

## Design of Experiments to Determine Causes of Flex Cable Solder Wicking, Discoloration and Hole Location Defects

Federal Manufacturing & Technologies

Larry Wolfe

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Final Report  
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## Abstract

*Design of Experiments (DoE) were developed and performed in an effort to discover and resolve the causes of three different manufacturing issues; large panel voids after Hot Air Solder Leveling (HASL), cable hole locations out of tolerance after lamination and delamination/solder wicking around flat flex cable circuit lands after HASL. Results from a first DoE indicated large panel voids could be eliminated by removing the pre-HASL cleaning. It also revealed eliminating the pre-HASL bake would not be detrimental when using a hard press pad lamination stackup. A second DoE indicated a reduction in hard press pad stackup lamination pressure reduced panel stretch in the y axis approximately 70%. A third DoE illustrated increasing the pre-HASL bake temperature could reduce delamination/solder wicking when using a soft press pad lamination stackup.*

## Summary

Flat flex cable lamination entails the use of a press pad stackup placed between lamination press platens. There are two lamination press pad stackups presently being utilized in production, hard press pad and soft press pad. The hard press pad stackup has been used almost exclusively for the past twenty years. A soft press pad stackup has recently been utilized to reduce panel stretching and adhesive squeeze out. The differing ways these two press pad stackups affect the quality of lamination adhesion is the basis for the activities described in this report. These activities were conducted in an effort to resolve manufacturing issues related to the quality of adherence after lamination.

In July of 2006 after completion of a department's Hot Air Solder Leveling (HASL) process, large voids and/or delamination appeared immediately on several lots of panels, Main and Aux cables. A full factorial DoE was conducted in an effort to understand the cause of the voids/delamination. Utilizing the most likely variables, lamination stackup, bake, and clean did not recreate the large voids, but did illustrate other possible processing modifications of interest.

The hard press pad stackup obtained the best results with the least amount of delamination/solder wicking when panels were not baked or cleaned prior to HASL. This was also the combination of variable factors exhibiting the best adhesion of all variables for both press pad stackups. The soft press pad stackup obtained the best results when panels were baked and either cleaned or not cleaned prior to HASL. All twenty-four cables laminated using the soft press pad stackup that were not baked had significant amounts of solder wicking under the coverlay. This implies inadequate adhesion.

A second manufacturing issue related to out of tolerance hole locations became apparent on the Firing Set flex cables, the first to require hole location measurement after plating and lamination. A full factorial DoE was performed to resolve this problem by reducing pressure during lamination. Based on the results, a reduction in lamination pressure from 190 tons to 90 tons should not affect the quality of adhesion between coverlay and copper laminate, but could reduce panel stretch in the y axis up to 70%.

The final issue addressed by this report was the appearance of minor delamination/solder wicking around circuit lands after HASL when using the soft press pad stackup. In an effort to determine which variable or variables had the greatest effect on delamination/solder wicking, a fractional factorial DoE was developed. The experiment varied lamination pressure, lamination temperature, lamination time, pre-HASL bake time and temperature. Two ounce copper laminate cables used for this experiment exhibited no coverlay delamination or solder wicking around circuit lands when an increased bake temperature was used for the HASL pre-bake. A shorten bake time at the increased bake temperature also did not exhibit any coverlay delamination or solder wicking.

Performing the second part of this experiment with one ounce copper laminate cables, there was an increase in delamination/solder wicking with all variable combinations. Data analysis indicated longer HASL pre-bake times will produce less delamination/solder wicking. This data implies different processing for two and one ounce copper laminates.

## **Activity**

The activities contained in this report were conducted in an effort to resolve manufacturing issues related to the quality of adherence after lamination. These activities are grouped into phases which are described as:

***Phase One*** – A full factorial DoE conducted in an effort to understand why several lots of part numbers, Main and Aux cables, exhibited voids/delamination after HASL.

***Phase Two*** – A full factorial DoE performed to resolve flex cable hole location out of tolerance conditions. This issue became apparent on the Firing Set flex cables, the first to require hole location measurement after plating and lamination.

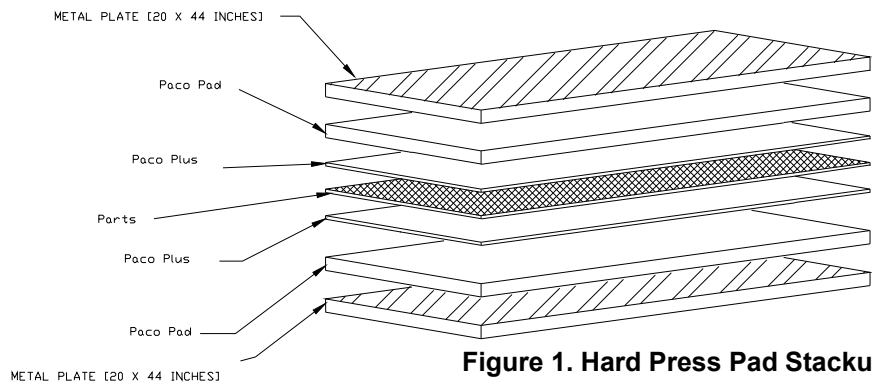
***Phase Three*** - A fractional factorial DoE performed to determine if variations in lamination and pre-HASL process variables affect coverlay delamination/solder wicking around circuit lands when using the lamination soft press pad stackup.

## **Background**

Flat flex cable lamination entails the use of a press pad stackup placed between lamination press platens. To adhere coverlay to copper laminate the cable panels are placed in the center of a press pad stackup and then placed between the press platens. There are two lamination press pad stackups presently being utilized in production, hard press pad and soft press pad. The hard press pad stackup has been used almost exclusively for the past twenty years. A soft press pad stackup has been utilized recently on cables to reduce panel stretching and adhesive squeeze out. The different press pad stackups and their contents are listed below.

### Hard press pad stackup

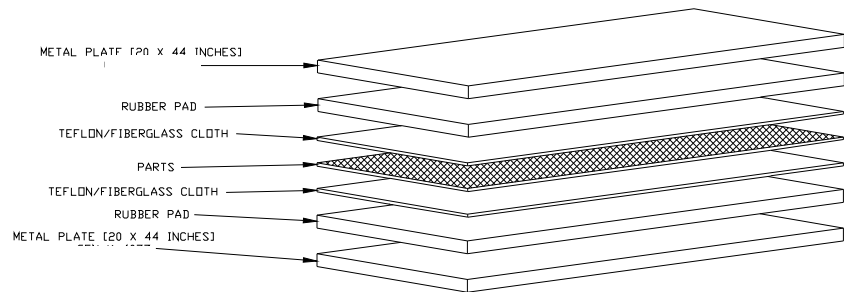
Metal plate  
Rubber  
Teflon  
Parts  
Teflon  
Rubber  
Metal plate



**Figure 1. Hard Press Pad Stackup**

### Soft press pad stackup

Metal plate  
Pacopad  
Paco Plus  
Parts  
Paco Plus  
Pacopad  
Metal plate



**Figure 2. Soft Press Pad Stackup**

All activities and experiments contained in this report utilized one or both of the above press pad stackups.

## **Phase One**

In July of 2006 after completion of a department's HASL process, large voids and/or delamination appeared immediately on several lots of panels, Main and Aux cables. This DoE's objective was to determine the cause by recreating the large voids in a structured experiment.

