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Test Pattern Artwork and Sample

Preparation for UL 796

This document is intended to assist NTS' customers with preparing their samples for submission for testing under the Third-Party Test Data Program (TPTDP) in order to obtain or modify their UL listing. UL 796, Tenth Edition (October 8, 2010) for printed wiring boards, covers test requirements for single-sided, double-sided, multilayer, metal base and fl exible printed wiring boards.

The standard requires several qualification tests in order for a printed wiring fabricator to have his product Recognized by UL. Various test patterns are required for the testing, and UL 796 displays typical test patterns - Figure 10.1. 10.2, 10.3 and 25.1 for this purpose. UL does not supply copies of the test pattern artwork, but NTS has created optimized artwork that can be used to manufacture the test patterns. These patterns can be altered, if necessary, in order to achieve the specific pattern limits for which the fabricator desires UL Recognition.

Some variations in Recognized pattern limits are not significant to most printed wiring boards users; but, in general, it is beneficial to have Recognition for pattern limits near the state-of-the-art extremes for such things as minimum line width, minimum dielectric thickness, mini-mum supplied copper thickness, maximum supplied copper thickness (if greater than 3 oz.), and maximum un-pierced conductor area (typically found on Voltage/Ground planes). Each of these Recognition limits will be dis-cussed in conjunction with each artwork pattern. Your selection of which test pattern best fits your requirements will provide you a standardized test vehicle for Recognition.

Figures for Patterns

All base materials used for the manufacture of UL Listed PWBs must be UL Recognized as specified in the final Sample Requirements Table (SRT). UL uses several terms for the materials used to make PWBs. Any references to "laminates" and "prepreg" in the following text should be considered interchangeable with the words "base material" and "bonding material", respectively.

NTS' Test Patterns (see Figure 1 and 2) are at the end of this document. NTS supplies test patterns for the Bond Strength test (Figure 1) and Delamination Test (Figure 2). These patterns are similar to Figure 10.1, 10.2 and 10.3 shown in UL 796. The various features incorporated on these artworks have been designed to give you a greater possibility of achieving optimum Recognition limits of features listed below Figure 10.1, 10.2 and 10.3 of UL 796.

Conductor Widths

A conductor width of 1/16" provides the testing data for industry comparison of peel strength (bond strength). The minimum acceptable value is 2 lb. per inch of width after 10 days of oven conditioning and 1 lb. per inch of width after 56 day oven conditioning. Minimum conductor widths starting at 0.002 inch to 0.015 inch are provided on the test patterns. The artwork has already been compensated for a typical ½ oz. copper etch factor. The increas-ing circuit widths provided on the panel are advantageous. If the minimum conductor width fails to meet the peel strength requirements and the next wider conductor passes, UL can extend Recognition to that conductor width which passed without requiring new test coupons to be submitted.

Edge Conductor

There are slots routed into the center of the panel between the different circuit widths (see Figure 1). There is a 1/16" circuit in the center of the slot, placed there for improved circuit density. (It will be routed away). The circuits next to the slots are there to satisfy the require-ment for "edge conductor", which if not applied to the sample will automatically be rated at 3 times your minimum line width. This slot arrangement allows you to get the edge conductor width rating limit the same as your minimum line width.

Connector Contacts

For connector contacts you will need to use the supplied pattern (Figure 1) and lay it up into a panel that suits your manufacturing format. Make sure to lay it up in a manner that allows nickel/gold plating on the simulated fingers. The connector contacts or edge finger patterns provided on these artworks are standard for most Printed Wiring Boards. Please take into account that if you require Nickel/Gold contact finger recognition, the simulated fingers must be Nickel/Gold coated. These connector contacts must be plated with the metal you will use in your standard production, normally nickel and gold.

