SAE International®

SURFACE VEHICLE STANDARD

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Low Voltage Primary Cable

RATIONALE

Conversion of document back to SAE Conductor Size No.'s to eliminate industry confusion and differentiate from ISO metric standards

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1. SCOPE

This standard covers 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.

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

SAE R-257 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 263 Method for Determination of Cross-Sectional Area of Standard Conductors

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 412 Standard Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers - Tension

ASTM D 471 Standard Test Method for Rubber Property - Effect of Liquids

ASTM D 573 Standard Test Method for Rubber - Deterioration in an Air Oven

ASTM D 833 Standard Terminology Relating to Plastics

ASTM D 5374 Standard Test Methods for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation

ASTM D 5423 Standard Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation

2.1.3 IEC Publications

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

IEC 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 J1654 High Voltage Primary Cable

SAE J1673 High Voltage Automotive Wiring Assembly Design

SAE J1678 Low Voltage Ultra Thin Wall Primary Cable

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 American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.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 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 ANSI, 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, screened and unscreened, 60 V and 600 V multicore sheathed cables—Basic and high performance test methods and requirements

3. DEFINITIONS

3.1 ADDITIONAL MASS (Reference “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.

3.2 CABLE

See primary cable.

3.3 CABLE FAMILY

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

3.4 COATED WIRE

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

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 CONDUCTOR SIZE

See “SAE Conductor Size”.

3.7 CORE

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

3.8 FLUID COMPATIBILITY

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

3.9 HOT PLATE

An electrically heated device used to test thermoset cables.

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

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

3.13 PLASTICS

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

A class designation based on the retention of “Mechanical Properties” (tensile & elongation) after 168 h of heat aging at 30 °C above the 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.

Type TWP Thin Wall, Thermoplastic Insulated
Type GPT General Purpose, Thermoplastic Insulated
Type HDT Heavy Duty, Thermoplastic Insulated
Type HTS Heavy Duty, Thermoset Elastomer (Synthetic Rubber) Insulated
Type TXL Thin Wall, Cross (X) Linked Polyolefin Insulated
Type GXL General Purpose, Cross (X) Linked Polyolefin Insulated
Type SXL Special Purpose, Cross (X) Linked Polyolefin Insulated

Insulation	SAE Cable Types			
	Thin Wall	General Purpose	Special Purpose	Heavy Wall
Thermoplastic	TWP	GPT		HDT
Thermoset Elastomer				HTS
Crosslinked Polyolefin	TXL	GXL	SXL	

FIGURE 1 - CABLE TYPES
Reference 4.1

4.2 General Test Conditions

Test samples 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 D 5374 Type II and D 5423 Type I. The air contained in the oven shall be completely changed at least 100 times but not more than 200 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 For SAE Cable Types: TWP GPT HDT	Required For SAE Cable Types: HTS TXL GXL SXL	If Required
5	General Specifications			
5.1	Conductor	*	*	
5.2	Insulation			
5.3	Outside Cable Diameter	*	*	
5.4	Wall Thickness	*	*	
5.5	Winding			
6	Tests			
6.1	Strand Coating	Note 1	Note 1	
6.2	Solderability	*	*	
6.3	Mechanical Properties	Note 2	Note 2	
6.4	Dielectric	*	*	
6.5	Cold Bend	*	*	
6.6	Resistance to Flame Propagation	*	*	
6.7	Fluid Compatibility	Note 2	Note 2	
6.8	Resistance to Ozone			Notes 2, 5, & 6
6.9	Resistance to Pinch	*	*	
6.10	Resistance to Sandpaper Abrasion	*	*	
6.11	Crosslinking			*
6.12	Strip Force	*	*	Notes 3, & 6
6.13	Resistance to Hot Water			Notes 2, 5, & 6
6.14	Insulation Volume Resistivity			Notes 4, & 6
6.15	Temperature and Humidity Cycling			Notes 2, 5, & 6

Notes:
1. This test is only required for coated copper wires.
2. Compliance for a cable family may be demonstrated by using “Representative Conductor Sizes for Testing”, see 4.5.
3. 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.
6. The usage of “If Required” tests will be established by agreement between customer and supplier.

FIGURE 2 - GENERAL SPECIFICATIONS
Reference Clause 5

5.1 Conductors

When tin, silver, or nickel coated wires are used, they shall withstand the applicable “Strand Coating” test specified in 6.1 and Figure 2. The cross-sectional area of stranded conductors shall not be less than the values specified in Figure 3. The cross-sectional area may be verified by measuring actual strand sizes or by using the weight method in ASTM B 263 with a calculated factor to account for the twist loss.