Hole diameter and location Coordinate Measuring Machine (CMM) data also was collected from the sample panels used for this experiment. This data provided insight into the amount of panel stretch resulting from the use of a hard press pad stackup during lamination.

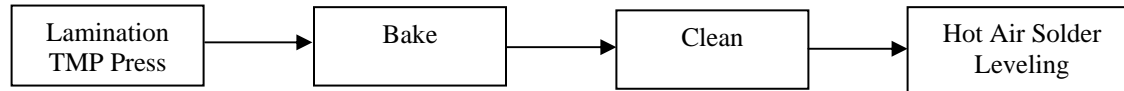
## **Sample**

A twelve-by-twelve inch, two ounce copper, double-sided laminate sample was generated, which contained two circuit patterns. The coverlay laminated to both sides of the laminate samples was two mil polyimide/two mil pyralux adhesive.

## Experiment

A full factorial DoE was developed to determine if variations in lamination press pad stackup, bake or cleaning resulted in large voids/delamination after HASL. Since the objective was to recreate large voids if possible extreme values of each variable was used.

The diagram below illustrates the process flow from lamination through HASL and the DoE variables/factors. Four panels/eight parts were processed for each variable factor combination resulting in a total of thirty-two panels/sixty-four parts.



Hard press pad stackup	Bake	Clean
	No bake	No clean
Soft press pad stackup	Bake	Clean
	No Bake	No clean

After lamination each panel's nine .093 holes were measured for diameter and location by a department's CMM. The results were recorded and are displayed in Appendix A.

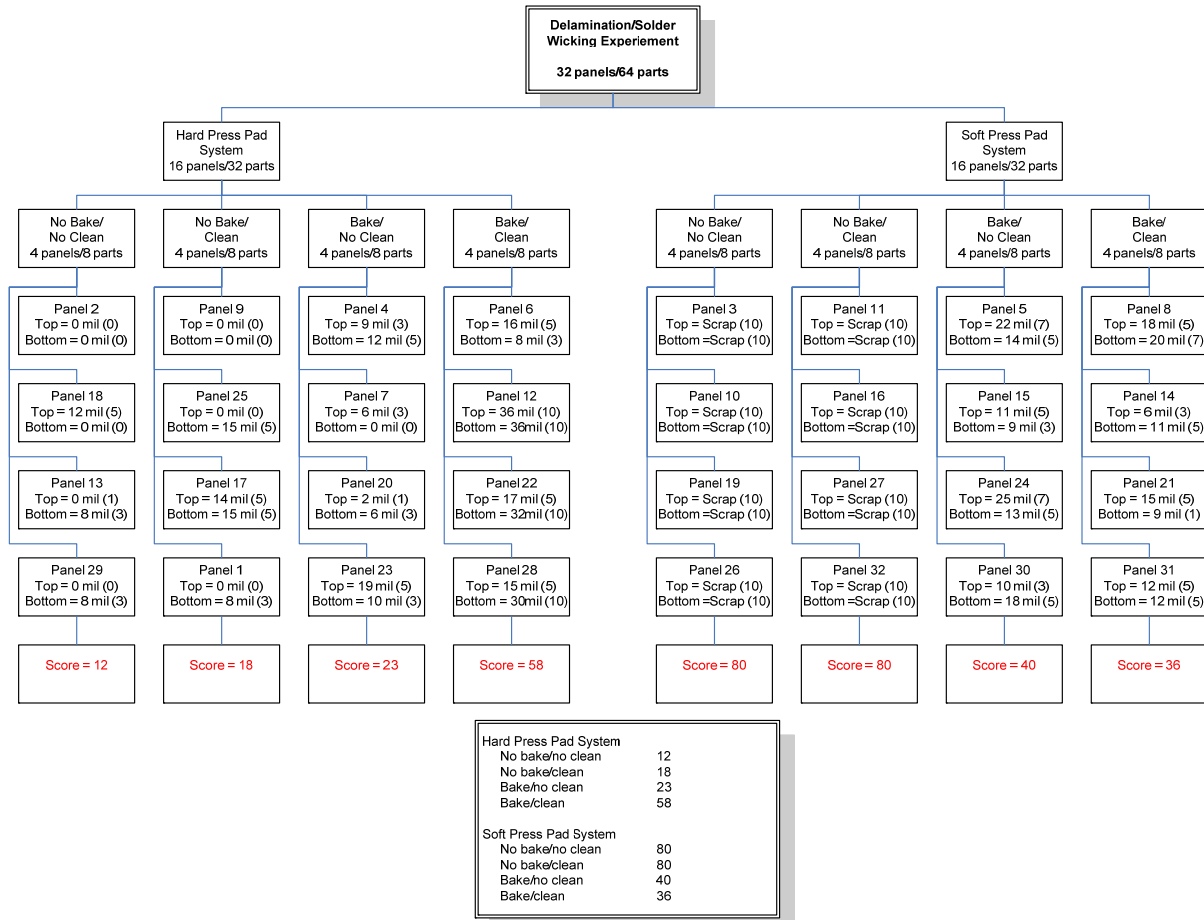
## Analysis of Discoloration/Solder Wicking Information

The HASL process is considered a test of adhesion quality between the coverlay and laminate panel. Therefore, large areas of delamination could be a lack of adhesion/contamination or insufficient adhesion. These areas of delamination have in the past been identified as discoloration, delamination or solder wicking. To score this experiment's panels objectively and consistently these three characteristics were considered equal. The magnitude of these characteristics was used to determine a numerical score for each part.

Each cable on each panel was inspected and the magnitude of discoloration/solder wicking was measured. If there was more than one area of discoloration/solder wicking, the magnitude of each area was added together to provide a total cable discoloration/solder wicking value. Then each total cable value was assigned a ranking as listed below.

Ranking value	Amount of discoloration/solder wicking
1 =	1 to 10mils (.001 to .010)
3 =	10 to 20 mils (.010 to .020)
7 =	20 to 30 mils (.020 to .030)
10 =	Over 30 mils (.030)

Cable rankings were summed to produce an overall variable ranking as shown in the following illustration.



**Figure 3. Variable Ranking**

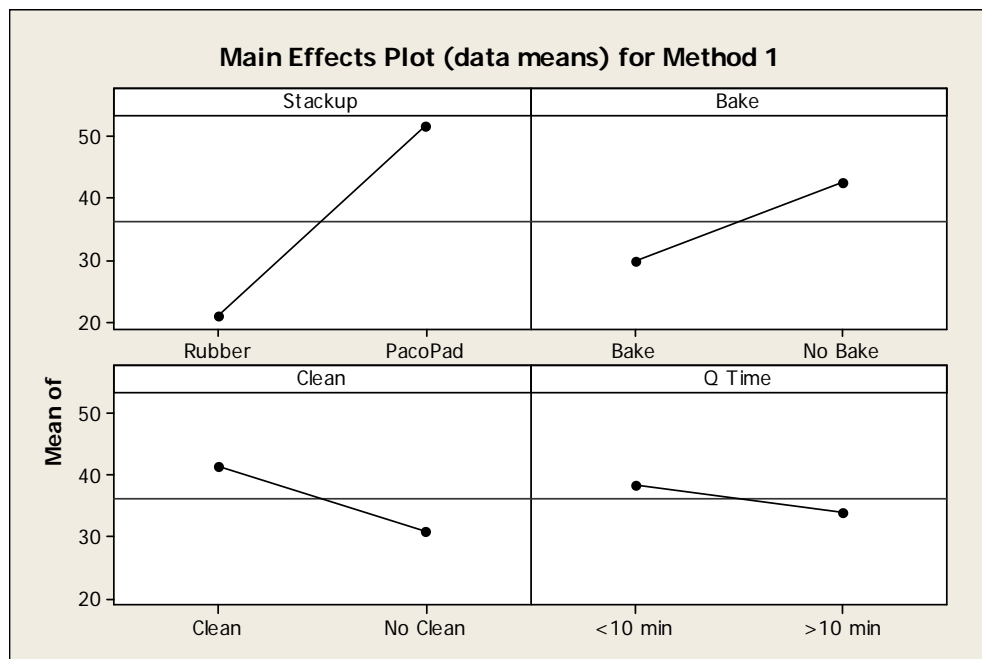
The hard press pad stackup sample panels not baked or cleaned before HASL had the least amount of discoloration/solder wicking. The soft press pad stackup sample panels had significant solder wicking on the panels not baked and cleaned/not cleaned.

