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SURFACE VEHICLE STANDARD

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AUTOMOTIVE PRINTED CIRCUITS

Foreword—This Document has not changed other than to put it into the new SAE Technical Standards Board Format.

1. ***Scope***—This report relates to recommendations and specifications governing the classification, composition, test procedures, and properties of printed circuits commonly used to replace cable in automotive low voltage systems. It is not applicable to miniature circuits for solid state devices, high impedance or high voltage functions.

2. ***References***

2.1 Applicable Publications—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated the lastest revision of SAE publications shall apply

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

ASTM D149—Methods of Test for Dielectric Breakdown Voltage and Dielectric Strength of Electrical Insulating Materials at Commercial Power Frequencies
ASTM D229—Testing Rigid Sheet and Plate Materials Used for Electrical Insulation
ASTM D256—Methods of Test for Impact Resistance of Plastics and Electrical Insulating Materials
ASTM D568—Test for Flammability of Plastics 0.127 cm (0.050 in) and Under in Thickness
ASTM D635—Tests for Flammability of Rigid Plastics Over 0.127 cm (0.050 in) in Thickness
ASTM D638—Method of Test for Tensile Properties of Plastics
ASTM D648—Method of Test for Deflection Temperature of Plastics Under Load
ASTM D709—Specification for Laminated Thermosetting Materials: 0.025 in/in (0.025 mm/mm)
ASTM D790—Method of Test for Flexural Properties of Plastics
ASTM D882—Methods of Test for Tensile Properties of Thin Plastic Sheeting (Method A-100% Elongation Per Minute)
ASTM D1004—Method of Test for Tear Resistance of Plastic Film and Sheeting
ASTM D2210-64—Modified, Standard Method of Test for Bursting Strength of Leather, with Bulge Diameter of 1.250 in (32 mm)
ASTM E 53-48

3. Base Materials—The base insulating materials fall into three categories: Phenolic Laminates, Plastic Molding Materials, and Flexible Plastic Films of the type which will meet the following flame retardancy requirement.

3.1 Flame Retardancy—Flame resistance of the material used for base or overlay shall be equal to or better than phenolic laminates, acrylonitrile butadiene, styrene, or polyester films from polyethylene terephthalate, respectively, as measured by ASTM D 635. Tests for Flammability of Rigid Plastics Over 0.127 cm (0.050 in) in Thickness, or ASTM D 568, Test for Flammability of Plastics 0.127 cm (0.050 in) and Under in Thickness.

3.1.1 PHENOLIC LAMINATES—When plastic laminate base material is used, the quality characteristics and tolerances must conform to the following:

a. Paper laminate thoroughly impregnated with thermosetting phenolic resin binder and properly cured.
b. The material shall be opaque unless otherwise specified.
c. Thickness shall be 0.062 in (1.58 mm) unless otherwise specified. (Refer to item E under Design Considerations.)
d. Flexural strength shall not be less than 13,000 psi (89.6 MPa) with the grain or less than 11,000 psi (75.8 MPa) across the grain (ASTM D 229, Testing Rigid Sheet and Plate Materials Used for Electrical Insulation, and ASTM D 790, Method of Test for Flexural Properties of Plastics).

3.1.2 PLASTIC MOLDING MATERIALS—When plastic molding material is used, the quality characteristics and tolerances must conform to the following:

a. The material must be opaque in cross section of 0.062 ± 0.005 in (1.58 ± 0.13 mm) thickness.
b. Minimum physical properties:

   1. Impact strength: 1.3 ft-lb/in (69.4 N·m/m) notch 1/4 in (6.35 mm) bar sample notches at 73 °F (22.8 °C) (ASTM D 256, Methods of Test for Impact Resistance of Plastics and Electrical Insulating Materials).
   2. Flexural strength: 11,220 psi (77.36 MPa) (ASTM D 790).
   3. Tensile strength: 7750 psi (53.4 MPa) (ASTM D 638, Method of Test for Tensile Properties of Plastics).
   4. Heat distortion temperature 225 °F (107.2 °C) at 264 psi (1.8 MPa) (ASTM D 648, Method of Test for Deflection Temperature of Plastics Under Load).