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.

When agreed between the supplier and the purchaser, splices may be used for the conductor as a whole provided that they meet the following conditions:

- The break strength shall not be reduced by more than 20%.
- The resistance shall not be increased.
- The diameter of the splice must not exceed the diameter of the un-insulated conductor.

English	
SAE Conductor Size No.	Minimum Conductor Area circular mils
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
Reference 5.1

5.2 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.

5.3 Outside Cable Diameter

The “Outside Cable Diameter” shall be measured at five separate cross sections spaced 50 mm apart with an optical device accurate to at least 0.01 mm. Other devices may be used; however, in case of dispute, the referee shall be the optical device. A minimum of two readings shall be taken at each cross section. The sample should be rotated 90 deg between readings. The mean of the diameter readings shall determine the ”Outside Cable Diameter” and shall be in accordance with Figure 4 for the various cable types.

5.4 Wall Thickness

The minimum “Wall Thickness” shall be measured at five separate cross sections spaced 400 mm apart using the equipment described in 5.3. No single value shall be less than the appropriate “Wall Thickness, Minimum” specified in Figure 4.

5.5 Winding

"Winding" is not a separate test. It is included as a part of several other tests. When it is required, 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 sample and the mandrel.

SAE Conductor Size	SAE Cable Type											
	TWP TXL			GPT GXL			SXL			HDT HTS		
	Wall Thickness		Maximum Outside Cable Diameter	Wall Thickness		Maximum Outside Cable Diameter	Wall Thickness		Maximum Outside Cable Diameter	Wall Thickness		Maximum Outside Cable Diameter
No.	Nominal mm	Minimum mm	mm	Nominal mm	Minimum mm	mm	Nominal mm	Minimum mm	mm	Nominal mm	Minimum mm	mm
24	0.40	0.28	1.50	--	--	--	--	--	--	--	--	--
22	0.40	0.28	1.70	--	--	--	--	--	--	--	--	--
20	0.40	0.28	1.90	0.58	0.41	2.40	0.74	0.52	2.80	0.91	0.64	3.10
18	0.40	0.28	2.20	0.58	0.41	2.50	0.76	0.53	3.00	0.94	0.66	3.40
16	0.40	0.28	2.40	0.58	0.41	2.90	0.81	0.57	3.40	1.02	0.71	3.70
14	0.40	0.28	2.70	0.58	0.41	3.20	0.89	0.62	3.90	1.04	0.73	4.20
12	0.46	0.32	3.30	0.66	0.46	3.80	0.94	0.66	4.60	1.17	0.82	5.10
10	0.50	0.35	4.00	0.79	0.55	4.70	1.04	0.73	5.30	1.17	0.82	5.70
8	0.55	0.39	4.90	0.94	0.66	6.00	1.09	0.76	6.20	1.40	0.98	7.00

NOTE: For reference only, English units are included in Appendix A.

FIGURE 4 - "OUTSIDE CABLE DIAMETER" AND "WALL THICKNESS"
Reference 5.3 and 5.4

SAE Conductor Size a	Mandrel Size		Winding Speed s^{-1}	Number of Turns Minimum
	Reference Clause 6.15	Reference Clauses 6.5, 6.7, 6.8, & 6.13		
$a \leq 14$	≤ 1.5 X Outside Cable Diameter Maximum	≤ 5 X Outside Cable Diameter Maximum	0.2	3
$14 < a \leq 8$				2
$8 < a$				0.5

FIGURE 5 - WINDING TEST CONDITIONS
References 6.5, 6.7, 6.8, 6.13, and 6.15

6. TESTS

6.1 Strand Coating

The “Strand Coating” test shall be conducted on individual strands prior to stranding and shall be conducted per ASTM B 33, ASTM B 298, or ASTM B 355. This test is not required for uncoated strands.

6.2 Solderability

25 mm of insulation shall be removed from a 300 mm sample of finished cable. 12 mm of the stripped end shall be immersed into a component lead tinning flux such as Kester #2166BN, water soluble flux for 3 s to 5 s. The stripped end shall then be immersed in solder (30% to 40% Sn, remainder Pb) at 400 °C to 425 °C for 3 s to 5 s. Other fluxes, solders, and temperatures may be used; however, in case of a dispute, the referee shall be the Kester #2166BN and the solder and temperature shown in this specification. A visual inspection shall reveal no area in the immersed section which is not covered by solder.