The amount of delamination/solder wicking was measured in mils and the statistical analysis is shown below. Any P value less than .1 is statistically significant.

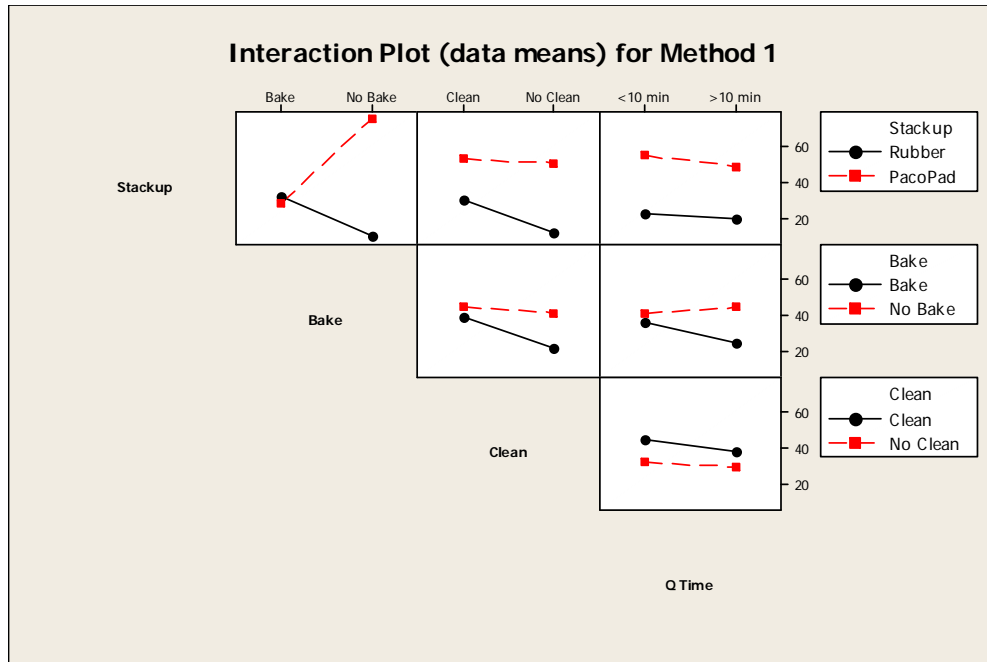
Source	DF	Seq SS	Adj SS	Adj MS	F	P
Blocks	1	108.8	108.8	108.8	1.13	0.300
Stackup	1	7533.8	7533.8	7533.8	78.25	0.000
Bake	1	1262.5	1262.5	1262.5	13.11	0.002
Clean	1	871.5	871.5	871.5	9.05	0.007
Stackup*Bake	1	9418.8	9418.8	9418.8	97.83	0.000
Stackup*Clean	1	552.8	552.8	552.8	5.74	0.026
Bake*Clean	1	442.5	442.5	442.5	4.60	0.045
Error	20	1925.6	1925.6	96.3		
Total	31	22801.5				

S = 9.81230    R-Sq = 91.55%    R-Sq(adj) = 86.91%

Although several factors were significant the lamination stackup and pre-HASL bake had the greatest effect. The main effect and interaction plots are shown in Figures 4 and 5.



**Figure 4. Main Effects Plot for Method 1**



**Figure 5. Interaction Plot for Method 1**

The main effects plot shows lamination stackup is most significant with pre-HASL bake and clean, as the data indicates at about the same level (13.11 vs 9.05). The only interaction is between the lamination stackup and pre-HASL bake as illustrated in Figure 5.

### Analysis of Hole Location and Diameter Information

The average deviation from drilled hole diameter was -.00057 inches. The statistical data shows none of the parameters had a significant impact on hole diameter. To be significant the P value would have to be less than .1. The data is displayed by panel as a radar chart in Figure 6 and the interaction and main effects plots in Figures 7 and 8. Although the main effects plots show bake and clean affect hole diameter, the amount of deviation is well within what is expected from a non-plated through hole in Kapton as displayed in Figure 9.

Analysis of Variance for Dia, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Blocks	1	0.0000000	0.0000000	0.0000000	0.95	0.343
Stackup	1	0.0000000	0.0000000	0.0000000	0.00	0.960
Bake	1	0.0000000	0.0000000	0.0000000	0.32	0.575
Clean	1	0.0000000	0.0000000	0.0000000	0.47	0.500
Stackup*Bake	1	0.0000001	0.0000001	0.0000001	1.42	0.248
Stackup*Cln	1	0.0000000	0.0000000	0.0000000	0.09	0.766
Bake*Cln	1	0.0000001	0.0000001	0.0000001	1.75	0.200
Error	20	0.0000009	0.0000009	0.0000000		
Total	31	0.0000013				

