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MILITARY STANDARD

FLEXIBLE AND RIGID-FLEX PRINTED-WIRING FOR ELECTRONIC EQUIPMENT DESIGN REQUIREMENTS FOR

FSC 5999

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DEPARTMENT OF DEFENSE

WASHINGTON, DC 20360

Flexible and Rigid-Flex Printed-Wiring for Electronic Equipment

MIL-STD-2118

1. This Military Standard is approved for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Electronic Systems Command, ATTN: ELEX 8111, Department of the Navy, Washington, DC 20363 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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1. SCOPE

1.1 Purpose. This standard establishes design requirements governing flexible printed-wiring with or without shields or stiffeners and rigid to flexible printed-wiring (hereinafter referred to as rigid-flex) with or without plated-through holes and design considerations for the mounting of parts and assemblies thereon. In the rigid-flex application, the conductor layers that are in the flexible portion are also a layer in the rigid multilayer board. All board types shall have the conductor patterns (excluding the lands) protected by an insulating layer, except for the external conductors on the rigid section of type 4 boards. When components are mounted on flexible and rigid-flex printed-wiring, the mounting area shall be conformally coated. Conformal coating shall be in accordance with MIL-I-46058.

1.2 Classification. The flexible and rigid-flex printed-wiring covered by this standard shall be the following types and classes as specified.

1.2.1 Types:

Type 1 - Single-sided flexible material with or without shields or stiffener (one conductor layer).
Type 2 - Double-sided flexible material with or without shields or stiffener (two conductor layers) with plated-through holes.
Type 3 - Multilayer flexible material with or without shields or stiffener (more than two conductor layers) with plated-through holes.
Type 4 - Multilayer rigid and flexible material combinations (more than two conductor layers) with plated-through holes.
Type 5 - Bonded rigid or flexible material combinations (more than one conductive layer) without plated-through holes.

NOTE: Shields used in types 1, 2, or 3 boards shall not be considered as conductor layers (see 5.11).

1.2.2 Classes:

Class A - Capable of withstanding flexing during installation.
Class B - Capable of withstanding continuous flexing for a number of cycles specified on the master drawing. (Generally not used for more than two conductor layers).

2. REFERENCED DOCUMENTS

2.1 Issues of documents. The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of this standard to the extent specified herein.

SPECIFICATIONS

FEDERAL

QQ-N-290 - Nickel plating (Electrodeposited).
L-F-340 - Film, Sensitized, Wash-Off Process, Diazotype, Moist and Dry Process, Brownprint, Roll and Sheet.
QQ-W-343 - Wire, Electrical, Copper (Uninsulated).
QQ-S-571 - Solder, Tin Alloy; Tin-Lead Alloy; and Lead Alloy.
QQ-C-576 - Copper Flat Products with Slit, Slit and Edge-Rolled, Sheared, Sawed, or Machined Edges, (Plate, Bar, Sheet, and Strip).

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MIL-D-8510 - Drawings, Undimensioned, Reproducibles, Photographic and Contact: Preparation Of.
MIL-P-13949 - Plastic Sheet, Laminated, Metal Clad (For Printed Wiring Boards).
MIL-C-14550 - Copper Plating (Electrodeposited).
MIL-P-28809 - Printed Wiring Assemblies.
MIL-G-45204 - Gold Plating, Electrodeposited.
MIL-I-46058 - Insulating Compound, Electrical (For Coating Printed Circuit Assemblies).
MIL-P-81728 - Plating, Tin-Lead (Electrodeposited).

STANDARDS

MILITARY

DOD-STD-100 - Engineering Drawing Practices.
MIL-STD-130 - Identification Marking of US Military Property.

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer).

2.2 Other publications. The following documents form a part of this standard to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI-Y14.5M - Dimensioning and Tolerancing.

(Application for copies should be addressed to the American National Standards Institute, 1430 Broadway, New York, NY 10018).

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM-E53 - Chemical Analysis for Copper (Electrolytic Determination of Copper), Method for.

(Application for copies should be addressed to American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103).

INSTITUTE FOR INTERCONNECTING AND PACKAGING ELECTRONIC CIRCUITS (IPC)

IPC-T-50 - Circuit, Electronic, Terms and Definitions, for Interconnecting and Packaging.
IPC-CF-150 - Copper Foil for Printed Wiring Applications.
IPC-FC-231 - Flexible Bare Dielectric for Use in Flexible Printed-Wiring.
IPC-FC-232 - Specification for Adhesive Coated Dielectric Films for Use as Cover Sheets for Flexible Printed-Wiring.
IPC-FC-233 - Flexible Adhesive Bonding Films.
IPC-FC-241 - Metal-Clad Flexible Dielectrics for Use in Fabrication of Flexible Printed-Wiring.
IPC-D-350 - End Product Description in Numeric Form.
IPC-S-815 - General Requirements for Soldering Electronic Interconnections.
IPC-SM-840 - Qualification and Performance of Permanent Polymer Coating (Solder Mask) for Printed Boards.

(Application for copies should be addressed to the Institute for Interconnecting and Packaging Electronic Circuits, 3451 Church Street, Evanston, IL 60203).

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3. DEFINITIONS

3.1 Terms and definitions. The definitions of all terms used herein shall be in accordance with IPC-T-50.

3.1.1 Splay. Splay is the tendency of a rotating drill to drill off-center, out of round, or nonperpendicular holes.

4. GENERAL REQUIREMENTS

4.1 Design features. Design features for flexible and rigid-flex printed-wiring shall be in accordance with this standard. The quality conformance test coupon shall be in accordance with figure 1 and shall be included on the production master, master drawing, and artwork. The test coupon shall be not more than 0.5 inch (13 mm) and shall be not less than 0.25 inch (6.4 mm) from the edge of the board, and reflect all of the manufacturing processes including the coverlayer. On types 3 and 4 flexible and rigid-flex printed-wiring designs, quality conformance test coupons shall be provided for the most complex rigidized and flexible sections.

4.2 Master drawing. The master drawing shall be prepared in accordance with DOD-STD-100 except as otherwise specified herein, and shall establish the type, size, and shape of the flexible and rigid-flex printed-wiring, the size and location of all holes herein, if etchback is required, location of traceability markings, dielectric separation between layers, number and location of quality conformance coupons, and the shape and arrangement of both conductor and nonconductor patterns or elements, with separate views of each conductor layer of the flexible and rigid-flex printed-wiring. Any and all pattern features not controlled by the hole sizes and locations shall be adequately dimensioned, either specifically or by notes; step or repeat of the pattern or repositioning of the quality conformance coupons shall be controlled to meet the requirements of paragraph 4.3. The definitions of all terms used on the master drawing shall be in accordance with IPC-T-50. The plating and coating thickness shall be specified on the master drawing.

The master drawing shall indicate the artwork considerations that were used in the design of the flexible and rigid-flex printed-wiring (see 4.2.5). The master drawing shall include copies of the production masters or copies of the artwork. All appropriate detail requirements (section 5) shall be defined on the master drawing.

When automatic techniques are specified in the contract or purchase order, a magnetic tape containing all computer instructions necessary for making each production master or the card deck containing all instructions necessary for making each production master shall be furnished. The data shall meet the requirements of IPC-D-350.

4.2.1 Single-sheet master drawing. Whenever practical, all information shall be placed on one sheet; however, if the multiplicity of holes or the complexity of the pattern would cause a drawing to become too complicated or difficult to interpret, a multisheet master drawing shall be prepared.

4.2.2 Multisheet master drawing. The first sheets of a multisheet master drawing shall establish the size and shape of the flexible or rigid-flex printed-wiring, stiffeners, diameter, tolerance, and location of all holes, and shall contain all notes. Any and all pattern features not controlled by the hole sizes and locations shall be adequately dimensioned, either specifically or by notes. Subsequent sheets shall establish the shape and arrangement of the conductor and nonconductor patterns on each layer of the flexible or rigid-flex printed-wiring. Conductor layers shall be numbered consecutively starting with the component side as layer 1. If there are no conductors or lands on the component side, the next layer shall be layer 1. Silkscreen or other photo-process markings controlled by the master artwork (as opposed to manually applied ink stampings and etched-in markings) shall be depicted in the master drawing in such a manner as will establish their dependency upon the specified phototools, marking process, and intended pattern registration. Whenever practicable, such markings shall be depicted on a separate sheet of the master drawing, and preferably the last sheet. Manually applied markings, such as serial numbers and date or lot codes, shall be distinctively located and prescribed by appropriate notes and specification (see MIL-STD-130).

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4.2.3 Location dimensioning. All holes, test points, lands and overall complete flexible and rigid-flex printed-wiring dimensions shall be dimensioned by use of a modular grid system, except where necessary to mate parts not on grid (such as, some connector, some transistor, and so forth). The basic modular units of length shall be 0.100, 0.050, 0.025, or other multiples of 0.005 inch in that order of preference and shall be applied in the X and Y axes of the Cartesian coordinates. Critical pattern features which may affect circuit performance (such as distributed inductance, capacitance effects, and so forth) shall also be dimensioned, unless the contract requires the delivery of a stable master produced within the tolerance required for circuit performance. Dimensioning and tolerance practices used in master drawings shall be in accordance with ANSI-Y14.5M.

4.2.4 Hole location tolerance. Unless otherwise specified, the location of holes shall be dimensioned with respect to single or secondary grid systems. Each distinctive hole pattern (such as, plated-through holes, tooling holes, mounting holes, windows, access holes, and so forth), may require separate consideration or specification of tolerance. Produceability considerations are presented in table VII of the appendix.

4.2.5 Artwork allowances. The processing allowances which were considered in the design shall be documented and defined on the master drawing in either note form or by reference to another drawing which contains artwork specifications. This information shall be expressed in terms of the maximum variation between the end-product conductor widths and spacings and what may appear on the artwork; the minimum land, in reference to the drilled or plated hole, and what may appear on the artwork; or any other feature conditions considered in the design where the variation between end-product and artwork configuration play a role in the producibility of the flexible and rigid-flex printed-wiring.

4.2.6 Datums. There shall be a minimum of two mutually perpendicular datums for each board. Datums shall be established by at least two holes, points, symbols, and so forth. Critical feature locations may require the use of secondary datums. The master drawing shall establish the relationship and acceptable tolerance between primary and secondary datums. Both primary and secondary datums shall be located on grid or establish grid criterion, as defined on the master drawing, and should be within the outline of the flexible or rigid-flex printed-wiring board.

4.2.7 Government furnished master drawings. When master drawings are furnished to the contractor by the Government, the design features of this standard shall apply. Any deviation from the standard shall have been recorded on the Government approved master drawing. When a change to the master drawing is necessary, before proceeding further, the contractor shall furnish one copy of each master drawing which is to be revised as a result of changes to the Government agency concerned for approval. Any changes made to the master drawing shall also meet the requirements of this standard and any approved deviations, or a new deviation shall be requested in conjunction with the change request with information justifying the deviation. When approved, all deviations granted shall be documented on the master drawing.

4.2.8 Conflict. In the event of any conflict between the approved master drawing and the requirements of this standard, the approved master drawing shall take precedence.

4.3 Production master. When specified in the contract or purchase order, a production master of each layer shall be provided as part of the drawing set. When a production master is not supplied, the manufacturer shall be responsible for the preparation of the production master with sufficient accuracy to meet the requirements of the flexible or rigid-flex product detailed on the master drawing. The production master shall be as defined in ANSI/IPC-T-50 and shall be supplied or prepared on 0.0075 ±0.0005 inch thick biaxially oriented, dimensionally stable polyester type film or equal, in accordance with MIL-D-0510, type II; L-F-340 film, photographic type 1, class 2, style 1A; or photographic glass plates. The accuracy of the production master (single image, multiple image, or any associated quality assurance coupons) shall be such that the centers of lands, conductors, and other features shall be located within 0.002 inch radius of the true grid position established for the layer, and that for the composite production master, the features of all layers shall coincide within 0.003 inch radius of the true grid position, when

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measured at 20 degrees ±1 degree C, and 50 ±5 percent relative humidity after the material has stabilized; this dimensional requirement need not necessarily apply to legend or permanent solder mask production masters. In the event that tighter tolerances are required in order to produce flexible or rigid-flex products, the production master precision requirements as considered in the design process shall be defined on the master drawing.

4.4 Printed-wiring assembly drawing. The printed-wiring assembly drawing shall cover flexible and rigid-flex printed-wiring on which separately manufactured parts have been added. The printed-wiring assembly drawing shall be in accordance with DOD-STD-100 and should include at least the following:

a. Lead forming requirements.
b. Cleanliness requirements per MIL-P-28809.
c. Type of materials (conformal coating, masking, and potting).
d. Location and identification of all components.
e. Component orientation and polarity.
f. Applicable ordering data from MIL-P-28809.
g. Structural details when required for support and rigidity.
h. Electrical circuitry test requirements.
i. Marking requirements.

All appropriate assembly requirements, allowances, and necessary manufacturing data shall be documented and defined on the printed-wiring assembly drawing. The printed-wiring assembly drawing shall also include any other feature conditions considered in the design where the variation between the end product and assembly configuration play a role in the producibility of flexible or rigid-flex printed-wiring.

4.4.1 Government furnished printed-wiring assembly drawings. When printed-wiring assembly drawings are furnished to the contractor by the Government, the design features of this standard shall apply. Any deviation from this standard shall have been recorded on the Government approved assembly drawing. When a change to the assembly drawing is necessary, before proceeding further, the contractor shall furnish one copy of each assembly drawing which is to be revised as a result of changes to the Government agency concerned for approval. Any changes made to the assembly drawing shall also meet the requirements of this standard and any approved deviations, or a new deviation shall be requested in conjunction with the change request with information justifying the deviation. When approved, all deviations granted shall be documented on the printed-wiring assembly drawing.

4.4.2 Conflict. In the event of any conflict between the approved printed-wiring assembly drawing and the requirements of this standard, the approved printed-wiring assembly drawing shall take precedence.