All metals that are plated after pattern etching and that are desired for Recognition must be provided for on the pattern (i.e. gold, rhodium, etc.). These contacts must meet an adhesion test. These contacts also must meet the 2 lb. per inch peel strength after 10 days and the 1 lb. per inch width after 56 days. The critical factor here is "after pattern etching". Since plating solutions after pattern etching (particularly nickel-gold, rhodium, etc., plating solutions) can adversely affect both the laminate surface and the "undercut" area, material inspection of the laminate surface and the bond strength of the contact can be compromised.

Plated-Through Holes

The small solid lands found on the NTS artwork pattern are to be used for plated through-holes (PTH) and can be drilled at any diameter you wish. Samples must contain at least 4 PTHs as shown on Figure 1 and Figure 2. If your final manufacturing process calls out for Non-Plugged (NPPTHs), Plugged (PPTHS) or Encapsulated Plated Through Holes (EPPTHs) at least one of each must be present on the samples. Plated through-holes are examined visually for plating quality (voids). Plated through-hole diameter are not restricted in your UL Recognition, but a diameter of 0.040" to 0.060" is recommended.

Maximum Unpierced Conductor Areas

The pattern (Figure 2) with the larger solid lands is to be used for the delamination tests and will be examined after solder shock and after 10 or 56 day oven conditioning for signs of blistering, peeling or delamination. The maximum size of these solid metal lands will be a Recognized production limit for maximum un-pierced con-ductor diameter in your UL qualification. Do not pierce these lands. The artwork provided contains a variety of un-pierced diameters. The largest diameter un-pierced area that does not delaminate in subsequent testing is what will limit your rating. Artwork has been generated in both Metric and English (separate files) and either one or the other should be used depending on whether you want your UL listing to contain English or Metric units.

Making the Test Coupons

The Test coupons are to be fabricated from a UL Recognized base material and must be processed using all the maximum limits listed in the production processes in your UL files for printed wiring board fabrication, even though the samples must not always retain the effects of the process. For example, Peel strength coupons and Bond Strength Coupons must be subjected to the heat for solder mask cure, etc. even though these coupons must not have solder mask coverage. NTS has put together on the website another document that describes general process descriptions, along with the considerations for optimizing your processing procedures. Just remember that your test samples must endure the MAXIMUM of each process listed that includes all time, temperature and pressure settings. Don't get carried away with your process definition!

If you submit test coupons with double-sided patterns and plated-through holes, you can request Recognition for the same pattern limits, conductor widths, un-pierced area, etc. for non-plated through double-sided, and single-sided printed wiring boards.

If you fabricate and wish Recognition for only single-sided printed wiring boards, the pattern in Figure 1 & 2 should be used on your single-sided base material. If you wish Recognition for double-sided boards with or without plated through-holes, Figure 1 should be registered to itself on both sides of the material so that the circuits are registered to each other on layer 1 to layer 2, and Figure 2 should be registered to itself so that each large solid land is opposite its counterpart on the opposite side. The use of 1/8 oz. to 1oz. copper on the outer layers will cover external foil limits up to 3 oz.

On a multilayer package, the circuits on the internal layers of the artwork have been compensated for the etch factor of thicker copper foil. The width of these internal circuits is not used for UL listing purposes, so do not put too much effort into maintaining conductor width on the internal layers. We recommend that you use internal cores with your maximum internal copper (typically 3 oz.)(Layer 2) on one side and your thinnest internal copper (typically 1/8 to 1/2 oz.) (Layer 3) on the other side.

If you wish Recognition for a multilayer printed wiring board, you must manufacture a 4-layer multilayer printed wiring board with the pattern (see Figure 3) registered to itself on all four lay-ers. For ease of processing all copper thick-nesses, the internal conductors may be adjusted to any width wider than the external conductors. Multilayer coupons may represent double-sided boards if you use the same

a. Manufacturer's grade of thin laminate and/or prepreg used to manufacture the coupons.

b. Temperature rating (MOT) and minimum build up thickness of the finished boards (example: 105° C)

c. Manufacturing process

Multilayer Coupon Construction

The overall coupon thickness must be the minimum you desire to have Recognized (0.015" to 0.030" is very common). This minimum overall measurement is taken of the base material. UL 796, 17.8: “Boards shall be built up to the minimum thickness specified for the metal-clad base material when measured to exclude the conductors.” The flammability coupons are typically measured because they contain no copper conductors. It is recommended, therefore, that the fabricator laminate separate packages: one for the flammability samples, and one for the circuits and delamination circles.

