coated Soft or Annealed Copper Wire

ASTM D471 Standard Test Method for Rubber Property - Effect of Liquids

ASTM D833 Standard Terminology Relating to Plastics

ASTM D5374 Standard Test Methods for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation

ASTM D5423 Standard Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation

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.

60811-2-1 Common Test Methods for Insulating and Sheathing Materials of Electrical Cables - Part 2: Methods Specific to Elastomeric Compounds - Section 1: Ozone Resistance Test - Hot Set Test - Mineral Oil Immersion Test

IEC, Electricity, Electronics and Telecommunications, Multilingual Dictionary

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 J156	Fusible Links
SAE J1127	Low Voltage Battery Cable
SAE J1128	Low Voltage Primary Cable
SAE J1654	Unshielded High Voltage Primary Cable
SAE J1673	High Voltage Automotive Wiring Assembly Design
SAE J2183	60 V and 600 V Single-Core Cables
SAE J2501	Round, Screened and Unscreened, 60 V and 600 V Multi-Core Sheathed Cables
SAE J2840	High Voltage Shielded and Jacketed Cable

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	Concentric-Lay-Stranded Copper conductors, Hard, Medium-Hard, or Soft
ASTM B174	Standard Specification for Bunch-Stranded Copper Conductors for Electrical Conductors
ASTM B263	Method for Determination of Cross-Sectional Area of Standard Conductors
ASTM B452	Standard Specification for Copper-Clad Steel Wire for Electronic Application
ASTM B787	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 6722-1 Road Vehicles - 60 V and 600 V Single Core Cables - Test Methods, Dimensions and Requirements

ISO 14572 Road Vehicles - Round, Unscreened, 60 V and 600 V Multicore Sheathed Cables - Basic and High Performance Test Methods and Requirements

3. DEFINITIONS

3.1 3000 HOUR TEMPERATURE CLASS RATING (TCR)

A letter designation (class) based on the maximum test temperature (rating) at which a primary cable successfully passes the minimum requirements of 3000 hours of heat aging.

3.2 ADDITIONAL MASS

The mass which 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.)

3.3 COATED WIRE

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

3.4 CABLE

See primary cable.

3.5 CABLE FAMILY

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

3.6 CONDUCTOR

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

3.7 CONDUCTOR SIZE

See SAE conductor size.

3.8 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.

3.9 FLUID COMPATIBILITY

The ability of a cable to resist the effects of various fluids found in surface vehicles.

3.10 LOW VOLTAGE (LOW TENSION)

Usually considered to be ≤ 60 VDC (25 VAC).

3.11 MINIMUM WALL (THICKNESS)

The lowest allowable insulation thickness at any point.

3.12 NOMINAL

A suitable approximate value used to designate or identify a component.

3.13 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 D833.)

3.14 PRIMARY CABLE

An insulated small conductor (24 to 8 gauge), used for signal, low current, or power applications.

Examples include standard wiring harness applications such as body, instrument panel, engine, front end modules, and doors. The cable is not limited to these applications and may be used wherever signal, low current, or power circuits are required.

3.15 RESISTANCE TO OZONE

The ability of a material to withstand the deteriorating effect of ozone (surface cracking). (Dictionary of Materials and Testing.)

3.16 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.

3.17 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.)

3.18 STRIP FORCE

The peak axial force required to overcome the adhesion between the conductor and the insulation.

3.19 STRAND

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

3.20 TCR

Temperature class rating.

3.21 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.)

3.22 THERMOSET

A plastic 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.)

3.23 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. GENERAL

4.1 Cable Types

See Figure 1.