5. DETAIL REQUIREMENTS

5.1 Conductor pattern.

5.1.1 Conductor thickness and width. The thickness and width of conductors on the finished flexible and rigid-flex printed-wiring shall be selected in accordance with figure 2 based on the current carrying capacity required and the allowable design temperature rise. Conductor width and spacing requirements shall be maximized, consistent with design requirements, for ease of manufacture and durability in usage. The minimum conductor width indicated on the master drawing shall be not less than 0.004 inch (0.10 mm). To maintain the conductor width indicated on the master drawing, the line widths on the production master shall compensate for process allowances (see table VII of the appendix, conductor width tolerances).

5.1.2 Conductors having exterior corners less than 90 degrees included angle. All conductors having exterior corners less than 90 degrees included angle shall be rounded.

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5.1.3 Conductors. The length of a conductor between any two lands should be held to a minimum. However, conductors which are straight lines and run in X and Y or 45 degree direction in general are preferred to aid computerized documentation. When conductors are required on opposite sides of a dielectric to be flexed, the opposing conductor patterns shall be offset. This practice shall be repeated for multiple layers. Flexing of flexible and rigid-flex printed-wiring shall be made in areas where the conductors are straight and where the bend axis is perpendicular to the direction of the conductor path (see figure 3).

5.1.4 Conductor spacing. The largest practical spacings shall be used. The minimum spacing between conductors, between conductor patterns and between conductive materials (such as conductive markings or mounting hardware) and conductors shall be in accordance with table I (see table VII in the appendix).

5.1.5 Jumper wires. Jumper wires may be used on flexible and rigid-flex printed-wiring. They shall be terminated in holes, standoffs, or lands (with prior approval of the Government procuring activity), and be considered as components. They shall be short as practical and shall not be applied over or under other parts. Jumper wires less than 0.5 inch (13 mm) in length whose path does not pass over conductive areas and that do not violate the spacing requirements of table I may be uninsulated. Insulation, when required on jumper wires, shall be compatible with the conformal coating.

TABLE I. Conductor spacing.

Voltage between conductors DC or AC peak (volts)	Minimum spacing (inches)	
	Surface	Encapsulated 2/
0 - 100	0.005 (0.13 mm)	0.004 (0.10 mm)
101 - 300	0.015 (0.38 mm)	0.008 (0.20 mm)
301 - 500	0.030 (0.76 mm)	0.010 (0.25 mm)
Greater than 500 1/	0.00012 (0.0030 mm) per volt	0.0001 (0.003 mm) per volt

1/ For reference only, voltage greater than 500 should be evaluated for the specific design application.
2/ Encapsulated means the internal layers bonded together or external layers with cover coat or potting, as opposed to conformal coating or soldermask.

5.1.6 Edge spacing. The minimum spacing between conductive patterns and the edge of the flexible and rigid-flex printed-wiring or any adjacent conductive surface, such as supporting structure or frames (nonmoving), shall be not less than the minimum spacing specified in table I, provided the edges are protected from physical harm in the installed assembly configuration. Flexible and rigid-flex printed-wiring not so protected shall have a minimum conductor to edge distance of 0.100 inch (2.5 mm). The edge spacing requirement is not applicable to shield/ground planes or heat sinks.

5.1.7 Large conductive areas. Large conductive areas increase the possibility for blistering or bowing during the soldering operation. The pattern and location of large conductive areas should be in accordance with 5.1.7.1 and 5.1.7.2. Design of conductive areas should provide balanced construction.

5.1.7.1 Large external conductive areas. External conductive areas that extend beyond a one-inch diameter circle should contain etched areas that will break up the large conductive area but will retain the continutity and functionality of the conductor. If etched areas are not provided, other methods should be used to minimize blistering or bowing. Large conductive areas should, if possible, be on the component side of type 3 flexible and type 4 rigid-flex printed-wiring (see 5.9.7).

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5.1.7.2 Large internal conductive areas (types 3 and 4). When a conductive area that extends beyond a one-inch diameter circle is used on an internal layer, the layer should be placed as near the center of the board as possible and should contain etched areas that will break up the large conductive area but will retain the continuity and functionality of the conductor. If more than one internal layer has a large conductive area, the layers should be located in the board to provide balanced construction.

5.1.8 Interfacial connections. Interfacial connections on type 2 flexible printed-wiring shall be made by use of clinched wires (see 6.1.4) or plated-through holes. Interfacial connections on types 3 and 4 flexible and rigid-flex printed-wiring shall be made with plated-through holes only. Standoff terminals, eyelets, rivets, or pins shall not be used to provide interfacial connections.

NOTE: Clinched wires used as interfacial connections are considered to be part of the assembly and shall be identified on the printed-wiring assembly drawing.

5.1.8.1 Solder plugs. Printed boards subjected to wave or dip soldering typically have solder flow up around leads and into plated-through holes without leads, creating a solder plug. The printed wiring assembly drawing shall define the solder plug requirements and shall, as a minimum, require that all electrically functional plated-through holes with a lead have a 360° solder plug at the time the wave or dip soldering operation is completed. Plated-through holes without leads shall not be touched up; however, the nonfilling of properly designed holes (board to hole ratios not less than 2:1 or more than 4:1) shall be cause for examination of the soldering process.

Solder plugs need not be called for on the assembly drawing for:

a. Unsupported hole with a lead.
b. Nonfunctional plated-through hole (hand-soldered).
c. Any electrically functional plated-through hole (without a lead) not subjected to wave or dip soldering.
d. Any plated-through hole covered with permanent solder mask or other polymeric cover layer (not conformal coating).

5.1.9 Test points. When required by the design, test points for probing shall be provided as part of the conductor pattern. These "probe points" shall require that a land be available for probing as opposed to a conductor. Vias or component lead mounting lands may be considered as probe points provided that sufficient area is available for probing and maintaining the integrity of the via or component lead mounting joint. Probe points do not necessarily have to be on grid. Probe points shall have access holes provided in any cover coat. Probe points shall meet the plating requirements of 5.9.7. All probe points requirements shall be defined on the master drawing.

5.2 Lands.

5.2.1 Lands. Lands shall be provided for each point of attachment of a part lead or other electrical connection to the flexible and rigid-flex printed-wiring.

5.2.1.2 Lands for "flat pack" configuration (ribbon leads). The external lands for surface terminated "flat pack" configurations shall preferably be rectangular. The minimum land width shall equal or exceed the maximum lead width. The minimum land length shall be at least twice the land width (see figure 4). Flat pack termination should be staggered to permit greater spacings.

5.2.1.3 Offset lands. Upon approval of the command or agency concerned, lands when used in conjunction with clinched leads, may be located adjacent to (not surrounding) the lead termination hole. The land shall be a sufficient distance from the hole to allow clipping of the part lead prior to unsoldering the part lead from the land.

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5.2.1.4 Etchback. Etchback, when required, shall be specified on the master drawing and shall be 0.0001 inch (0.003 mm) minimum and 0.003 inch (0.08 mm) maximum, with 0.0005 inch (0.013 mm) being a preferred value of etchback. The maximum allowance shall be utilized in the determination of minimum diameters of lands for type 3 and 4 flexible and rigid-flex printed-wiring (see 5.2.2). This is not intended to apply to the unsupported polyimide film.

5.2.1.5 Negative etchback. A negative etchback of 0.003 inch maximum shall be allowed.

5.2.2 Land area considerations. When eyelets or standoff terminals are used, the lands on type 1, type 2, and external layers of type 3 and 4 shall be designed as to have a minimum diameter of at least 0.020 inch (0.51 mm) greater than the maximum diameter of the projection of the flange, of eyelets or standoff terminals. The minimum diameter of a land surrounding an unsupported hole or a plated-through hole shall be determined by considering the following. All lands and annular rings shall be maximized whenever feasible, consistent with good design practice and electrical clearance requirements. The following considerations shall be incorporated into the minimum land provided on the production master such that:
Minimum land = a + 2b + 2c (when required) + d, where:

a = Maximum diameter of the drilled hole for internal lands and finished hole for external lands.
b = Minimum annular ring requirements (see 5.2.3).
c = Maximum allowance for etchback, when required.
d = A standard fabrication allowance, determined by statistical survey, which considers tooling and process variations required to fabricate boards (see table II).

TABLE II. Standard fabrication allowances.

Greatest board dimension	Allowances (inches)		
	Preferred	Standard	Reduced producibility
Up to 12 inches	0.028 (0.71 mm)	0.020 (0.51 mm)	0.012 (0.30 mm)
12 to 18 inches	0.034 (0.86 mm)	0.024 (0.61 mm)	0.016 (0.41 mm)
More than 18 inches	Drawing tolerances must reflect bend and fold allowances between component mounting rigid areas.		

5.2.3 Annular ring considerations. The minimum annular ring on external layers is the minimum amount of copper (at the narrowest point) between the edge of hole and the edge of the land after plating of the hole. The minimum annular ring on internal layers is the minimum amount of copper (at the narrowest point) between the edge of the hole and the edge of the land after drilling of the hole.

External - The minimum annular ring for an unsupported hole shall be 0.015 inch (0.38 mm). The annular ring may be less than the minimum providing the land is anchored by use of anchoring spurs or if the land is elongated providing an equivalent soldering surface. The minimum annular ring for a plated-through hole in type 2, and external layers of type 3 and 4 shall be 0.005 inch (0.13 mm).
Internal - The minimum annular ring for functional internal lands on type 3 and 4 shall be 0.002 inch (0.051 mm).

5.2.4 Nonfunctional lands on type 3 and 4 printed-wiring (internal layers). Nonfunctional lands may be used on internal layers of type 3 and 4 flexible and rigid-flex printed-wiring. They should not be used on ground planes, voltage planes, heat sinking planes, and in areas where required electrical clearances do not permit.

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5.2.5 Location. All land and hole locations shall be in the grid intersections of the modular dimensioning system (see 4.2.3) controlled by either primary or secondary datums (see 4.2.6) used for flexible and rigid-flex printed-wiring except as specified in 5.2.5.1.

5.2.5.1 Pattern variations. Parts where leads emanate in a pattern which varies from the grid intersections established by the master drawing shall be mounted or attached to the flexible or rigid-flex printed-wiring with one of the following patterns:

a. A hole pattern where the hole for at least one part lead is located at a grid intersection of the modular dimensioning system and the other holes of the pattern are dimensioned from that grid location.
b. A hole pattern where the center of the pattern is located at a grid intersection of the modular dimensioning system and all holes of the pattern are dimensioned from that grid location.

5.2.6 Lands in ground planes. Lands associated with large conductor areas (ground planes, voltage planes, heat sink, and so forth) shall be relieved locally in the area of the plated-through connection in a manner similar to that shown on figure 5.

5.3 Bends. The number of bends should be kept to a minimum. Conductors should approach and traverse a bend or fold perpendicular to the fold line. Plated-through holes, component mounting holes, or surface mounting lands shall be located at least 0.100 inch (2.54 mm) away from the bend areas (see figure 3). Class B continuous flex application shall not have plating in the bend area.

5.3.1 Bend radii. Bend radii shall be kept as large as possible. The suggested minimum allowable bend radius should be six times the maximum overall thickness for one and two conductor layer flexible product and 12 times the maximum overall thickness of the completed piece of flexible printed-wiring for bonded flexible printed-wiring in excess of two conductor layers.

5.3.2 Strain reliefs or clamps. Strain reliefs or clamps shall be used to relieve strain of solder joints (see figure 6).

5.3.3 Preforming or prebending. Avoid preforming or prebending wherever possible. If preforming or prebending is necessary, then the tolerance locating the bend (center of fold) shall be ±0.03 inch minimum (0.8 mm).

5.3.4 Bend strengthening. When a bend occurs in an area with few conductors, copper strips of varying length shall be used to strengthen the area (see figure 7).

5.4 Periphery. The shape shall be as simple as possible avoiding sharp corners. In areas where sharp interior corners must be used, tear restraints shall be specified as shown on figure 8, such as holes, copper dams, and so forth. Outside corners shall be chamfered or radiused 0.015 inch (0.38 mm) minimum.

5.5 Cover sheets and access holes. For adequate solder area, the cover sheet access holes shall have a diameter at least 0.030 inch (0.76 mm) larger than the diameter of the component hole in the copper layer. If overlap of the cover sheet on the copper land is less than 0.010 inch (0.25 mm) all around unsupported holes used in flexible printed-wiring applications, anchoring spurs shall be added to the copper to help resist lifting the copper from the surface of the base material (see figure 9). When using reduced produciability per table II, all the lands shall have anchoring spurs added.

5.5.1 Closely positioned solder locations. Where closely positioned solder locations make the use of individual cover sheet access holes impractical (as in connector configurations), then such access holes can take the forms shown on figure 10. In such cases on unsupported holes used in flexible printed-wiring applications, anchoring spurs shall be added to the copper land.

5.6 Holes.

5.6.1 Quantity. A separate component hole shall be provided for each lead or terminal of a part or end of jumper wire except as specified in 5.2.1.2.

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5.6.2 Diameter of unsupported holes. The maximum diameter of an unsupported component hole shall not exceed by more than 0.020 inch (0.51 mm) the nominal diameter of the lead to be inserted, unless the lead is clinched. The number of different hole sizes shall be kept to a minimum. When flat ribbon leads are mounted through unsupported holes, the difference between the nominal diagonal of the lead and the maximum inside diameter of the unsupported hole shall not exceed 0.028 inch (0.71 mm) as shown on figure 11.

5.6.3 Eyelet hole diameter. The maximum diameter of holes in which eyelets are inserted shall not exceed the nominal outside diameter of the barrel of the eyelet by more than 0.010 inch (0.25 mm). The maximum inside diameter of the eyelets shall be not more than 0.028 inch (0.71 mm) greater than the nominal diameter of the lead or terminal to be inserted in the eyelet, unless the lead is clinched. (see 6.1.7.3).

NOTE: Interfacial connections shall not be made with eyelets.