Even laminating three separate panels is not uncommon.

The multilayer package of circuits and delamination circles are checked to verify that the base materials used to produce the flammability samples are identical to the base materials used to produce the bond strength and delamination samples even though the thickness of the multilayer package with copper will almost invariably exceed the thickness of the flammability samples. Both sets of samples must contain the same construction.

Copper Layer 1 (Figure 3 and 4)

L1: Must be the minimum foil thickness that you wish to have Recognized for external copper (3/8 or ½ oz. being very common, 1/8-1/4 oz. also are sometimes employed). Copper foil only may be used if foil lamination is your standard production practice.

For the multilayer package, layer 1 and layer 2 may be on both sides of a double-sided laminate (Cap Lamination construction, Figure 4) if the requirement for minimum bonding material (prepreg) for which you wish Recognition can be met between layer 2 and 3 (VERY DIFFICULT with > 1oz. Copper).

Copper Layer 2 (Figure 3 and 4)

L2: Must be the maximum copper thickness for which you wish internal copper recognition. Three oz. copper is quite standard but heavier copper foil– 4, 5 or even 10 oz. are sometimes used. Recognition of the heaviest copper extends coverage to all thinner coppers.

If greater than 1 oz. internal copper is desired (i.e. 3oz.), Figure 3 (Foil Lamination) construction may be the best choice. In this instance layer 1 will be foil or single sided laminate which is bonded to layer 2 with the necessary prepreg thickness required for filling layer 2 copper and meeting the bond/ delamination requirements. Since only the surface conductor lines are used for peel strength, the line conductors on layer 2 or 3 may be any width. The copper lands at the plated through-holes must be retained and registered on layers 2 and 3. If the construction depicted in Figure 3 (Foil Lamination) is used, layer 2 should be on a laminate core thickness, which is minimum for your Recognition (0.002" to 0.005" is very com-mon).

Copper Layer 3 (Figure 3 and 4)

L3 may be any copper thickness (typically ½ to 1 oz.).

Copper Layer 4 (Figure 3 and 4)

Layer 4 may be copper which is bonded to a thin laminate or may be unsupported copper foil bonded by the prepreg during lamination. Remember between layer 3 and layer 4 is the area of minimum prepreg thickness. If you request recognition for the foil lamination process, layer 4, must be unsupported foil against the prepreg if the peel strength testing of the minimum and maximum copper weight is to be done on both sides of the same coupon.

Laminates and prepreg from different manufacturers and different grades of material from the same manufacturer are allowed in combination if they are the same generic type (i.e. FR-4). Combinations of generic types have certain restrictions. Consult with your NTS Client Agent for further details.

Laminates and prepreg from different manufac-turers and different grades of material from the same manufacturer are allowed in combination if they are the same generic type (i.e. FR-4). Combinations of generic types have certain restrictions. Consult with your NTS Client Agent for further details.

Flexibility Test Pattern

The test pattern found in UL 796F are used for flexibility testing of Flexible PWBs. The continu-ous conductor is a 1/16" wide etched conductor. Coupons of both the minimum dielectric film and copper thickness plus separate coupons with maximum build-up thickness including maximum dielectric film and maximum copper weights are required testing. Reference the sample requirement table for final samples and constructions needed.

Note: The cover lay lamination test for flexible PWBs requires test pattern coupons of Figure 1 and Figure 2.

