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INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

SURFACE VEHICLE STANDARD

SAE J1678

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Submitted for recognition as an American National Standard

Low-Voltage Ultrathin Wall Primary Cable

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1. Scope—This SAE Standard covers low-voltage, ultrathin wall, primary cable intended for use at a nominal system voltage of 60 V DC 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 document covers SAE wire sizes which usually differ from ISO wire sizes.

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. Unless otherwise stated, the latest issue of SAE publications shall apply.

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
SAE Dictionary of Materials and Testing

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

ASTM B 33—Standard Specification for Tinned Soft or Annealed Copper Wire
ASTM B 193—Standard Test Method for Resistivity of Electrical Conductor Materials
ASTM B 298—Standard Specification for Silver-Coated Soft or Annealed Copper Wire
ASTM B 354—Definitions of Terms Relating to Uninsulated metallic Electrical Conductors
ASTM B 355—Standard Specification for Nickel-Coated Soft or Annealed Copper Wire
ASTM D 471—Standard Test Method for Rubber Property – Effect of Liquids
ASTM F 1251—Standard Terminology Relating to Polymeric Biomaterials in Medical and Surgical Device

2.1.3 IEC PUBLICATIONS—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002

IEC 811-2-1—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 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 Tension Battery Cable
SAE J1128—Low Tension 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

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

ASTM B 1—Standard Specification for Hard-Drawn Copper Wire
ASTM B 3—Standard Specification for Soft or Annealed Copper Wire
ASTM B 8—Concentric-Lay-Stranded Copper conductors, Hard, Medium-Hard, or Soft
ASTM B 174—Standard Specification for Bunch-Stranded Copper Conductors for Electrical Conductors
ASTM B 263—Method for Determination of Cross-Sectional Area of Standard Conductors
ASTM B 452—Standard Specification for Copper-Clad Steel Wire for Electronic Application
ASTM B 787—19 Wire Combination Unilay-Stranded Copper Conductors for Subsequent Insulation
ASTM E 145—Standard Specification for Gravity-Convection and Forced-Ventilation Ovens

2.2.3 ISO PUBLICATIONS—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

3. *Definitions*

3.1 **3000 h Temperature Class Rating—**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. "Sandpaper Abrasion Resistance" 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 **Conductor—**A wire or combination of wires not insulated from one another, suitable for carrying an electrical current. (ASTM B 354)

3.6 **Fluid Compatibility—**The ability of a cable to resist the effects of various fluids found in surface vehicles.

3.7 **Hot Plate—**An electrically heated device used to test thermoset cables.

3.8 **Low Voltage—**Usually considered to be ≤60 V DC.

3.9 **Minimum Wall (Thickness)—**The lowest allowable insulation thickness at any point.

3.10 **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.

3.11 **Ozone Resistance—**The ability of a material to withstand the deteriorating effect of ozone (surface cracking). SAE, Dictionary of Materials and Testing.

3.12 **Plastic—**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)

3.13 **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.

3.14 **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)

3.15 **Strip Force—**The peak axial force required to overcome the adhesion between the conductor and the insulation.

3.16 **Strand—**See wire.

3.17 **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)

3.18 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)

3.19 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 B 354)