S = 0.000210906 R-Sq = 32.22% R-Sq(adj) = 0.00%



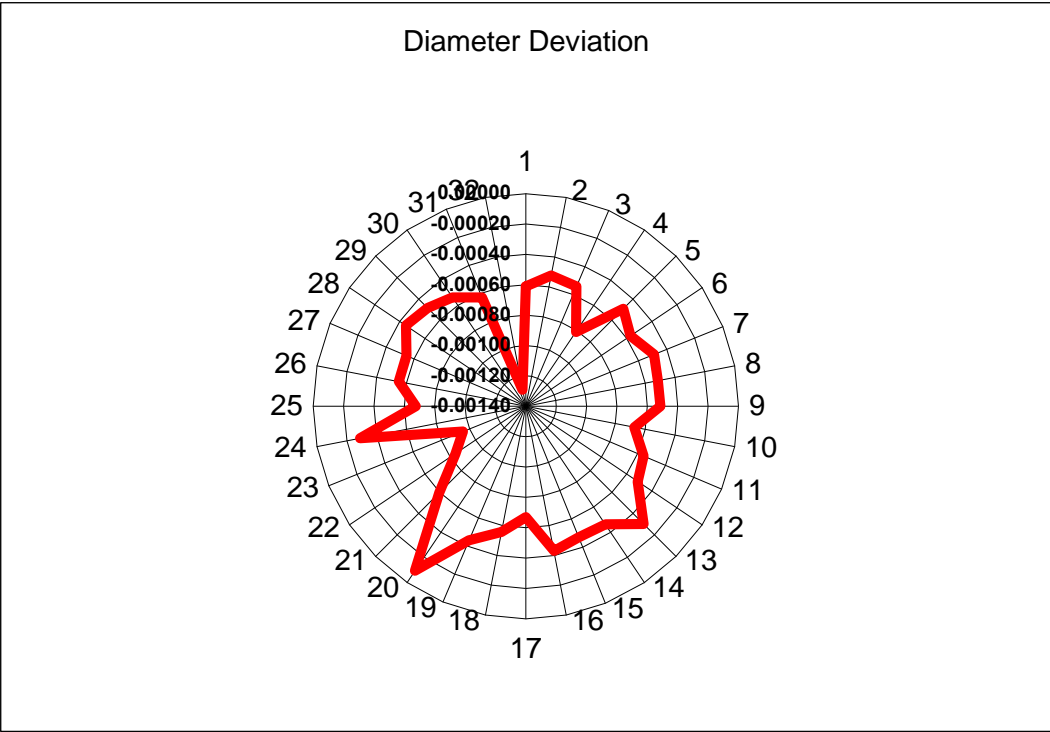


Figure 6. Diameter Deviation

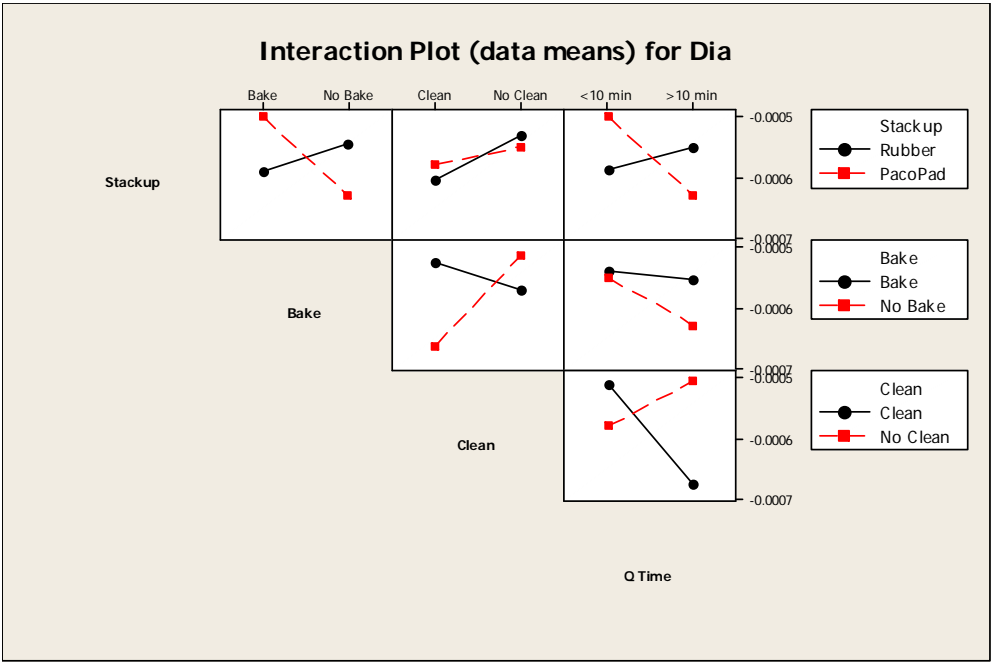
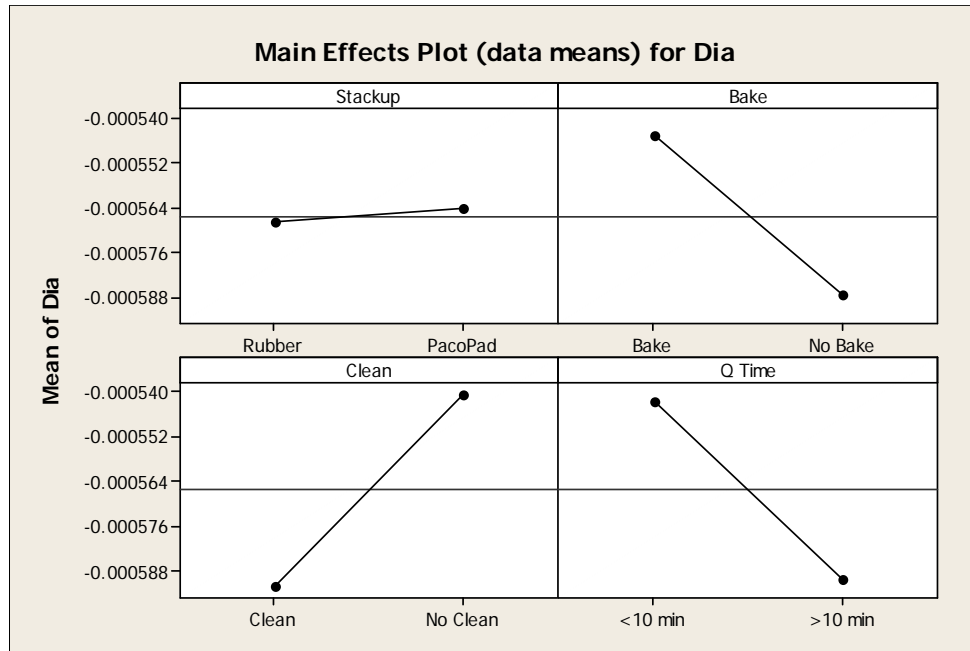
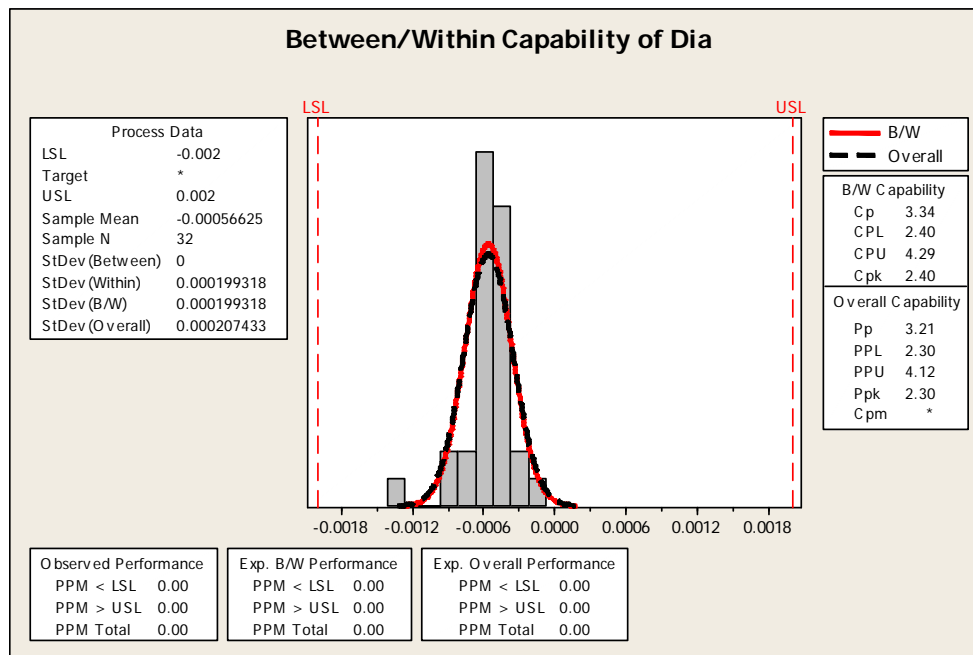