Mass Lamination Test Pattern

This test pattern is to be used by laminate manufacturers who wish to obtain Recognition for a multilayer mass lamination product per UL 796 or Metal Clad Laminates (CCIL) per UL 746E. This test pattern is used to construct a multilayer coupon with the same construction requirements and limitations, as those described in the "Multilayer Coupon Construction" section above. There are these noted exceptions.

1. The external conductors are standardized at 0.060", 0.030" wide.
2. The unpierced conductor area maximum is 2.0" in diameter. This means that the mass lamination product may be used by a printed wiring board fabricator even if the fabricator's limit is greater than 2.0" in diameter.
3. The other parameters of minimum external copper, maximum internal copper, minimum overall thickness, minimum core thickness, and minimum prepreg thickness apply to these coupons. There are no plated through-holes or plated connector contacts in these coupons.

Marking

While UL 796 contains specific requirements for the marking of printed wiring boards, there are no specific instructions for the marking of the coupons for testing other than each printed-wiring board shall be plainly and permanently marked. The only requirement is that the coupons for testing actually be processed through all of the same processes as the production boards see.

The Tests

1. Solder Shock

The fabricator must specify the solder shock time and the solder shock temperature for which the board would be listed. The development of alternative solder methods (IR heating, vapor phase, etc.) may require longer times at elevat-ed temperature and should be considered when making your decision on temperatures and times. The board fabricator should specify as long a time as possible within the limits of the base materials rating (example: 20 seconds at 525° F for FR-4 for most manufacturers). NTS has provided enough coupons to submit for both a conservative and aggressive solder shock requirement. Also keep in mind that higher Glass Transition Temperature (Tg) material does not necessarily mean better sol-der shock resistance! Many low Tg materials outperform high Tg materials in this area.

Pay attention to the "Time to Delamination" numbers provided by your material supplier for an indication of this attribute.

2. The Delamination Circles (See Figure 2).

A coupon for the un-pierced conductor areas needs to be fabricated for the delamination testing. This test procedure includes a solder shock per your requested time and temperature limits plus oven conditioning for 10 and/or 56 days, followed by examination for delamination or blistering. This artwork includes un-pierced areas, which range from ½" in diameter to 4.0" in diameter. Most common recognition in the industry is two to four inches in diameter.

The benefits of this test pattern are similar to those of the various conductor widths incorporated on the Bond Strength pattern (Figure 1). If there is delamination or blistering in the larger diameters on single-sided, double-sided, multilayer, or flexible boards, UL may extend Recognition to you for the largest area which does not show delamination. Therefore, if the 4.0" fails, but the 3.0" passes, UL will extend Recognition for the 3.0" diameter limit without additional testing.

The multilayer layer-to-layer build-up and con-struction requirements on this test coupon are the same as those for Bond Strength testing (Figure 1) as if they were cut from the same panel. The external coppers must also be plated up along with the plated through-holes. The same requirements of minimum prepreg, minimum overall thickness, and maximum/minimum external coppers apply.

3. Flammability Testing Coupons

Flammability testing is required initially for each PWB fabricator, but may not be required for additions of double-sided laminates to your listing if those laminates have already been tested by the laminator.

Flammability testing of multilayer coupons for the fabricator may not be required if the materials have been previously tested by the laminator and the solder limit and thickness parameters are compatible between the fabricator and the laminator.

When multilayer flammability tests are request-ed by UL, coupons should be made with the same thin laminates and prepreg and with the construction build up as Figure 1, 2, 3, 4 coupons except that all internal and external copper must be removed by etching.

Be certain that when you make the ½" x 5.0" coupons that you carefully and evenly smooth the edges by wet sanding or some similar operation. Be sure that the edges of the coupons have no voids, protruding fibers, or other roughness that can increase the surface area. Many flammability coupons fail because of sample preparation and not because of flammability properties of the material.