4. General

4.1 Cable Types—See Figure 1.

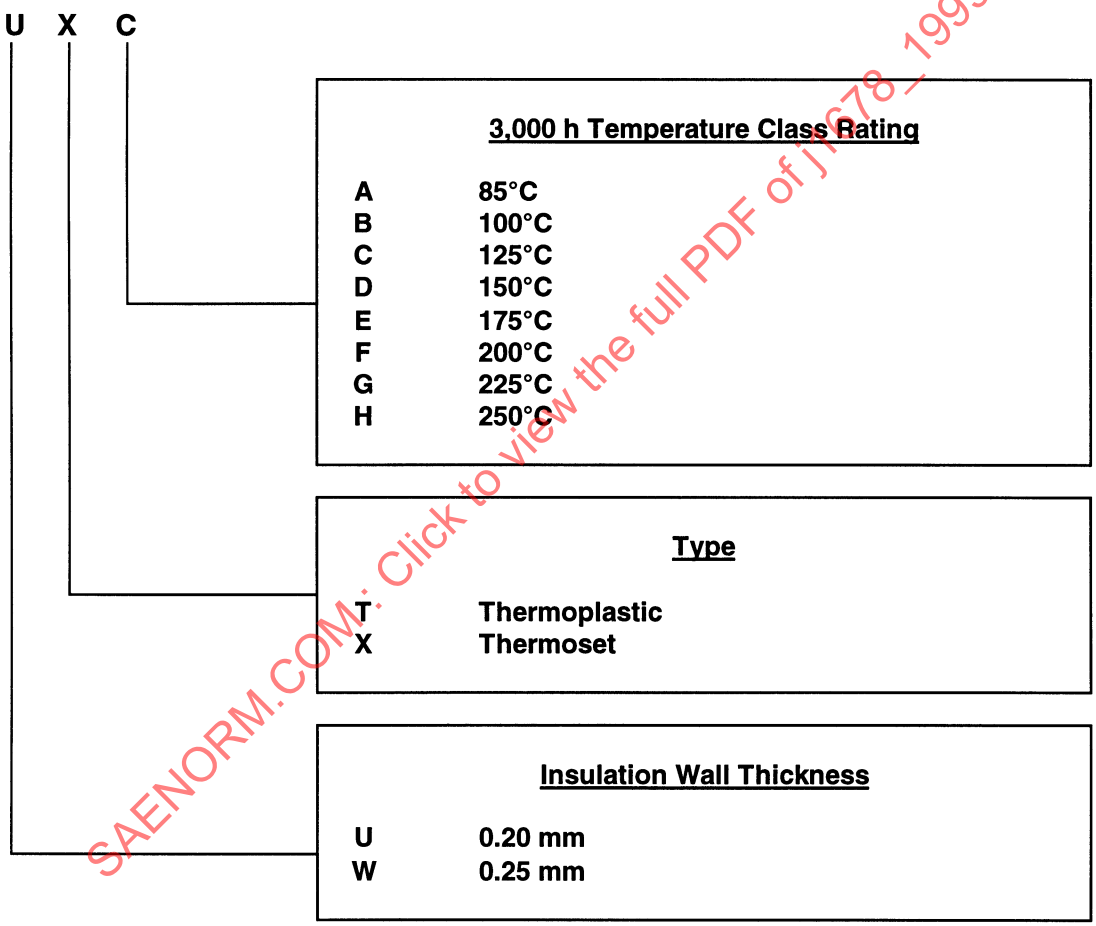

FIGURE 1—CABLE TYPES
(REF. 4.1)

In this example, UXC, the cable has an insulation wall thickness of 0.20 mm, Thermoset, with a 3000 h temperature 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. 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.

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

Section	Description	Required for SAE Cable Type		If Required
		T = Thermoplastic	X = Thermoset	
5	**General Specifications**			
5.1	Conductor			
5.2	Conductor Resistance	*	*	
5.3	Insulation			
5.4	Outside Diameter	*	*	
5.5	Minimum Wall Thickness	*	*	
6	**Tests**			
6.1	Strand Coating	Note 1	Note 1	
6.2	Solderability	*	*	
6.3	Long Term Aging, 3000 h	Note 5	Note 5	
6.4	Short Term Aging, 240 h	*	*	
6.5	Withstand Voltage	*	*	
6.6	Cold Bend	*	*	
6.7	Flame Resistance	*	*	
6.8	Fluid Compatibility	*	*	
6.9	Ozone Resistance			Notes 2 & 5
6.10	Pinch Resistance	*	*	
6.11	Sandpaper Abrasion Resistance	*	*	
6.12	Hot Plate		*	
6.13	Strip Force			Note 3
6.14	Hot Water Resistance			Notes 2 & 5
6.15	Insulation Volume Resistivity			Note 4
6.16	Environmental Cycling			Notes 2 & 5

Notes:

1) This test is only required for coated copper wires.
2) At least one wire size shall be tested; however, for comparative purposes 0.8 mm^2 is preferred.
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 "Hot Water Resistance" test
5) This test is for initial qualification only.

FIGURE 2—GENERAL SPECIFICATIONS
(REF. Section 5)

5.1 Conductors—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 values 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.

SAE[1] Wire Size mm^2	Maximum Resistance @ 20°C		
	Silver Coated & Uncoated Copper mΩ/m	Tin Coated Copper mΩ/m	Nickel[2] Coated Copper mΩ/m
0.13	136	146	142
0.22	84.9	91.2	88.5
0.35	53.9	57.8	56.1
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 wire size is the approximate nominal area of the conductor.
2) Class 2, Nickel Coated Copper

FIGURE 3—CONDUCTOR RESISTANCE
(REF. 5.2)

5.2.1 TEST SAMPLE—The test sample length shall be 1 m plus the length necessary for connections. The ends of the test sample may be soldered.