Figure 7. Interaction Plot for Diameter



**Figure 8. Main Effects Plot for Diameter**



**Figure 9. Between/Within Capability of Diameter**

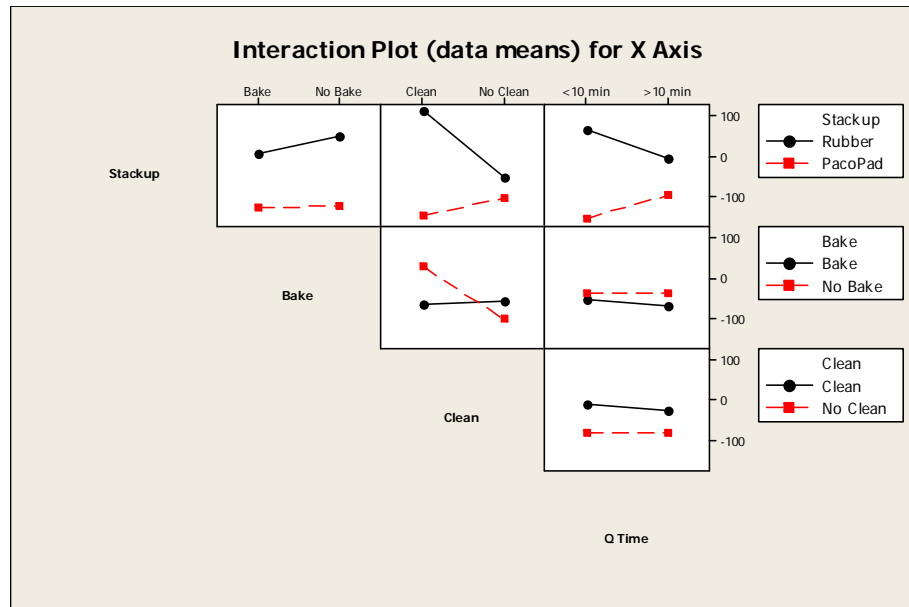
### Panel Movement in the X Axis

The panels were next measured for stretch in the X axis using the CMM. Again P values less than .1 are statistically significant. In this case the lamination stackup and lamination stackup / clean interaction are both significant. However, the mean stretch in the X axis was only -50.44 ppm and not significant for either press pad stackup.

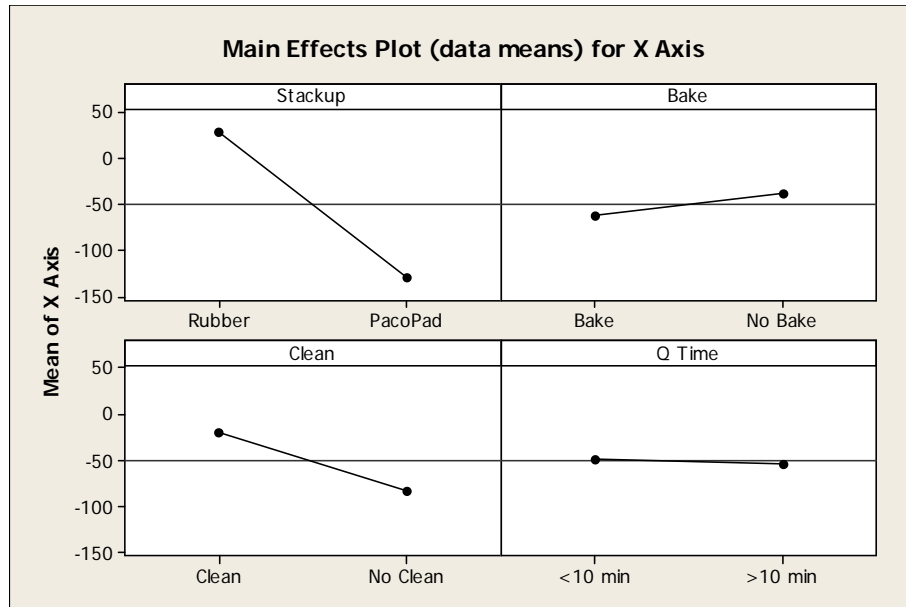
# Analysis of Variance for X Axis, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Blocks	1	108408	108408	108408	5.89	0.025
Stackup	1	195947	195947	195947	10.64	<b>0.004</b>
Bake	1	4687	4687	4687	0.25	0.619
Clean	1	32037	32037	32037	1.74	0.202
Stackup*Bake	1	3069	3069	3069	0.17	0.687
Stackup*Clean	1	88274	88274	88274	4.79	<b>0.041</b>
Bake*Clean	1	37090	37090	37090	2.01	0.171
Error	20	368419	368419	18421		
Total	31	873203				

S = 135.724    R-Sq = 57.81%    R-Sq(adj) = 34.60%



**Figure 10. Interaction Plot for X Axis**



**Figure 11. Main Effects Plot for X Axis**

### Panel Movement in the Y Axis

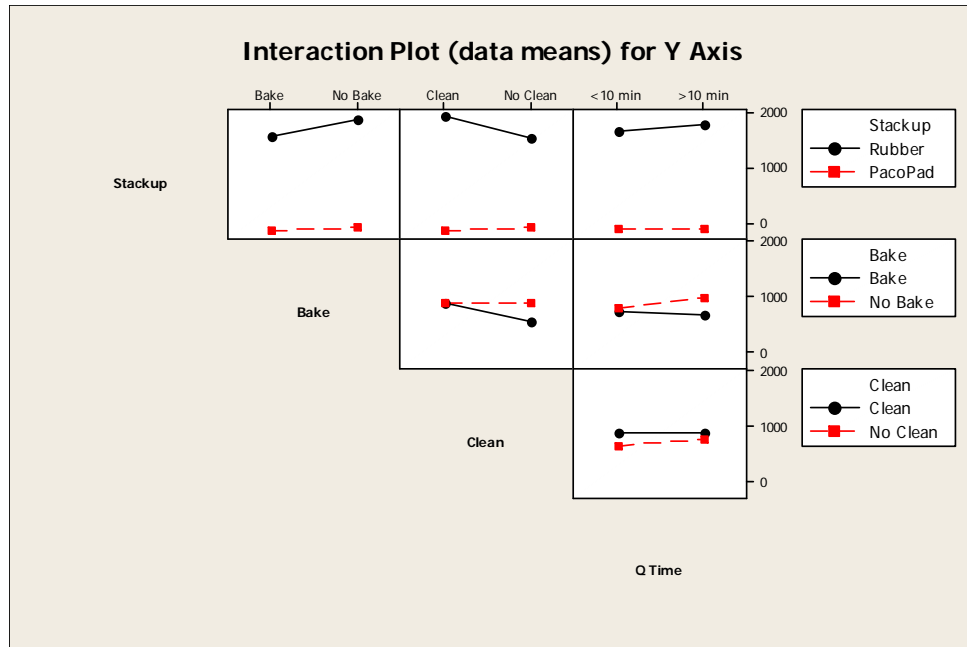
The panels were next measured for stretch in the Y axis using the CMM. Again P values less than .1 are statistically significant.

