

Low Voltage Ultra Thin Wall Primary Cable**RATIONALE**

- Clarified system voltage 60 V DC (60 V AC rms)
- Updated definition of plastic and referenced ASTM D-833 versus ASTM F-1251
- Referenced ASTM D5374 and ASTM D5423 versus ASTM E145
- Removes SAE J1067 and J1292 from related or referenced specifications
- Updated definition of thermoset
- Updated title of SAE J1654
- Use of separators are now optional
- Revised the Resistance to Sandpaper Abrasion test to allow conductive strip width tolerance
- Revised the AFT fluid to Dexron VI
- Revised Appendix C with current SAE Reference Material information

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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 (60 V AC 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 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 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 D-833 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 ANSI, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

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 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	High Voltage Unshielded 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

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 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

2.2.3 ISO Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

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 B 354)

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 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

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 D-833)

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 B 354)

4. GENERAL

4.1 Cable Types

See Figure 1.

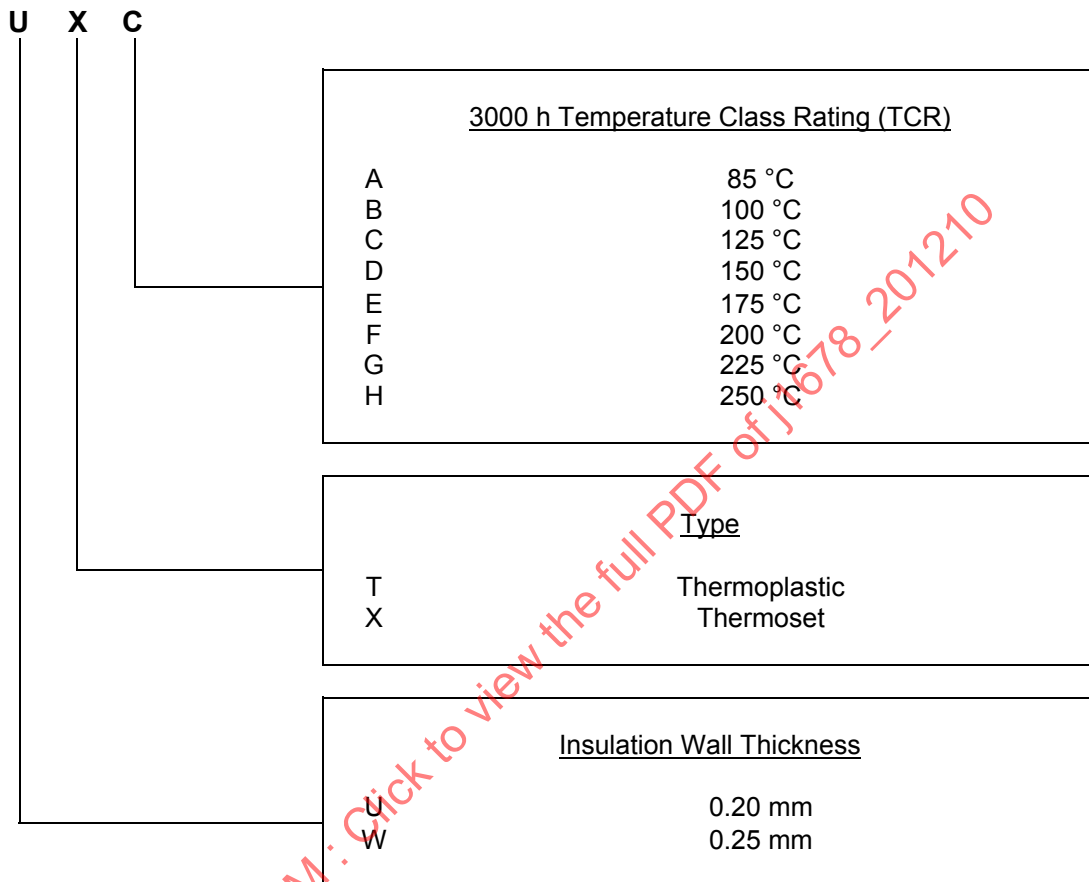


FIGURE 1 - CABLE TYPES (REF. 4.1)

In this example, UXC, the cable has an “Insulation Wall Thickness” of 0.20 mm, “Thermoset”, with a “3000 h Temperature 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 D5374 Type II and D5423 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 may 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.

