SAE International™

SURFACE VEHICLE STANDARD

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Low Voltage Ultra Thin Wall Primary Cable

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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 V DC (25 V AC) 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 Publications

The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply.

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: custsvc@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

2.1.1 SAE PUBLICATIONS

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

SAE EA-1128—Wire Color Charts
SAE J311—Fluid for Passenger Car Type Automatic Transmission
Dictionary of Materials and Testing

2.1.2 ASTM DOCUMENTS

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

ASTM B33—Standard Specification for Tinned Soft or Annealed Copper Wire
ASTM B193—Standard Test Method for Resistivity of Electrical Conductor Materials
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 E145—Standard Specification for Gravity-Convection and Forced-Ventilation Ovens
ASTM F1251—Standard Terminology Relating to Polymeric Biomaterials in Medical and Surgical Device

2.1.3 IEC DOCUMENTS

Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002

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 Specifications

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

2.2.1 SAE PUBLICATIONS

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

SAE J156—Fusible Links
SAE J1067—Seven Conductor Jacketed Cable for Truck Trailer Connections
SAE J1127—Low Voltage Battery Cable
SAE J1128—Low Voltage Primary Cable
SAE J1292—Automobile, Truck, Truck-Tractor, Trailer, And Motor Coach Wiring
SAE J1654—High Voltage Primary Cable
SAE J1673—High Voltage Automotive Wiring
SAE J2183—60 V and 600 V single core cables - Test methods, dimensions and requirements
SAE J2501—Round, unscreened, 60 V and 600 V multicore sheathed cables - Basic and high performance test methods and requirements

2.2.2 ASTM DOCUMENTS

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

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 DOCUMENTS

Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002

ISO 6722—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 h 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 h of heat aging.

3.2 Additional Mass (ref. "Resistance to Sandpaper Abrasion" test)

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.

3.3 Coated Wire

Wire comprised of a given metal covered with a relatively thin application of a different metal. (ASTM B 354)

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 finshed 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 V DC (25 V AC).

3.11 Minimum Wall (Thickness)

The lowest allowable insulation thickness at any point.

3.12 Nominal

Name or identifying value of a measurable property by which a conductor or component or property identified, and to which tolerances may be applied.

3.13 Plastics

Any of numerous polymeric materials that are usually thermoplastic or thermosetting, of high molecular weight and that can be molded, cast, extruded, drawn, laminated, or otherwise fabricated into objects, powders, beads, films, filaments, fibers, or other shapes. (ASTM F-1251)

3.14 Primary Cable

The single or multi-stranded, single conductor, insulated cable used to carry electric current, by attachment to the low voltage side of an ignition coil in surface vehicles.

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

See “Wire”.