The materials in paragraphs 2.1.1 and 2.1.2 shall not be subjected to temperatures in excess of 225 °F (107.2 °C).

3.1.3 FLEXIBLE PLASTIC FILM—When flexible plastic film is used, the quality characteristics and tolerances must conform to the following:

a. Tensile strength: 17,000 psi (117.2 MPa) (minimum), ASTM D 882, Methods of Test for Tensile Properties of Thin Plastic Sheeting (Method A-100% elongation per minute).
b. Tensile modulus: 450,000 psi (3.1 GPa) (minimum), ASTM D 882 (Method A-100% elongation per minute).
c. Tear initiation: 2000 lb/in (226 N·m) (minimum) Graves, ASTM D 1004, Method of Test for Tear Resistance of Plastic Film and Sheeting.
d. Thermal coefficient of linear expansion: 15 x 10^{-6} (maximum) 70–120 °F (21–49 °C).
e. Moisture absorption, water immersion: less than 0.5%, 24 h.
f. Dielectric strength: 500 V/mil (19.7 kV/mm) minimum per ASTM D 149, Methods of Test for Dielectric Breakdown Voltage and Dielectric Strength of Electrical Insulating Materials at Commercial Power Frequencies.
g. Melting point: more than 350 °F (177 °C).
h. Thickness to be 0.003 in (0.08 mm) minimum.

4. Copper

4.1 Printed circuit grade electrodeposited copper foil with:

a. 99.8% minimum purity per ASTM E 53-48.
b. Maximum oxygen content 0.1% per ASTM E 53-48.
c. Minimum elongation of 10%, both transverse and longitudinal. Measurement shall be made using a 2 in (50.80 mm) gage length with an extension rate of 2 in/min (0.85 mm/s).
d. Tensile strength: Longitudinal - 25,000 psi (172 MPa) minimum, transverse - 25,000 psi (172 MPa) minimum.
e. Bulge height: For test method, see Appendix. Bulge height shall be 0.180 in (4.57 mm) minimum.
f. Resistivity: The resistivity shall not exceed 0.15940 m^2 at 68 °F (20 °C).
g. The foil shall be free of any lead inclusions or other foreign materials.
h. The foil shall have an antitarnish treatment which is compatible with the subsequent bonding or lamination process and which will offer no additional significant increase in the electrical resistance between the foil surface and any component.

4.2 Thicknesses employed may be 0.00135 in (0.034 mm), which is 1 oz/ft^2 (0.305 kg/m^2); 0.0027 in (0.069 mm), which is 2 oz ft^2 (0.610 kg/m^2); or 0.004 in (0.102 mm), which is 3 oz/ft^2 (0.915 kg/m^2). The choice of thickness is made on the basis of the thinnest copper foil that will meet the current-carrying requirements for any specific applications. (See Figure A1.) Discoloration of the copper faces shall not be considered objectionable.

5. Coating—On phenolic laminate or molded plastics, a scratch resistant protective insulating coating film shall be bonded to all foil side surfaces which will not require contact with other components. The coating film or overlay used on circuits with flexible plastic base must be firmly bonded such that the fold endurance (see Physical Test Requirements) will be maintained.