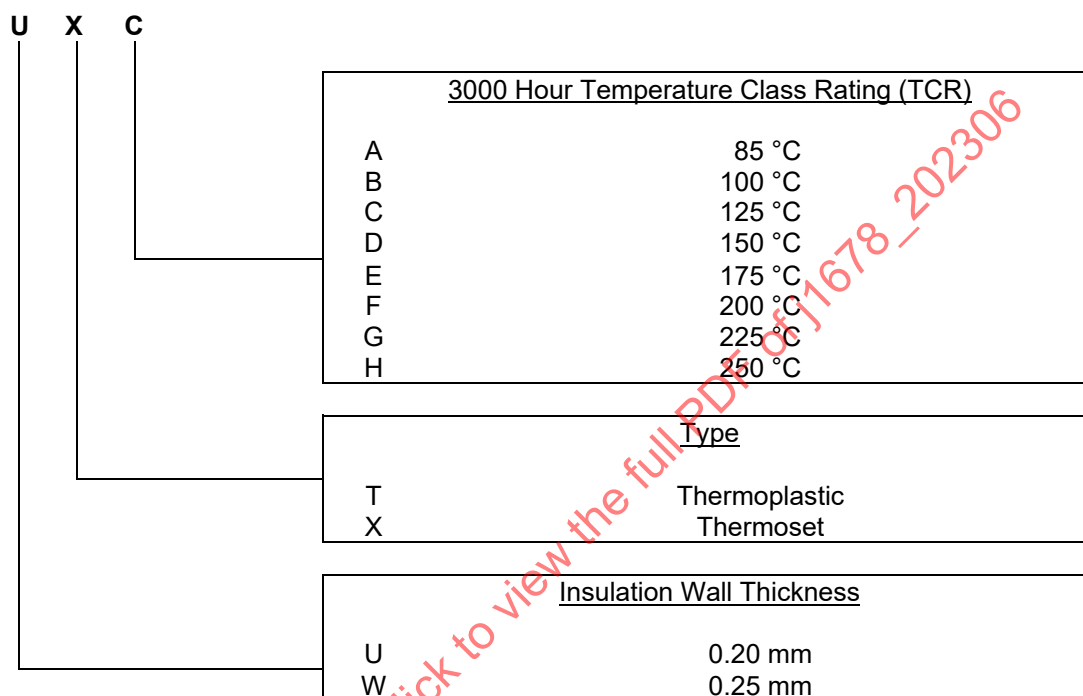


Figure 1 - Cable types

In this example, UXC, the cable, has an insulation wall thickness of 0.20 mm, thermoset, with a 3000 hour temperature class rating of 125 °C. Not all combinations of letter designations are commercially available.

4.2 General Test Conditions

Test samples for all tests except 6.3 shall be preconditioned for at least 16 hours at a room temperature of 23 °C ± 3 °C. Unless otherwise specified, all tests shall be conducted at this same temperature.

All specimens shall pass. In the case where the test result is based on an average, the average shall meet the requirement.

4.3 Ovens

Unless otherwise specified, when an oven is required, it shall be a hot air oven in accordance with ASTM D5374 and D5423 Type I. The air contained in the oven shall be completely changed at least eight times, but not more than 20 times per hour, at the specified temperature.

4.4 Tolerances

Unless otherwise specified, all values are considered to be approximate. Temperature tolerances are <125 °C = ±2 °C and ≥125 °C = ±3 °C, except where otherwise specified.

4.5 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.

5. GENERAL SPECIFICATIONS

The finished cable shall meet the requirements for all tests specified in Figure 2 for each cable type.

Clause	Description	Initial Qualification Tests	Periodic Qualification Tests ⁵
5	General Specifications		
5.1	Conductor	x	x
5.2	Insulation		
5.3	Outside Cable Diameter	x	x
5.4	Wall Thickness	x	x
5.5	Winding		
6	Tests		
6.1	Strand Coating	x ¹	
6.2	Solderability	x	x
6.3	Heat Aging	x ²	x ²
6.4	Thermal Excursions	x ²	x ²
6.5	Withstand Voltage	x	x
6.6	Insulation Faults	In-Process Test	In-Process Test
6.7	Cold Bend	x	x
6.8	Resistance to Flame Propagation	x	x
6.9	Fluid Compatibility	x ²	
6.10	Resistance to Ozone	x ^{2,4}	
6.11	Resistance to Pinch	x	x
6.12	Resistance to Sandpaper Abrasion	x	x
6.13	Strip Force	X ⁴	x ⁴
6.14	Resistance to Hot Water	x ^{2,4}	
6.15	Insulation Volume Resistivity	X ^{3,4}	
6.16	Temperature and Humidity Cycling	x ^{2,4}	
6.17	Crosslinking Test	X ^{4,6}	X ^{4,6}

NOTES:

¹ This test is only required for coated copper wires.