3.20 TCR

See “3000 h 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

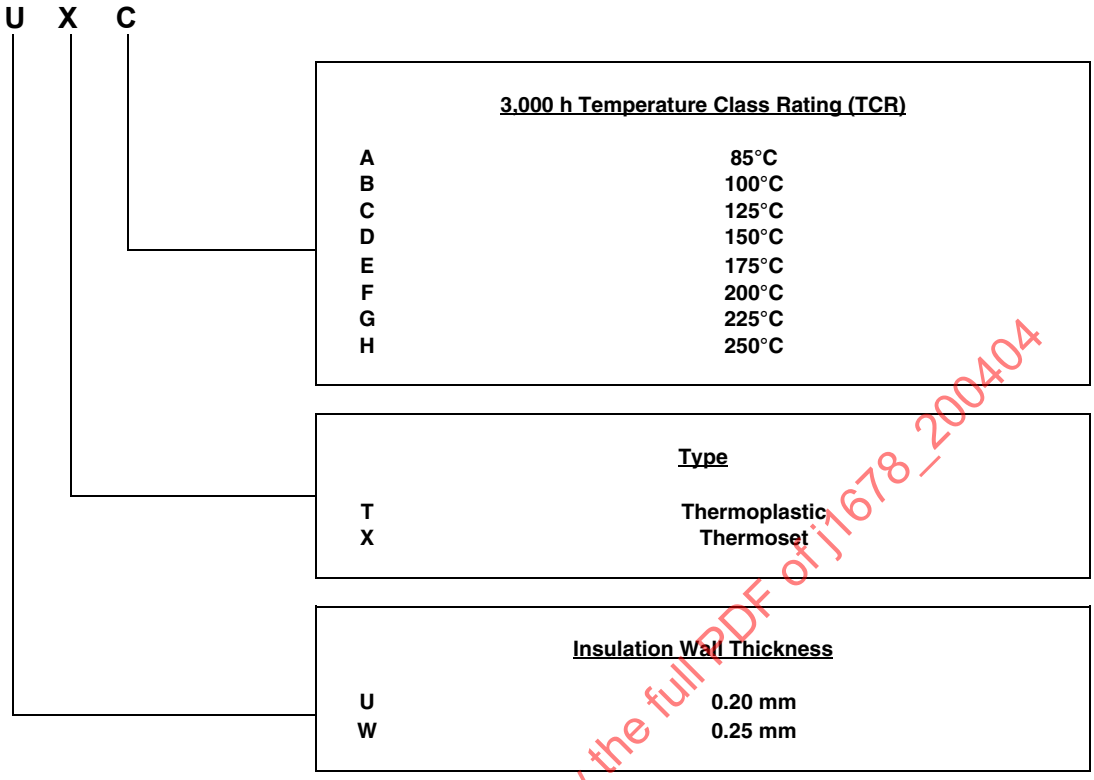


FIGURE 1—CABLE TYPES (REF. 4.1)

In this example, UXC, the cable has an "Insulation Wall Thickness" of 0.20 mm, "Thermoset", with a "3,000 h Temperature Class Rating" of 125°C.

4.2 General Test Conditions

Test samples for all tests except 6.3 shall be preconditioned for at least 16 h at a room temperature of 23°C ± 5°C. Unless otherwise specified, all tests shall be conducted at this same temperature.

4.3 Ovens

Unless otherwise specified, when an oven is required, it shall be a hot air oven in accordance with ASTM E145 Type I. The air contained in the oven shall be completely changed at least 8 times but not more than 20 times per h at the specified temperature.

4.4 Tolerances

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

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	Required	If Required
5	**General Specifications**		
5.1	Conductor		
5.2	Conductor Resistance	*	
5.3	Insulation		
5.4	Outside Cable Diameter	*	
5.5	Wall Thickness	*	
5.6	Winding		
6	**Tests**		
6.1	Strand Coating	Note 1	
6.2	Solderability	*	
6.3	Heat Aging	Note 2	
6.4	Thermal Excursions	Note 2	
6.5	Withstand Voltage	*	
6.6	Cold Bend	*	
6.7	Resistance to Flame Propagation	*	
6.8	Fluid Compatibility	Note 2	
6.9	Resistance to Ozone		Notes 2 & 5
6.10	Resistance to Pinch	*	
6.11	Resistance to Sandpaper Abrasion	*	
6.12	Strip Force		Note 3
6.13	Resistance to Hot Water		Notes 2 & 5
6.14	Insulation Volume Resistivity		Note 4
6.15	Temperature and Humidity Cycling		Notes 2 & 5

Notes:
1) This test is only required for coated copper wires.
2) Compliance for a cable family my be demonstrated by using "Representative Conductor Sizes for Testing", see 4.5.
3) The requirements for the "Strip Force" test, if any, will be established by agreement between the supplier and the customer.
4) This test is only used as part of the "Resistance to Hot Water" test
5) This test is for initial qualification only.

FIGURE 2—GENERAL SPECIFICATIONS (REF. CLAUSE 5)

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.

5.2 Conductor Resistance

The resistance of uncoated, silver coated, tin coated, and nickel coated conductors shall not be greater than the "Conductor Resistance Maximum" specified in Figure 3. When another material is used as the conductor, the maximum resistance shall be established by agreement between the supplier and customer.

5.2.1 Test Sample

Prepare a test sample of 1 m length plus the length necessary for connections. Other lengths may be used providing that the resistance reading is adjusted using the method shown in 5.2.3. The ends of the test sample may be soldered.