5.2.2 APPARATUS—The accuracy of the resistance measuring device shall be ±0.15% of the measured value. A thermometer with an accuracy of ±0.5 °C shall be used.

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 B 193. 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 maximum resistance 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.

5.4 Outside 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 finished cable diameter. Measurements shall be taken to determine the outside diameter of each test sample to ±0.01 mm.

5.4.4 REQUIREMENT—The mean of the diameter readings shall not exceed the maximum cable diameter specified in Figure 4.

SAE Wire Size mm^2	Wall Thickness, U			Wall Thickness, W		
	Wall Thickness Nominal (mm)	Wall Thickness Minimum (mm)	Maximum Diameter (mm)	Wall Thickness Nominal (mm)	Wall Thickness Minimum (mm)	Maximum Diameter (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 DIAMETER AND MINIMUM WALL THICKNESS
(REF. 5.4 AND 5.5)

5.5 Minimum Wall Thickness

5.5.1 TEST SAMPLES—The test samples shall consist of three separate cross sections spaced 1 m apart. The insulation shall be stripped from the cable. A test sample shall consist of a thin cross-section of insulation. Care should be taken not to deform the test sample.

5.5.2 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.

5.5.3 PROCEDURE—Measurements shall be taken to determine the minimum insulation thickness of each test sample to ±0.01 mm.

5.5.4 REQUIREMENT—No single value shall be less than the appropriate minimum insulation thickness specified in Figure 4.

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 B 33, B 298, or B 355.

6.1.2 APPARATUS—See the applicable section of ASTM B 33, B 298, or B 355.

6.1.3 PROCEDURE—See the applicable section of ASTM B 33, B 298, or B 355.

6.1.4 REQUIREMENT—See the applicable section of ASTM B 33, B 298, or B 355.

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 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 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 Long-Term Aging, 3000 h—This test is for initial qualification only.

6.3.1 TEST SAMPLES—Prepare two test samples of 350 mm minimum and remove 25 mm of insulation from each end.

6.3.2 APPARATUS—The “Long-Term Aging” test shall be performed using an oven at the temperature specified in Figure 5. The mandrels used in the winding test are specified in Figure 6. When a rotating mandrel is used, the mass shall be adequate to maintain continuous contact between the cable and the mandrel.

6.3.3 PROCEDURE—Test samples shall be placed for 3000 (+8, –0) h, in the oven. The samples shall be fixed by the conductor to avoid any contact between the insulation and the supports. The 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 in the same oven at the same time. Immediately after aging, the samples are withdrawn from the oven and maintained at 23 °C ± 5 °C for at least 16 h, and then perform the winding test in 6.6 except the winding is performed at room temperature. 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.

Temperature Class Rating	Test Temperature (°C) Ref. Clauses 6.3 & 6.16	Ref. Clause 6.4
A	85 ± 2	110 ± 3
B	100 ± 2	125 ± 3
C	125 ± 3	150 ± 3
D	150 ± 3	175 ± 3
E	175 ± 3	200 ± 3
F	200 ± 3	225 ± 3
G	225 ± 3	250 ± 3
H	250 ± 3	275 ± 3

FIGURE 5—LONG- AND SHORT-TERM AGING ENVIRONMENTAL CYCLING TEST CONDITIONS
(REF. 6.3, 6.4, AND 6.16)

SAE Wire Size mm^2	Mandrel Diameter Ref. Clause 6.3 & 6.16 d x 1.8 (+0.0, -0.6d)	Ref. Clauses 6.4 & 6.6 d x 6 (+0, -2d)	Ref. Clause 6.8 (mm)	Winding speed s^{-1}	Minimum Number Of Turns
0.13	1.8 x d	6 x d	25	0.2	3
0.22	1.8 x d	6 x d	25	0.2	3
0.35	1.8 x d	6 x d	25	0.2	3
0.5	1.8 x d	6 x d	75	0.2	3
0.8	1.8 x d	6 x d	75	0.2	3
1	1.8 x d	6 x d	75	0.2	3
2	1.8 x d	6 x d	150	0.2	3
3	1.8 x d	6 x d	150	0.2	3