5.6.4 Spacing of adjacent holes. The spacing of adjacent component holes shall be such that the lands surrounding the holes meet the spacing requirements of 5.1.4. The spacing between adjacent holes of any other type shall be not less than the flexible printed-wiring thickness or the hole diameter, whichever is smaller.

5.6.5 Indexing holes. If indexing holes are to appear on the flexible printed-wiring, they shall be dimensioned on the master drawing.

5.7 Eyelets and standoff terminals.

5.7.1 Material. The eyelets shall be made of copper conforming to QQ-C-576.

5.7.2 Coating and plating. The eyelets shall be tin/lead plated (see 5.9.7.5).

5.7.3 Standoff terminals. The standoff terminal shall also be finished in accordance with 5.9.7.5 or 5.9.7.6, after having been underplated with 0.0001 inch (0.003 mm) copper in accordance with MIL-C-14550.

5.8 Plated-through holes. The maximum diameter of the plated-through hole shall be not more than 0.028 inch (0.71 mm) larger than the nominal diameter of the inserted lead or the nominal diagonal of a flat ribbon lead as shown on figure 11, and the minimum diameter of the plated-through hole diameter shall be not less than 0.010 inch (0.25 mm) larger than the nominal diameter of the inserted lead, or nominal diagonal of a flat ribbon lead. Unless otherwise specified, the hole size shall be the finished plated size after solder coating or solder plating (unfused).

Plated-through holes used for internal conductor interconnections shall not be used for the mounting of eyelets, standoff terminals, rivets, or other devices which put the plated-through hole in compression.

When plated-through holes are to be used for lead terminations, the walls of plated-through holes shall be solder coated (see 5.9.7.6) or tin/lead plated and fused (see 5.9.7.5) except that the solder coating or fused tin/lead plating in the hole shall be 0.0001 inch (0.003 mm) thick minimum. Plated-through holes under the coverlayer need not be solder coated or tin/lead plated. The end product diameter of plated-through holes shall be specified on the master drawing.

5.9 Materials. All materials used in flexible and rigid-flex printed-wiring shall be specified on the master drawing. Flexible and rigid-flex printed-wiring designs shall be such that internal temperature rise due to current flow in the conductor (see 5.1.1) when added to the specified ambient temperature shall not result in an operating temperature in excess of 125°C. Since heat dissipated by parts mounted on the boards will also contribute to the effective operating temperature, material selection and board design shall also take this factor into account. Hot spot temperatures shall not exceed 125°C.

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5.9.1 Metal-clad materials. Metal-clad materials, when specified on the master drawing, shall be type GF or GI in accordance with MIL-P-13949. Flexible-metal clad dielectric shall be in accordance with IPC-FC-241 and table III (for metal-clading see 5.9.5).

5.9.1.1 Minimum thickness of metal-clad materials.

5.9.1.1.1 Metal-clad laminates. The thickness of the thin laminate shall be 0.002 inch (0.05 mm) or greater, provided the resulting dielectric layer in the finished board shall meet the requirements of 5.10.3.1.

5.9.1.1.2 Flexible metal-clad dielectric. The thickness of the flexible-clad dielectric (base material only) shall be 0.001 inch (0.03 mm) or greater provided the resulting dielectric layer in the finished board shall meet the requirements of 5.10.3.2.

5.9.2 Insulation material. Insulation material shall be in accordance with table IV.

5.9.3 Coverlayer. The coverlayer shall be in accordance with IPC-FC-232 and table V. The minimum thickness (base material plus adhesive) shall be 0.001 inch (0.03 mm).

5.9.4 Adhesives. Adhesives shall meet the requirements of 5.9.4.1 or 5.9.4.2, and shall be in accordance with table VI.

5.9.4.1 Preimpregnated bonding material (prepreg). When preimpregnated bonding materials are used on flexible and rigid-flex printed-wiring, the material shall conform to type GE, GF, or GI in accordance with MIL-P-13949 (see also 5.9.4.2). The areas to require adhesive and those to be free of adhesive shall be defined on the master drawing.

5.9.4.2 Flexible adhesive bonding films (cast). When flexible adhesive bonding films are used on flexible and rigid-flex printed-wiring, the material shall be in accordance with IPC-FC-233 (see also 5.9.4.1). The areas to require adhesive and those to be free of adhesive shall be defined on the master drawing.

NOTE: Interchangeability of adhesives specified in 5.9.4.1 and 5.9.4.2 shall be allowed in the rigidized areas of type 4 boards provided the resultant dielectric material in the finished board meets the requirements of 5.10.3.2.

5.9.4.3 Adhesive fillets (strain reliefs). When adhesive fillets (strain reliefs) are used at the junctures of the flexible portions and the rigid portions of type 4 printed-wiring or at the junctures of types 1, 2, and 3 boards with partial stiffeners, the fillet requirement shall be defined on the master drawing (see figure 12).

5.9.5 Stiffeners or heat sinking planes. When stiffener or heat sinking plane materials are required, material type (metallic and nonmetallic), size thickness, and adhesive type shall be specified on the master drawing. Registration of access holes in the stiffener to termination holes in the flexible and rigid-flex printed-wiring shall be defined on the master drawing (see figure 13). Stiffeners may be external or internal. The edge of the stiffener next to the flexible portion of the circuit should be radiused or chamfered to prevent damage to the conductor (see figure 14).

5.9.6 Copper circuitry layers. The thickness of the copper conductor shall be not less than 1/2 ounce per square foot (oz/ft^2) for all external layers. Copper foil properties shall be in accordance with IPC-CF-150, flexible layers shall be type W, class 7, and rigid layers shall be type E, class 1, 2, 3, or 4, or type W, class 7, and shall be specified on the master drawing. For class B flexible and flexible sections of rigid-flex printed-wiring, type W, class 7 shall be used.

5.9.7 Plating.

5.9.7.1 Electroless copper plating. An electroless deposition system shall be specified as a prelimiary process for providing the conductive layer over nonconductive materials for subsequent electrodeposition of metal in plated-through holes.

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TABLE III. Flexible metal-clad dielectric.

Specification sheet	Material identification
IPC-FC-241/1	Copper Clad, Polyimide with Acrylic Adhesive
IPC-FC-241/2	Copper Clad, Polyimide with Epoxy Adhesive
IPC-FC-241/3	Copper Clad, Fluorinated Poly (Ethylene-Proplylene) (FEP) with Acrylic Adhesive
IPC-FC-241/4	Copper Clad, Fluorinated Poly (Ethylene-Proplylene) (FEP) with Epoxy Adhesive

TABLE IV. Insulation material.

Specification sheet	Material identification
IPC-FC-231/1	Polyimide Base Dielectric
IPC-FC-231/2	Fluorinated Poly (Ethylene-Proplyene) (FEP) Base Dielectric

TABLE V. Cover layer.

Specification sheet	Material identification
IPC-FC-232/1	Polyimide Base Dielectric with Acrylic Adhesive
IPC-FC-232/2	Polyimide Base Dielectric with Epoxy Adhesive
IPC-FC-232/3	FEP Base Dielectric (Fluorinated Poly (Ethylene Proplyene)) with Acrylic Adhesive
IPC-FC-232/4	FEP Base Dielectric (Fluorinated Poly (Ethylene Proplyene)) with Epoxy Adhesive

TABLE VI. Adhesives.

Specification sheet	Material identification
IPC-FC-233/1	Acrylic Adhesive
IPC-FC-233/2	Epoxy Adhesive

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5.9.7.2 Electrolytic copper plating. All electrolytically deposited copper plating shall be in accordance with MIL-C-14550 and shall have a minimum purity of 99.5 percent as determined by ASTM-E53. The minimum thickness shall be 0.001 inch (0.03 mm).

5.9.7.3 Gold plating. All electrolytically deposited gold shall be in accordance with MIL-G-45204. The minimum thickness shall be 0.000050 inch (0.0013 mm). A low stress nickel (see 5.9.7.4) shall be specified between gold overplating and copper.

5.9.7.4 Nickel plating. All electrolytically deposited nickel plating shall be low stress and conform to QQ-N-290, class 2, except the minimum thickness shall be 0.0002 inch (0.005 mm).

5.9.7.5 Tin/Lead plating. Tin/lead plating shall be in accordance with MIL-P-81728. Fusing shall be performed on all tin/lead plated surfaces. The fused tin/lead shall be 0.0003 inch (0.008 mm) thick minimum, when measured at the crest of the conductor and shall be homogeneous and completely cover the conductors. This does not apply to the vertical conductor edges when fused tin/lead plating is used (see 6.2.12 for surface mounted components).

5.9.7.6 Solder coating. Unless otherwise specified, solder coating shall be in accordance with composition SN60, SN62, and SN63 of QQ-S-571. The solder coating shall be 0.0003 inch (0.008 mm) thick minimum, when measured on the surface at the crest of the conductor and shall be homogeneous and completely cover the conductors (see 6.2.12 for surface mounted components).

5.9.8 Solder mask. Polymer mask coatings shall be limited to the rigid sections of type 4 rigid-flex printed-wiring. The coatings shall meet the requirements of IPC-SM-840, class 3 and, when required, shall be specified on the master drawing.

5.9.8.1 Solder mask over melting metals. Polymer mask coatings do not typically adhere to molten metals. When coatings are required over melting metal (such as solder) with areas of metal larger than 0.050 inch (1.3 mm) in two directions, the design shall provide relief through the metal to the rigid-flex printed-wiring substrate. The relief shall be at least 0.010 square inches (0.25 sq mm) in size and located on a grid no greater than 0.250 inch (6.4 mm). When an area of melting metal is left uncovered, the design shall provide for the coating to extend onto the area of melting metal by at least 0.010 inch (0.25 mm), but not greater than 0.025 inch (0.64 mm).

5.9.8.2 Solder mask over nonmelting metals. When polymer mask coatings are required over nonmelting metals (such as copper), the design shall provide that conductor areas not covered by the mask shall be tin/lead plated and fused (see 5.9.7.5) or solder coated (see 5.9.7.6). Other platings require approval by the Government procuring activity.

5.10 Flexible and rigid-flex printed-wiring dimensions. The flexible and rigid-flex printed-wiring design shall meet the requirements specified in 5.10.1 through 5.10.4.

5.10.1 Overall flexible and rigid-flex printed-wiring. Overall flexible and rigid-flex printed-wiring dimensions (length and width), wherever practicable, shall coincide with lines of the modular dimensioning system.

5.10.2 Flexible and rigid-flex printed-wiring thickness and tolerances. The thickness requirements of flexible and rigid-flex printed-wiring shall be specified on the master drawing in a manner that limits the thickness measurements to those areas of the product that require specific thickness control. Areas with part mounting or surface contact to circuitry should be defined and measured across the plating extremities; areas where base material dimensions are critical should be measured across the dielectric. The tolerances on all dimensions should be as liberal as possible and shall be defined on the master drawing.

5.10.3 Minimum dielectric thickness.

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5.10.3.1 MIL-P-13949 dielectric materials. When type 4 rigid-flex printed-wiring is constructed from material in accordance with MIL-P-13949, there shall be a minimum of 0.0035 inch (0.089 mm) of dielectric material between the consecutive conductor layers, when cured. The dielectric material shall be comprised of multiple layers of rigid laminate, and prepreg. No less than two sheets of glass base (B-stage), laminate (C-stage), or combination thereof shall be used between each pair of adjacent conductor layers.

5.10.3.2 IPC-FC-231, IPC-FC-232, IPC-FC-233, and IPC-FC-241 dielectric materials. When finished type 2, 3, or 4 flexible and rigid-flex printed-wiring is constructed from material in accordance with IPC-FC-231, IPC-FC-232, IPC-FC-233, or IPC-FC-241, there shall be a minimum of 0.0015 inch (0.038 mm) of dielectric (base material and adhesive) between the consecutive layers, when cured.

5.10.4 Bow and twist. Unless otherwise specified on the master drawing, the maximum allowable bow and twist shall be 1.5 percent for the rigid section of type 4 rigid-flex printed-wiring.

5.11 Shielding. All shielding shall be protected by a covercoat. Shielding material (such as silver epoxy, vapor deposited metal and so forth) other than copper foil shall be approved by the Government procuring activity and included on the master drawing. When approved, shielding layers reflecting the end product shall be incorporated into the quality conformance coupons and included on the master drawing.

6. DETAIL PART MOUNTING REQUIREMENTS

6.1 Approved methods of attachment. Component leads shall pass through lead component holes and be attached or the component terminals (leads) shall be surface mounted to the land pattern. Part attachment shall be described on the assembly drawing following the methods specified in 6.1.2 through 6.1.7. Paragraph 6.1.1 establishes general mounting requirements.

6.1.1 Constraints on mounting to flexible sections. Designs shall not place a component in an area of continuous flexing or in an area flexed, folded, or bent to install. Leads, mounted through flexible material, shall be fully clinched (see 6.1.3) or if unclinched leads are required, supporting hardware, encapsulant, or stiffener shall be designed as a part of the assembly to ensure that no flexure-related stresses are exerted on the solder joints.

6.1.2 Unclinched leads. Unless otherwise specified, unclinched leads (either straight or partially bent for retention) shall be soldered in component holes or eyelets in accordance with IPC-S-815. If no clinching requirements are specified on the assembly drawing, unclinched lead termination shall apply.

6.1.2.1 In unsupported holes. Lead tip projection shall be dimensioned to extend from 0.020 inch (0.51 mm) minimum to 0.060 inch 1.5 mm) maximum from the surface of the foil.

6.1.2.2 In plated-through or eyeletted holes. The lead shall be required to extend at least to the surface of the plating or rim of the eyelet and extend no more than 0.060 inch (1.5 mm) from the plating surface or eyelet. The end of the lead shall be discernible in the solder fillet, but is not required to be covered with solder.