² Compliance for a cable family may be demonstrated by using representative conductor sizes for testing; see 4.5.

³ This test is only used as part of the resistance to hot water test.

⁴ The usage will be established by agreement between customer and supplier.

⁵ All tests listed under periodic qualification shall be repeated within a frequency determined by agreement between the supplier and the customer.

⁶ This test is only applicable for crosslinkable and thermoset materials.

Figure 2 - General specifications

5.1 Conductor

The conductor construction is established by agreement between the supplier and the customer. Typical constructions include, but are not limited to, annealed copper, compacted copper, coated copper, hard drawn copper, alloys, or copper clad steel. SAE conductor size and minimum conductor area are shown in Figure 3. See Figure A1 for the approximate metric equivalents. Test three samples.

English	
SAE Conductor Size No.	Minimum Conductor Area (Circular Mils)
26	250
24	405
22	681
20	1072
18	1537
16	2336
14	3702
12	5833

NOTES:

- ¹ The SAE wire conductor size number indicates that the cross sectional area of the conductor approximates the area of the American Wire Gauge for the equivalent size.
- ² As agreed between the customer and supplier, the metric dimensions shown in Figure A1 can be used.

Figure 3 - Conductors

5.2 Insulation

5.3 The insulation shall be homogeneous, and shall be placed concentrically within commercial tolerances about the conductor. The insulation shall adhere closely to, but strip readily from, the conductors leaving them in suitable condition for terminating. Separators are optional. The recommended colors are shown in Figure B1. Outside Cable Diameter

5.3.1 Test Samples

The test samples shall consist of three separate cross sections spaced 1 minute apart.

5.3.2 Apparatus

The apparatus shall be a measuring device that does not cause deformation. Other devices may be used; however, in case of dispute, the referee shall be the measuring device that does not cause deformation.

5.3.3 Procedure

The outside cable diameter shall be determined by taking a minimum of two readings at each cross section. The sample should be rotated to obtain equal spacing between readings. The mean of the diameter readings shall determine the outside cable diameter. Measurements shall be taken to determine the outside cable diameter of each test sample to ± 0.01 mm.

5.3.4 Requirement

The mean of the diameter readings shall not exceed the values specified in Figure 4.

SAE Conductor Size No.	Wall Thickness, U			Wall Thickness, W		
	Wall Thickness		Outside Cable Diameter	Wall Thickness		Outside Cable Diameter
	Nominal (mm)	Minimum (mm)	Maximum (mm)	Nominal (mm)	Minimum (mm)	Maximum (mm)
26	0.20	0.16	1.10	0.25	0.20	1.20
24	0.20	0.16	1.20	0.25	0.20	1.30
22	0.20	0.16	1.40	0.25	0.20	1.50
20	0.20	0.16	1.60	0.25	0.20	1.70
18	0.20	0.16	1.90	0.25	0.20	2.00
16	0.20	0.16	2.20	0.25	0.20	2.30
14	0.20	0.16	2.60	0.25	0.20	2.70
12	0.25	0.20	3.20	0.30	0.24	3.30

Figure 4 - Outside cable diameter and wall thickness

5.4 Wall Thickness

5.4.1 Test Samples

Prepare three test samples from a cable sample 3 minutes in length. Take the test samples at 1 minute intervals. Strip the insulation from the cable. A test sample consists of a thin cross section of insulation. Take care not to deform the test sample during the preparation process. If cable marking causes indentation of the insulation, take the first test sample through this indentation.

5.4.2 Apparatus

Use a measuring device with an accuracy of ± 0.01 mm that does not cause deformation. Other devices may be used; however, in case of dispute, the referee shall be the measuring device that does not cause deformation.

5.4.3 Procedure

Place the test sample under the measuring equipment with the plane of the cut perpendicular to the optical axis. Determine the minimum wall thickness.

5.4.4 Requirement

No single value shall be less than the appropriate minimum wall thickness specified in Figure 4.

5.5 Winding

Winding is not a separate test. It is included as a part of several other tests.

5.5.1 Test Samples

See individual test.

5.5.2 Apparatus

See Figure 5.