6. Design Considerations

6.1 Practical Tolerances on Critical Dimensions

a. Hole diameters:

Up to 0.500 ± 0.004 in (12.7 ± 0.10 mm)
0.500 to 1.000 ± 0.005 in (12.7–25.4 ± 0.13 mm)
Over 1.000 ± 0.006 in (25.4 ± 0.15 mm)

For slots and notches, consider both length and width as hole diameters.

b. Hole-to-hole centerline tolerance: ±0.005 in (±0.13 mm). Add ±0.001 in (±0.03 mm) for every inch (25.4 mm) over 1 in (25.4 mm).
c. Line width and spacing tolerance: ±0.010 in (±0.25 mm). Line width tolerances do not include nicks, pin holes, and scratches. These imperfections are acceptable provided the line is not reduced by more than 20% in a local area.
d. Warpage on phenolic laminate: Measured according to ASTM D 709, Specification for Laminated Thermosetting Materials: 0.025 in/in (0.025 mm/mm). Closer warp tolerances may limit the selection of raw materials or make necessary unusual manufacturing operations or shipping procedures.
e. Panel thickness (0.062 in or 1.58 mm): Tolerance with copper foil:

oz/ft2	kg/m2	No. of Sides	Tolerance in	Tolerance mm
1	0.305	1	±0.0055	±0.14
1	0.305	2	±0.0060	±0.15
2	0.610	1	±0.0060	±0.15
2	0.610	1	±0.0065	±0.16

f. Bond strength: Normal peel strength testing method to be used: a suitable universal testing machine (See Figure A2.) pulling the foil from the laminate within 5 deg (0.083 rad) of the perpendicular to the face of the sample. Jaws must grip foil across entire foil width. Convert results to pounds per inch width (newton/meter). Bond strength to base material 4 lb/in (0.45 N·m) of width minimum (6 lb/in (0.68 N·m) of width average) on 10 samples, one line each.
g. Registration of circuit pattern to part: ±0.015 in (0.38 mm).

6.2 Good Practice—Line widths, spacings, etc. [1]

a. Minimum width of conductor: 0.060 in (1.52 mm). (See Figure A1 and Figure A3 for special application and typical pattern.)
b. Minimum spacing between conductors: 0.060 in (1.52 mm).
c. Minimum distance between copper conductors and edge of board: 0.060 in (1.52 mm).
d. Minimum distance from a hole to the edge of the board should equal the diameter of the hole and should never be less than the thickness of the base material.
e. Where conductor pad diameter is to be used for circuit mounting and grounding conductor, diameter should exceed screw head diameter by a minimum of 0.090 in (2.29 mm). Conductor fillet radii should be as large as possible, and in no case less than 0.03 in (0.76 mm) R.
f. Maximum distance from edge of lamp socket hole to copper foil pad on phenolic laminate or plastic molded bases shall be 0.030 in (0.76 mm). (See Figure A4.) Maximum distance from edge of lamp socket hole to copper foil pad on flexible plastic films shall be 0.065 in (1.65 mm). (See Figure A5.)
g. A radius shall be applied to all corners, notches, and slots, and shall not be less than 0.03 in (0.76 mm) R.
h. Additional layout considerations. (See Figure A3, Figure A4, Figure A5.)

7. Test Requirements

7.1 Electrical

a. Dielectric: 200,000 minimum resistance must exist between any two conductors after conditioning for 24 h at 170 °F (77 °C), and 100% relative humidity, when using a low voltage type resistance meter. Moisture present on sample surface to be wiped off or blown off with compressed air prior to the resistance check.

1. The 0.060 in (1.52 mm) minimum conductor widths and spacing refer to printed circuits commonly used to replace cable in automotive wiring. Miniature circuits for solid-state devices, etc., will normally have special requirements and specifications determined by the function.

b. Millivolt drop: Tests to be conducted at ambient room temperature of 75 ± 5 °F (24 ± 2.8 °C) in draft free area.