6.1.3 Clinched leads. When maximum mechanical retention of a lead or terminal is required by design, the lead or terminal shall be clinched. The component holes may be plated-through holes, unsupported holes, or eyeletted holes. Clinching requirements shall be defined on the assembly drawing. The lead end shall not extend beyond the edge of its land or its electrically connected conductor pattern in violation of the minimum spacing requirements. The outline of the lead shall be visible in the solder fillet. Partial clinching of leads for part retention shall be considered under the requirements of 6.1.2.

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6.1.4 Clinched wire. When interfacial connections must be made by the use of solid wire clinched on both sides of the board through a hole (see 5.1.8), uninsulated wire type S in accordance with QQ-W-343 shall be used. Part lead wires do not qualify for interfacial connections. The assembly drawing shall indicate that the wire shall make contact with the conductor pattern on each side of the type 2 flexible printed-wiring before soldering and the end shall not extend beyond the edge of its land or its electrically connected conductor pattern in violation of the minimum spacing requirements and be in accordance with figure 15. The top and bottom portions of the wire need not be alined in the same vertical plane.

6.1.5 Surface terminated ribbon leads. Flat-wire ribbon leads may be attached to lands on the flexible printed-wiring. Connections shall be made by soldering only. The contact area between any lead and land shall be not less than a square having each side equal to the nominal width of the lead (see figure 16). Minimum conductor spacing indicated in 5.1.4 shall be maintained. Attachment details (see figure 16) may be conveyed by an assembly drawing reference to IPC-S-815. Refer to paragraph 6.2.11 for additional mounting notes and considerations.

6.1.6 Surface terminated round leads. With prior approval by the Government procuring activity, designs may stipulate that parts shall be attached with their round leads soldered to surface terminals (lands) without first passing through a hole. The lands shall be designed with proper shape and spacing to comply with proper soldering techniques (see IPC-S-815).

6.1.7 Standoff terminals, eyelets, or fasteners.

6.1.7.1 Component attachment to standoffs. Component attachment to standoff terminals shall be defined on the assembly drawing and meet the requirements of IPC-S-815. Placement of terminals shall be specified to suit each application.

6.1.7.2 Attachment of standoffs to boards. Standoff terminals shall only be located in stiffened or rigid sections of flexible or rigid-flex printed-wiring assemblies. Proper selection shall provide a terminal of the funnel flanged type wherever the flange must be soldered for electrical connection to a land. The included angle of such flange shall be between 35 and 120 degrees.

6.1.7.3 Eyelets. Eyelet applications used in design shall be in compliance with the following:

a. Inside diameter. The specified eyelet shall have an inside diameter no larger than 0.028 inch (0.71 mm) greater than the lead or terminal to be soldered in the eyelet, unless clinching is prescribed.
b. Attachment requirements. Interfacial connections shall not be made with eyelets. Eyelets shown installed at an electrically functional land shall be required to be soldered to that land as well as to the lead or wire supported by the eyelet. Acceptance criteria shall be provided by the assembly drawing.
c. Proper selection.

6.1.7.4 Fastening hardware. The installed location or installation orientation shall be prescribed on the assembly drawing for any fastening devices such as rivets, machine screws, washers, inserts, nuts, bracketry, and so forth. Precautions, such as the specification of tightening torque values, shall be provided wherever general assembly practices might be inadequate or detrimental to the board assembly's structure or functioning.

6.2 Electrical part mounting. The following are requirements the designer must consider and detail on the assembly drawing in specific notes or illustrations. All such electrical parts, hereinafter referred to as components, shall also be selected so as to withstand the vibration, mechanical shock, humidity, and other environmental conditions the design must endure when the components are installed in accordance with paragraphs 6.2.1 through 6.2.13.1.

6.2.1 One side only. Parts shall be mounted on only one side of the individual rigid or stiffened sections of the flexible and rigid-flex assembly, whenever possible.

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6.2.2 Accessibility. Lands and terminals shall be located and spaced so that the terminations of each component are not obscured by any other component, or by any other permanently installed parts. Each component shall be capable of being removed from the assembly without having to remove any other component.

6.2.3 Design perimeter. Unless otherwise detailed on the assembly drawing, the board edge is regarded as the extreme perimeter of the assembly, beyond which no portion of a component is allowed to extend. The designer shall prescribe the perimeter with due respect for maximum part body dimensions and the mounting provisions dictated by the board and assembly documentation.

6.2.4 Over conductive areas. No parts shall be mounted in direct contact with external conductor areas unless required for thermal dissipation. If design limitations require placement of parts over conductive areas, the part shall be mounted so that subsequent insulating coating will cover the conductive area under the part or conductive areas under parts shall be insulated or protected against moisture entrapment by applying conformal coating, cured resin coating, laminating low-flow prepreg material in accordance with MIL-P-13949, or by solder masking over the area prior to mounting the part.

6.2.5 Thermal transfer. Components, which for thermal reasons require extensive surface contact with the board or with a heat sink mounted on the board, shall be protected from processing solutions at the conductive interface. To prevent risk of entrapment, compatible materials or methods shall be specified to seal the interface from entry of corrosive or conductive contaminants.

NOTE: Even totally nonmetallic interfaces that are prone to entrap fluids can have adverse effects on the fabricator's ability to pass required cleanliness tests.

6.2.6 Components dissipating one or more watts. Heat dissipation of components shall insure that the maximum allowable temperature of the board material is not exceeded under operating conditions specified in 5.9. Heat dissipation may be accomplished by requiring a gap between board and component, using a clamp or thermal mounting plate, or attaching a compatible, thermally conductive material working in conjunction with a thermal bus plane to the component.

6.2.7 Stress relief bends. Parts shall be mounted or provided with stress relief bends in such a manner that the leads cannot overstress the part lead interface when subjected to the anticipated environments of temperature, vibration, and shock of MIL-P-28809. The lead length for stress relief and lead bend radius shall be in accordance with figure 17. Where lead bending must be unusual to achieve design goals, the bends shall be detailed on the assembly drawing.

6.2.8 Mechanical support. All parts weighing 0.25 ounce (7.1 g) or more per lead shall be supported by clamps or other specified means which will insure that the soldered joints and leads are not relied upon for any appreciable mechanical strength.

6.2.9 Axial-leaded parts. Axial-leaded parts shall be mounted as specified on the approved assembly drawing and mounted so that a portion of the body is as close to the flexible and rigid-flex printed-wiring as possible. The leads shall be shaped in accordance with 6.2.7. This does not apply to parts mounted on standoff terminals (see 6.1.7.1).

6.2.9.1 Perpendicular mounting. With prior approval by the Government procuring activity, axial-leaded components weighing less than 0.50 ounce (14 g) may be mounted on the assembly using perpendicular mounting criteria. The assembly drawing shall prescribe a minimum of 0.015 inch (0.38 mm) space between the end of the component body (or the lead-weld) and the board. Unless otherwise noted on the assembly drawing, components required to be perpendicularly mounted shall be installed with their major axis within ±15 degrees of a right angle with board surface. Unless otherwise specified, vertical height from the board surface shall be 0.55 inch (14 mm) maximum (see figure 18).

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6.2.10 Nonaxial-leaded parts. Nonaxial-leaded parts shall be mounted with the surface from which the lead projects (end of the part) (see 6.2.9.1) a minimum of 0.010 inch (0.25 mm) above the flexible and rigid-flex printed-wiring surface. Dimensioning of the required spacing under these components is generally not required unless the component package design could result in an assembly error. For thermal considerations see paragraphs 6.2.5 and 6.2.6.

6.2.11 Multiple-leaded components. Multiple-leaded components (components with three or more leads), except multiple leaded components mounted to thermal planes or heat sinks, shall be mounted in such a manner that components are spaced off the board to facilitate cleaning, provide electical isolation, and to prevent moisture traps. The necessary gap may be prescribed as an exceptional fabrication requirement by identifying the subject component and prescribing the required underbody clearance dimension or the gap may be achieved by virtue of the component's own standoff features. Unless otherwise specified, a clearance of 0.010 inch (0.25 mm) applies.

6.2.11.1 Spacers. Special spacers (such as feet, ribs, or projections) with minimal contact may be prescribed to go under the component, provided they will not impair soldering or the assembly's performance.

6.2.11.2 Sealing. The need for a gap between component body and board may be avoided by requiring the interface under the component to be sealed with adhesive or a combination of adhesive and insulation material, which is compatible with the board, parts, and conformal coating. This option exists only if all lead terminations are external to the seal. Repairability shall not be precluded by the method or material selection.

6.2.12 Surface mounted components. The requirements and considerations of 6.2.4 apply to this class of components. Space for cleaning shall be provided to reduce entrapment. Sufficient solder thickness of 0.0008 inch (0.020 mm) minimum on the land mounting pattern shall be specified to insure adequate solder fillets between the flexible and rigid-flex printed-wiring and the component terminal. See paragraph 6.1.1 for location constraints.

6.2.12.1 Flat-pack types with ribbon leads. Lead forming is a major design consideration and shall be detailed on the assembly drawing to provide for lead stress relief, fit to the land pattern, underbody clearance for cleaning, and any designed-in provisions for thermal transfer (see figure 16 and 6.1.5).

6.2.12.2 Chip carrier type. Leadless components may be attached to the surface of a land. The component shall be attached to the land of the flexible or rigid-flexible printed-wiring in a way that provide sufficient space under the body of the component to facilitate cleaning. Land pattern design shall facilitate adequate solder fillets between the conductor pattern and the component.

6.2.13 Two-part connectors (plug and receptacle). Two-part connectors containing male and female quick disconnect electrical contacts and integral alining hardware to assure proper mating of the contacts shall be specified as the only means to integrate plug-in printed-wiring assemblies. Their attachment and mounting methods are subject to the design concerns of 6.1, 6.2.3 and 6.2.4.

6.2.13.1 Wires. Use of hard wiring directly to plug in flexible and rigid-flex assemblies shall not be permitted. Plug in assemblies shall have all external electrical connections accomplished through the use of two-part connectors.

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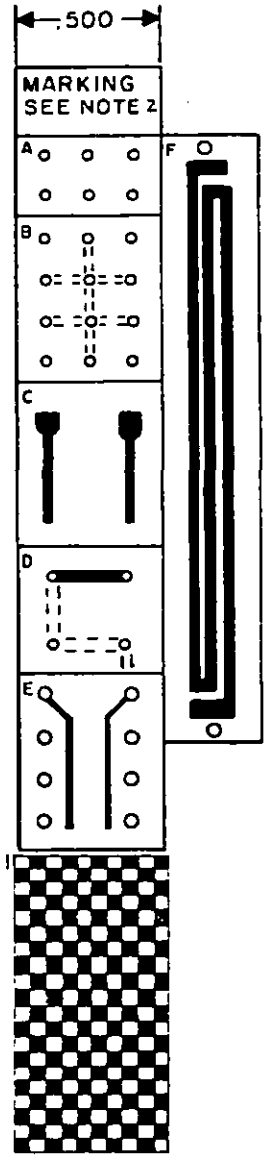
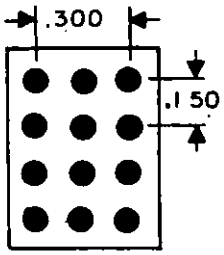
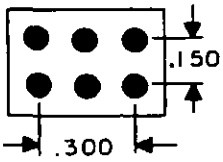
INCH	MM
.150	3.81
.300	7.62
.500	12.70

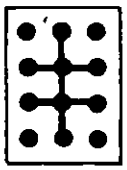




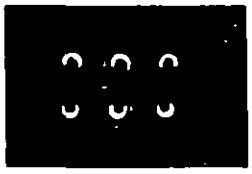
TEST CIRCUIT B
SURFACE LAYERS



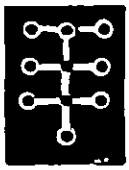
TEST CIRCUIT A
SURFACE AND
INTERNAL LAYERS



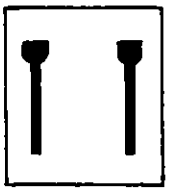
TEST CIRCUIT B
INTERNAL LAYERS



TEST CIRCUIT A
INTERNAL
PLANE LAYER



TEST CIRCUIT B
INTERNAL LAYERS
(POSITIVE IMAGE)



TEST CIRCUIT C
SURFACE LAYERS

Quality conformance test circuitry (individual coupons).

Quality conformance test circuitry layout.

FIGURE 1. Quality conformance test circuitry.

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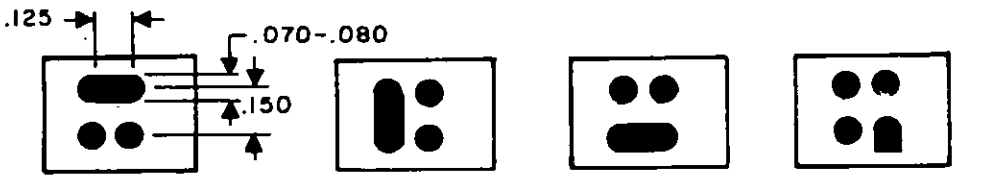
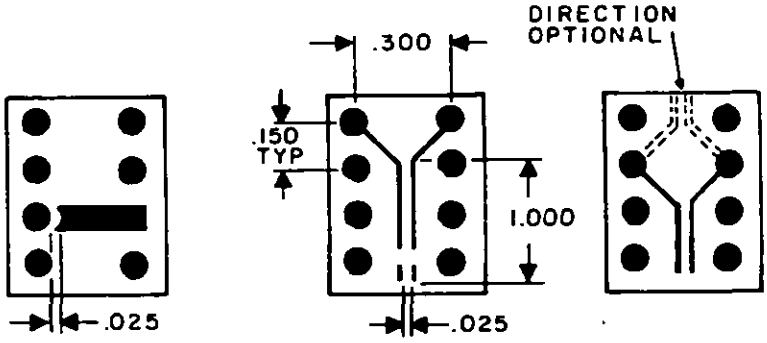
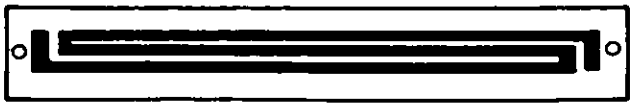


TEST CIRCUIT D SURFACE LAYER | TEST CIRCUIT D SECOND LAYER | TEST CIRCUIT D THIRD LAYER | TEST CIRCUIT D FOURTH LAYER

INCH	MM
.025	0.63
.070	1.77
.080	2.03
.125	3.17
.150	3.81
.300	7.62
1.000	25.40



TEST CIRCUIT E INTERNAL PLANE LAYER | TEST CIRCUIT E SURFACE LAYER | TEST CIRCUIT E INTERNAL SIGNAL LAYER



TEST CIRCUIT F
SURFACE AND INTERNAL
FLEX LAYERS

Quality conformance test circuitry (individual coupons).