5.5.3 Procedure

Wind the test sample around the mandrel using the mandrel size, winding speed, and minimum number of turns shown in Figure 5. Either a revolving or stationary mandrel may be used. Care shall be taken to ensure that there is continuous contact between the test samples and the mandrel.

5.5.4 Requirement

See individual test.

Mandrel Diameter		Winding Speed, S ⁻¹	Minimum Number of Turns
Reference Clauses	Reference Clauses		
6.3 - Heat Aging 6.4 - Thermal Excursions 6.16 - Temperature Humidity Cycling	6.7 - Cold Bend 6.9 Fluid Compatibility 6.10 Resistance to Ozone 6.14 Resistance to Hot Water		
≤1.5 X Outside Cable Diameter Maximum	≤5 X Outside Cable Diameter Maximum	0.2	3

Figure 5 - Winding

6. TESTS

6.1 Strand Coating

This test is not required for uncoated strands.

6.1.1 Test Samples

The continuity of coating test shall be conducted on individual strands prior to stranding and shall be conducted per the applicable section of ASTM B33, ASTM B298, or ASTM B355.

6.1.2 Apparatus

Refer to the applicable section of ASTM B33, ASTM B298, or ASTM B355.

6.1.3 Procedure

Refer to the applicable section of ASTM B33, ASTM B298, or ASTM B355.

6.1.4 Requirement

Refer to the applicable section of ASTM B33, ASTM B298, or ASTM B355.

6.2 Solderability

The usage of this test shall be established by agreement between customer and supplier.

The specific solder and soldering flux used for this test shall be established by agreement between customer and supplier and shall comply with all applicable health and environmental laws and regulations in the nation of manufacture and use.

25 mm of insulation shall be removed from a 300 mm sample of finished cable. 12 mm of the stripped end shall be immersed into a flux for 3 to 5 seconds. The stripped end shall then be immersed in solder, at the appropriate temperature for the chosen solder, for 3 to 5 seconds. A visual inspection shall reveal no area in the immersed section which is not covered by solder.

6.3 Heat Aging

Compliance for a cable family may be demonstrated by using 4.5.

6.3.1 Initial Certification of the TCR

6.3.1.1 Long Term Aging, 3000 Hours

This test is intended to confirm the TCR during initial certification.

6.3.1.1.1 Test Samples

Prepare two test samples, each of a minimum length of 350 mm, and remove 25 mm of insulation from each end.

6.3.1.1.2 Apparatus

Perform the long term aging test using an oven set at the TCR as specified in Figure 1. See 4.4 for the temperature tolerance.

6.3.1.1.3 Procedure

Place the test samples in the oven for 3000 hours. Fix the test samples by the conductor to avoid any contact between the insulation and the supports. The test samples shall be separated by at least 20 mm from each other and from the inner surface of the oven. Cable insulations made of different materials shall not be tested at the same time in the same oven. After aging, withdraw the test samples from the oven and maintain them at $23\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ for at least 16 hours. After conditioning at room temperature, perform the winding test in 5.5. After winding, make a visual examination of the insulation. If no exposed conductor is visible, perform the withstand voltage test in 6.5, except the voltage will be applied after immersion in the salt solution for a minimum of 10 minutes.

6.3.1.1.4 Requirements

After winding, no conductor shall be visible. During the withstand voltage test, breakdown shall not occur.

6.3.1.2 Accelerated Aging, Test Development

This section is intended to develop a test temperature for periodic certification. This development is only performed during the initial certification testing.

6.3.1.2.1 Test Samples

Prepare four test samples for each test temperature, each of a minimum length of 350 mm, and remove 25 mm of insulation from each end.

6.3.1.3 Apparatus

Perform the accelerated aging test using an oven at the temperature specified in 6.3.1.4. See 4.4 for the temperature tolerance.

6.3.1.4 Procedure

Set the oven temperature at the TCR (Figure 1) + $25\text{ }^{\circ}\text{C}$. Follow the procedure in 6.3.1.1.3; however, the aging time shall be 240 hours. If all test samples meet the requirement in 6.3.1.1.4, increase the oven temperature by $5\text{ }^{\circ}\text{C}$ and repeat the procedure. Continue to increase the test temperature in $5\text{ }^{\circ}\text{C}$ increments until at least one test sample fails the requirements in 6.3.1.1.4. The highest temperature at which all test samples pass the requirements will become the test temperature used for periodic certification. However, the accelerated aging test temperature shall not be less than the TCR + $25\text{ }^{\circ}\text{C}$.