6.3 Mechanical Properties

Compliance for a cable family may be demonstrated by using “Representative Conductor Sizes for Testing”, see 4.5. An accelerated aging test shall be conducted in accordance with ASTM D 412 and ASTM D 573 except using specimens of insulation removed from finished cable. The sample shall be stretched at a rate of 50 mm/min. 500 mm/min may be used as the strain rate; however, in case of a dispute, the referee method will be a 50 mm/min strain rate. The original and conditioned samples must both be elongated at the same strain rate. The original properties shall conform to the values shown in Figure 6. Samples of insulation shall be aged 168 h in an oven at the test temperature shown in Figure 6. After aging, the tensile strength shall not be less than 80% of the original test value and the elongation shall not be less than 50% of the original test value.

SAE Cable Type	Tensile Strength MPa Minimum	Elongation % Minimum	Test Temperature °C Ref. Clause 6.3	Temperature Class Rating °C Ref. Clause 6.15
TWP GPT HDT	11	125	110 ± 2	80 ± 2
HTS	7	150	110 ± 2	80 ± 2
TXL GXL SXL	10	150	155 ± 3	125 ± 3

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

FIGURE 6 - “MECHANICAL PROPERTIES” AND “TEMPERATURE AND HUMIDITY CYCLING”, TEST CONDITIONS
References 6.3 and 6.15

6.4 Dielectric

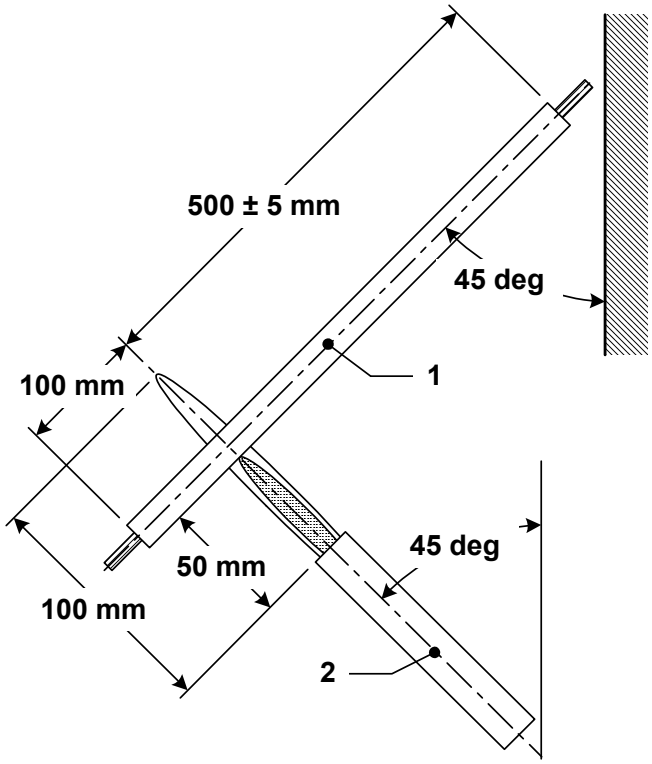
25 mm of insulation shall be removed from each end of a 600 mm sample of finished cable and the two ends twisted together. The loop thus formed shall be immersed in water containing 5% salt by weight at room temperature so that not more than 150 mm of each end of the sample protrudes above the solution. After being immersed for 5 h and while still immersed, the sample shall withstand the application of 1000 V rms at 50 to 60 Hz between the conductor and the solution for 1 min without failure of the insulation.

6.5 Cold Bend

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 °C ± 2 °C for a period of 3 h. While the sample is still at this low temperature, perform the winding test in clause 5.5. A visual inspection shall reveal no cracks or splits. The sample is to be returned to room temperature and then subjected to the dielectric test specified in 6.4.

6.6 Resistance to Flame Propagation

A 600 mm sample of finished cable shall be suspended taut at 45 deg to a horizontal plane within a partial enclosure which allows a flow of sufficient air for complete combustion but is free from drafts. A gas burner shall be used having a 13 mm inlet, a nominal core of 10 mm, and a length of 100 mm above the primary inlets. The gas burner shall be adjusted to produce a 100 mm gas flame with an inner cone ½ of its height. The gas burner shall be positioned beneath the test sample and perpendicular to the axis of the test sample. The top of the inner cone of the flame shall be applied as shown in Figure 7. The time of application of the flame shall be 15 s. However, the exposure time shall not be longer than the time at which the conductor becomes visible. After removal of the gas burner flame, the test sample shall not continue to burn for more than 70 s and a minimum 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 “FLAME RESISTANCE” TEST
Reference 6.6

6.7 Fluid Compatibility

Compliance for a cable family may be demonstrated by using “Representative Conductor Sizes for Testing”, see clause 4.5. 25 mm of insulation shall be removed from each end of 1000 mm samples of finished cable. A separate sample shall be used for each fluid. The original “Outside Cable Diameter” shall be measured using the procedure described in 5.3. The area of the sample to be subjected to the “Winding” 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 and then condition the sample for 4 h at room temperature. After conditioning, the diameter shall again be measured using the procedure in 5.3. The mean of the diameter readings taken after conditioning shall be compared to the mean of the original diameter readings. The “Outside Cable Diameter, Maximum Change” shall be in accordance with Figure 8. After conditioning at room temperature, perform the “Winding” test in 5.5. A visual inspection shall reveal no cracks or splits. If no exposed conductor is visible, subject the sample to the dielectric test specified in 6.4.