FIGURE 1. Quality conformance test circuitry - Continued.

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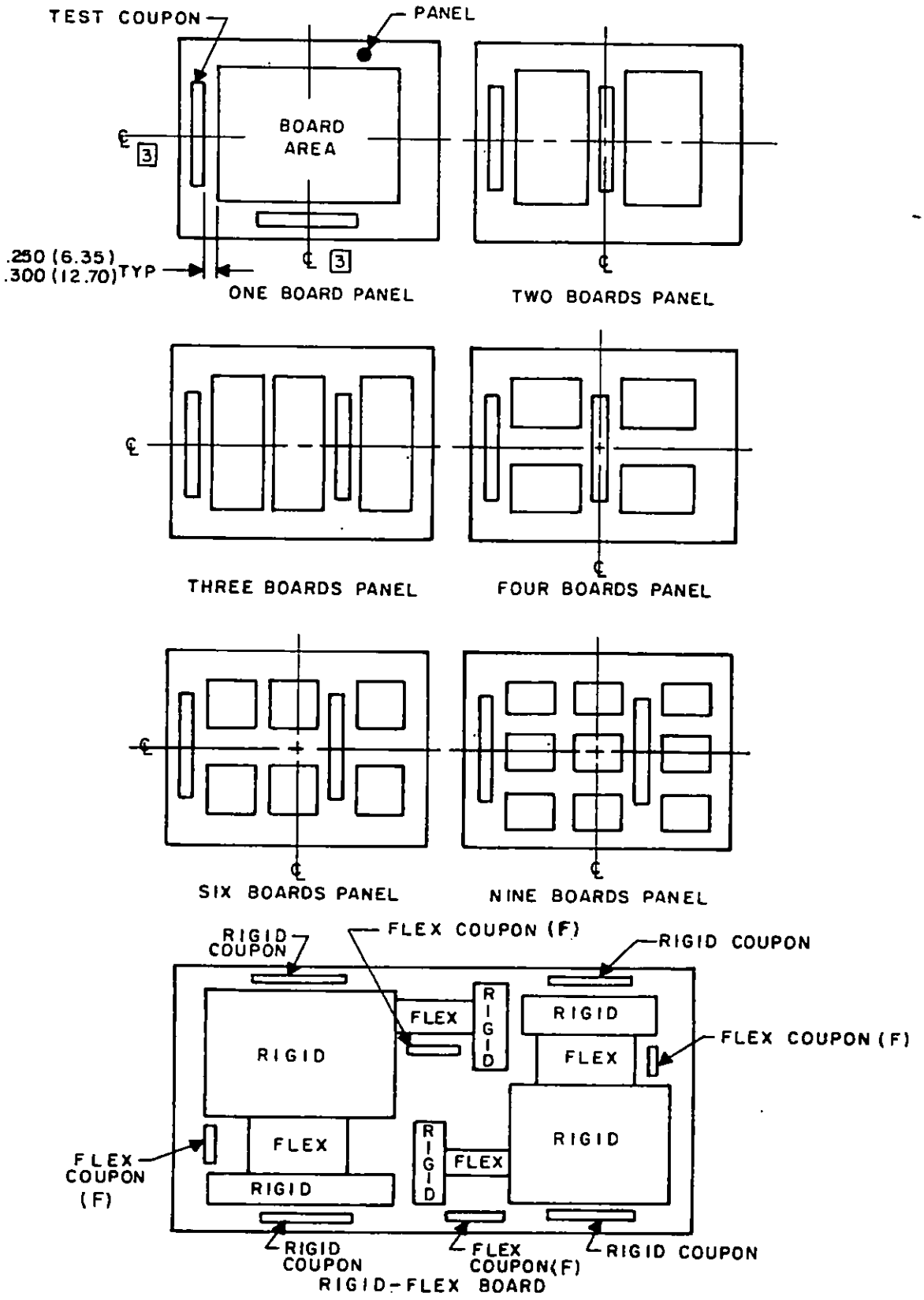

Typical location of test coupon based on number of boards fabricated per panel.

FIGURE 1. Quality conformance test circuitry - Continued.

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NOTES:
1. Dimensions are in inches.
2. Test coupons are to be identified with the following:
   a. FSCM.
   b. Part number and revision letter.
   c. Board traceability or lot number.
3. All lines shall be .020 (0.51 mm) ±.003 (0.08 mm), unless otherwise specified.
4. Unless otherwise specified, the tolerances shall meet the requirements of this standard.
5. The minimum land dimension shall be .070 (1.78 mm) ±.005 (0.13 mm) and represent the land shape used on the associated board. Holes in lands shall be the diameter of the smallest component hole in the associated board.
6. All first layers and internal layers shall be as specified on the master drawing. Copper plane areas shall be used on all coupons on appropriate plane layers, except for the D and E segments. When shields are used (see 5.11) appropriate layers shall be added to the coupons.
7. The lengths of test circuits D and E are dependent upon the number of layers in the panel. For test circuits D, a pair of holes and a conductor between same shall be provided for each layer. Electrical connection shall be in series, stepwise, through each conductor layer of the board. For test circuit E, a pair of holes and conductors shall be provided for the first layer and each internal layer.
8. Coupon F shall be positioned in the flexible area on the associated board.
9. The quality conformance test circuitry may be segmented; however, test circuitry A and B shall be joined together. Test circuit C, D, E, and F may be arranged to optimize board layout. All test coupons illustrated shall appear on each panel. The number of layers shall be identical to the number of layers in the boards derived from the panel.
10. Letters on coupons are for identification purposes only and shall be etched or applied by the use of a permanent ink which will withstand board processing. Location of letters on applicable coupons is optional.
11. Number of layers shown in these test coupons are for illustration purposes only. Conductor layer number 1 shall be the first layer on the component side, and all other conductor layers shall be counted consecutively downward through the laminated board to the bottom conductor layer which is the solder side. Surface layers shall consist of the outer layers of a printed-wiring board, the first layer (component side) and the last layer (solder side).

FIGURE 1. Quality conformance test circuitry - Continued.

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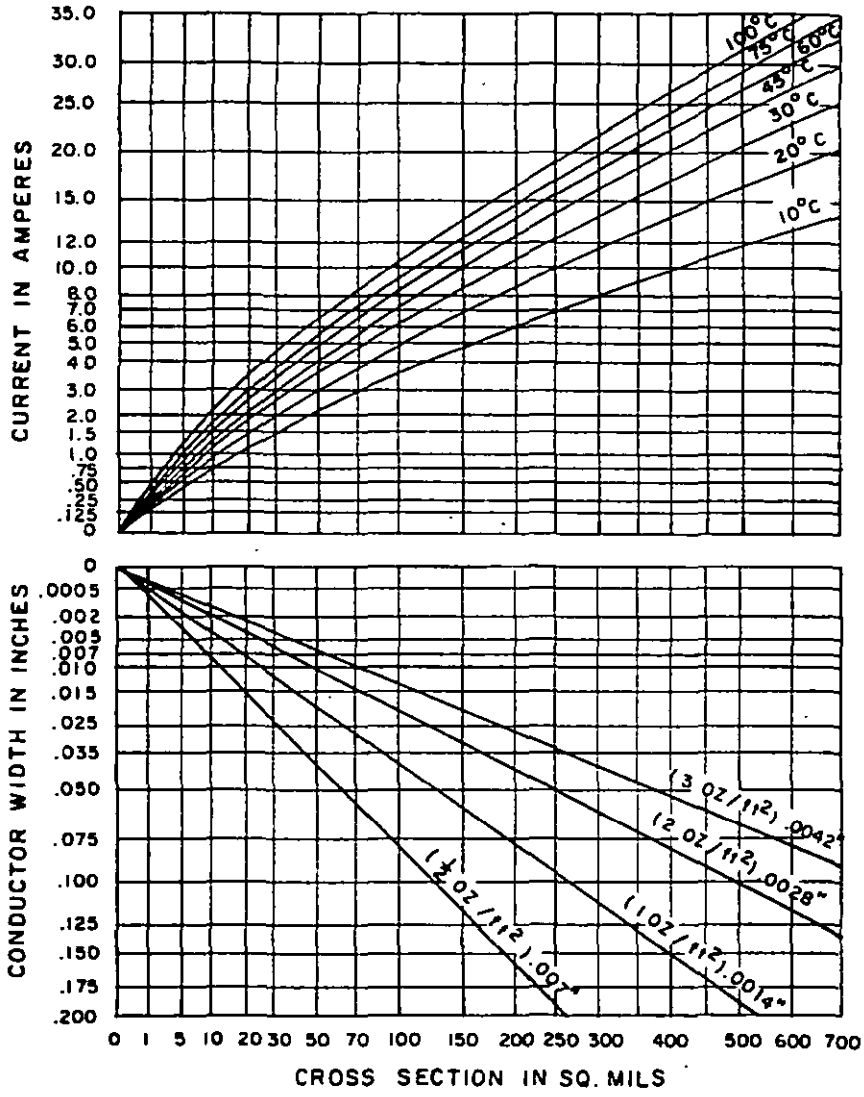
(FOR USE IN DETERMINING CURRENT CARRYING CAPACITY AND SIZES OF ETCHED COPPER CONDUCTORS FOR VARIOUS TEMPERATURE RISES ABOVE AMBIENT)



NOTES:

1. The design chart has been prepared as an aid in estimating temperature rises (above ambient) vs current for various cross-sectional areas of etched copper conductors. It is assumed that for normal design conditions prevail where the conductor surface area is relatively small compared to the adjacent free panel area. The curves as presented include a nominal 10 percent derating (on a current basis) to allow for normal variations in etching techniques, copper thickness, conductor width estimates, and cross-sectional area.
2. Additional derating of 15 percent (current-wise) is suggested under the following conditions:
   (a) For panel thickness of 1/32 inch or less.
   (b) For conductor thickness of 0.0042 inch (3 oz/ft^2) or thicker.
3. For general use the permissible temperature rise is defined as the difference between the maximum safe operating temperature of the laminate and the maximum ambient temperature in the location where the panel will be used.
4. For single conductor applications the chart may be used directly for determining conductor widths, conductor thickness, cross-sectional area, and current-carrying capacity for various temperature rises.
5. For groups of similar parallel conductors, if closely spaced, the temperature rise may be found by using an equivalent cross-section and an equivalent current. The equivalent cross-section is equal to the sum of the cross-sections of the parallel conductors, and the equivalent current is the sum of the currents in the conductors.
6. The effect of heating due to attachment of power dissipating parts is not included.
7. The conductor thicknesses in the design chart do not include conductor overplating with metals other than copper.

Current-carry capacity for surface layers.

FIGURE 2. Current-carrying capacities.

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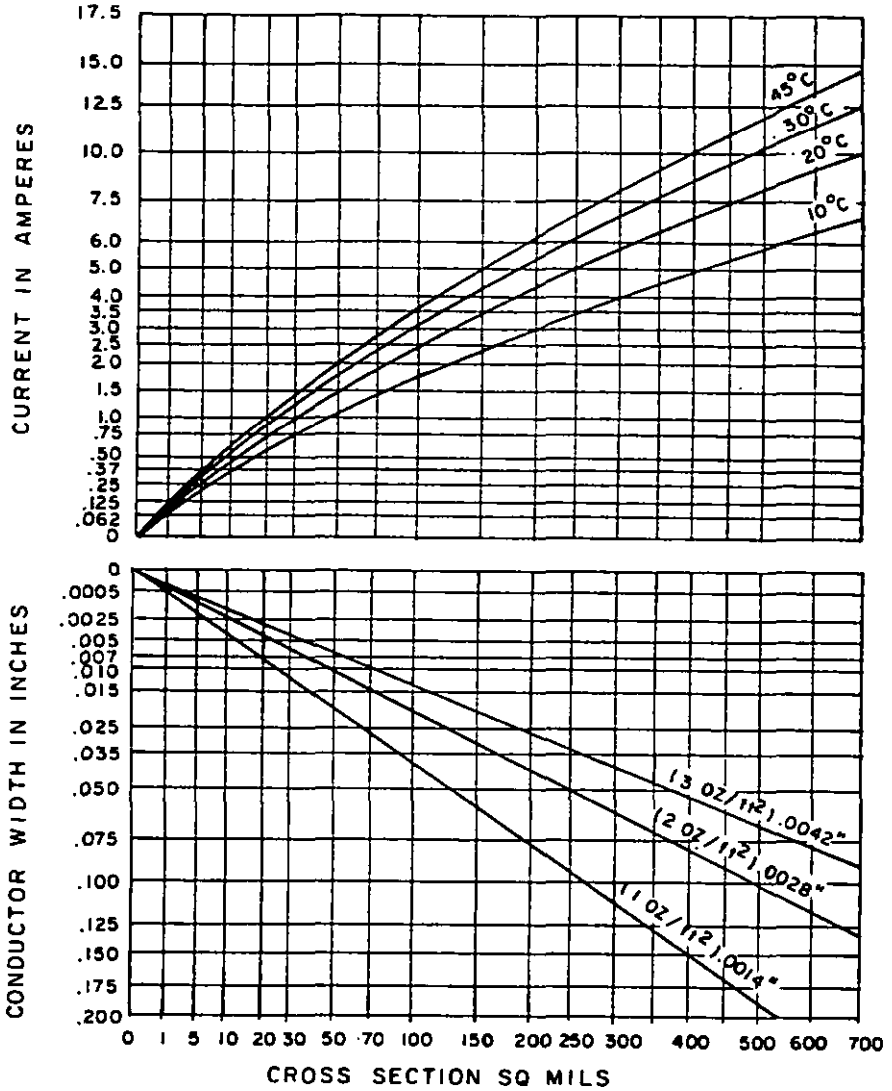
(FOR USE IN DETERMINING CURRENT CARRYING CAPACITY AND SIZES OF ETCHED COPPER CONDUCTORS FOR VARIOUS TEMPERATURE RISES ABOVE AMBIENT)



NOTES:

1. The design chart has been prepared as an aid in estimating temperature rises (above ambient) vs current for various cross-sectional areas of etched copper conductors. It is assumed that for normal design conditions prevail where the conductor surface area is relatively small compared to the adjacent free panel area. The curves as presented include a nominal 10 percent derating (on a current basis) to allow for normal variations in etching techniques, copper thickness, conductor width estimates, and cross-sectional area.
2. Additional derating of 15 percent (current-wise) is suggested under the following conditions:
   (a) For panel thickness of 1/32 inch or less.
   (b) For conductor thickness of 0.0042 inch (3 oz/ft^2) or thicker.
3. For general use the permissible temperature rise is defined as the difference between the maximum safe operating temperature of the laminate and the maximum ambient temperature in the location where the panel will be used.
4. For single conductor applications the chart may be used directly for determining conductor widths, conductor thickness, cross-sectional area, and current-carrying capacity for various temperature rises.
5. For groups of similar parallel conductors, if closely spaced, the temperature rise may be found by using an equivalent cross-section and an equivalent current. The equivalent cross-section is equal to the sum of the cross-sections of the parallel conductors, and the equivalent current is the sum of the currents in the conductors.
6. The effect of heating due to attachment of power dissipating parts is not included.
7. The conductor thicknesses in the design chart do not include conductor overplating with metals other than copper.

