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Automotive Printed Circuits — SAE J771c

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Report of Electrical Equipment Committee approved June 1961
and last revised April 1975.

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.

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.

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.

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 the 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).

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 $\pm$ 0.005 in (1.58 $\pm$ 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 1 and 2 shall not be subjected to temperatures in excess of 225°F (107.2°C).

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: 15×10^{-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.

COPPER

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 4%, 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 $0.15940 \Omega/\text{m}^2$ 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.

2. Thicknesses employed may be 0.00135 in (0.034 mm), which is 1 oz/ft² (0.305 kg/m²); 0.0027 in (0.069 mm), which is 2 oz/ft² (0.610 kg/m²); or 0.004 in (0.102 mm), which is 3 oz/ft² (0.915 kg/m²). 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 Fig. 1). Discoloration of the copper faces shall not be considered objectionable.

COATING—On phenolic laminate or molded plastics, a scratch resist 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.

DESIGN CONSIDERATIONS

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/ft ²	kg/m ²	No. of Sides	Tolerance	
			in	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	2	± 0.0065	± 0.16

(f) Bond strength: Normal peel strength testing method to be used: a suitable universal testing machine (Fig. 2) 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/metre). 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).

2. GOOD PRACTICE (line widths, spacings, etc.¹)

¹The 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.

(a) Minimum width of conductor: 0.060 in (1.52 mm). (See Figs. 1 and 3 for special application and typical patterns.)

(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) (Fig. 4). Maximum distance from edge of lamp socket hole to copper foil pad on flexible plastic films shall be 0.065 in (1.65 mm) (Fig. 5).

(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 (Figs. 3-5).

TEST REQUIREMENTS

1. ELECTRICAL

(a) Dielectric: 200,000 Ω minimum resistance must exist between any two conductors after conditioning for 24h 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.

(b) Millivolt drop: Tests to be conducted at ambient room temperature of 75 $\pm$ 5 F (24 $\pm$ 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 (50°C), each cycle is to consist of:

- 15 min at -3°F (-34.5 $\pm$ 1.7°C)
- 15 min at 75 $\pm$ 5°F (24 $\pm$ 2.8°C)
- 15 min at 175 $\pm$ 3°F (80 $\pm$ 1.7°C)
- 15 min at 75 $\pm$ 5°F (24 $\pm$ 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 $\pm$ 3°F (121 $\pm$ 1.7°C).

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 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 14 h at room ambient conditions.

(c) After being subjected to five continuous cycles as follows: 100 $\pm$ 5°F (37.8 $\pm$ 2.9°C) at 95-100% relative humidity for 2 h. Temperature then to be raised gradually to 160 $\pm$ 5°F (71 $\pm$ 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 $\pm$ 5°F (37.8 $\pm$ 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 $\pm$ 3°F (-34.5 $\pm$ 1.7°C) for one hour. Temperature then to be raised gradually to 250 $\pm$ 3°F (121 $\pm$ 1.7°C) over a 3 h period and then maintained for one hour. The temperature is then to be lowered gradually to -30 $\pm$ 3°F (-34.5 $\pm$ 1.7°C) of a 3 h period and then maintained for one 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 1h before examination for fractures or delaminations.

(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 $-30 \pm 3^{\circ}\text{F}$ ($-34.5 \pm 1.7^{\circ}\text{C}$) for 1 h. The assembly is then immediately subjected to a simple harmonic motion having an amplitude of 0.015 in. (0.38 mm) and 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 to 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 $250 \pm 3^{\circ}\text{F}$ ($121 \pm 1.7^{\circ}\text{C}$) 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

APPENDIX

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

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.

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

3. Test Procedure:

3.1 Set the bulge height indicator

to zero using a flat rigid sheet between the plates.

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.