6.3.1.4.1 Requirement

See 6.3.1.1.4.

6.3.2 Periodic Certification of the TCR

This section is intended to confirm the TCR during periodic certification. Compliance may be demonstrated by completion of 6.3.2.1 or 6.3.2.2.

6.3.2.1 Accelerated Aging Method

This method shall be used if an accelerated aging temperature was established in 6.3.1.2. If no test temperature was established in 6.3.1.2, the long term aging method in 6.3.2.2 must be used.

6.3.2.1.1 Test Samples

Prepare two test samples, each of a minimum length of 350 mm, and remove 25 mm of insulation from each end.

6.3.2.1.2 Apparatus

Perform the accelerated aging test using an oven at the temperature developed in 6.3.1.2. The mandrels are specified in Figure 5.

6.3.2.1.3 Procedure

Follow the same procedure as 6.3.1.1.3; however, the aging time shall be 240 hours.

6.3.2.1.4 Requirement

See 6.3.1.1.4.

6.3.2.2 Long Term Aging Method

If an accelerated aging temperature was not developed in 6.3.1.2, use 6.3.1.1.

6.4 Thermal Excursions

This test is intended to simulate thermal excursions. Compliance for a cable family may be demonstrated by using 4.5.

6.4.1 Test Samples

Prepare two test samples, each of a minimum length of 350 mm, and remove 25 mm of insulation from each end.

6.4.2 Apparatus

Perform the thermal excursions test using an oven set at the TCR + 50 °C. The mandrels are specified in Figure 5.

6.4.3 Procedure

Place the test samples in the oven for 6 hours. Attach the test samples by the conductor to avoid any contact between the insulation and the supports. The test samples shall be separated by at least 20 mm from each other and from the inner surface of the oven. Cable insulations made of different materials shall not be tested at the same time in the same oven. After aging, withdraw the test samples from the oven and maintain them at $23\text{ °C} \pm 5\text{ °C}$ for at least 16 hours. After conditioning at room temperature, perform the winding test in 5.5. After winding, make a visual examination of the insulation. If no exposed conductor is visible, perform the withstand voltage test in 6.5, except the voltage will be applied after immersion in the salt solution for a minimum of 10 minutes.

6.4.4 Requirement

After winding no conductor shall be visible. During the withstand voltage test, breakdown shall not occur.

6.5 Withstand Voltage

6.5.1 Test Sample

Prepare a test sample of a minimum length of 350 mm, strip 25 mm of insulation from each end and twist them together to form a loop.

6.5.2 Apparatus

Partially fill an electrically non-conductive vessel with a salt solution (3% of NaCl by weight in water) with the ends of the test sample emerging above the solution. A 50 Hz or 60 Hz voltage source shall be used.

6.5.3 Procedure

Immerse the test sample for 4 hours in the salt solution and then apply a test voltage of 1 kV (rms) for 1 minute between conductor and the solution.

6.5.4 Requirement

Breakdown shall not occur.

6.6 Insulation 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 kVAC.

6.7 Cold Bend

6.7.1 Test Samples

Prepare two test samples of 600 mm and remove 25 mm of insulation from each end.

6.7.2 Apparatus

A freezing chamber at $-40\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$. The mandrel size is specified in Figure 5.

6.7.3 Procedure

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 5.5. A visual inspection shall reveal no cracks or splits. The sample is to be returned to room temperature and then subjected to the withstand voltage test specified in 6.5.

6.7.4 Requirement

After winding, a visual inspection of the insulation shall not show cracks, fractures, or other defects. During the withstand voltage test, breakdown shall not occur.

6.8 Resistance to Flame Propagation

6.8.1 Test Sample

Prepare five test samples with at least 600 mm of insulation.

6.8.2 Apparatus

A gas burner 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.

6.8.3 Procedure

Suspend the test sample in a draught free chamber and expose the test sample to the tip of the inner cone of the flame, as shown in Figure 6. The time of exposure to the test flame shall be 15 seconds. However, the exposure time shall not be longer than the time at which the conductor becomes visible.