   1. Maximum permissible millivolt drop from any component contacting the foil on any printed circuit board or flexible plastic film shall be 5.0 mV at 2.0 A before conditioning.
   2. Maximum millivolt drop from any component to the foil after one humidity cycle of 100 h at 100% relative humidity at 100 °F (37.8 °C), must not exceed 10.0 mV at 2.0 A.

c. Continuity of all electrical connections and circuits must be maintained after 25 thermal shock cycles. For printed circuits used in applications where the maximum ambient temperature does not exceed 175 °F (80 °C), each cycle is to consist of:

   15 min at –30 ± 3 °F (–34.5 ± 1.7 °C)
   15 min at 75 ± 5 °F (24 ± 2.8 °C)
   15 min at 175 ± 3 °F (80 ± 1.7 °C)
   15 min at 75 ± 5 °F (24 ± 2.8 °C)

   For printed circuits used in applications where the maximum ambient temperature is greater than 175 °F (80 °C) but does not exceed 250 °F (121 °C), the third 15 min of each cycle will be at 250 ± 3 °F (121 ± 1.7 °C).

7.2 Physical—No fractures of the conductors permitted on flexible circuits or on rigid circuits properly attached to the supporting structure after conditioning separate samples as follows:

a. After 50 heat cycles in test requirement 6.1(c).
b. After two humidity cycles. One cycle to consist of 100 h at 100% relative humidity at 100°F (37.8 °C), followed by 24 h at room ambient conditions.
c. After being subjected to five continuous cycles as follows: 100 ± 5 °F (37.8 ± 2.8 °C) at 95–100% relative humidity for 2 h. Temperature then to be raised gradually to 160 ± 5 °F (71 ± 2.8 °C) at the same relative humidity over a 1 h period and then maintained for an additional 3 h. The temperature is then to be lowered gradually to 100 ± 5 °F (37.8 ± 2.8 °C), while at the 95–100% relative humidity, over a period of 6 h. This would constitute one cycle. After completion of five cycles, parts examination should be initiated following 1 h minimum rest at room ambient conditions. If the printed circuit being tested is used in an application where the maximum ambient temperature is greater than 175 °F (80 °C) but does not exceed 250 °F (121 °C) at the completion of the preceding five cycles it shall be subjected immediately to an additional five continuous cycles as follows: –30 ± 3 °F (–34.5 ± 1.7 °C) for 1 h. Temperature then to be raised gradually to 250 ± 3 °F (121 ± 1.7 °C) over a 3 h period and then maintained for 1 h. The temperature is then to be lowered gradually to –30 ± 3 °F (–34.5 ± 1.7 °C) over a 3 h period and then maintained for 1 h. This would constitute one cycle. After completion of five cycles, the printed circuit would be placed in room ambient conditions for a minimum of 1 h before examination for fractures or delamination.
d. After being subjected to one cycle of vibration in each of three mutually perpendicular directions. Each cycle shall be as follows: The printed circuit shall be mounted or fastened as it normally would be in the application and contain all components and attachment devices. This assembly is then exposed to a temperature of –30 ± 3 °F (–34.5 ± 1.7 °C) for 1 h. The assembly is then immediately subjected to a simple harmonic motion having an amplitude of 0.015 in (0.38 mm) with 0.03 in (0.76 mm) peak-to-peak maximum excursion. The frequency shall be varied uniformly between the limits of 10 and 55 Hz. The entire range from 10 – 55 Hz and returning to 10 Hz shall be traversed in approximately 1 min. This motion shall be applied for a period of 30 min. During this portion of the test the sample shall not be subjected to any temperature other than room ambient. Examination of the sample shall be after the third cycle.

If the sample being tested is used in an application where the maximum ambient temperature is greater than 175 °F (80 °C) but does not exceed 250 °F (121 °C), at the completion of the preceding three cycles, it shall be subjected immediately to an additional three cycles. These cycles will be similar to the first three except the conditioning temperature shall be 250 ± 3 °F (121 ± 1.7 °C) instead of –30 °F (–34.5 °C). Examination of the sample shall be after all six cycles are completed.

e. Method for determining ductility of copper material intended for use in printed circuits: See Appendix.