Analysis of Variance for Y Axis, using Adjusted SS for Tests

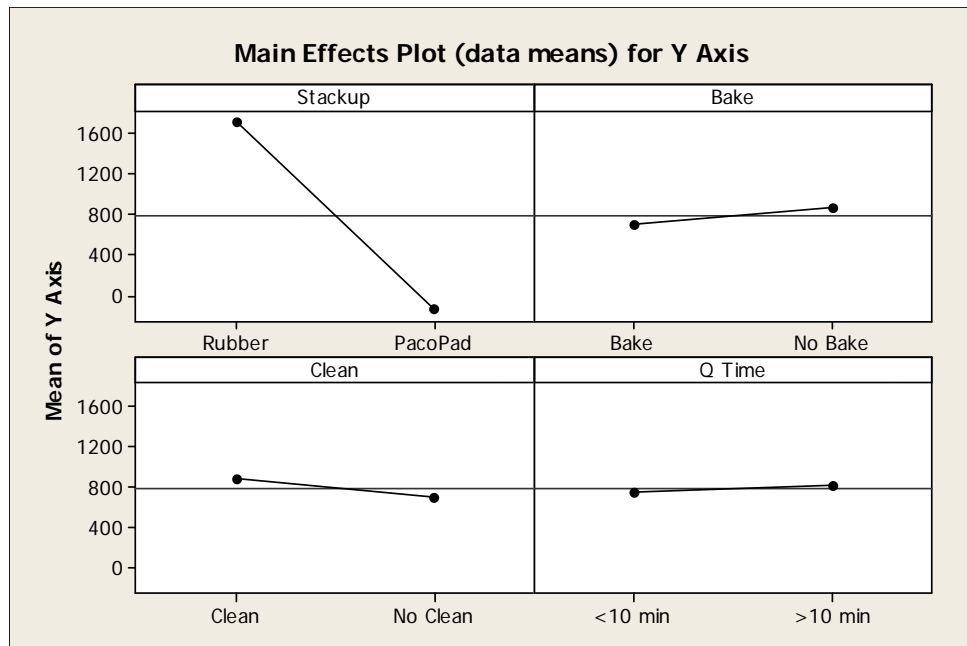
Source	DF	Seq SS	Adj SS	Adj MS	F	P
Blocks	1	443991	443991	443991	4.29	0.052
Stackup	1	27366663	27366663	27366663	264.16	<b>0.000</b>
Bake	1	236027	236027	236027	2.28	0.147
Clean	1	259317	259317	259317	2.50	0.129
Stackup*Bake	1	112776	112776	112776	1.09	0.309
Stackup*Clean	1	427140	427140	427140	4.12	<b>0.056</b>
Bake*Clean	1	229525	229525	229525	2.22	0.152
Error	20	2071965	2071965	103598		
Total	31	31343918				

S = 321.867    R-Sq = 93.39%    R-Sq(adj) = 89.75%

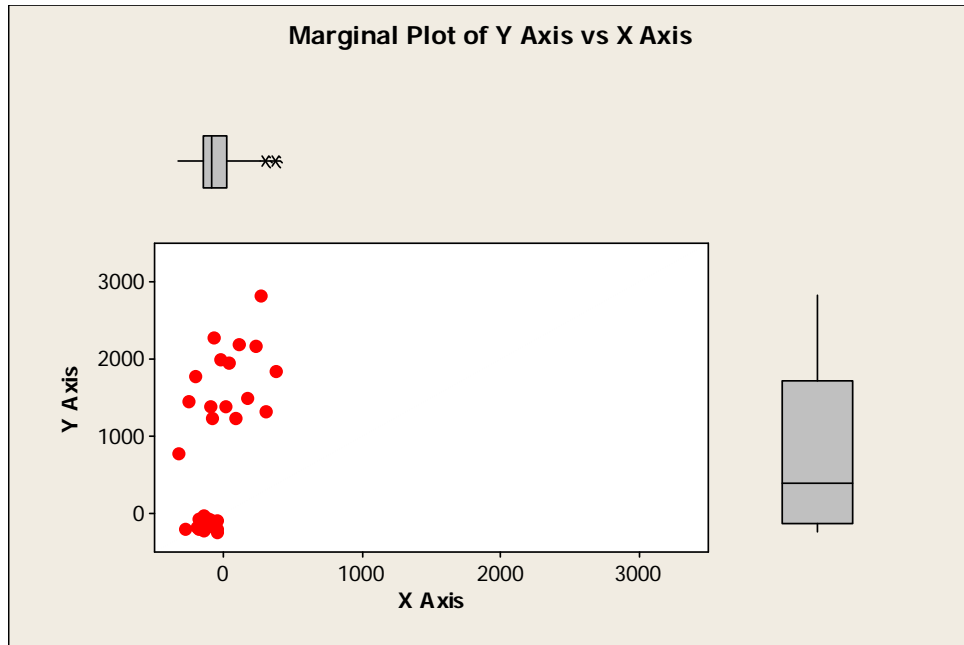
As with the X axis the lamination stackup and lamination stackup/clean interaction are statistically significant. The total average stretch in the Y axis was 787.43 ppm. The main effects plots in Figure 13 show the large differences in stretch between the soft press pad stackup vs. the hard press pad stackup. The relationship between the stretch in X and Y is shown in Figure 14. The two populations represent the two press pad stackups. The average stretch for the hard press pad stackup was X=27.81 and Y=1712.20 and the soft press pad stackup X=-128.7 and Y=-137.35



**Figure 12. Interaction Plot for Y Axis**



**Figure 13. Main Effects Plot for Y Axis**



**Figure 14. Marginal Plot of Y Axis vs. X Axis**

### **Validation of Phase One Data and Analysis**

Prior to incorporation of process changes suggested by Phase One, the conclusions were validated by performing the experiment a second time with half the number of panels. Two panels/four parts were processed for each variable factor combination resulting in a total of sixteen panels/thirty-two parts.



**Figure 15. Variable Ranking of Validation Data**

The validation data repeated the results from the initial experiment. The hard press pad stackup sample panels not baked or cleaned before HASL had the least amount of discoloration/solder wicking. The difference between baked and not baked was more pronounced on these hard press pad stackup sample panels. The soft press pad stackup sample panels had significant solder wicking on the panels not baked and cleaned/not cleaned.

### Original DoE Results

32 panels/64 cables

Hard Press Pad System	Score
No bake/no clean	12
No bake/clean	18
Bake/no clean	23
Bake/clean	58
Soft Press Pad System	
No bake/no clean	80
No bake/clean	80
Bake/no clean	40
Bake/clean	36

### Validation DoE Results

16 panels/32 cables

Hard Press Pad System	Score
No bake/no clean	4
No bake/clean	2
Bake/no clean	20
Bake/clean	32
Soft Press Pad System	
No bake/no clean	40
No bake/clean	40
Bake/no clean	22
Bake/clean	12

Hard Press Pad System	
No bake/no clean	16
No bake/clean	20
Bake/no clean	43
Bake/clean	90
Soft Press Pad System	
No bake/no clean	120
No bake/clean	120
Bake/no clean	62
Bake/clean	48

### Combined DoE Results

48 panels/96 cables

Figure 16. Original, Validation and Combined Variable Ranking

## Conclusions

Performing the DoE utilizing the most likely variables did not recreate the large voids, but did illustrate other possible processing modifications of interest.

The hard press pad stackup obtained the best results or the least amount of discoloration/solder wicking with variable factors of “no bake/no clean.” This also was the combination of variable factors exhibiting the best adhesion of all variables for both press pad stackups. None of the “bake/clean” results were as good. Thirteen of the twenty-four cables had no observable characteristics for a 54% yield.