6.8.4 Requirement

Any combustion flame of insulating material shall extinguish within 30 seconds, and a minimum of 50 mm of insulation at the top of the test sample shall remain unburned.

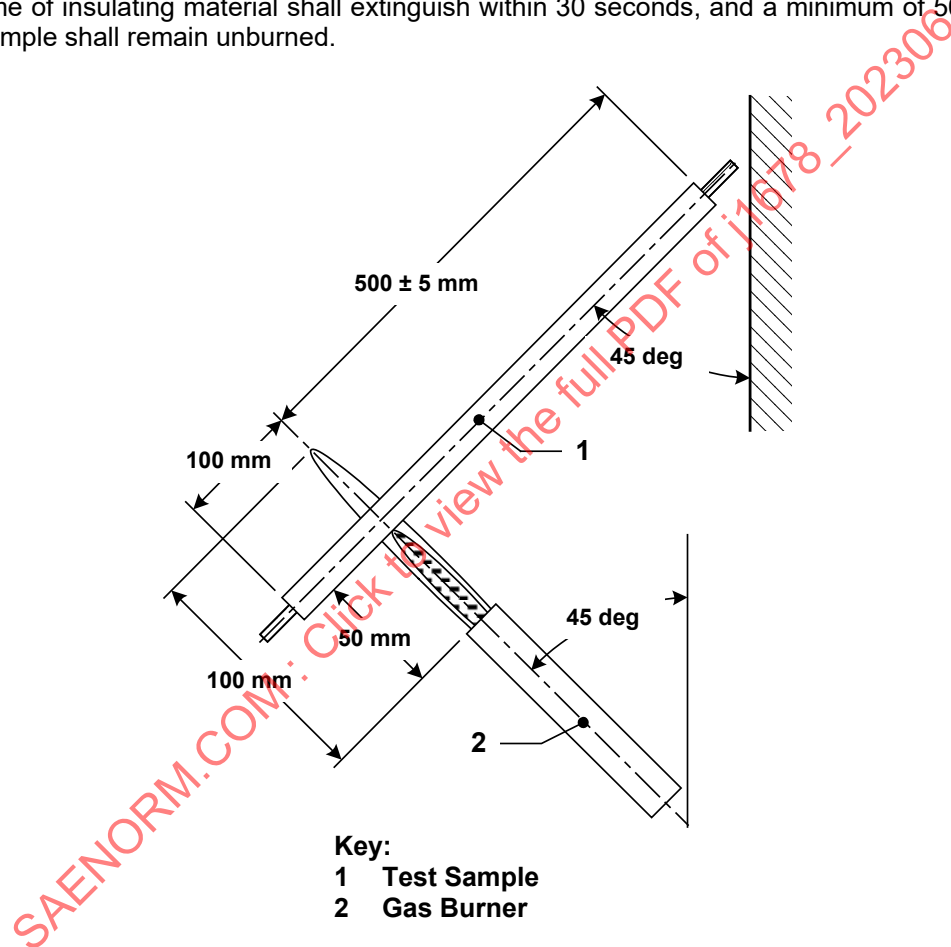


Figure 6 - Apparatus for resistance to flame propagation

6.9 Fluid Compatibility

The tests are intended to qualify cables for limited exposure to fluids. Additional tests will be necessary to qualify cables for continuous immersion. Compliance for a cable family may be demonstrated by using 4.5.

6.9.1 Test Samples

Prepare three test samples for each fluid to be tested. Each test sample shall be 600 mm long with 25 mm of insulation removed from each end.

6.9.2 Apparatus

The apparatus for measuring the cable diameter shall be the same as that shown in 5.3. Vessels shall be filled with the fluids at the temperatures shown in Figure 7. See Figure 5 for mandrels.

6.9.3 Procedure

The outside cable diameter of each test sample shall be determined using the procedure described in 5.3. The area of the sample to be subjected to the bend test shall be immersed in the fluid shown in Figure 7 for a period of 20 (+1, -0) hours. After removal from the fluid, remove excess fluid from the sample. Allow it to dry at room temperature for 4 hours. Within the 5 minutes after the end of drying period, measure the outside cable diameter at the same place as before the immersion. The mean of the diameter readings taken after conditioning shall be compared to the mean of the original diameter readings. After conditioning at room temperature, perform the winding test in 5.5. If no exposed conductor is visible, perform the withstand voltage test in 6.5, except the voltage will be applied after immersion in the salt solution for a minimum of 10 minutes.