5.2.2 Apparatus

Use a resistance measuring device with an accuracy of ± 0.5 % of the measured value and a thermometer with an accuracy of ± 0.5°C.

5.2.3 Procedure

Measure the temperature of the test sample and the unsoldered length. Care should be taken to insure that connections are secure. Measure the resistance of the test sample. Calculate the resistance at 20°C using the method in ASTM B193. Other methods may be used; however, in case of a dispute, the referee shall be the resistance method.

5.2.4 Requirement

The corrected value shall not exceed the appropriate "Conductor Resistance Maximum" specified in Figure 3.

5.3 Insulation

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. A separator shall be used between uncoated conductors and insulations with a sulfur cure. Separators are optional for other constructions.

SAE[1] Conductor Size mm²	Conductor Resistance Maximum mΩ/m @ 20°C		
	Silver Coated & Uncoated Copper	Tin Coated Copper	Nickel[2] Coated Copper
0.13	136	146	142
0.22	84.9	91.2	88.5
0.35	53.9	57.8	45.1
0.5	34.3	36.4	35.7
0.8	23.0	24.7	23.9
1	15.5	16.6	16.1
2	9.44	10.0	9.83
3	6.00	6.37	6.25

Notes:
1) The conductor size is the approximate nominal area of the conductor.
2) Class 2, Nickel Coated Copper

FIGURE 3—CONDUCTOR RESISTANCE (REF. 5.2)

5.4 Outside Cable Diameter

5.4.1 Test Samples

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

5.4.2 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.

5.4.3 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.

5.4.4 Requirement

The mean of the diameter readings shall not exceed the “Outside Cable Diameter Maximum” specified in Figure 4.

SAE Conductor Size mm^2	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)
0.13	0.20	0.16	1.10	0.25	0.20	1.20
0.22	0.20	0.16	1.20	0.25	0.20	1.30
0.35	0.20	0.16	1.40	0.25	0.20	1.50
0.5	0.20	0.16	1.60	0.25	0.20	1.70
0.8	0.20	0.16	1.90	0.25	0.20	2.00
1	0.20	0.16	2.20	0.25	0.20	2.30
2	0.20	0.16	2.60	0.25	0.20	2.70
3	0.25	0.20	3.20	0.30	0.24	3.30

FIGURE 4—OUTSIDE CABLE DIAMETER AND WALL THICKNESS (REF. 5.4 & 5.5)

5.5 Wall Thickness

5.5.1 Test Samples

Prepare three test samples from a cable sample 3 m in length. Take the test samples at 1 m 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.

5.5.2 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.

5.5.3 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”.

5.5.4 Requirement

No single value shall be less than the appropriate “Wall Thickness, Minimum” specified in Figure 4.

5.6 Winding

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

5.6.1 Test Samples

See individual test.

5.6.2 Apparatus

See Figure 5 for mandrel sizes

5.6.3 Procedure

Wind the test sample around the mandrel using the "Mandrel Size", "Winding Speed", and "Number of Turns, Minimum" 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.

5.6.4 Requirement

See individual test.

Mandrel Diameter		Winding speed	Minimum Number
Reference Clauses	Reference Clauses		
6.3, 6.4, & 6.15	6.6, 6.8, 6.9, & 6.13	s^{-1}	Of Turns
≤ 1.5 X Outside Cable Diameter Maximum	≤ 5 X Outside Cable Diameter Maximum	0.2	3

FIGURE 5—WINDING (REF. 6.3, 6.4, 6.6, 6.8, 6.9, 6.13 & 6.15)

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, B298, or B355.

6.1.2 APPARATUS

See the applicable section of ASTM B33, B298, or B355.

6.1.3 PROCEDURE

See the applicable section of ASTM B33, B298, or B355.

6.1.4 REQUIREMENT

See the applicable section of ASTM B33, B298, or B355.

6.2 Solderability

This test is not required for coated strands.

6.2.1 TEST SAMPLES

25 mm of insulation shall be removed from a 300 mm sample of finished cable.