The soft press pad stackup obtained the best results with variable factors “bake/clean” and “bake/no clean.” Variable factor “bake/clean” performed slightly better than variable factor “bake/no clean.” All twenty-four cables not baked, cleaned or not cleaned, had significant amounts of solder wicking under the coverlay. This combination of variables implied inadequate adhesion.



The baking and cleaning parameters had no significant effect on hole diameter. Any stretch in the X direction was insignificant for all combinations. Stretch in the Y direction using the hard press pad stackup was significantly more than the soft press pad stackup. The average X and Y stretch by press pad stackup is shown below.

	Average X Stretch (ppm)	Average Y Stretch (ppm)
Hard Press Pad Stackup	27.81	1712.20
Soft Press Pad Stackup	-128.70	-137.35

## **Phase Two**

This DoE's objective was to determine if a lower lamination pressure would reduce panel stretch without adversely affecting coverlay/laminate adhesion when using the hard press pad stackup.

## **Sample**

A twelve-by-twelve inch, two ounce copper, double-sided laminate sample was generated which contained the circuit patterns of five cables. The coverlay laminated to both sides of the laminate samples was two mil polyimide/two mil pyralux adhesive. Nine holes with a diameter of .060 inch were strategically located on the sample panel for CMM hole location measurements.

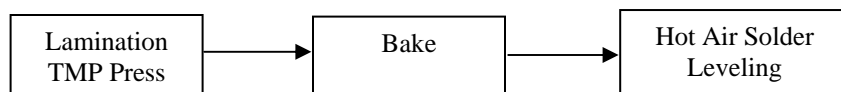
## **Experiment**

A full factorial experiment with one independent variable, pressure, was developed. Three pressure values were selected with the 190 ton factor the standard for presently built flex cables.

Variable	Level	Level	Level
Pressure	190 ton	140 ton	90 ton

Three sample panels were processed at each lamination pressure. All were laminated in the Technical Machine Products (TMP) lamination press over a period of three days. Each lamination cycle's actual temperature, pressure, and soak time were recorded at one minute intervals. After lamination each panel's nine holes were measured for location by a Department's CMM and recorded.

It has been acknowledged that the HASL process is an acceptable test of laminated adhesion quality. To determine the acceptability of adhesion of each group of sample panels they were processed through the normal HASL process after lamination.



There have been some indications suggesting discoloration around lands is a precursor to delamination. Therefore, measuring the depth of solder wicking/discoloration on each land of all

five cables per panel was determined to be an acceptable method of quantifying adhesion quality. The greater the solder wicking/discoloration the more likely there is inadequate adhesion. The total number of lands per panel was fifty-nine.

### Hole Location Analysis

The chart below illustrates Parts Per Million (PPM) stretch of sample panels in both the x and y axis. Sample panels 1, 2, and 3 were laminated at 190 tons, sample panels 4, 5, and 6 were laminated at 140 tons and sample panels 7, 8, and 9 were laminated at 90 tons. The nine .060 inch hole location measurements were used to generate the chart.

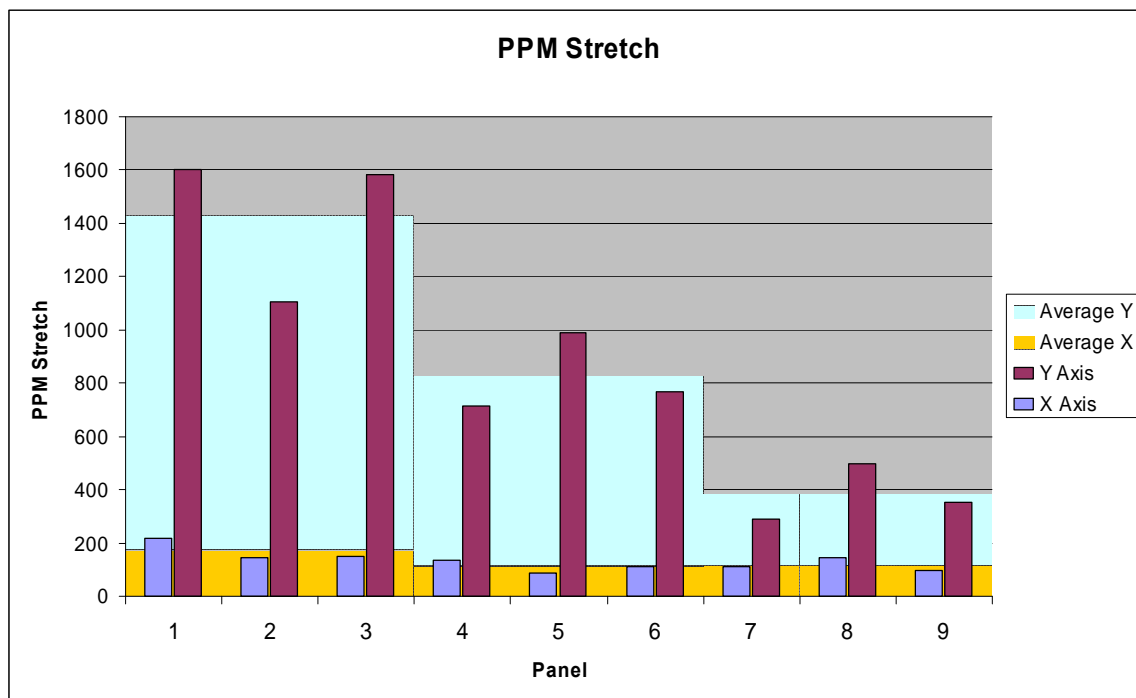


Figure 17. Parts Per Million Stretch of Sample Panels

## Adhesion Quality Analysis

Each part was given a ranking using a scoring technique similar to the method used on Phase 1 panels. The illustration below summarizes each part per panel ranking and each panels ranking as a sum of each parts ranking. The panel rankings are then summed to provide an overall lamination pressure score.