Flammability testing is also required when the board manufacturing process is revised for higher temperatures and/or longer times than presently described in the fabricator's manufacturing process contained in its UL file.

Many solder masks for printed wiring boards are now Recognized as separate components by UL and have been tested on laminate materials. Therefore, to get Recognition to use a new solder mask, flammability testing may not be necessary provided you have previous Recognition with a different solder mask. Be sure to contact the solder mask manufacturer concerning his UL yellow card Recognition before using the materials.

In order to accomplish the testing required to get UL Recognition, NTS has put together an Appendix to this document that shows what testing is required for the addition/modification to your UL listings.

Suggestions for Parameters for Test Samples meant for UL Recognition Testing

There are several test parameters which can be standardized that can eliminate confusion with the Recognized limits of various printed wiring fabricators. There are some procedures which can be used when requesting Recognition testing which will greatly enhance your chance of achieving the Recognition limits which you request with the minimum amount of testing. You should:

1. Always fabricate your coupons with the very best fabrication procedures you have available. Use the maximum exposure to time and temperatures in excess of 100° C. Reprocess coupons through any required process steps if you expect to be able to rework production boards by repeat processing. List all repeat steps in your process description along with maximum temperatures used. Be sure that your process listed in your UL file contains the maximum tolerances used in actual production (e.g. A process of 300±20°C for 50±10 minutes would translate to "320°C for 60 minutes maximum"). Be sure to use clean materials, clean solutions, and careful operators.
2. Where possible, test your coupons prior to submittal to UL. Fabricate enough coupons so that you have extras for in-house testing of solder shock, peel strength, delamination, and flammability.
3. Always fabricate enough coupons for both the 10-day and the 56-day test. If you are submitting separate coupons for the delamination test (Figure 2), you must supply ten coupons for each conditioning for a total of twelve. Submit two or three extras if possible. The 10-day oven-conditioning test is considerably more stringent than the 56-day test due to the higher tempera-ture of the oven (e.g. For a 130°C MOT the 10-day temperature is 177°C and the 56 day temperature is 154°C).

An example of the test oven temperature follows:

Oven Temperatures For Continuous Operation		
Temperature	**10-Day**	**56-day**
105°C	150°C	128°C
120°C	167°C	144°C
130°C	177°C	154°C

10-Day Test Temperature = 1.076 (Operating Temp°C . + 288) - 273
56-Day Test Temperature = 1.02 (Operating Temp°C + 288) - 273