Test Fluid		Test Temperature	Outside Cable Diameter Maximum Change
Name	Fluid	°C	%
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	90% ASTM D 471, 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_2SO_4, Specific Gravity = 1.260 ± .005	23 ± 5	5

NOTE: Solutions are determined as % by volume.

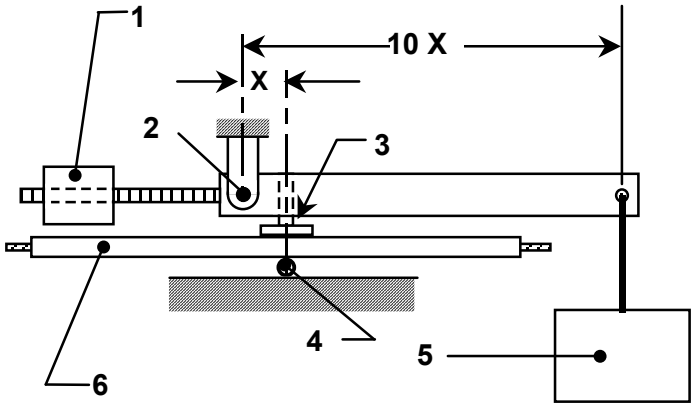
FIGURE 8 - FLUID COMPATIBILITY
Reference 6.7

6.8 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 4.5. Prepare a 300 mm test sample of finished cable, perform the “Winding” test in 5.5, and secure the ends. The assembly shall then be conditioned for 192 (+1, –0) h at 65 °C ± 3 °C in an atmosphere containing 100 pphm ± 5 pphm (parts per hundred million) of ozone. A visual inspection shall reveal no cracks or splits.

6.9 Resistance to Pinch

25 mm of insulation shall be removed from one end of a 900 mm sample of finished cable. The test sample shall then be placed taut without stretching across a 3 mm diameter steel rod as shown in Figure 9. The counter balance shall be adjusted so that no force will be exerted on the test sample until a mass is applied to the end of the lever with a mechanical advantage of 10. The test sample shall then be subjected to an increasing force applied through the steel anvil by increasing the applied mass at a rate of 2.3 kg/min. At the moment the insulation is pinched through, the 3 mm diameter rod will contact the conductor and the test shall stop. The applied mass shall then be recorded. After each reading the test sample shall be moved 50 mm and rotated clockwise 90 deg. Four readings shall be obtained for each test sample. The mean of the four readings shall determine the “Resistance to Pinch” of the test sample. The minimum values for each cable type and size are shown in Figure 10.



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

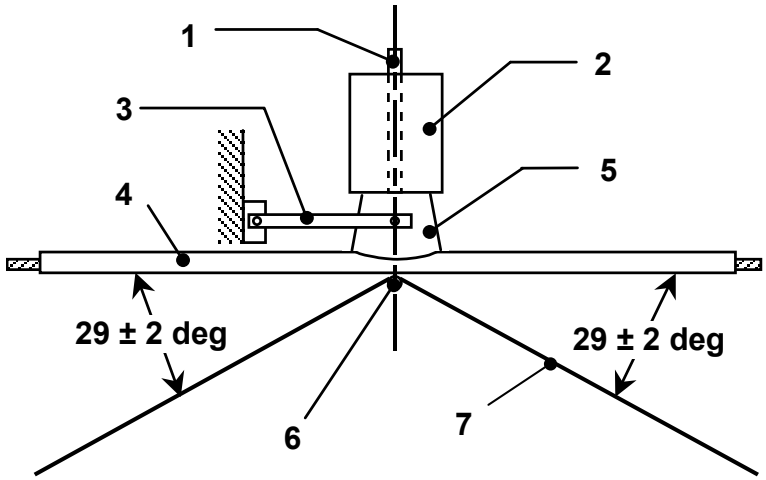
FIGURE 9 - APPARATUS FOR “RESISTANCE TO PINCH” TEST
Reference 6.9