Current-carry capacity for internal layers (includes conductors with coverlayers).

FIGURE 2. Current-carrying capacities - Continued.

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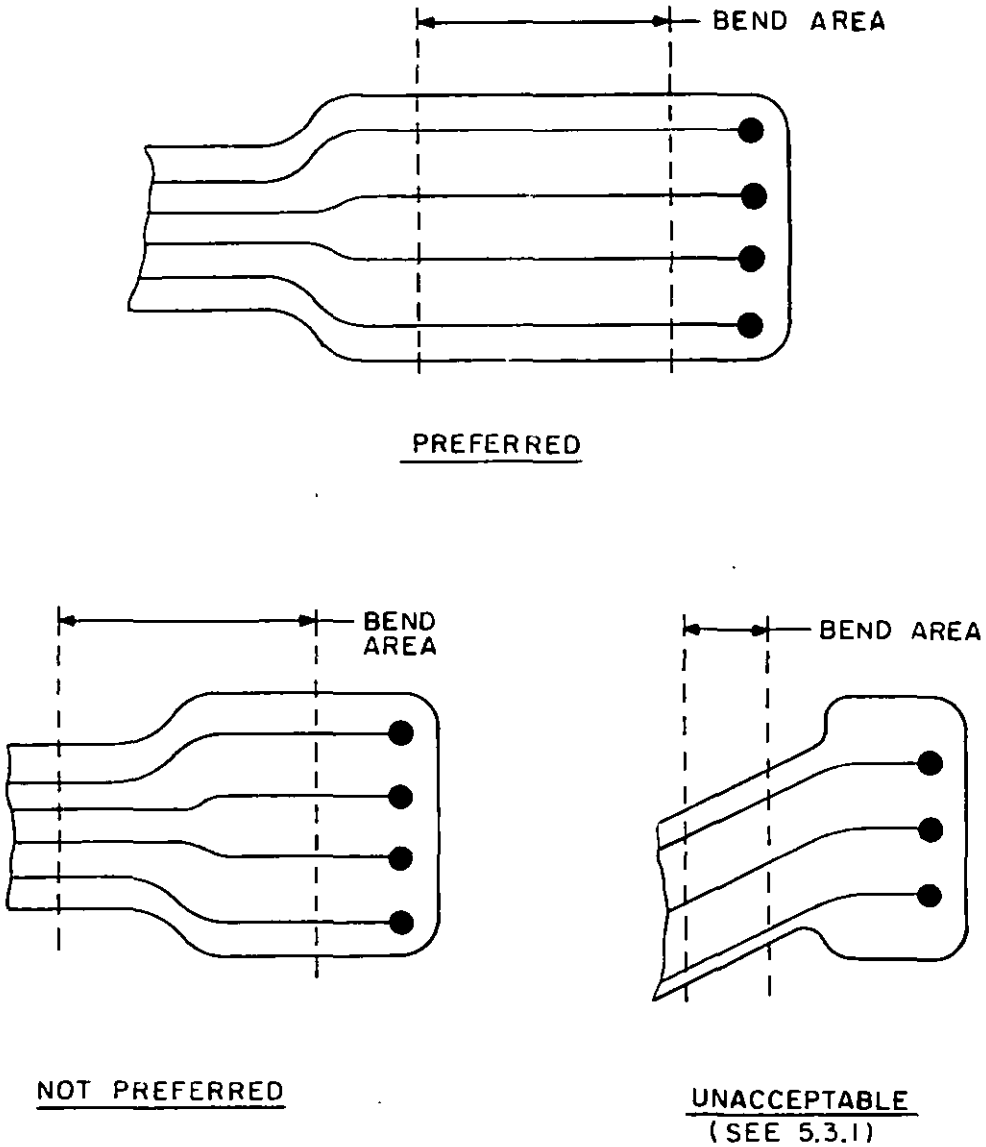

FIGURE 3. Bend position.

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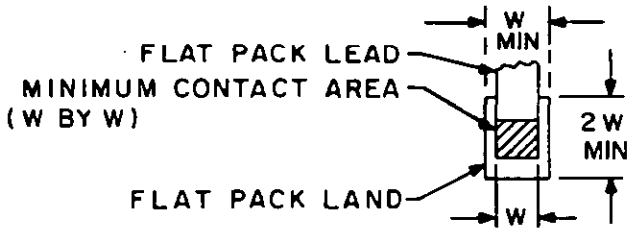

FIGURE 4. Typical flat pack land.

LAND BEFORE DRILLING

LAND AFTER DRILLING

FIGURE 5. Ground plane land (typical).

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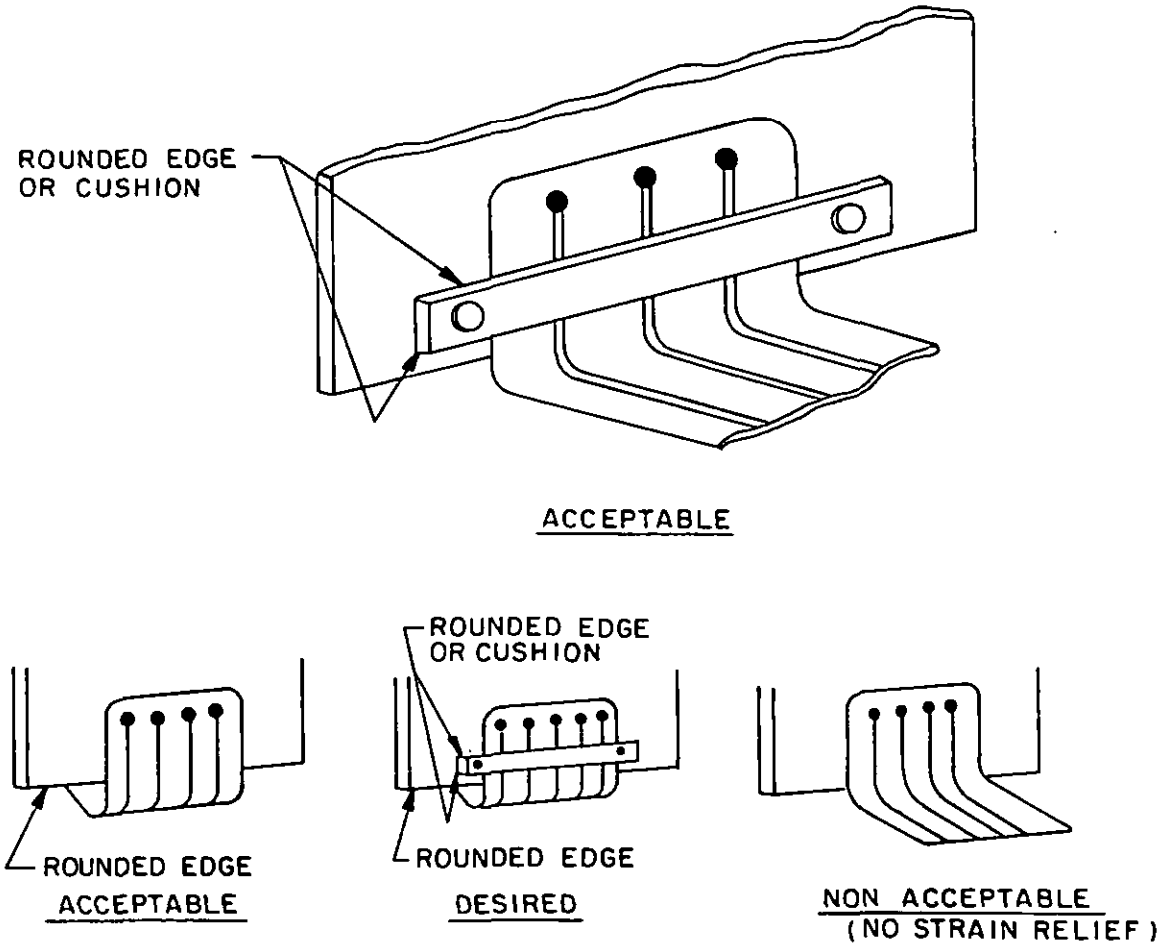

FIGURE 6. Flexible printed-wiring mounting (strain relief).

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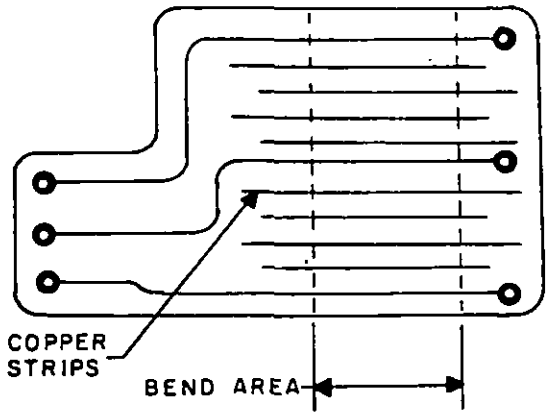

FIGURE 7. Method of increasing bend strength.

INCHES	MM
.010	.25
.015	.38
.0625	1.59
.125	3.2

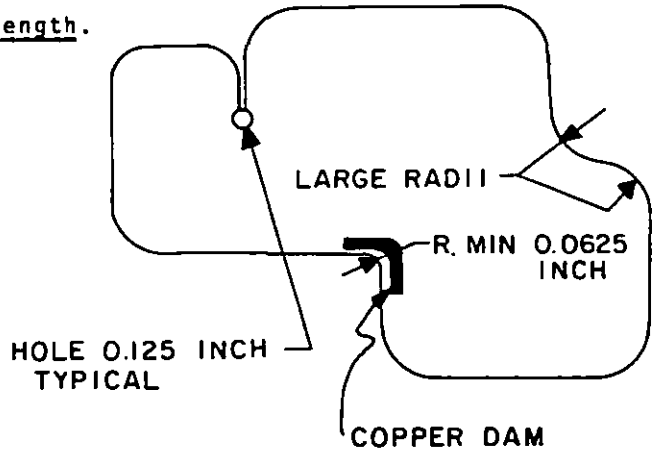

FIGURE 8. Flexible printed-wiring shape.

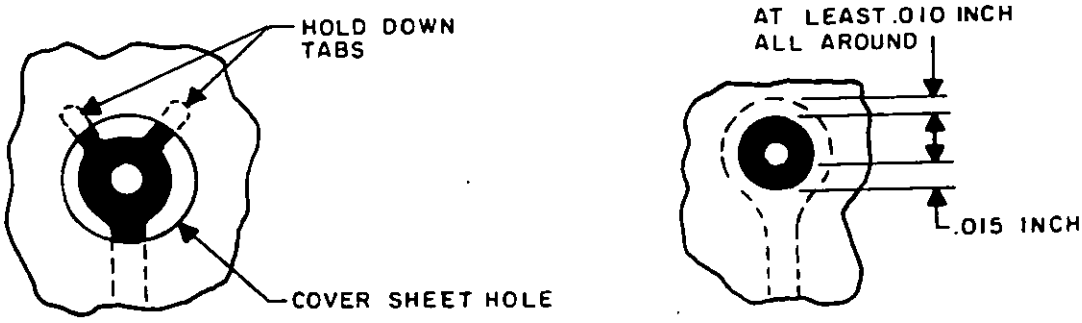

FIGURE 9. Flexible printed-wiring tear restraints shape.