Note:
d = the maximum cable diameter specified in FIGURE 4

FIGURE 6—WINDING TEST
(REF. 6.3, 6.4, 6.6, 6.8, AND 6.16)

6.3.4 REQUIREMENT—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.

6.4 Short-Term Aging, 240 h

6.4.1 TEST SAMPLES—Prepare two test samples of 350 mm minimum and remove 25 mm of insulation from each end.

6.4.2 APPARATUS—The “Short-Term Aging” test shall be performed using an oven at the temperature specified in Figure 5 and a freezing chamber at –25 °C ± 2 °C. The mandrels used in the winding test are specified in Figure 6. When a rotating mandrel is used, the mass shall be adequate to maintain continuous contact between the cable and the mandrel.

6.4.3 PROCEDURE—Test samples shall be placed for 240 h (+1, –0 h) in the oven. The samples shall be fixed by the conductor to avoid any contact between the insulation and the supports. The 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 in the same oven at the same time. Immediately after aging, the samples are withdrawn from the oven and maintained at 23 °C ± 5 °C for at least 16 h, and then perform the winding test in 6.6 using the freezing chamber and the mandrels described in 6.4.2. After 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.

6.4.4 REQUIREMENT—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.

6.5 Withstand Voltage

6.5.1 TEST SAMPLE—The test sample length shall be a minimum of 350 mm. Strip approximately 25 mm of insulation from each end of the test sample and twist them together to form a loop.

6.5.2 APPARATUS—Partially fill a glass jar with a salt solution [5% 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 6. Either a rotatable or stationary mandrel may be used.

6.6.2.1 Rotatable Mandrel—When a rotatable mandrel is used, the mass shall be adequate to maintain continuous contact between the cable and the mandrel.

6.6.2.2 Stationary Mandrel—When a stationary mandrel is used, no mass is used.

6.6.3 PROCEDURE—The test samples and mandrel shall be conditioned for a minimum of 4 h in the freezing chamber. Wind at least the minimum number of turns specified in Figure 6 around the mandrel within the freezing chamber at winding speed as specified in Figure 6. Care shall be taken to ensure that there is continuous contact between the test samples and the mandrel. 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 Flame Resistance

6.7.1 TEST SAMPLE—Prepare a test sample of 600 mm.

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 minimum of 50 mm of insulation at the top of the test sample shall remain unburned.

6.8 Fluid Compatibility

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 6 for mandrels. Either a rotatable or stationary mandrel may be used.

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 30 min. 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. The conditioned sample shall be wrapped around the mandrel using the winding speed and number of turns specified in Figure 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.

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.

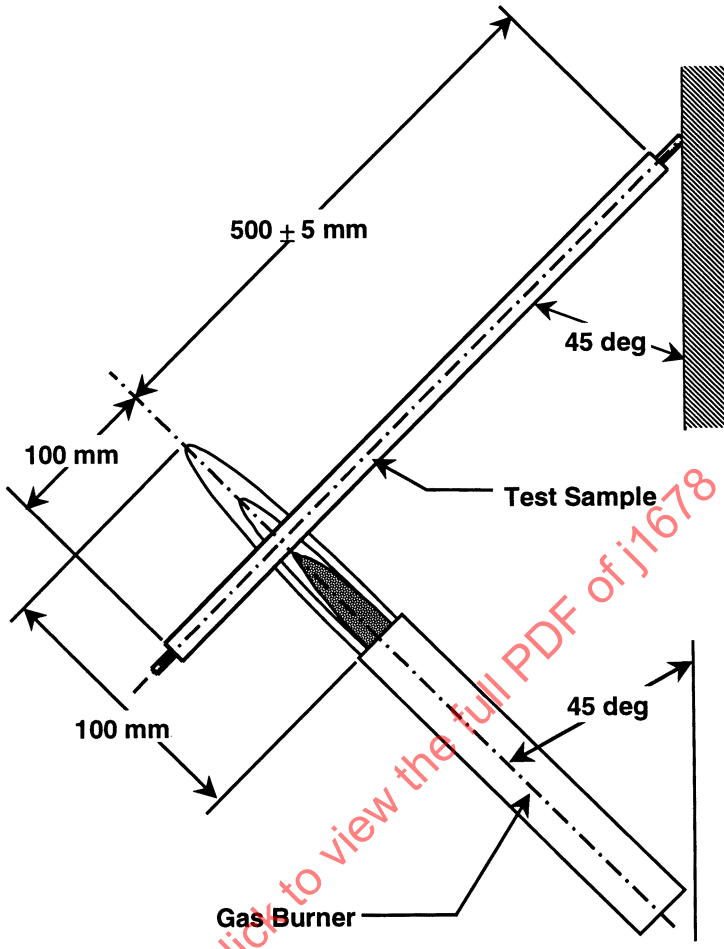

FIGURE 7—FLAME RESISTANCE TEST
(REF. 6.7)