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

3.4 Observe and record the maximum bulge height at burst.

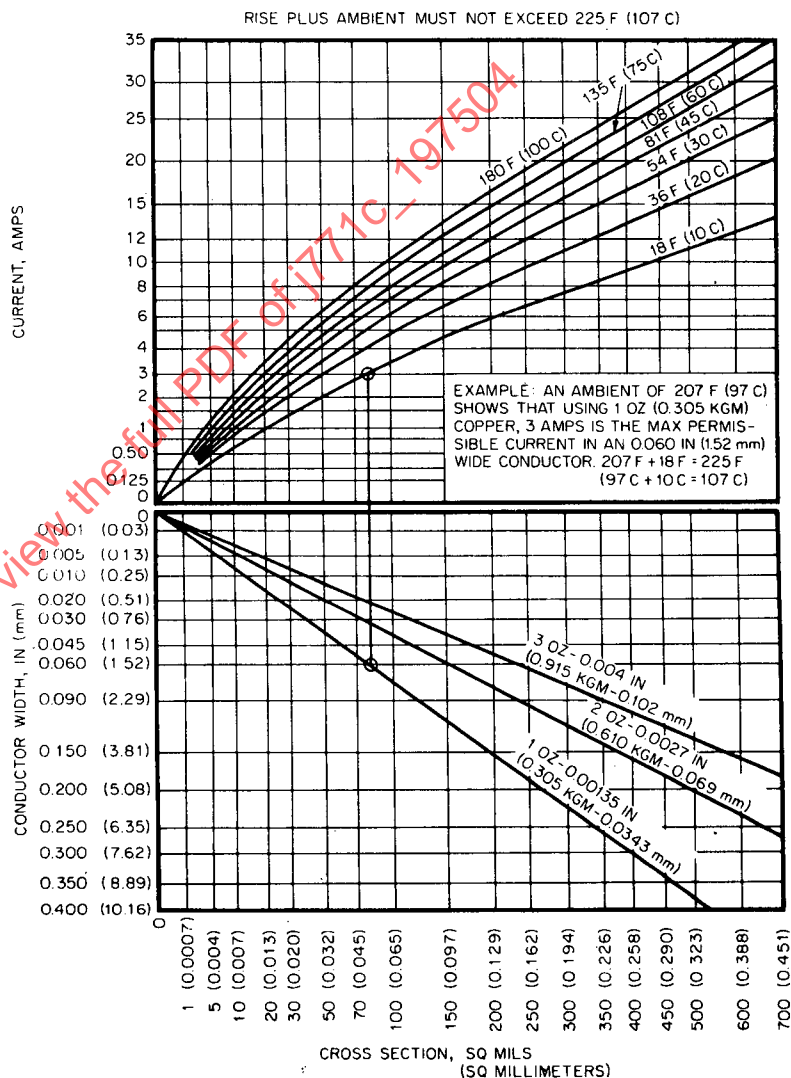


FIG. 1 - CONDUCTOR THICKNESS AND WIDTH