6.2.2 APPARATUS

A component lead tinning flux such as Kester #2164 flux and solder [30 % to 40 % Sn, remainder Pb] at 400°C to 425°C. Other fluxes and solders may be used; however, in case of a dispute, the referee shall be the Kester #2164 and solder shown in this specification.

6.2.3 PROCEDURE

Immerse the test sample in the solder for 3 s to 5 s. Make a visual inspection of the area which was immersed in the solder.

6.2.4 REQUIREMENT

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 “Representative Conductor Sizes for Testing”, see clause 4.5.

6.3.1 INITIAL CERTIFICATION OF THE “TEMPERATURE CLASS RATING”

6.3.1.1 Long term aging, 3000 h

This test is intended to confirm the “Temperature class rating” 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 at the temperature specified in Figure 6.

6.3.1.1.3 Procedure

Place the test samples in the oven for 3000 h. 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 ± 5)°C for at least 16 h. After conditioning at room temperature, perform the "Winding" test in clause 5.6. 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 min.

6.3.1.1.4 Requirements

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

Temperature Class Rating (TCR)	Test Temperature (°C)	
	Ref. Clauses 6.3 & 6.15	Ref. Clause 6.4
A	85 ± 2	135 ± 3
B	100 ± 2	150 ± 3
C	125 ± 3	175 ± 3
D	150 ± 3	200 ± 3
E	175 ± 3	225 ± 3
F	200 ± 3	250 ± 3
G	225 ± 3	275 ± 3
H	250 ± 3	300 ± 3

FIGURE 6—LONG-TERM AGING, SHORT-TERM AGING, AND TEMPERATURE AND HUMIDITY CYCLING TEST CONDITIONS (REF. 6.3, 6.4, & 6.15)

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 6.3.1.2.3.

6.3.1.4 Procedure

Set the oven temperature at the TCR + 25°C. Follow the procedure in 6.3.1.1.3; however, the aging time shall be 240 h. If all test samples meet the requirement in 6.3.1.1.4, increase the oven temperature by 5°C and repeat the procedure. Continue to increase the test temperature in 5°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°C.

6.3.1.4.1 Requirement

See clause 6.3.1.1.4

6.3.2 PERIODIC CERTIFICATION OF THE “TEMPERATURE CLASS RATING”

This section is intended to confirm the “Temperature class rating” 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 h.

6.3.2.1.4 Requirement

See clause 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, Long term aging, 3000 h.

6.4 Thermal Excursions

This test is intended to simulate thermal excursions. Compliance for a cable family may be demonstrated by using “Representative Conductor Sizes for Testing”, see clause 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 at the temperature specified in Figure 6. The mandrels are specified in Figure 5.

6.4.3 PROCEDURE

Place the test samples in the oven for 6 h. 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 ± 5)°C for at least 16 h. After conditioning at room temperature, perform the "Winding” test in clause 5.6. 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 min.

6.4.4 REQUIREMENT

After winding no conductor shall be visible. During the "Withstand voltage” test, breakdown shall notoccur.

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 or 60 Hz voltage source shall be used.

6.5.3 PROCEDURE

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

6.5.4 REQUIREMENT

Breakdown shall not occur.

6.6 Cold Bend

6.6.1 TEST SAMPLES

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

6.6.2 APPARATUS

A freezing chamber at -40°C ± 2°C. The mandrel size is specified in Figure 5.

6.6.3 PROCEDURE

The test samples and mandrel shall be conditioned for a minimum of 4 h in the freezing chamber. Perform the “Winding” test in clause 5.6. After the cold winding, allow the test sample to return to room temperature, and make a visual inspection of the insulation. If no exposed conductor is visible, perform the "Withstand Voltage" test (see 6.5) except the voltage will be applied after immersion in the salt solution for a minimum of 10 min.

6.6.4 REQUIREMENT

After winding, a visual inspection of the insulation shall show neither cracks, fractures nor other defects. During the "Withstand Voltage” test, breakdown shall not occur.

6.7 Resistance to Flame Propagation

6.7.1 TEST SAMPLE

Prepare a test sample with at least 600 mm of insulation.