English	
SAE Conductor Size No.	Minimum Conductor Area circular mils
26	250
24	405
22	681
20	1 072
18	1 537
16	2 336
14	3 702
12	5 833
10	9 343
8	14 810
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 (REF. 5.1)

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 $\pm 0.5\%$ of the measured value and a thermometer with an accuracy of $\pm 0.5^\circ\text{C}$.

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 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 "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. Separators are optional.

SAE ⁽¹⁾ Conductor Size No	Conductor Resistance Maximum mΩ/m @ 20 °C		
	Silver Coated & Uncoated Copper	Tin Coated Copper	Nickel ⁽²⁾ Coated Copper
26	136	146	142
24	84.9	91.2	88.5
22	53.9	57.8	45.1
20	34.3	36.4	35.7
18	23.0	24.7	23.9
16	15.5	16.6	16.1
14	9.44	10.0	9.83
12	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 4 - 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 No	Wall Thickness, U			Wall Thickness, W		
	Wall Thickness		Outside Cable Diameter Maximum (mm)	Wall Thickness		Outside Cable Diameter Maximum (mm)
	Nominal (mm)	Minimum (mm)		Nominal (mm)	Minimum (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 5 - OUTSIDE CABLE DIAMETER AND WALL THICKNESS (REF. 5.4 AND 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 Of Turns
Reference Clauses	Reference Clauses		
6.3, 6.4, & 6.15	6.6, 6.8, 6.9, & 6.13	s ⁻¹	
≤ 1.5 X Outside Cable Diameter Maximum	≤ 5 X Outside Cable Diameter Maximum	0.2	3

FIGURE 6 - WINDING (REF. 6.3, 6.4, 6.6, 6.8, 6.9, 6.13 AND 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 B 33, ASTM B 298, or ASTM B 355.

6.1.2 Apparatus

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

6.1.3 Procedure

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

6.1.4 Requirement

See the applicable section of ASTM B 33, ASTM B 298, or ASTM 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 and solder at 400 °C to 425 °C. The test details such as type of solder and flux are to be agreed upon between the customer and the supplier

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 $(23 \pm 5) ^\circ\text{C}$ 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 7 - LONG-TERM AGING, SHORT-TERM AGING, AND TEMPERATURE AND HUMIDITY CYCLING TEST CONDITIONS (REF. 6.3, 6.4, AND 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 $(23 \pm 5) ^\circ\text{C}$ 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 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 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 $-40^{\circ}\text{C} \pm 2^{\circ}\text{C}$. The mandrel size is specified in Figure 5.

6.6.3 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 $-40^{\circ}\text{C} \pm 2^{\circ}\text{C}$ for a period of 3 h. While the sample is still at this low temperature perform the "Winding" test in clause 5.6. 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.

6.6.4 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.

FIGURE 8 - 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 to qualify cables for continuous immersion. Compliance for a cable family may be demonstrated by using "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 Temperature °C	Outside Cable Diameter Maximum Change %
Name	Fluid		
Engine Oil	ASTM D 471, IRM-902	50 ± 3	15
Gasoline	ASTM D 471, Ref. Fuel C	23 ± 5	15
Ethanol	85% Ethanol + 15% ASTM D 471, Ref. Fuel C	23 ± 5	15
Diesel Fuel	ASTM D 471, 90% IRM 903 + 10% p-xylene	23 ± 5	15
Power Steering	ASTM D 471, 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 ± .005	23 ± 5	5
Note: Solutions are determined as % by volume.			

FIGURE 9 - 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 $65 \text{ }^{\circ}\text{C} \pm 3 \text{ }^{\circ}\text{C}$. 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.