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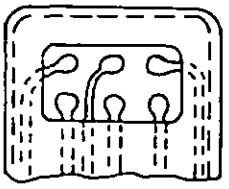
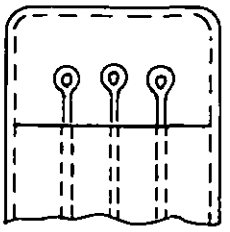
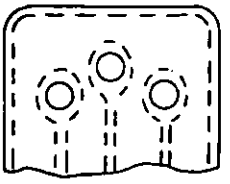


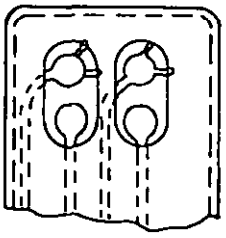
SEE NOTE 6



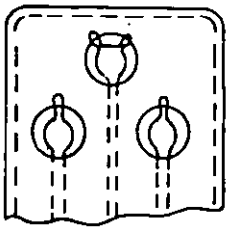
STRIP METHOD
SEE NOTE 6



PREFERRED
SEE NOTE 7



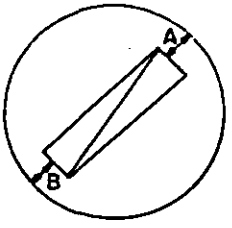
COMBINATION METHOD
SEE NOTE 6



ACCEPTABLE
INDIVIDUAL METHOD
SEE NOTE 7

NOTES:
1. The combination and individual methods are the most costly. The strip method creates a weak spot where the copper and the base material may crack.
2. The individual method shall be used for flexible printed-wiring with low density lands (>.15 centers).
3. Strip or combination methods shall be used for flexible printed-wiring with high density lands (<.15 centers).
4. Strip method (baring conductors) shall always be encapsulated at assembly and be provided with strain relief.
5. Combination method (baring conductors) shall always be conformal coated or encapsulated at assembly.
6. For use with plated through holes only.
7. For use with unsupported and plated through holes.

FIGURE 10. Forms of access holes.



A + B = { .028 INCH (0.71mm) MAX
.010 INCH (0.25mm) MIN

FIGURE 11. Hole diameter for flat lead.

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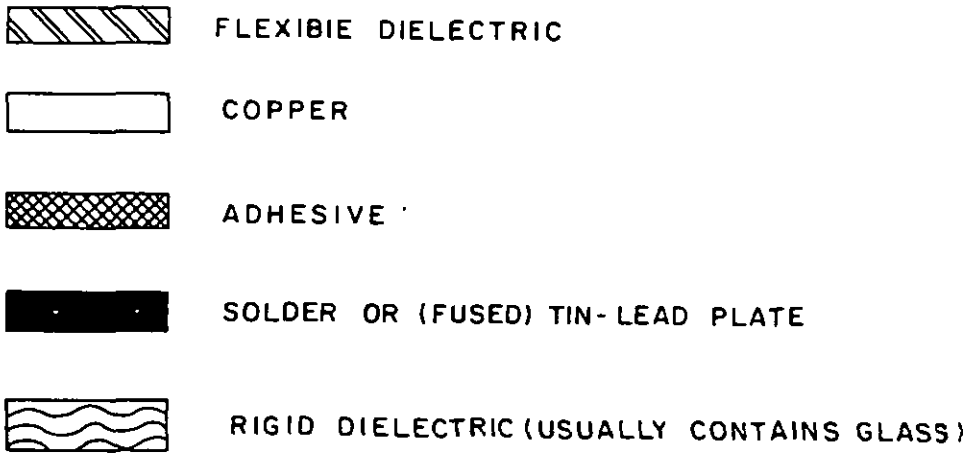
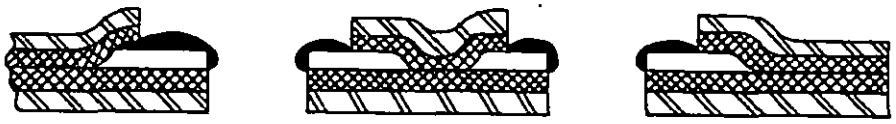
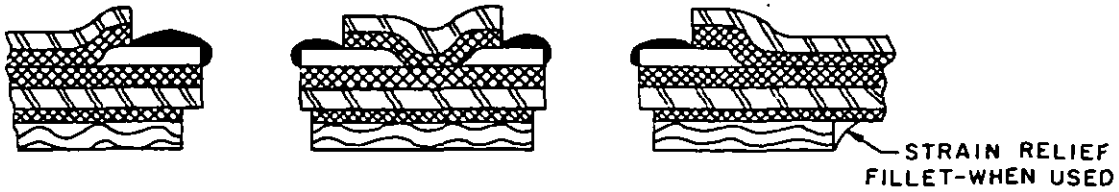


MATERIAL LEGEND

WITHOUT STIFFENER



WITH STIFFENER



Single-sided flexible printed wiring (type 1).

FIGURE 12. Typical constructions of flexible and rigid-flex printed-wiring.

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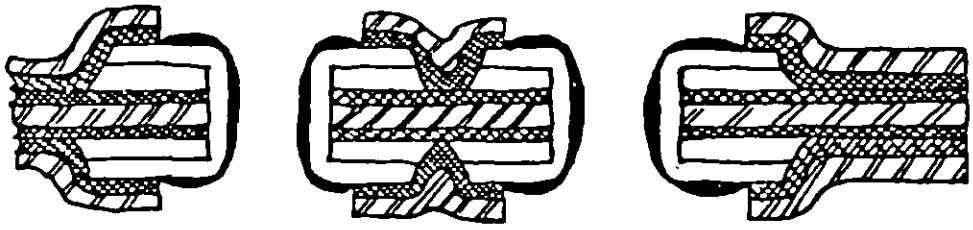
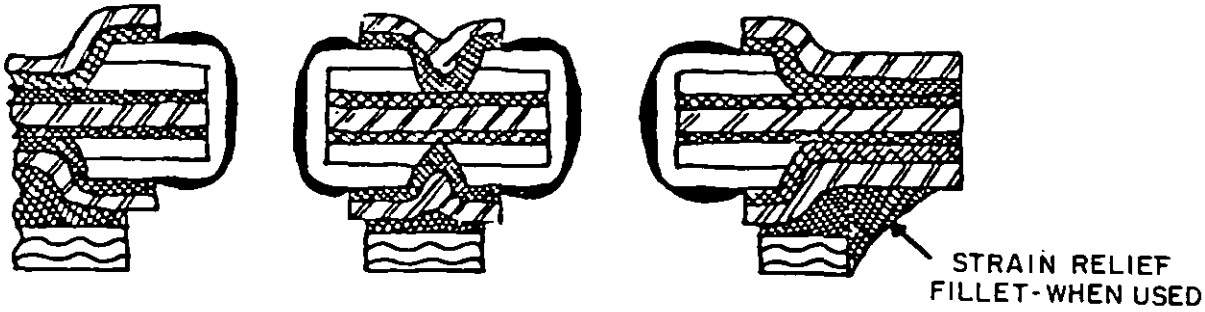
WITHOUT STIFFENER



WITH STIFFENER



Double-sided flexible printed-wiring (type 2).

FIGURE 12. Typical construction of flexible and rigid-flex printed-wiring - Continued.

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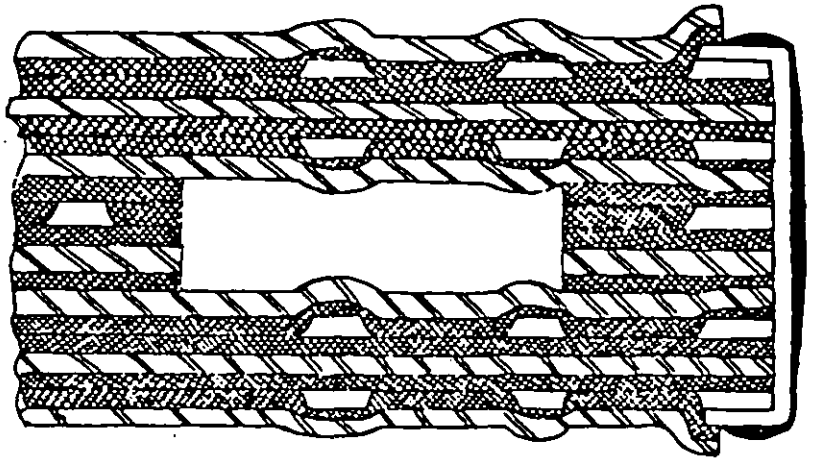
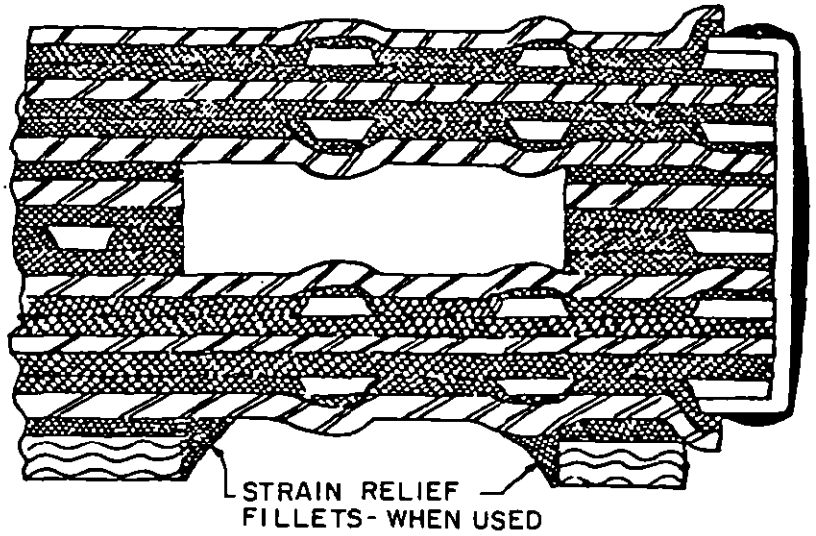
FLEXIBLE SECTION WITHOUT STIFFENER



Five layer depicted - 2 Double sided with coverlayers plus 1 Single layer (encapsulated)

FLEXIBLE SECTION WITH STIFFENER



Multilayer flexible printed-wiring (type 3).

FIGURE 12. Typical construction of flexible and rigid-flex printed-wiring - Continued.

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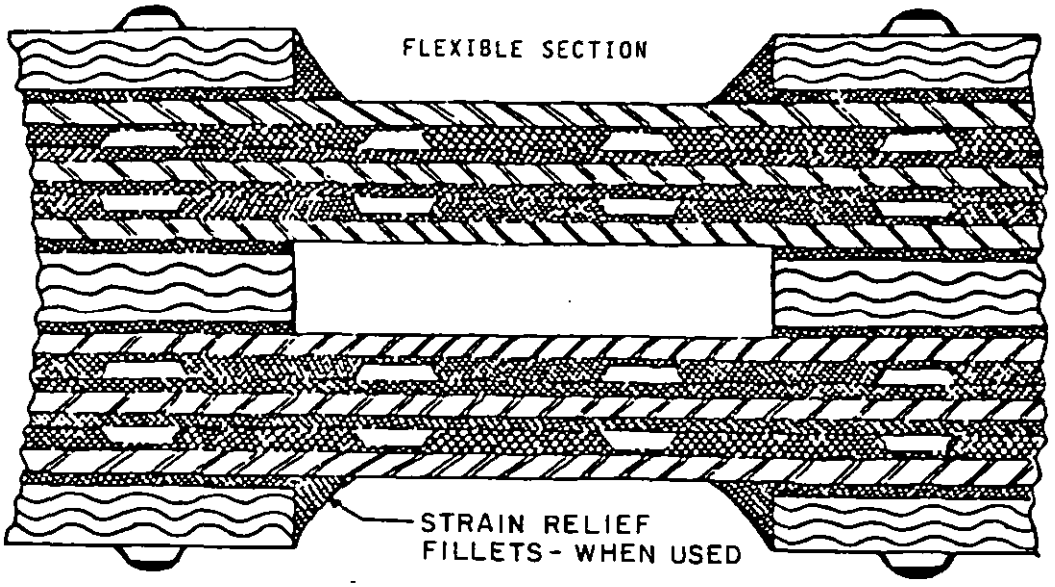
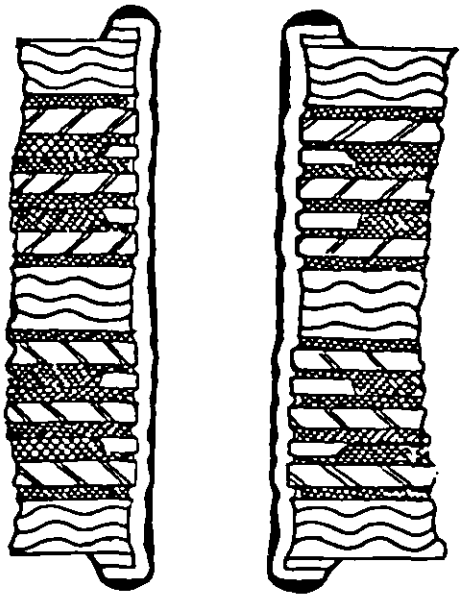


PLATED THROUGH HOLE SECTION



NOTE:

Varying degrees of preferential etchback amongst the various materials, as depicted is to be expected in finished product.

Multilayer composite combination rigid-flex printed-wiring (type 4).

FIGURE 12. Typical construction of flexible and rigid-flex printed-wiring - Continued.

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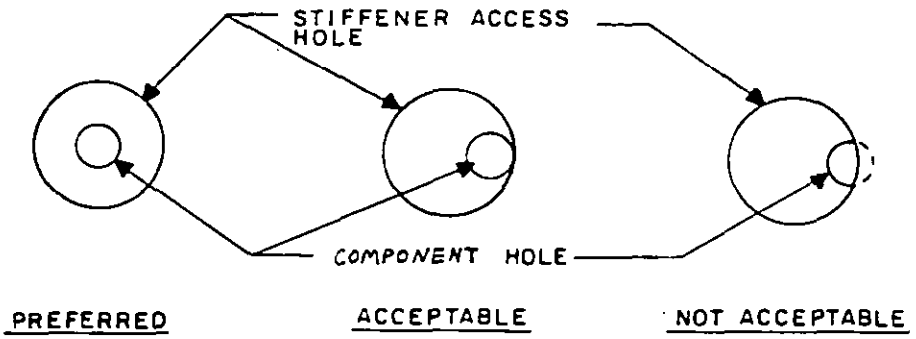

FIGURE 13. Stiffener registration.

FIGURE 14. Radiused edge of stiffener.