Test Fluid		Test Temp	Maximum OD 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	Citgo # 33123, 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

6.9 Ozone Resistance—This test is for initial qualification only. The usage of this test will be established by agreement between customer and supplier. At least one wire size shall be tested; however, for comparative purposes 0.8 mm^2 is preferred.

6.9.1 TEST SAMPLE—Prepare a sample of 300 mm.

6.9.2 APPARATUS—An ozone chamber in accordance with IEC 811-2-1, with an atmosphere containing 100 pphm ± 5 pphm of ozone at 65 °C ± 3 °C. See Figure 9 for mandrel sizes. Aluminum mandrels are preferred since other materials may affect the ozone concentration.

SAE Wire Size mm^2	Mandrel Diameter mm
0.13	6
0.22	6
0.35	6
0.5	6
0.8	6
1	6
2	6
3	13

FIGURE 9—OZONE RESISTANCE TEST CONDITIONS
(REF. 6.9)

6.9.3 PROCEDURE—Wind at least the minimum number of turns specified in Figure 6 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 Pinch Resistance

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 10. 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.

6.10.3 PROCEDURE—The sample shall then be placed taut without stretching across a 3 mm diameter steel rod as shown in Figure 10. 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 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.

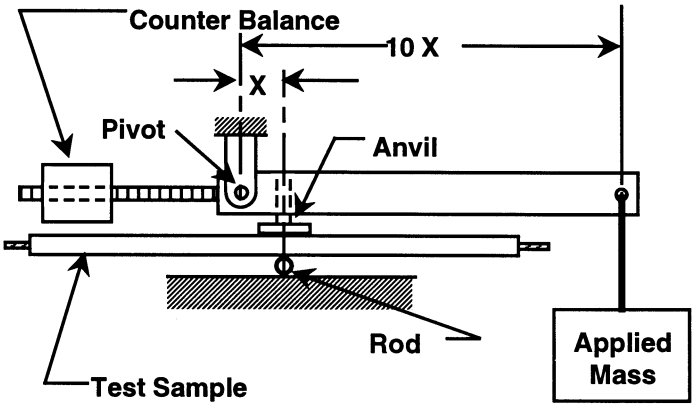

FIGURE 10—APPARATUS FOR "PINCH RESISTANCE" TEST
(REF. 6.10)

6.10.4 REQUIREMENT—The minimum value for each cable type and size is shown in Figure 11.

SAE Wire Size mm^2	Wall Thickness U kg	Wall Thickness 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 11—MINIMUM PINCH RESISTANCE
(REF. 6.10)

6.11 Sandpaper Abrasion Resistance

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—The sandpaper abrasion resistance shall be measured using 150J garnet sandpaper with 10 mm conductive strips perpendicular to the edge of the sandpaper spaced a maximum of every 75 mm. 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. The sandpaper shall approach and exit the sample from below at an angle of 29 degrees ± 2 degrees to the axis of the cable and shall be supported by a pin 6.9 mm ± 0.1 mm in diameter. The support arm (see Figure 12) will have a suitable bracket to maintain the cable position over an unused portion of the sandpaper. A total force of 0.63 N ± 0.05 N will be exerted 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 support bracket, pivot arm, support rod, and additional mass. See Figure 13 for the additional mass.