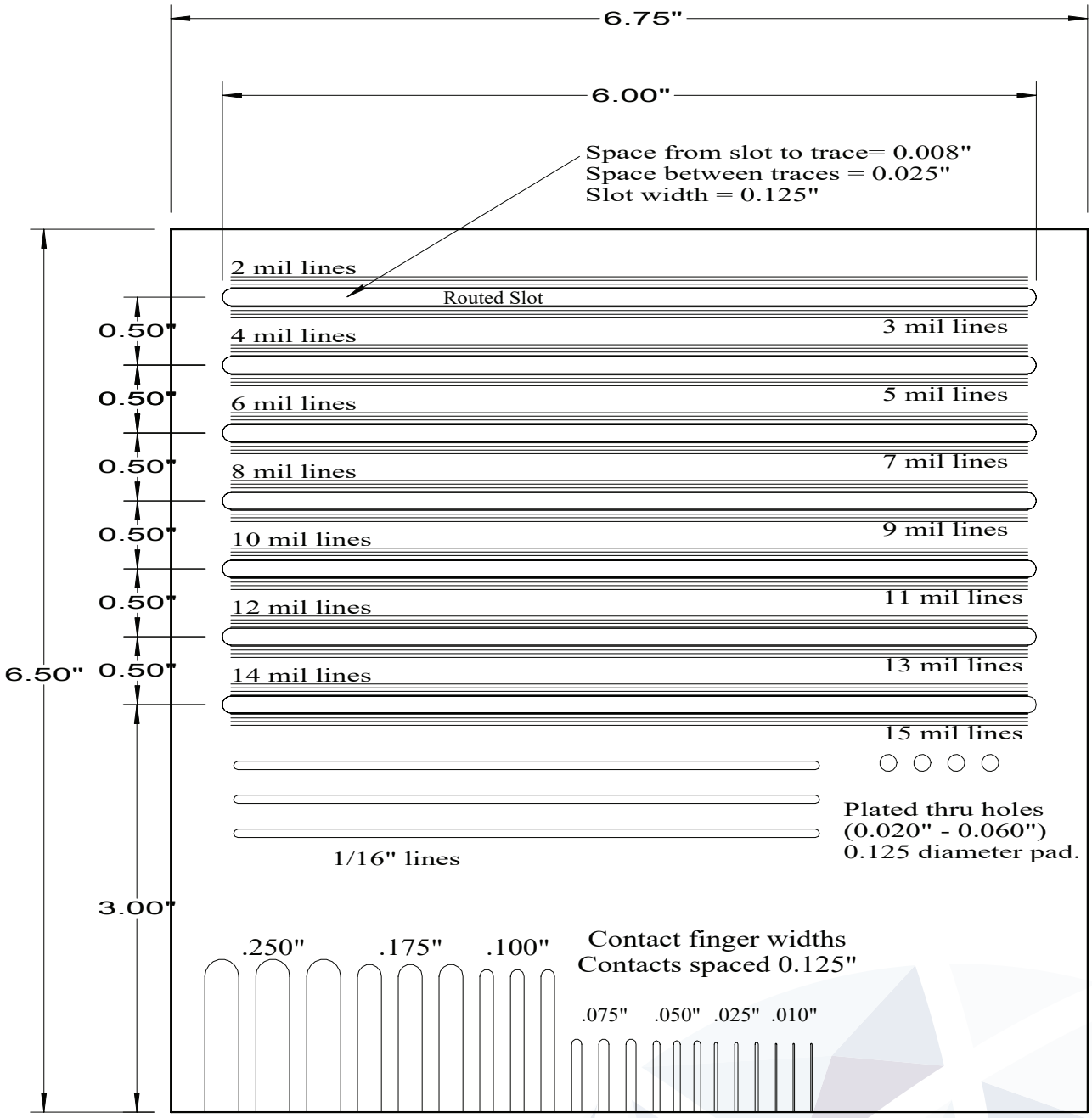
The test temperature depends on the temperature you request for maximum operation temperature (MOT) for your boards. It is recommended that whenever the maximum operating temperature of greater than 105° C is requested, you make enough coupons for both the 10-day test and the 56-day testing. If the 10-day coupons pass, the 56-day test is aborted. If the 10-day coupons fail, the 56-day test is continued to completion. If it passes, Recognition is given and the 10-day results are disregarded.

4. Be careful in etching narrow surface conductors so that you do not produce undercut. Remember that 3/8 and 1/2 oz. foils will allow for less undercut and extend your Recognition limits, but must be copper plated up to 1 oz. to permit peel strength testing.
5. Only one external plating is necessary for plated through-holes. It may be bare copper, tin-lead, tin nickel, nickel-gold or another pattern plating. As long as the plating does not contact the surface of the dielectric, one plating will qualify all others with the exception of silver, which has a tendency to migrate. Contact your regional UL office for details on the test program for silver conductors.
6. All test coupons (Figures 1, 2,) must be subjected to all steps of your manufac-turing process that exceed 100° C. For example:
   a. All process steps where temperature exceeds 100°C are also considered part of your process operations and must be done on both peel strength and delamination coupons.
   b. Peel strength coupons and Bond Strength Coupons must be subjected to the heat for solder mask cure, etc. even though these coupons must not have solder mask coverage. Flame samples may be coated with solder mask if recognition for a solder mask is being sought. If solder mask is not the reason for flammability sample submission, then the samples must go through the heat excursion of solder mask but must not be covered with mask.