PREPARED BY THE SAE ELECTRICAL DISTRIBUTION SYSTEMS SUBCOMMITTEE OF THE SAE ELECTRICAL AND ELECTRONIC SYSTEMS TECHNICAL COMMITTEE

APPENDIX A

METHOD FOR DETERMINING DUCTILITY OF COPPER MATERIAL INTENDED FOR USE IN FLEXIBLE PLASTIC FILM PRINTED CIRCUITS

A.1 Apparatus—The apparatus used shall conform to that described in ASTM D 2210-64 Modified, Standard Method of Test for Bursting Strength of Leather, with Bulge Diameter of 1.250 in (32 mm), so that the output shaft turns at 10 rpm.

A.2 Test Specimens—From the samples selected to determine the ductility property, cut at least three specimens 3-1/2 in (90 mm) square from sections located approximately at equal distances across the width of the material.

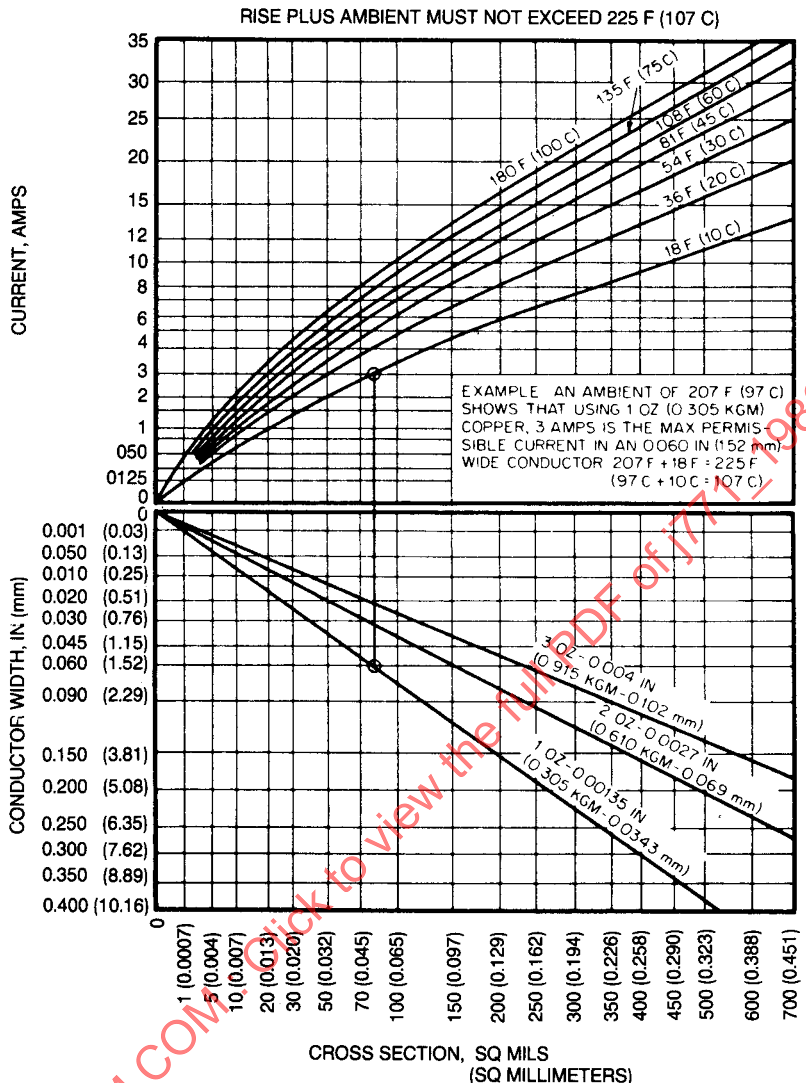
A.3 Test Procedure

A.3.1 Set the bulge height indicator to zero using a flat rigid sheet between the plates.

A.3.2 Clamp the specimen securely between the plates of the circular hydraulic bulge tester with the uncoated (bright) side of the material facing downward.