SAE Conductor Size No.	SAE Cable Type						
	TWP kg	GPT kg	HDT kg	HTS kg	TXL Kg	GXL kg	SXL kg
24	1.1	--	--	--	1.5	--	--
22	1.2	--	--	2.3	1.7	--	--
20	1.3	1.6	4.1	2.6	2.0	3.6	5.0
18	1.5	2.0	4.5	3.3	2.5	4.1	6.2
16	1.8	2.5	5.3	4.1	3.1	4.7	7.5
14	2.1	3.0	6.5	4.8	3.8	5.6	9.0
12	2.4	3.6	8.2	5.4	4.5	7.2	10.5
10	2.8	4.2	11	6.0	5.2	9.0	12.8
8	3.3	5.0	15	6.5	5.9	11	16

FIGURE 10 – MINIMUM “RESISTANCE TO PINCH”
Reference 6.9

6.10 Resistance to Sandpaper Abrasion

25 mm of insulation shall be removed from one end of a 900 mm sample of finished cable. The test sample shall then be placed taut, without stretching in a horizontal position (see Figure 11). The additional mass specified in Figure 12 and a suitable bracket shall be used to maintain the test sample position over an unused area of the abrasion tape. The total weight of the bracket, support rod, and pivoting arm shall be 0.63 N ± 0.05 N. 150J garnet or 180J aluminum oxide sandpaper with 5 to 10 mm conductive strips perpendicular to the edge of the sandpaper spaced a maximum of every 75 mm shall be used to abrade the insulation. 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. The sandpaper shall be pulled under the cable at a rate of 1500 mm/min ± 75 mm/min until a conductive strip contacts the metallic conductor. A reading shall be taken of the length of sandpaper used to abrade through the insulation. The sandpaper shall approach and exit the test sample from below at an angle of 29 deg ± 2 deg to the axis of the cable and shall be supported by a pin 6.9 mm ± 0.1 mm in diameter. After each reading, the test sample shall be moved 50 mm and rotated clockwise 90 deg. Four readings shall be obtained for each test sample. The mean of the readings will determine the "Resistance to Sandpaper Abrasion". The "Resistance to Sandpaper Abrasion" shall meet or exceed the "Minimum Length of Sandpaper" requirements in Figure 13.



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" TEST
Reference 6.10

SAE Wire Conductor No.	SAE Cable Types				
	TWP TXL Mass kg	GPT GXL Mass kg	HDT Mass kg	SXL Mass kg	HTS Mass kg
24	0.22	--	--	--	--
22	0.22	--	--	--	--
20	0.22	0.45	1.4	0.45	0.45
18	0.22	0.45	1.4	0.45	0.45
16	0.22	0.45	1.4	0.45	0.45
14	0.22	0.45	1.9	0.45	1.4
12	0.45	1.4	1.9	1.4	1.4
10	0.45	1.4	1.9	1.4	1.4
8	0.45	1.4	1.9	1.4	1.4

NOTE: See Figure 13 for minimum abrasion resistance.

FIGURE 12 - “RESISTANCE TO SANDPAPER ABRASION”, ADDITIONAL MASS
Reference 6.10

SAE Conductor Size No.	Minimum Length of Sandpaper mm SAE Cable Type						
	TWP	GPT	HDT	HTS	TXL	GXL	SXL
24	225				225		
22	250				250		
20	300	400	350	760	300	400	550
18	350	410	400	890	350	410	700
16	400	420	450	1020	400	420	850
14	450	430	400	460	450	430	1000
12	250	280	500	560	250	280	500
10	350	400	600	760	350	400	600
8	500	500	900	890	500	500	900

FIGURE 13 - “RESISTANCE TO SANDPAPER ABRASION”
REFERENCE 6.10

6.11 Crosslinking

The usage of this test will be established by agreement between customer and supplier. 25 mm of insulation shall be removed from each end of a 600 mm sample of finished cable. The test sample shall be bent a minimum of 135 deg around a 6 mm mandrel. The cable and mandrel shall be placed against a hot plate at least 150 mm by 150 mm which has been preheated to 250 °C ± 25 °C. A force of 5 N to 7 N shall be applied for 5 s to 6 s without rubbing or scraping the cable on the plate. After exposure, the cable conductor shall not be visible through the insulation. If the visual inspection is not conclusive, the sample is to be returned to room temperature and then subjected to a dielectric test similar to that specified in 6.4. However, the immersion time and application of the voltage shall be 1 min. The requirements for the "Crosslinking" test, if any, will be established by agreement between the supplier and the customer.