Etchants

UL categorizes all etchants except chrome sul-furic as one. It is not necessary that you identify the specific etchant used in the preparation of your samples or in your process listing, except to specify if it is chrome sulfuric. Because of the problem of pollution and waste disposal associated with chrome sulfuric etchants, the requests for Recognition of chrome sulfuric etchants is very seldom necessary. The interchangeability of all other etchants will give you adequate process versatility in the future.

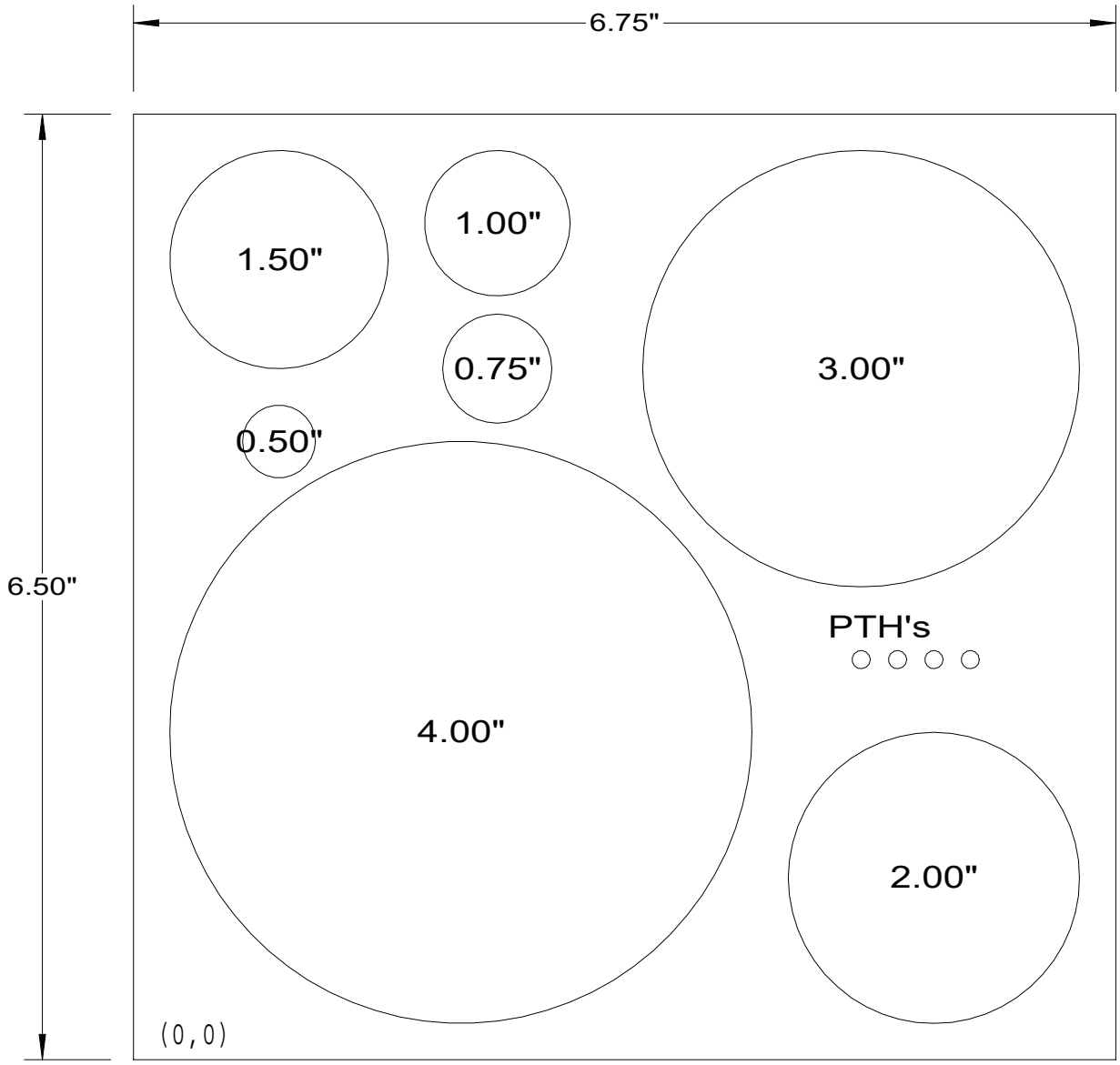
FIGURE 1: BOND STRENGTH COUPON



NOTE: Although samples must undergo all processes, samples cannot be coated with any soldermask. Samples must have a solder coating if final product has one.

Note: This drawing may vary slightly from provided Gerber files.

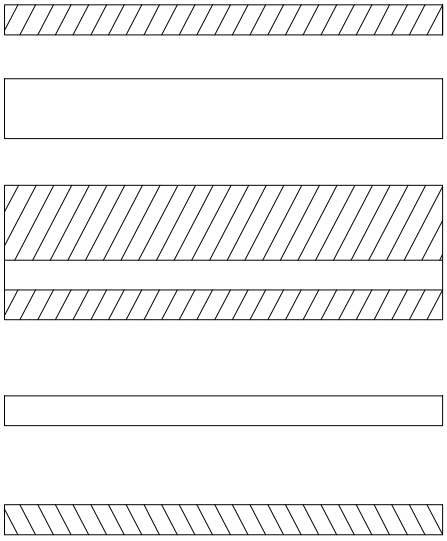
FIGURE 2: DELAMINATION COUPON



Pad Dia.	X	Y	Plated thru holes (0.020" - 0.060 recommended)		
4.00"	2.25	2.25			
3.00"	5.00	4.75	0.125"	5.00	2.75
2.00"	5.50	1.25	0.125"	5.00	2.75
1.50"	1.00	5.50	0.125"	5.25	2.75
1.00"	2.50	5.75	0.125"	5.50	2.75
0.75"	2.50	4.75	0.125"	5.75	2.75
0.50"	1.00	4.25			