A.3.3 Admit the hydraulic fluid to the bulging chamber between the plates.

A.3.4 Observe and record the maximum bulge height at burst.



FOR USE IN DETERMINING CURRENT CARRYING CAPACITY AND SIZES OF COPPER CONDUCTORS FOR VARIOUS TEMPERATURE RISES ABOVE AMBIENT. CURVES ARE DERATED A NOMINAL 10% TO ALLOW FOR VARIATIONS IN PRODUCTION TECHNIQUES

FIGURE A1—CONDUCTOR THICKNESS AND WIDTH

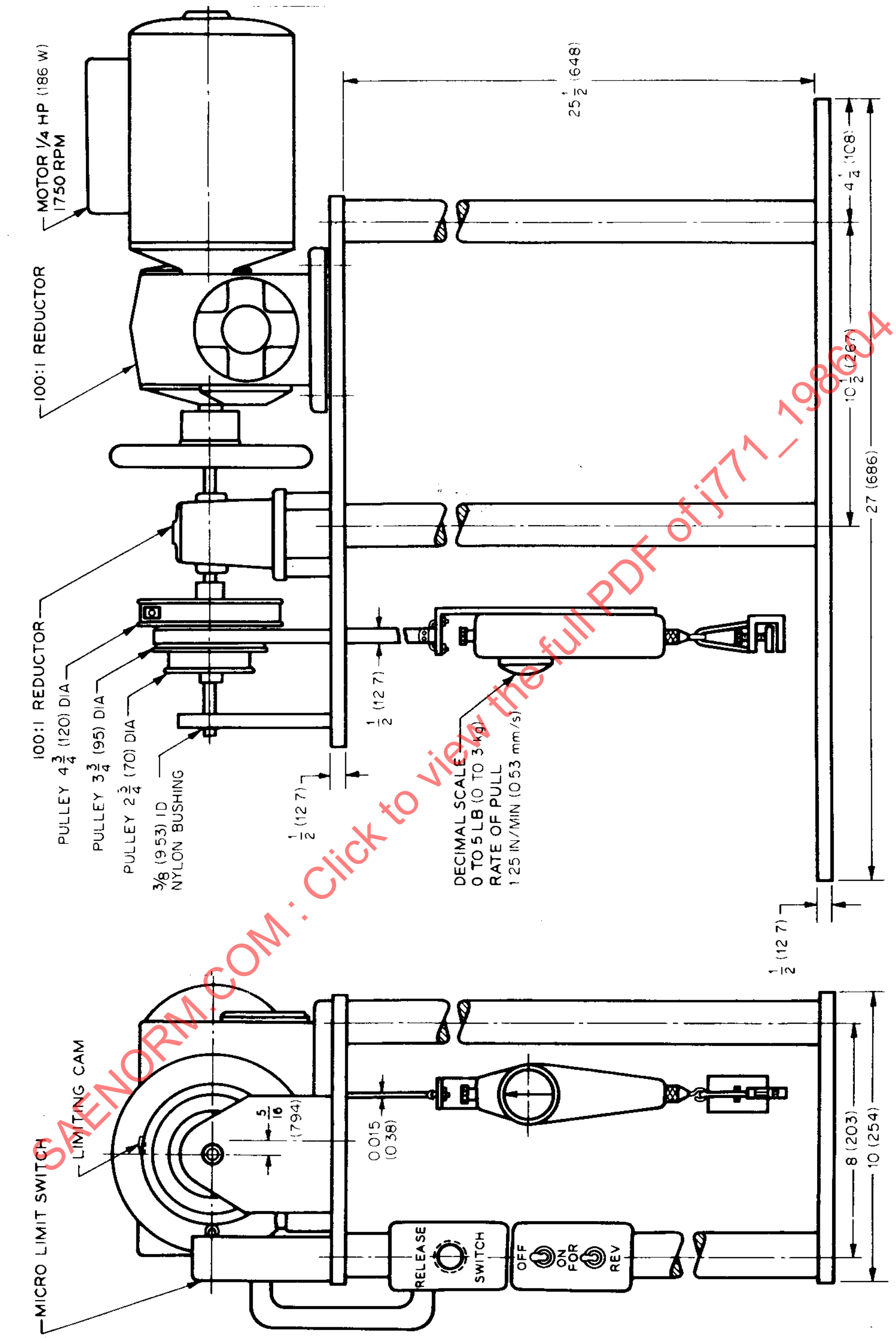


FIGURE A2—BOND STRENGTH TESTER

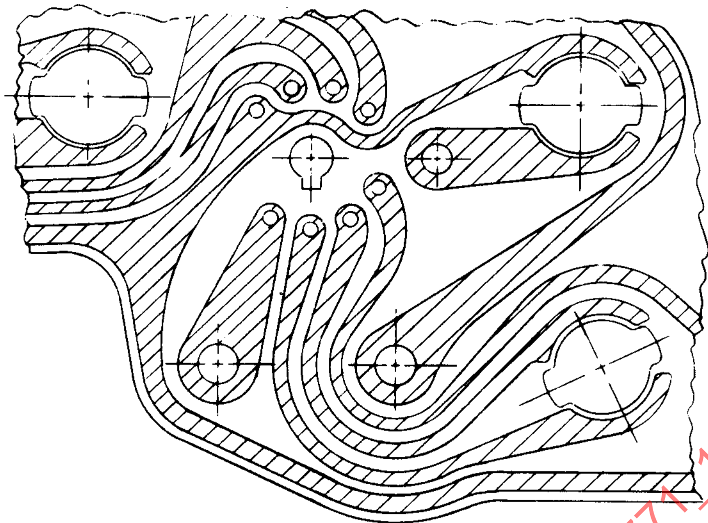


FIGURE A3—CONDUCTOR PATTERNS: RECOMMENDED TYPICAL SECTION, WIDE CONDUCTOR LINES AND FILLETS IN AREA OF PADS AND LANDS

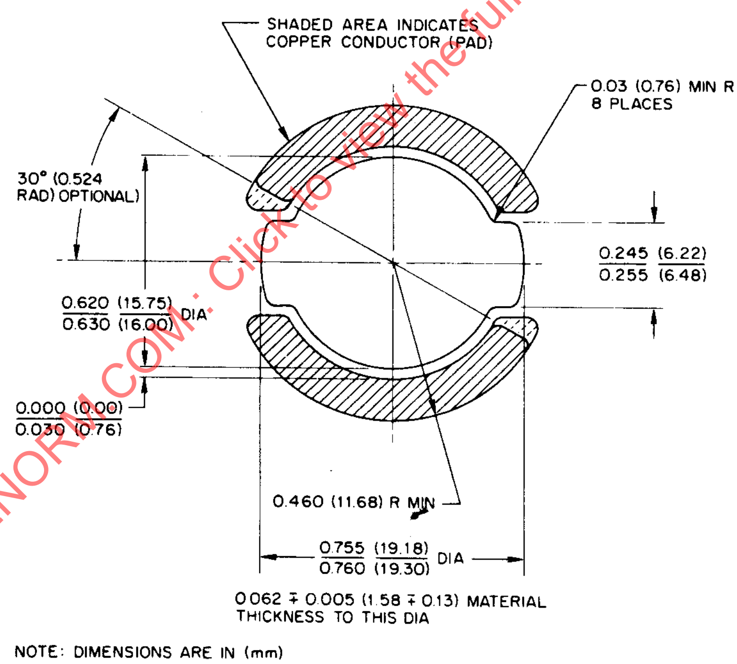


FIGURE A4—5/8 IN (15.9 MM) PRINTED CIRCUIT LAMP SOCKET HOLE STANDARD FOR RIGID PLASTIC OR PHENOLIC BASE