6.12 Strip Force

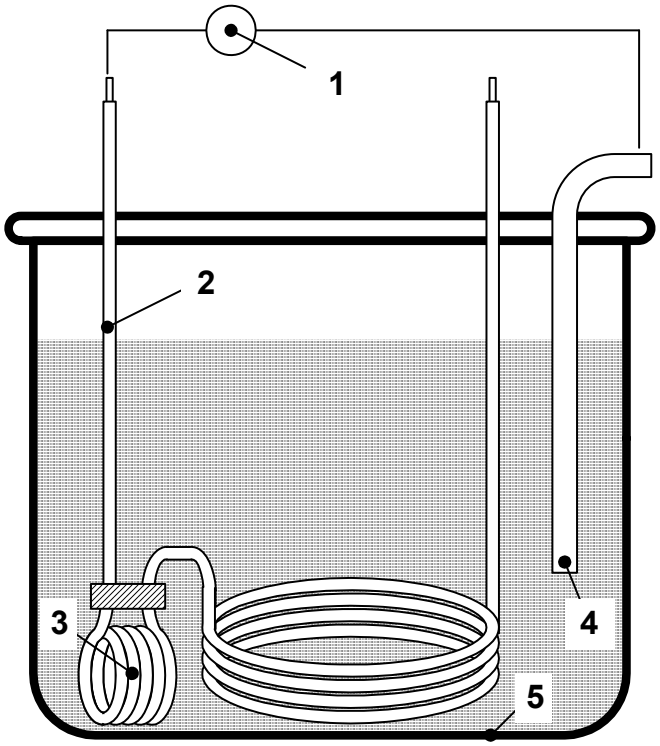
The usage of this test will be established by agreement between customer and supplier. Prepare a 75 mm test sample of finished cable. 25 mm of insulation shall be cleanly cut and carefully stripped from one end of the conductor. Care must be taken not to disturb the 50 mm ± 2 mm section when removing the residual insulation. No burrs are permitted on the ends of the metallic conductor. Insert the stripped end through a plate with an appropriate diameter hole. The conductor shall be pulled through the plate at a rate of 500 mm/min. The maximum force shall be recorded. A minimum of four readings shall be obtained. The mean of all readings shall determine the strip force of the cable under test. The requirements for the "Strip Force" test, if any, will be established by agreement between the supplier and the customer.

Alternative - A 25 mm ± 2 mm sample of undisturbed insulation may be used.

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 4.5. 25 mm of insulation shall be removed from each end of two 2.5 m ± 0.1 m test samples of finished cable. Other test sample lengths may be used; however, in case of a dispute, the referee method shall use the 2.5 m test sample length. Closely wind a minimum of three complete turns of the first test sample around the mandrel specified in Figure 5 and secure the coil as shown in Figure 14. After removing the mandrel, immerse the first test sample in a saltwater bath with 10 g/l of NaCl in distilled water at 85 °C ± 5 °C. To avoid interaction between compounds, test samples with different insulating compounds shall not be tested in the same bath. Also, a virgin saltwater bath shall be used for each test. Connect one end of the first test sample to the positive terminal of a 48 V DC power source. Connect the negative terminal to the copper electrode in the bath. After 7 days, disconnect the 48 V DC power source, measure the insulation resistance, and calculate the "Insulation Volume Resistivity" (see 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 tie, which secures the coils. If no exposed conductor is visible, perform the "Dielectric" test (see 6.4) 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 48 V 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" TEST
Reference 6.13

6.14 Insulation Volume Resistivity

This test is only used as part of the "Resistance to Hot Water" test (see 6.13). While still in the saltwater bath connect the sample to a resistance measuring device with a DC voltage of 500 V. Voltages between 100 V and 500 V are allowed; however, in case of a dispute, the referee apparatus shall be a resistance measuring device with a DC voltage of 500 V. The insulation resistance shall be measured 1 min after application of the voltage or after it reaches equilibrium, whichever comes last. Calculate the "Insulation Volume Resistivity" using the following formula:

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

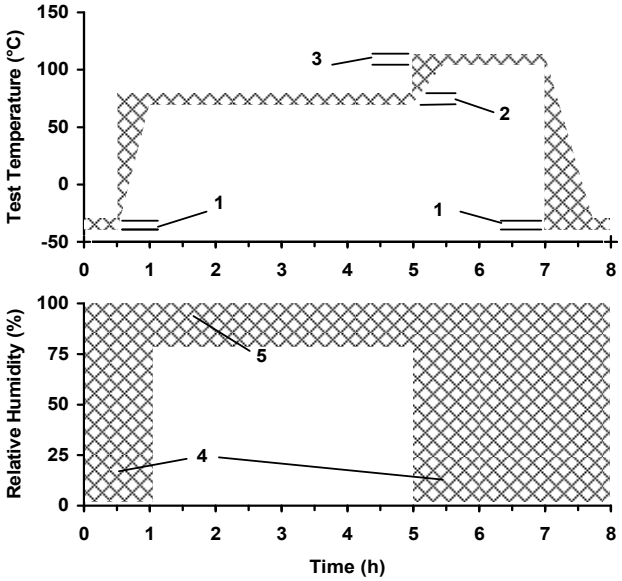
where:

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 5.3, expressed in mm
d is the conductor diameter, expressed in mm
log is log to the base 10

The "Insulation Volume Resistivity" shall not be less than 10^9 Ω•mm.

6.15 Temperature and Humidity Cycling

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 4.5. 25 mm of insulation shall be removed from each end of two 600 mm samples of finished cable. Wind the test sample around the mandrel according to 5.5 and secure the ends. Condition the sample according to the temperature and relative humidity shown in Figure 15. The “Temperature Class Rating” is shown in Figure 6. Extended transition times may be used as long as the dwell times at temperature are maintained. The cycle begins with the sample at –40 °C ± 2 °C and uncontrolled relative humidity. Completion of the schedule shown in Figure 15 will constitute one cycle. Repeat the cycle for a total of 40 cycles. While still on the mandrel, remove the test sample from the chamber, allow it to stabilize at room temperature for 30 min, and unwind it from the mandrel. Make a visual inspection of the insulation. Ignore any damage caused by the ties, which secure the ends. If no exposed conductor is visible, perform the “Dielectric” test (see 6.4) except the voltage will be applied after immersion in the salt solution for a minimum of 10 min.



Key:
1 (–40 ± 2) °C
2 (80 – 90) °C
3 Test temperature, see Figure 6
4 Relative humidity, uncontrolled
5 (80 – 100)% Relative humidity

FIGURE 15 - PROCEDURE FOR “TEMPERATURE AND HUMIDITY CYCLING” TEST
Reference 6.15

7. REFERENCE INFORMATION

7.1 Color Code

The purpose of the "color code" is to provide visual information during the building and servicing of wiring assemblies. Cables of different colors shall be distinguishable from each other.

7.1.1 Recommended Colors

The color of the cable should match as closely as possible the central color specified in Appendix B. The "Light" and "Dark" color limits are for guidelines only.

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.

8. NOTES

8.1 Marginal Indicia

A change bar (I) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY THE SAE CABLE TASK FORCE
OF THE SAE ELECTRICAL DISTRIBUTION SYSTEMS STANDARDS COMMITTEE

APPENDIX A - FOR INFORMATION ONLY CONDUCTOR AREA METRIC UNITS
Reference 5.1

SAE Conductor Size No.	Metric Conductor Size mm^2	Minimum Conductor Area mm^2
24	0.22	0.205
22	0.35	0.324
20	0.5	0.508
18	0.8	0.760
16	1.0	1.12
14	2.0	1.85
12	3.0	2.91
10	5.0	4.65
8	8.0	7.23

NOTES:
1. The conductor size is the approximate nominal area of the conductor.

FIGURE A1 - CONDUCTOR AREA (METRIC UNITS)
REFERENCE 5.1

SAE Conductor Size	SAE Cable Type											
	TWP TXL			GPT GXL			SXL			HDT HTS		
	Wall Thickness		Maximum Outside Cable Diameter	Wall Thickness		Maximum Outside Cable Diameter	Wall Thickness		Maximum Outside Cable Diameter	Wall Thickness		Maximum Outside Cable Diameter
No.	Nominal in	Minimum in	in	Nominal in	Minimum in	in	Nominal in	Minimum in	in	Nominal in	Minimum in	in
24	0.016	0.011	0.062									
22	0.016	0.011	0.069									
20	0.016	0.011	0.076	0.023	0.016	0.095	0.029	0.020	0.110	0.036	0.025	0.125
18	0.016	0.011	0.084	0.023	0.016	0.100	0.030	0.021	0.120	0.037	0.026	0.135
16	0.016	0.011	0.095	0.023	0.016	0.115	0.032	0.022	0.135	0.040	0.028	0.150
14	0.016	0.011	0.109	0.023	0.016	0.125	0.035	0.025	0.155	0.041	0.029	0.165
12	0.018	0.013	0.132	0.026	0.018	0.150	0.037	0.026	0.180	0.046	0.032	0.200
10	0.020	0.014	0.161	0.031	0.022	0.185	0.041	0.029	0.210	0.046	0.032	0.255
8	0.022	0.015	0.196	0.037	0.026	0.235	0.043	0.030	0.245	0.055	0.039	0.280

NOTE: English units for dimensions are included for information purposes only. They do not constitute a requirement for this standard.