NOTE: Although samples must undergo all processes, samples cannot be coated with any soldermask. Samples must have a solder coating if final product has one.

FIGURE 3: FOIL MULTILAYER BUILD-UP



Minimum copper thickness - Plated up to 1 oz. ***

Prepreg necessary for use with maximum internal copper thickness

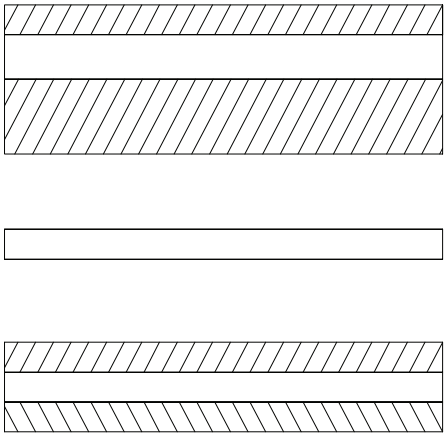
Maximum copper weight *

Minimum dielectric thickness
Any copper weight (1/2 oz recommended)**

Minimum prepreg thickness

Minimum copper thickness - Plated up to 1 oz. ***

FIGURE 4: CAP MULTILAYER BUILD-UP



Minimum copper thickness - Plated up to 1 oz. ***
Any laminate thickness

Maximum copper weight *

Minimum prepreg thickness

Any copper thickness (1/2 oz recommended)**
Minimum laminate thickness
Minimum copper weight - Plated up to 1 oz. ***

* Etch factor is not a concern as internal line widths are ignored.

** Lower copper weight improves minimum prepreg thickness and delamination characteristics.

*** For external copper thickness greater then 3 oz. additional coupons will be required with the maximum external copper.

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