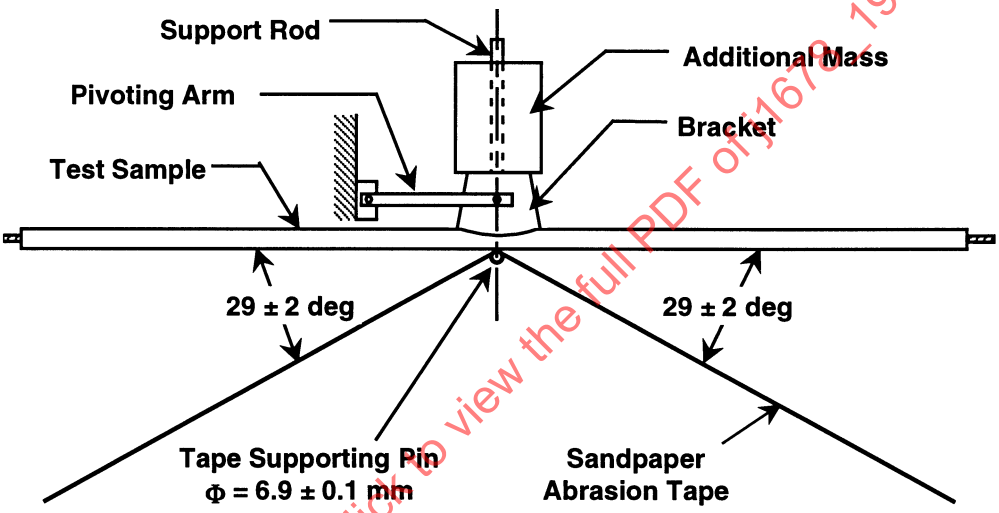

FIGURE 12—APPARATUS FOR "SANDPAPER ABRASION RESISTANCE" TEST (REF. 6.11)

SAE Wire Size mm^2	Wall Thickness U g	Wall Thickness W g
0.13	50	100
0.22	50	100
0.35	50	100
0.5	100	220
0.8	100	220
1	100	220
2	100	220
3	220	450

Note:
See FIGURE 14 for minimum Sandpaper Abrasion Resistance.

FIGURE 13—SANDPAPER ABRASION RESISTANCE ADDTIONAL MASS
(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 abrasion resistance.

6.11.4 REQUIREMENT—The sandpaper abrasion resistance shall meet or exceed the minimum abrasion requirements in Figure 14.

6.12 Hot Plate

6.12.1 TEST SAMPLE—Prepare a test sample of 350 mm minimum and remove 25 mm of insulation from each end.

6.12.2 APPARATUS—A hot plate at least 150 mm by 150 mm at 250 °C ± 25 °C and a 6 mm mandrel which exerts a force of 5 to 7 N.

6.12.3 PROCEDURE—The sample shall be bent a minimum of 135 degrees around the mandrel. The cable and mandrel shall be placed against the hot plate for 5 to 6 s without rubbing or scraping the cable on the plate. Visually inspect the area of exposure for conductor that is visible through the insulation. If the visual inspection is not conclusive, the sample is to be returned to room temperature and then 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.

6.12.4 REQUIREMENT—After exposure, the cable conductor shall not be visible through the insulation. During the "Withstand Voltage" test, breakdown shall not occur.

SAE Wire Size mm^2	Wall Thickness, U		Wall Thickness, W	
	Type		Type	
	Thermoplastic mm	Thermoset mm	Thermoplastic mm	Thermoset mm
0.13	150	150	200	300
0.22	175	175	300	350
0.35	200	200	350	400
0.5	175	175	200	300
0.8	200	200	300	350
1	225	225	350	400
2	250	250	400	450
3	150	150	250	250

FIGURE 14—MINIMUM SANDPAPER ABRASION RESISTANCE
(REF. 6.11)

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 Hot Water Resistance—This test is for initial qualification only. The usage of this test will be established by agreement between customer and supplier. At least one wire size shall be tested; however, for comparative purposes 0.8 mm^2 is preferred.

6.14.1 TEST SAMPLE—Prepare two test samples of 2.5 m ± 0.1 m and remove 25 mm of insulation from each end.

6.14.2 APPARATUS—A salt water bath with 10 g/L of NaCl in water at 85 °C. A 48 V DC power source. A mandrel 5 times the outside diameter of the test sample. A resistance measuring device per 6.15.2.

6.14.3 PROCEDURE—Closely wind three complete turns of the center section of the first test sample on the mandrel. Tie the remaining cable of the first test sample in a coil. Immerse the first test sample in the bath as shown in Figure 15 with both ends projecting 250 mm above the bath. Connect one end of the first test sample to the positive electrode to of the power source. Connect the negative electrode to the bath. After 7 days, disconnect the 48 V supply, measure the insulation resistance, and calculate the "Insulation Volume Resistivity" (see 6.15).