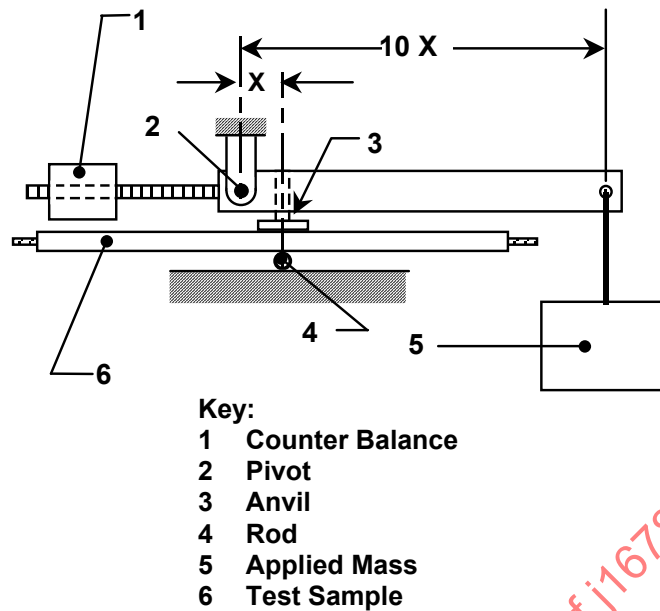


FIGURE 10 - APPARATUS FOR "RESISTANCE TO PINCH" TEST (REF. 6.10)

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 or 180J aluminum oxide sandpaper tape with 5-10 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 $\pm$ 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 12 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 11 - RESISTANCE TO PINCH, MINIMUM (REF. 6.10)

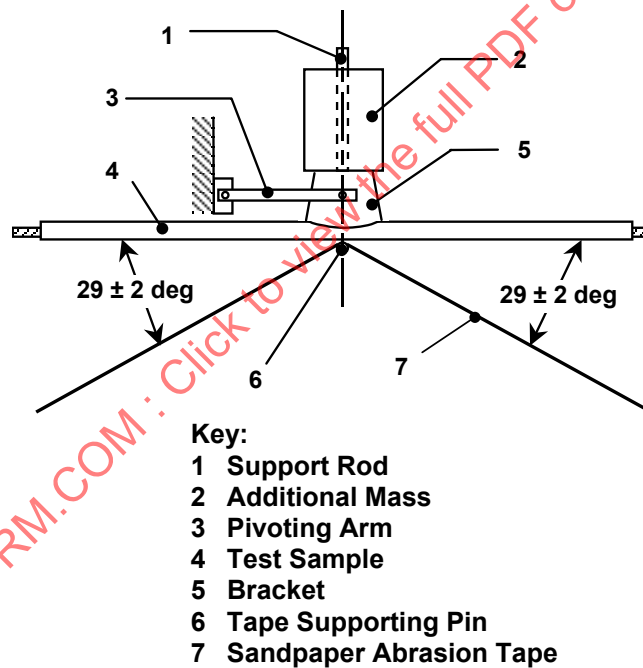


FIGURE 12 - APPARATUS FOR "RESISTANCE TO SANDPAPER ABRASION" (REF. 6.11)

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 $\pm$ 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".

6.11.4 Requirement

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

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 13 - "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 $2.5 \text{ m} \pm 0.1 \text{ m}$ and remove 25 mm of insulation from each end.

6.13.2 Apparatus

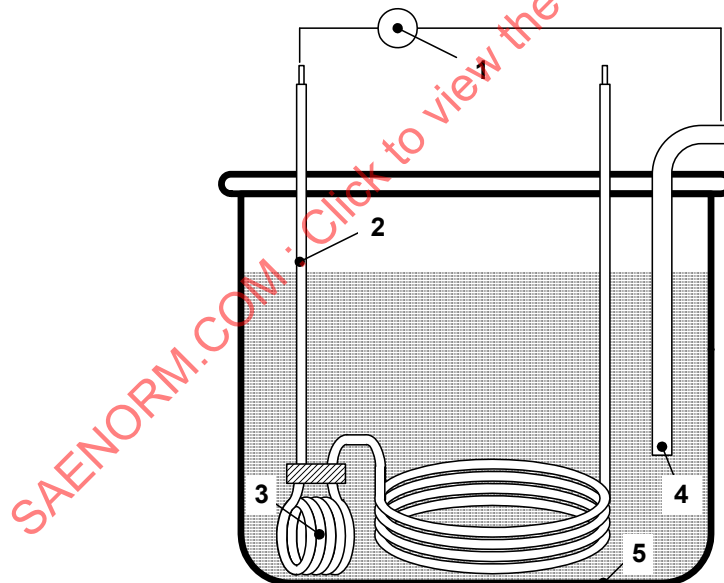
The apparatus consists of an electrically nonconductive vessel containing an unused salt water bath with 10 g/l of NaCl in water at $85^\circ\text{C} \pm 5^\circ\text{C}$ for each test, a 48 V DC power source. See Figure 5 for mandrel sizes.

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 14 - APPARATUS FOR "RESISTANCE TO HOT WATER" (REF. 6.13)