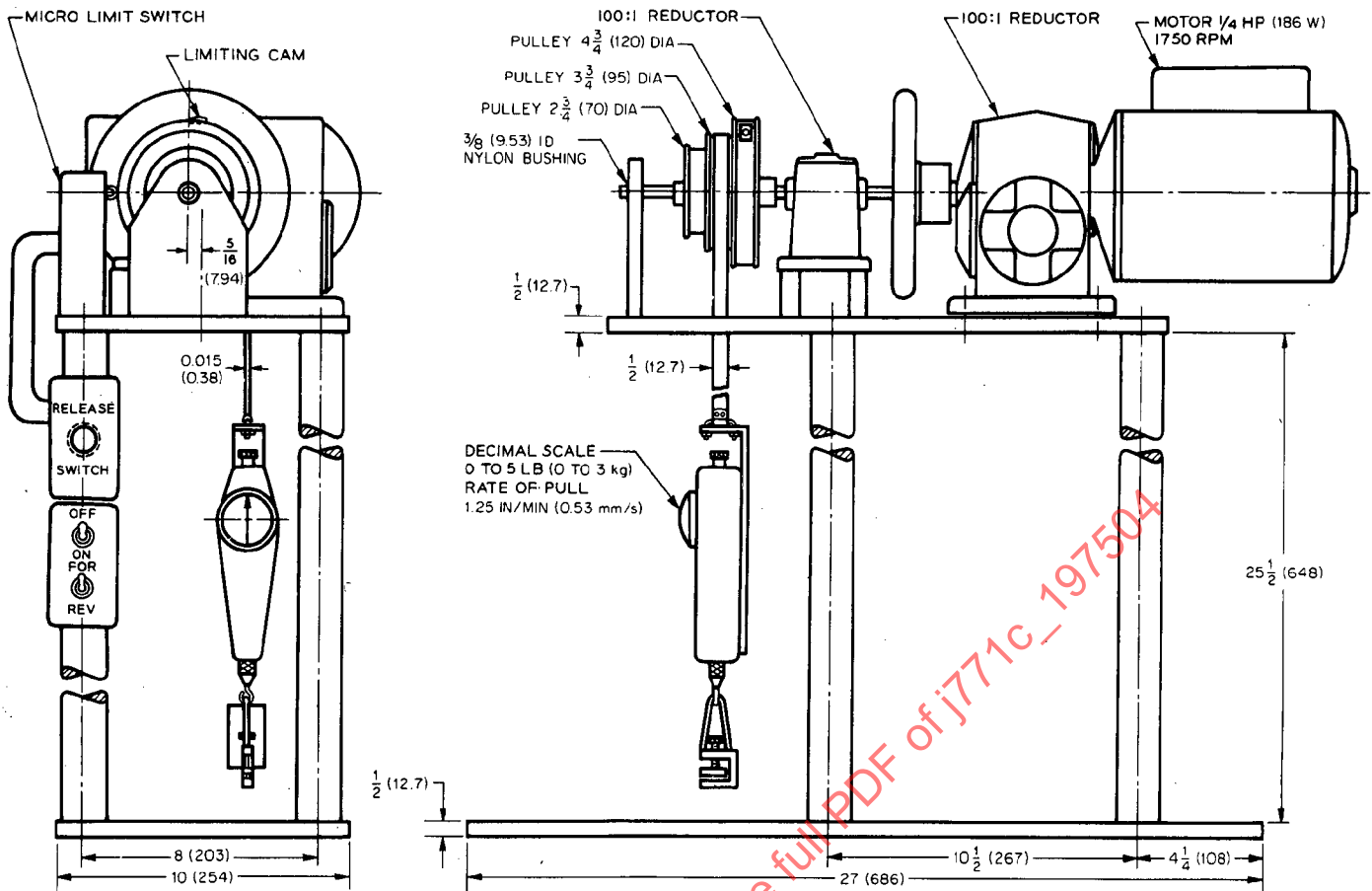


FIG. 2 - BOND STRENGTH TESTER

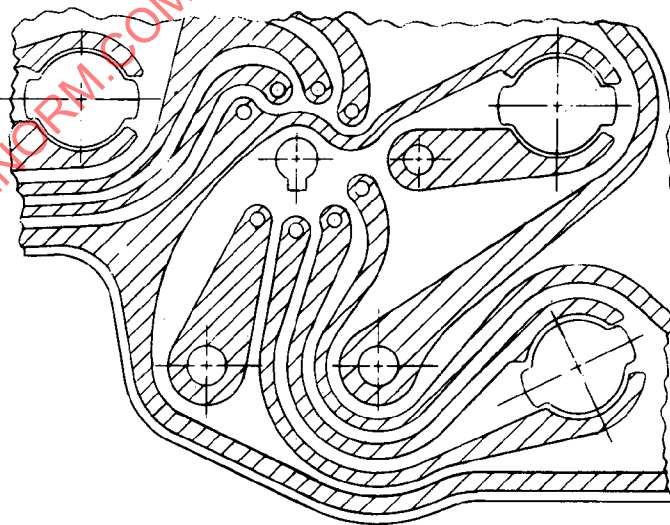


FIG. 3 - CONDUCTOR PATTERNS: RECOMMENDED TYPICAL SECTION, WIDE CONDUCTOR LINES AND FILLERS IN AREA OF PADS AND LANDS