6.7.2 APPARATUS

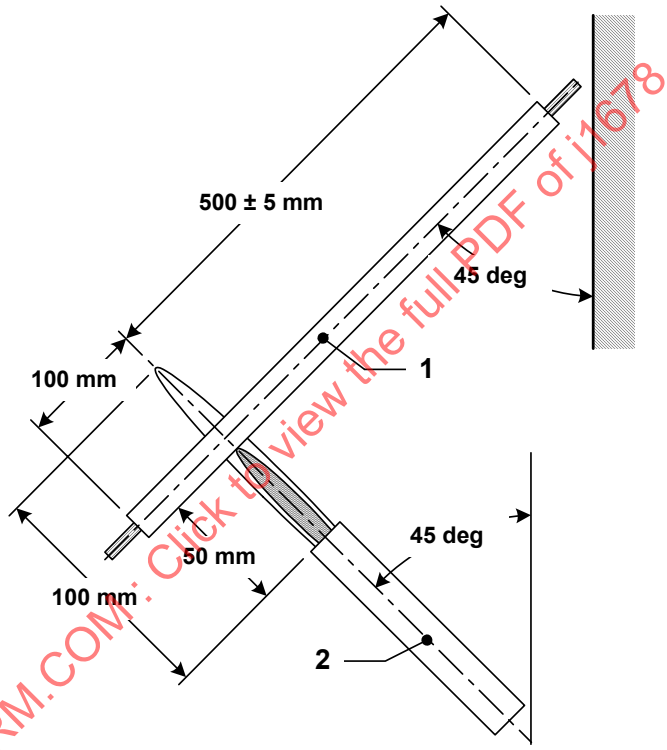
A gas burner having a 13 mm inlet, a nominal core of 10 mm, and a length of 100 mm above the primary inlets. The gas burner shall be adjusted to produce a 100 mm gas flame with an inner cone ½ of its height.

6.7.3 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 7. The time of exposure to the test flame shall be 15 s. However, the exposure time shall not be longer than the time at which the conductor becomes visible.

6.7.4 REQUIREMENT

Any combustion flame of insulating material shall extinguish within 70 s and a mnimum of 50 mm of insulation at the top of the test sample shall remain unburned.



Key:
1 Test sample
2 Gas burner

FIGURE 7—APPARATUS FOR “RESISTANCE TO FLAME PROPAGATION” (REF. 6.7)

6.8 Fluid Compatibility

The tests are intended to qualify cables for limited exposure to fluids. Additional tests will be necessary o qualify cables for continuous immersion. Compliance for a cable family may be demonstrated by sing “Representative Conductor Sizes for Testing”, see clause 4.5.

6.8.1 Test Samples

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

6.8.2 Apparatus

The apparatus for measuring the cable diameter shall be the same as that shown in 5.4. Vessels shall be filled with the fluids at the temperatures shown in Figure 8. See Figure 5 for mandrels.

6.8.3 Procedure

The “Outside Cable Diameter” of each test sample shall be determined using the procedure described in 5.4. The area of the sample to be subjected to the bend test shall be immersed in the fluid shown in Figure 8 for a period of 20 (+1, -0) h. After removal from the fluid, remove excess fluid from the sample. Allow it to dry at room temperature for 4 h. Within the 5 min 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 clause 5.6.If no exposed conductor is visible, perform the "Withstand Voltage" test (see 6.5) except the voltage will be applied after immersion in the salt solution for a minimum of 10 min.

Test Fluid		Test Tempperature	Outside Cable Diameter Maximum Change
Name	Fluid	°C	%
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 III, SAE J311	50 ± 3	25
Engine Coolant	50% Distilled Water + 50% Ethylene Glycol	50 ± 3	15
Battery Acid	H_2SO_4, Specific Gravity = 1.260 ± .005	23 ± 5	5

Note:
Solutions are determined as % by volume.

FIGURE 8—FLUID COMPATIBILITY (REF. 6.8)

6.8.4 Requirement

The maximum diameter change shall meet the requirements shown in Figure 8. After the winding test, a visual inspection of the insulation shall show neither cracks, fractures nor other defects. During the "Withstand Voltage" test, breakdown shall not occur.