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	ASTM D471, 90% 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 percent by volume.

Figure 7 - Fluid compatibility

6.9.4 Requirement

The maximum diameter change shall meet the requirements shown in Figure 7. After the winding test, a visual inspection of the insulation shall not show cracks, fractures, or other defects. During the withstand voltage test, breakdown shall not occur.

6.10 Resistance to Ozone

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 4.5.

6.10.1 Test Sample

Prepare three test samples of 300 mm.

6.10.2 Apparatus

An ozone chamber in accordance with IEC 60811-2-1, with an atmosphere containing 100 pphm ± 5 pphm (parts per hundred million) of ozone at 65 °C ± 3 °C. See Figure 5 for mandrel sizes. Aluminum mandrels are preferred since other materials may affect the ozone concentration.

6.10.3 Procedure

Wind at least the minimum number of turns specified in Figure 5 and secure the ends. Condition the test sample for 192 (+1, -0) hours in the ozone chamber. While still on the mandrel, remove the test sample from the ozone chamber, and allow it to cool to room temperature, and make a visual inspection of the insulation. Ignore any damage caused by the clamps, which secure the ends.

6.10.4 Requirement

A visual inspection of the insulation shall not show cracks, fractures, or other defects.

6.11 Resistance to Pinch

6.11.1 Test Sample

25 mm of insulation shall be removed from one end of a 900 mm sample of finished cable.

6.11.2 Apparatus

The apparatus shall be as shown in Figure 8. The counter balance shall be adjusted so that no force will be exerted on the sample until a mass is applied to the end of the lever with a mechanical advantage of ten.

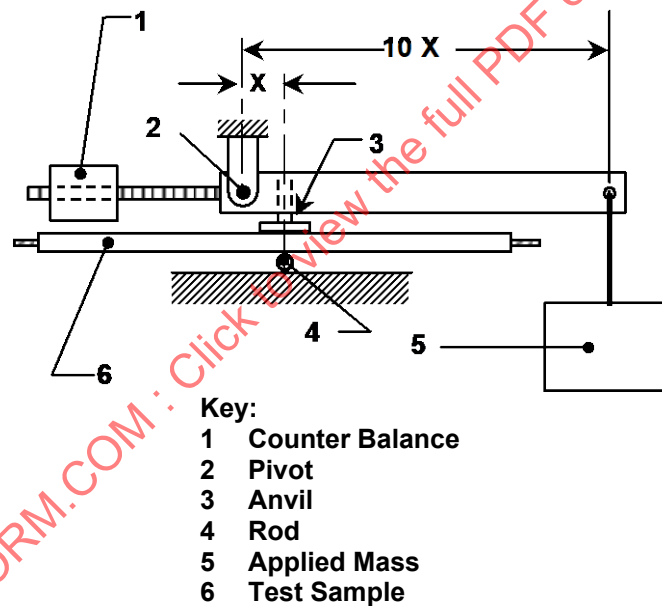


Figure 8 - Apparatus for resistance to pinch test

6.11.3 Procedure

The sample shall then be placed taut without stretching across a 3 mm diameter steel rod as shown in Figure 8. The sample shall then be subjected to an increasing force applied through the steel anvil by increasing the applied mass at a rate of 2.3 kg/min. At the moment the insulation is pinched through, the test shall stop. The applied mass shall then be recorded. After each reading the sample shall be moved 50 mm and rotated clockwise 90 degrees. Four readings shall be obtained for each sample. The mean of the four readings shall determine the pinch resistance of the cable under test.

6.11.4 Requirement

The resistance to pinch minimum for each cable type and size is shown in Figure 9.