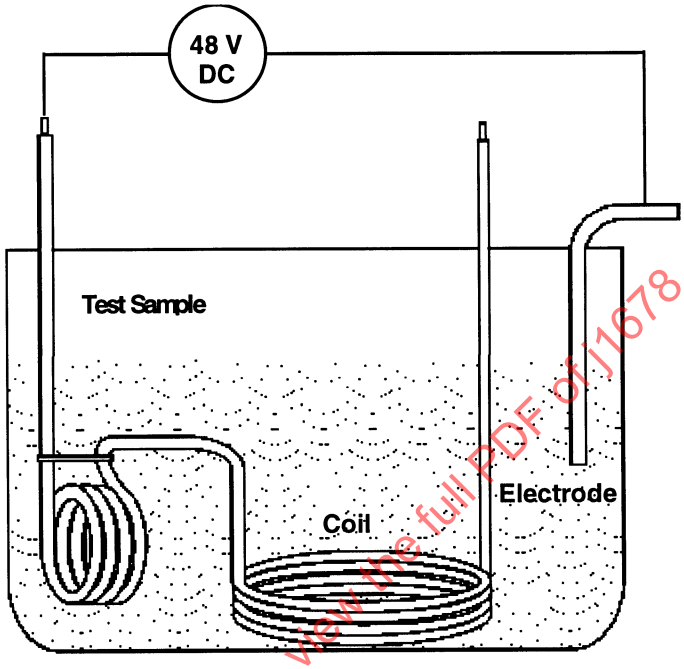

FIGURE 15—APPARATUS FOR "HOT WATER RESISTANCE"
(REF. 6.14)

This completes one cycle. Repeat this procedure for a total of five cycles, 35 days. After conditioning, remove the test sample from the bath, allow it to cool to room temperature, and make a visual inspection 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.

6.14.4 REQUIREMENT—The 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.

6.15 Insulation Volume Resistivity—This test is only used as part of the "Hot Water Resistance" test.

6.15.1 TEST SAMPLE—See 6.14.1.

6.15.2 APPARATUS—See 6.14.2 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.

6.15.3 PROCEDURE—Apply the DC voltage between the conductor and the water. The insulation resistance shall be measured 1 min after application of the voltage. Calculate the "Insulation Volume Resistivity" using the Equations 1:

$$\rho_0 = 2.725 \frac{lxR}{\log \frac{D}{d}} \quad \text{(Eq. 1)}$$

where:

ρ_0 is the "Insulation Volume Resistivity", expressed in Ω·mm;
l is the immersed length of the test sample, expressed in mm;
R is the measured insulation resistance, expressed in Ω
D is the outside cable diameter, in accordance with 5.4, expressed in mm;
d is the conductor diameter, expressed in mm

6.15.4 REQUIREMENT—The "Insulation Volume Resistivity" shall not be less than 10^9 Ω·mm.

6.16 Environmental Cycling—This test is for initial qualification only. The usage of this test will be established by agreement between customer and supplier. At least one wire size shall be tested; however, for comparative purposes 0.8 mm^2 is preferred.

6.16.1 TEST SAMPLES—Prepare two samples of approximately 600 mm and remove 25 mm of insulation from each end.

6.16.2 APPARATUS—The test shall be performed in a temperature chamber which is capable of cycling between –40 °C ± 2 °C and the test temperature specified in Figure 5 (Long-Term Aging, 3000 h). The chamber shall also be capable of controlling the relative humidity between 5% ± 5% and 90% ± 5%. See Figure 6 (Long-Term Aging, 3000 h) for mandrel sizes.

6.16.3 PROCEDURE—Wind at least thenumber of turns specified in Figure 6 around the mandrel and secure the ends. Condition the test sample according to the temperature and relative humidity shown in Figure 16. The cycle begins and ends with the chamber at –40 °C ± 2 °C and 5% ± 5% relative humidity. This 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 cool at room temperature for approximately 30 min, and unwind it from the mandrel. Make a visual inspection of the insulation. Ignore any damage caused by the clamps which secure the ends. 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.

6.16.4 REQUIREMENT—After unwinding, no conductor shall be visible. During the "Withstand Voltage" test, breakdown shall not occur.

7. Reference Information

7.1 Color Code

7.1.1 RECOMMENDED COLORS—The color of the cables should match as closely as possible the central colors specified in Appendix A.

7.1.2 STRIPES—When additional color coding is required, various colored stripes may be applied longitudinally, spirally, or by other manner agreed upon by the supplier and user. The color standards do not apply to stripes.