6.9 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 "Representative Conductor Sizes for Testing", see clause 4.5.

6.9.1 Test Sample

Prepare a sample of 300 mm.

6.9.2 Apparatus

An ozone chamber in accordance with IEC 60811-2-1, with an atmosphere containing 100 ± 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.

6.9.3 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) h 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.

6.9.4 Requirement

A visual inspection of the insulation shall show neither cracks, fractures, nor other defects.

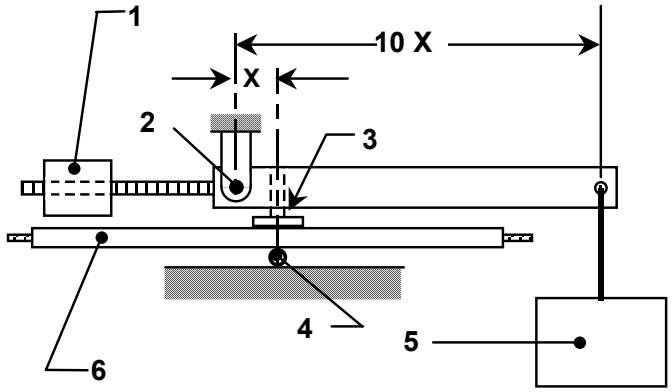
6.10 Resistance to Pinch

6.10.1 Test Sample

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

6.10.2 Apparatus

The apparatus shall be as shown in Figure 9. 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 10.



Key:
1 Counter Balance
2 Pivot
3 Anvil
4 Rod
5 Applied Mass
6 Test Sample

FIGURE 9—APPARATUS FOR "RESISTANCE TO PINCH" TEST (REF. 6.10)

6.10.3 PROCEDURE

The sample shall then be placed taut without stretching across a 3 mm diameter steel rod as shown in Figure 9. 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 per 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 deg. Four readings shall be obtained for each sample. The mean of the four readings shall determine the pinch resistance of the cable under test.

6.10.4 REQUIREMENT

The "Resistance to Pinch, Minimum" for each cable type and size is shown in Figure10.

6.11 Resistance to Sandpaper Abrasion

6.11.1 TEST SAMPLE

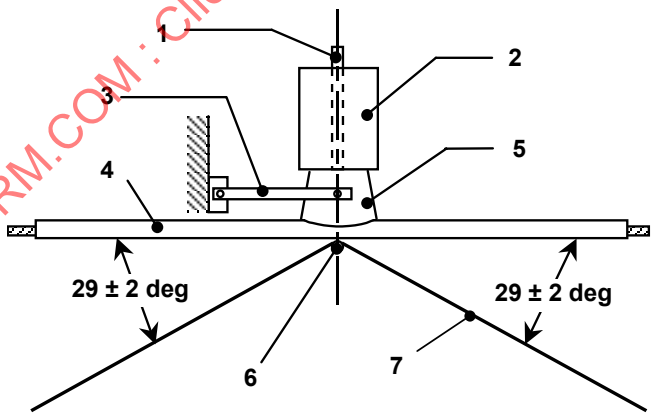
Prepare a test sample of 1 m and remove 25 mm of insulation from each end.

6.11.2 APPARATUS

Measure the "Resistance to sandpaper abrasion" using 150J garnet sandpaper tape with 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 15,000 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 (see Figure 11) to maintain the test sample position over an unused portion of the sandpaper abrasion tape. Exert a force of 0.63 N ± 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 12 for the additional mass.

SAE Conductor Size mm^2	Wall Thickness	
	U kg	W kg
0.13	0.3	0.7
0.22	0.4	1.0
0.35	0.5	1.0
0.5	0.7	1.0
0.8	0.9	1.5
1	1.1	1.5
2	1.3	1.5
3	1.5	1.5

FIGURE 10—RESISTANCE TO PINCH, MINIMUM (REF. 6.10)



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

FIGURE 11—APPARATUS FOR "RESISTANCE TO SANDPAPER ABRASION" (REF. 6.11)

6.11.3 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 ± 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".

6.11.4 REQUIREMENT

The "Resistance to Sandpaper Abrasion" shall meet or exceed the "Minimum Length of Sandpaper" requirements in Figure 13.