6.12 Resistance to Sandpaper Abrasion

6.12.1 Test Sample

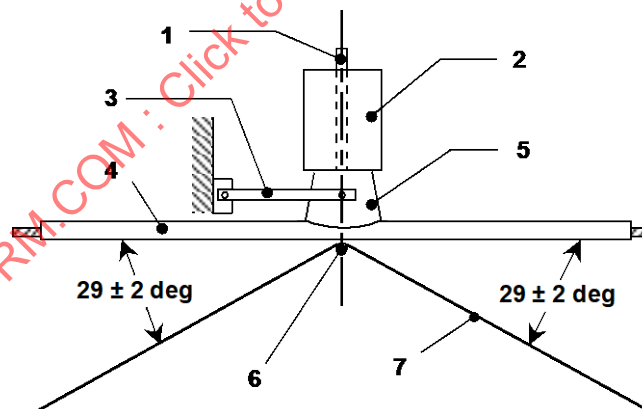
Prepare a test sample of 1 m and remove 25 mm of insulation from each end.

6.12.2 Apparatus

Measure the resistance to sandpaper abrasion using 150 J garnet or 180 J aluminum oxide sandpaper tape with 5 to 10 mm conductive strips perpendicular to the edge of the sandpaper spaced a maximum of every 75 mm. The DC resistance of the conductive strips shall be 15000 Ω (when measured across the width of the sandpaper) or low enough to allow the apparatus to detect exposed conductor. Mount a suitable bracket to the pivoting arm per Figure 10 to maintain the test sample position over an unused portion of the sandpaper abrasion tape. Exert a force of 0.63 N $\pm$ 0.05 N on the test sample by the combination of the bracket, support rod, and pivoting arm. The total vertical force exerted on the test sample will be the combination of the force exerted by the bracket, pivoting arm, support rod and additional mass. See Figure 11 for the additional mass.

SAE Conductor Size No.	Wall Thickness	
	U (kg)	W (kg)
26	0.3	0.7
24	0.4	1.0
22	0.5	1.0
20	0.7	1.0
18	0.9	1.5
16	1.1	1.5
14	1.3	1.5
12	1.5	1.5

Figure 9 - Resistance to pinch, minimum



Key:

- 1 Support Rod
- 2 Additional Mass
- 3 Pivoting Arm
- 4 Test Sample
- 5 Bracket
- 6 Tape Supporting Pin
- 7 Sandpaper Abrasion Tape

Figure 10 - Apparatus for resistance to sandpaper abrasion

6.12.3 Procedure

Mount the specimen taut, without stretching, in a horizontal position using an area of the abrasion tape not previously used. Place the additional mass and bracket on top of the cable. Draw the sandpaper under the specimen at a rate of 1500 mm/min $\pm$ 75 mm/min and record the length of sandpaper necessary to expose the conductor. Move the test sample 50 mm and rotate the test sample clockwise 90 degrees. Repeat the procedure for a total of four readings. The mean of the readings will determine the resistance to sandpaper abrasion.

6.12.4 Requirement

The resistance to sandpaper abrasion shall meet or exceed the minimum length of sandpaper requirements in Figure 11.

SAE Conductor Size No.	Additional Mass (g)		Minimum Length of Sandpaper (mm)	
	Type U	Type W	Type U	Type W
26	50	100	150	200
24	50	100	175	300
22	50	100	200	350
20	100	220	175	200
18	100	220	200	300
16	100	220	225	350
14	100	220	250	400
12	220	450	150	250

Figure 11 - Resistance to sandpaper abrasion

6.13 Strip Force

The usage of this test will be established by agreement between customer and supplier. The requirements for the strip force test, if any, will be established by agreement between the supplier and the customer.

6.13.1 Test Samples

Prepare three test samples which are 50 mm in length. 25 mm of insulation shall be cleanly cut and carefully stripped from one end of the conductor. When stripping the insulation, care must be taken not to disturb the remaining 25 mm section of insulation. No burrs are permitted on the ends of the metallic conductor.

6.13.2 Apparatus

A plate with an appropriate diameter hole. A tensile machine with a speed of 500 mm/min.

6.13.3 Procedure

Insert the stripped end through the plate. The conductor shall be pulled through the plate and the maximum force shall be recorded. Repeat the procedure for the remaining test samples. The mean of all readings shall determine the strip force of the cable under test.

6.13.4 Requirement

The strip force shall be established by agreement between the supplier and customer.

6.14 Resistance to Hot Water

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 4.5.