FIGURE A2 - “OUTSIDE CABLE DIAMETER” AND “WALL THICKNESS”
(ENGLISH UNITS)
References 5.3 and 5.4

APPENDIX B - RECOMMENDED COLORS
REFERENCE SAE EA-1128, WIRE COLOR CHARTS

Color	Abbreviation	Light	Central	Dark
Red	RD	2.5R 4.2/11.2	3.3R 3.8/11.0	4.4R 3.4/10.4
Orange	OG	8.75R 6.0/11.5	8.75R 5.75/12.5	8.75R 5.5/13.5
Brown	BN	10R 3.5/1.0	0.8YR 3.0/1.0	4.6YR 2.5/1.0
Beige (Tan)	BG	5YR 6.25/4.0	5YR 5.9/4.3	5YR 5.5/4.6
Yellow	YE	8.4Y 8.5/8.3	8.2Y 8.5/9.8	8Y 8.5/11.2
Lt Green	GN	0.5G 6.25/6.3	0.5G 5.6/7.0	0.5G 5.1/7.5
Dk Green	DG	2.2BG 4.75/9.4	1.3BG 4.25/9.4	0.5BG 3.75/9.4
Lt Blue	BU	9B 5.4/5.0	9B 5.0/5.0	9B 4.7/5.0
Dk Blue	DB	4.6PB 3.8/10.2	5.2PB 3.3/9.8	5.6PB 2.75/9.4
(Violet) Purple	VT	4.4P 3.9/6.7	3.9P 3.4/6.7	3.4P 2.8/6.7
Pink	PK	7RP 6.1/11.5	7.2RP 5.6/12.1	7.7RP 5.2/12.5
Gray	GY	N6.3/(10GY,0.2)	N5.7/(10GY,0.2)	N5.2/(10GY,0.2)
White	WH	Not Applicable	5Y 9/1	5Y 8.5/1
Black	BK	N3	N 2.25	Not Applicable

NOTES:
1. Comparison must be made by a person with normal color sensitivity, under cool white fluorescent lighting. The surface being inspected and the tolerance set must be in the same plane. Cable samples must be placed flat, overlapping the color standard.
2. FMII, measured under CIE illuminant C, 2 deg observer.

FIGURE B1 - RECOMMENDED COLORS
Reference SAE EA-1128, Wire Color Charts

APPENDIX C - SOURCES FOR SAE REFERENCE MATERIALS

Fluid	Supplier	Packaging
Engine Oil ASTM D 471 IRM 902 Oil	R. E. Carroll, Inc. P. O. Box 5806 Trenton, NJ 08638-0806 Phone: (800)-257-9365 Fax: (609)-695-0102 URL: http://www.recarroll.com	5 Gal Can
	Penreco 4426 East Washington Blvd. Los Angeles, CA 90023 Phone: (888)-227-5448 Fax: (323)-268-7972 URL: http://www.penreco.com	5 Gal Can
Power Steering ASTM D 471 IRM 903 Oil	R. E. Carroll, Inc. P. O. Box 5806 Trenton, NJ 08638-0806 Phone: (800)-257-9365 Fax: (609)-695-0102 URL: http://www.recarroll.com	5 Gal Can
	Penreco 4426 East Washington Blvd. Los Angeles, CA 90023 Phone: (888)-227-5448 Fax: (323)-268-7972 URL: http://www.penreco.com	5 Gal Can
Automatic Trans Fluid SAE J311, Dexron VI	Petro-Canada 2489 North Sheridan Way Mississauga, Ontario L5K 1A8 Phone: 1-905-804-4500 Fax: (905) 822-7450 URL: http://www.lubricants.petro-canada.ca	Case of 12 – 1 liter bottles or Case of 4 – 4 liter bottles
Kester #2166BN Flux	Kester Solder 515 East Touhy Avenue Des Plaines, IL 60018-2675 Phone: (800) 253-7837 Fax: (847) 699-5548 URL: http://www.kester.com	Pint Quart or Gallon
Sandpaper Abrasion Tape	Tek Sevice Group Inc. P.O.Box 538 2202 Niles Cortland Road – Suite A Cortland, Ohio 44410 Phone: (330) 638-5088 Fax: (330) 638-5017 URL: tammy@gsi-tek.com	2 Rolls ≥ 3 Rolls ≥ 11 Rolls ≥ 51 Rolls

FIGURE C1 - SOURCES FOR SAE REFERENCE MATERIALS