SAE Conductor Size mm^2	Additional Mass g		Minimum Length Of Sandpaper mm	
	Type U	Type W	Type U	Type W
0.13	50	100	150	200
0.22	50	100	175	300
0.35	50	100	200	350
0.5	100	220	175	200
0.8	100	220	200	300
1	100	220	225	350
2	100	220	250	400
3	220	450	150	250

FIGURE 12—"RESISTANCE TO SANDPAPER ABRASION (REF. 6.11)

6.12 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.

6.12.1 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.

6.12.2 APPARATUS

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

6.12.3 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.

6.12.4 REQUIREMENT

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

6.13 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 “Representative Conductor Sizes for Testing”, see clause 4.5.

6.13.1 TEST SAMPLE

Prepare a two test samples of 2.5 m ± 0.1 m and remove 25 mm of insulation from each end.

6.13.2 APPARATUS

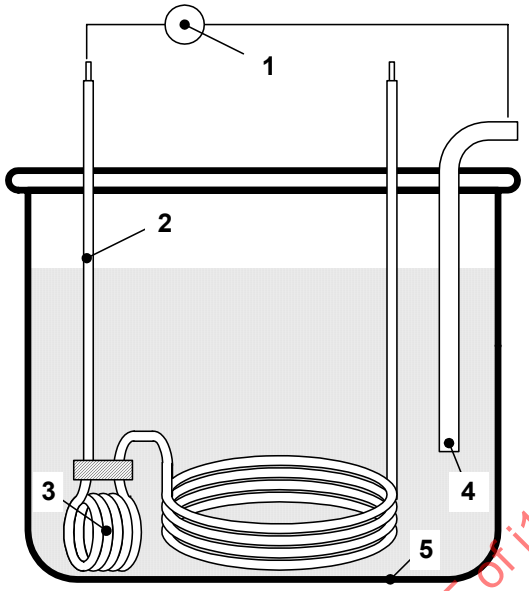
The apparatus consists of an electrically nonconductive vessel containing an unused salt water bath with 10 g/l of NaCl in water at 85°C ± 5°C for each test, a 48 V DC power source. See Figure 5 for mandrel sizes.

6.13.3 PROCEDURE

Closely wind at least three complete turns of a test sample on the mandrel and secure the wraps as shown in Figure 13. Immerse the test sample in the bath with both ends projecting 250 mm above the bath. To avoid interaction between materials, do not test samples with different insulating materials in the same bath. Connect one end of the test sample and the positive electrode of the power source. After 7 days, disconnect the power supply, and measure the “Insulation volume resistivity”. Make the following changes to the procedure in 6.15.

Measure the “Insulation volume resistivity” in the salt water bath and at the temperature described in 6.14.2.

This completes one cycle. Repeat this procedure for a total of 5 cycles, i.e. 35 days. After conditioning, remove the test sample from the bath, allow it to cool to room temperature, and make a visual examination of the insulation. Ignore any damage caused by the ties which secure the coils. If no exposed conductor is visible, perform the "Withstand voltage" test (see 6.5) except the voltage will be applied after immersion in the salt solution for a minimum of 10 min. Perform the entire procedure for the second test sample with the polarity of the DC power source reversed.



Key:
1 48 V DC power source
2 Test sample
3 Closely wound turns of test sample
4 Copper electrode
5 Non-conductive vessel

FIGURE 13—APPARATUS FOR "RESISTANCE TO HOT WATER" (REF. 6.13)

6.13.4 REQUIREMENT

The "Insulation Volume Resistivity" shall not be less than 10^9 Ω •mm. A visual inspection of the insulation shall show no cracks. During the "Withstand Voltage" test, breakdown shall not occur.

6.14 Insulation Volume Resistivity

This test is only used as part of the "Resistance to Hot Water" test

6.14.1 TEST SAMPLE

See 6.14.1.

6.14.2 APPARATUS

See 6.13.2 for the salt water bath. Use a resistance measuring device with a DC voltage of 500 V. Voltages between 100 V and 500 V are allowed, if measured results conform with the results obtained using 500 V.