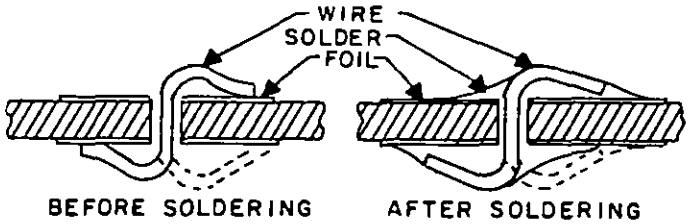

FIGURE 15. Clinched wire (interfacial connection) (direction of clinch optional).

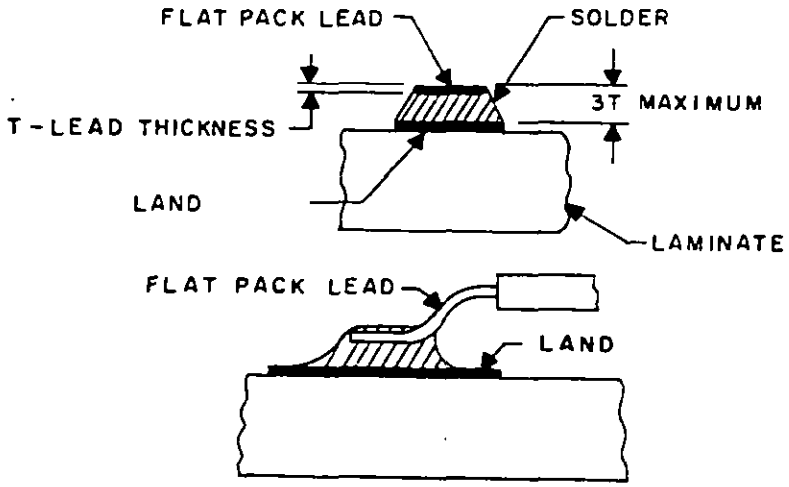

FIGURE 16. Flat lead termination.

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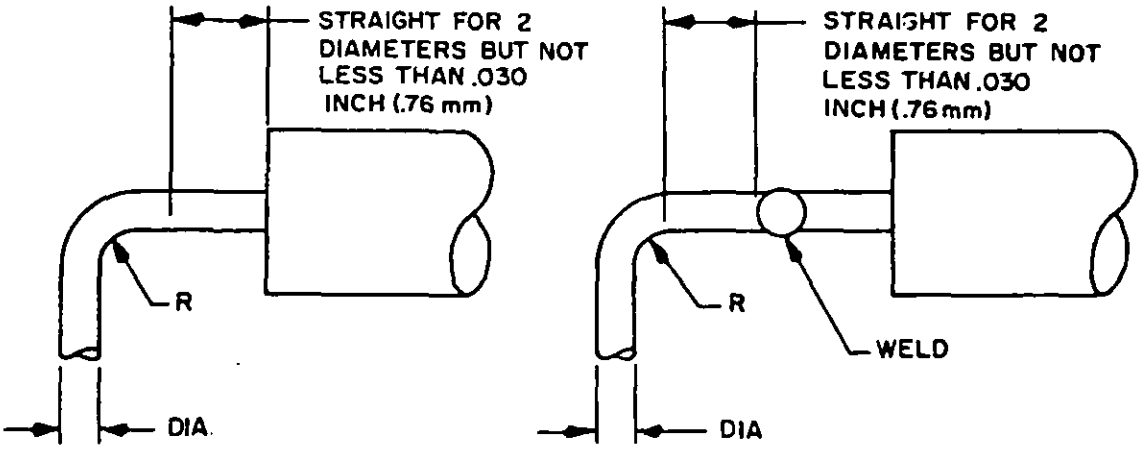

A. STANDARD BEND

B. WELDED BEND

NOTE:
1. Measurement shall be made from the end of the part. (The end of the part is defined to include any coating meniscus, solder seal, solder or weld bead, or any other extension.)

Lead diameter in inch	Minimum radius (R) inch
Up to .027 (.69 mm)	1 diameter
From .028 (.71 mm) to .047 (1.19 mm)	1.5 diameters
.048 (1.22 mm) and larger	2 diameters

FIGURE 17. Lead bend.

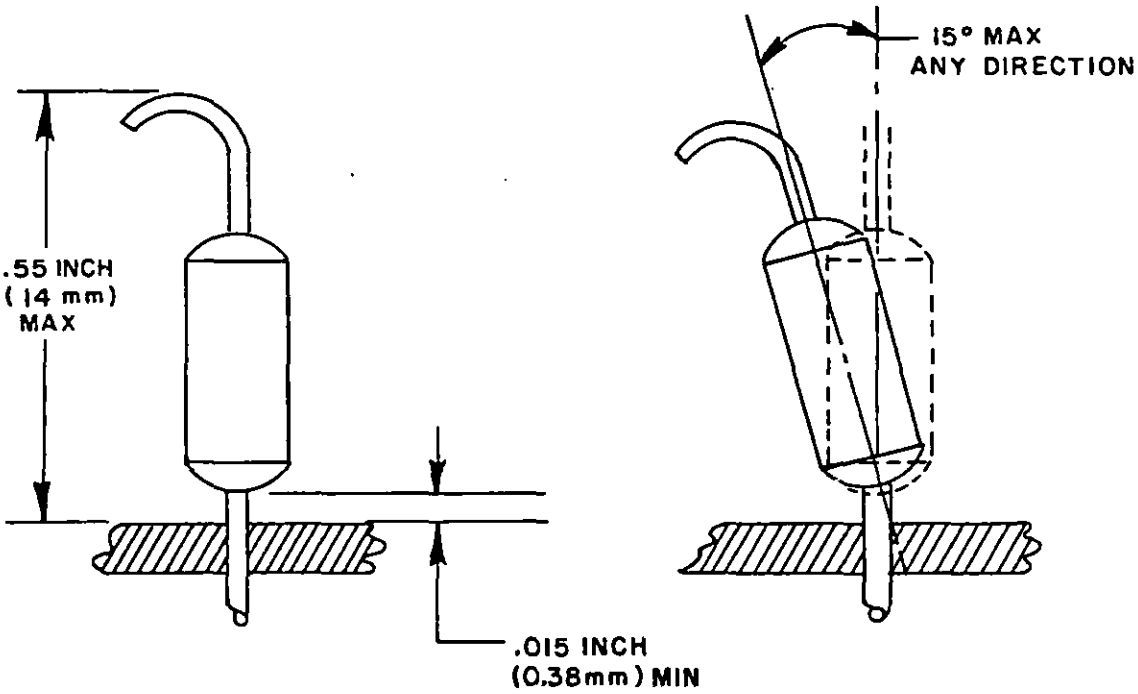

FIGURE 18. Perpendicular part mounting.

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Custodians:
Army - ER
Navy - EC
Air Force - 17

Review activities:
Army - AR, MI
Navy - OS, SH
Air Force - 11, 16, 85, 99
DLA - ES
NSA/S2

User activities:
Navy - AS, CG, MC
Air Force - 19

Agent:
DLA - ES

Preparing activity:
Navy - EC

(Project 5999-0115)

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APPENDIX

DESIGN GUIDELINES

10. SCOPE

10.1 Purpose. This appendix is for guidance to the designer of printed-wiring boards.

20. DESIGN CONSIDERATIONS

20.1 Design process tolerances and allowances. The data in table VII shall serve as a guide concerning the tolerances and allowances used in the design process. Due to tolerance buildup, the tradeoffs involved in arriving at the permissible limits for each particular tolerance for a particular design should be recognized. This data is needed to show the increasing difficulty of producing boards with tighter tolerances but does not express the limits attainable or permissible for any single aspect of board design. This data shall not be interpreted as end item board requirements.

20.2 Dimensional stability. While MIL-P-13949 and IPC-FC-241 limits the allowable dimensional change of the thin laminate, consideration must be given to the fact that during processing the thin laminate may either expand or contract within these limits and, in addition, the change may vary across different portions of the board. The result may be misregistration, and bow and twist beyond that which would be expected from a simple dimensional change.

20.3 Dielectric constant and dissipation factor. When designing circuits which depend on stable dielectric properties, consideration should be given to the fact that MIL-P-13949 and IPC-FC-241, IPC-FC-231, IPC-FC-232 and IPC-FC-233 sets forth only a maximum for these values and that some materials which meet the thin laminate specifications will have values 15 percent lower than the specification requirement.

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TABLE VII. Board design guidelines.

	Preferred	Standard	Reduced producibility
Number of conductive layers (type 3 and 4)	6	12	20
Composite thickness tolerance (types 1, 2, 3, and 4)	+, -20% of nominal	+, -15% of nominal	+, -10% of nominal or +, -0.010 inch, whichever is greater
Thickness of dielectric rigid materials-type 4 (min)	0.008 (0.20)	0.006 (0.15)	0.0035 (0.089)
Flex-Polymide-types 1, 2, 3, and 4 (min)	0.002 (0.05)	0.002 (0.05)	0.0015 (0.038)
Stiffeners	0.031 (0.79)	0.062 (1.6)	0.090 to 0.125 (2.3 to 3.2)
Minimum conductor width (or figure 4 value, whichever is greater)			
Internal	0.015 (0.38)	0.008 (0.20)	0.004 (0.10)
External	0.020 (0.51)	0.015 (0.38	0.008 (0.20)
Conductor width tolerance			
Unplated 2 oz/ft2	+0.004 (0.10 -0.006 (0.15)	+0.002 (0.05) -0.005 (0.13)	+0.001 (0.025) -0.003 (0.08)
Unplated 1 oz/ft2	+0.002 (0.05) -0.003 (0.08)	+0.001 (0.025) -0.002 (0.05)	+0.001 (0.025) -0.001 (0.025)
Unplated 1/2 oz/ft2	---	---	+.0005/-.001 (0.013/0.03)
Metallic etch resist in external layers			
over 2 oz/ft2 Cu	+0.008 (0.20) -0.006 (0.15)	+0.004 (0.10) -0.004 (0.10)	+0.002 (0.05) -0.002 (0.05)
Minimum conductor spacing (or table 1, whichever is greater)	0.015 (0.38)	0.008 (0.20)	0.004 (0.10)
Annular ring plated through hole (min) (see 5.2.2)			
Internal	0.008 (0.20)	0.005 (0.13)	0.002 (0.05)
External	0.010 (0.25)	0.008 (0.20)	0.005 (0.13)
Annular ring unsupported hole rigid and flex (min)	0.020 (0.51)	0.015 (0.38)	0.010 (0.25)

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TABLE VII. Board design guidelines - Continued.

	Preferred	Standard	Reduced producibility
Feature location tolerance (rtp) (types 1, 2, 3, and 4) (master pattern and registration)			
Longest dimension (12" or less)			
Feature pattern (RTP) area of types 3 and 4	0.006 (0.15)	0.005 (0.13)	0.004 (0.10)
Feature pattern (RTP) area of types 1 and 2	0.015 (0.38)	0.010 (0.25)	0.008 (0.20)
Longest dimension (over 12") (RTP)			
Feature pattern (RTP) area of types 3 and 4	0.008 (0.20)	0.007 (0.18)	0.006 (0.15)
Feature pattern (RTP) area of types 1 and 2	0.025 (0.64)	0.020 (0.51)	0.015 (0.38)
Predicted on total board configuration (see 4.2.6)			
Master pattern accuracy (RTP)			
Longest board dimension 12" or less	0.004 (0.10)	0.003 (0.08)	0.002 (0.05)
Longest board dimension over 12"	0.005 (0.13)	0.004 (0.10)	0.003 (0.08)
Feature size tolerance	+, -0.003 (0.08)	+, -0.002 (0.05)	+, -0.001 (0.025)
Composite thickness to hole diameter			
Rigid (types 3 and 4) max	3:1	4:1	5:1
Hole location tolerance (rtp)			
Component mounting area - dimension 12 inches or less	0.007 (0.18)	0.005 (0.13)	0.003 (0.08)
Component mounting area - dimension over 12 inches	0.010 (0.25)	0.008 (0.20)	0.005 (0.13)
Unplated hole diameter tolerance (unilateral)			
Up to 0.032 (0.81)	0.004 (0.10)	0.003 (0.08)	0.002 (0.05)
0.033 0.063	0.006 (0.15)	0.004 (0.10)	0.002 (0.05)
0.064 0.188	0.008 (0.20)	0.006 (0.15)	0.004 (0.10)

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TABLE VII. Board design guidelines - Continued.

	Preferred	Standard	Reduced producibility
Plated hole diameter tolerance (unilateral) for minimum hole diameter maximum board thickness ratios greater than 1.4, add 0.004 (0.10)			
0.015 (0.38)-0.030 (0.76)	0.008 (0.20)	0.005 (0.13)	0.003 (0.08)
0.031 (0.79)-0.061 (1.56)	0.010 (0.25)	0.006 (0.15)	0.004 (0.10)
0.062 (1.59)-0.186 (4.75)	0.012 (0.31)	0.008 (0.20)	0.006 (0.15)
Conductor including terminal pads to edge of composite (min)			
types 3 and 4	0.100 (2.54)	0.075 (1.90)	0.050 (1.27)
types 1 and 2	0.100 (2.54)	0.050 (1.27)	0.025 (0.63)
Bending of flex (internal radius) thickness			
Class A 0.003 to 0.010 (0.08 to 0.25)	6X material thickness	1X material thickness	
over 0.010 (0.25)	12X material thickness	2X material thickness	1X material thickness
Class B 0.020 max (0.51)	1"	1/2"	1/4"
Continuous flex cycles (based 1 oz/ft2 copper, .002 inch dielectric) thickness			
0.003 to 0.008 (0.08 to 0.20)	1,000	100,000	500,000
Over 0.008 to 0.014 (0.20 to 0.36)	500	50,000	250,000
Over 0.014 (0.36)	250	25,000	100,000

NOTE: Unless otherwise specified, all dimensions and tolerances are in inches. Data in parenthesis ( ) are expressed in millimeters.

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