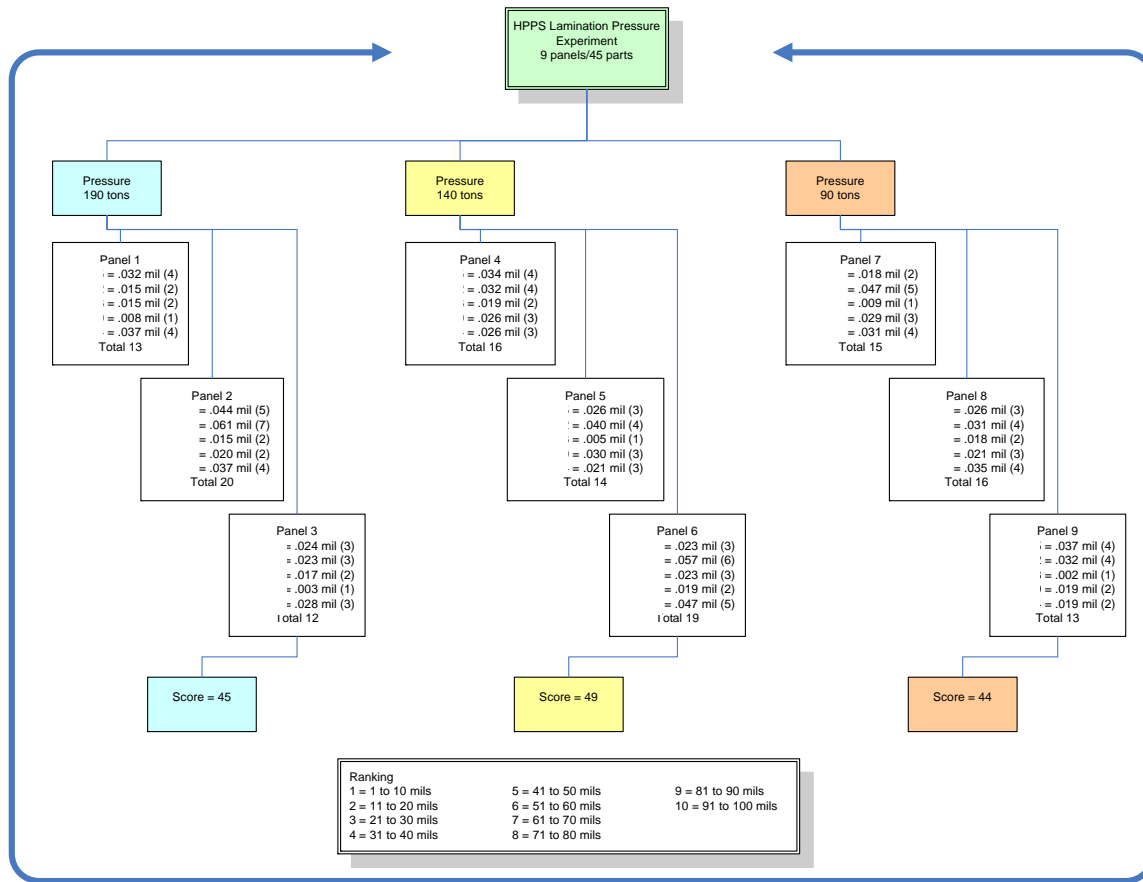


Figure 18. Panel Ranking

## Conclusions

A reduction in lamination pressure from 190 tons to 90 tons reduced panel stretch in the y direction by approximately 70%. Panel stretch was small in the x direction and was only slightly affected by a pressure change. The reduction in panel stretch could reduce or eliminate further out of tolerance occurrences on the hole location requirements for flat flex cables.

The adhesion quality results do not illustrate any lack of adhesion when using a lower lamination pressure. The differences in ranking scores are statistically insignificant. Based on these results, reducing the lamination pressure from 190 tons to 90 tons should not affect the quality of adhesion between coverlay and copper laminate.

### **Phase Three**

This DoE's objective was to determine if variations in lamination and pre-HASL process variables affected delamination/solder wicking around circuit lands when using the soft press pad lamination stackup.

#### **Sample (Two Ounce Copper Laminate)**

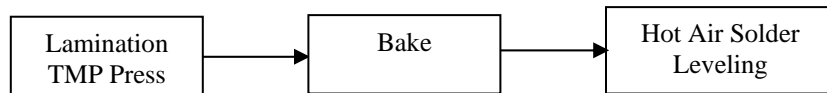
A twelve-by-twelve inch, two ounce copper, double-sided laminate sample was generated which contained the circuit patterns of five cables. The coverlay laminated to both sides of the laminate samples was two mil polyimide/two mil pyralux adhesive. Nine holes with a diameter of .060 inch were strategically located on the sample panel for CMM hole location measurements.

#### **Experiment**

A fractional factorial experiment with six independent variables was developed. Two factors were selected for each variable as shown in the table below.

Variable	Level	Level
Pressure	300 psi	350 psi
Time	60 min	80 min
Temperature	365 F	385 F
Bake	275F	350F
Bake Time	1	8
Coverlay Adhesive	2 mil	4 mil

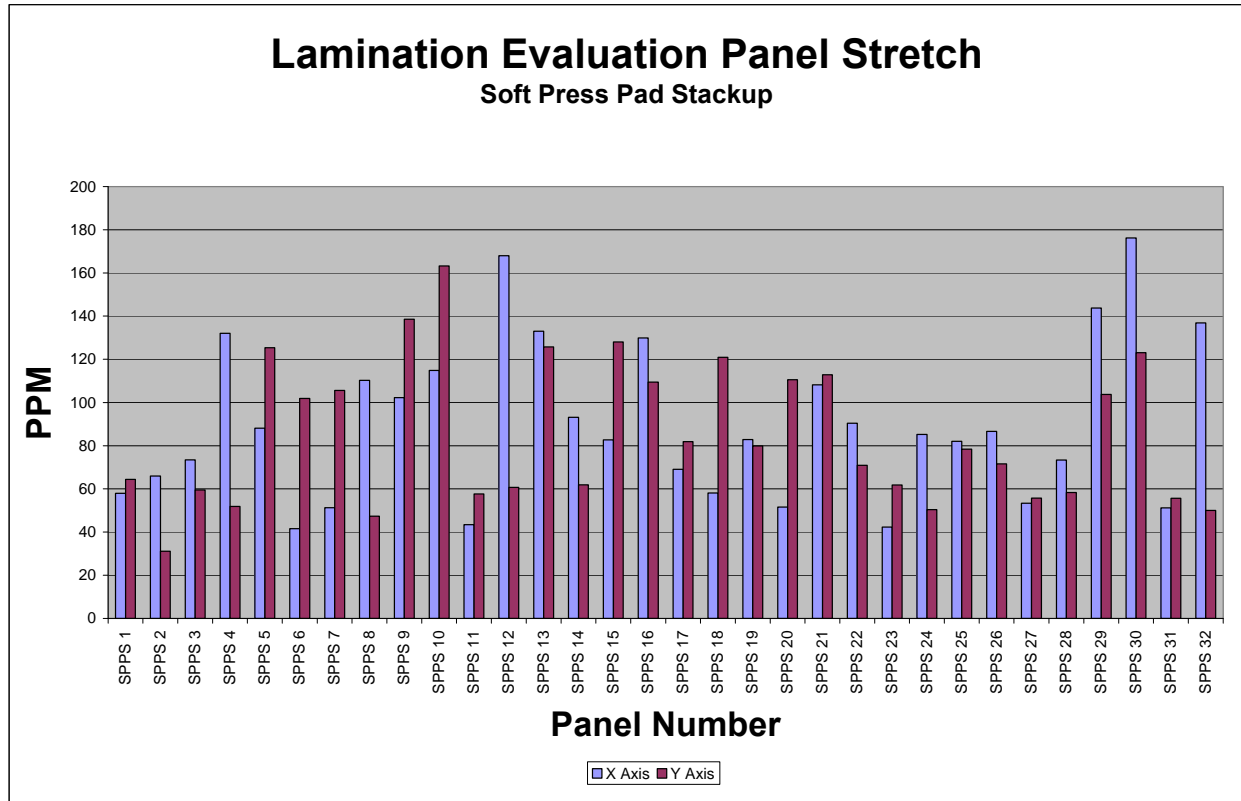
Two sample panels were processed for each variable and factor combination resulting in thirty-two panels total. All were laminated in the TMP lamination press over a period of five days. Each lamination cycle's actual temperature, pressure, and soak time were recorded at one minute intervals. After lamination each panel's nine holes were measured for location by a Department's CMM and recorded. Below is a process map of lamination through HASL.



Measuring the delamination/solder wicking depth on each land of all five cables per panel was determined to be an acceptable method of quantifying adhesion quality. The greater the delamination/solder wicking the more likely there is inadequate adhesion. The total number of lands per panel was fifty-nine.

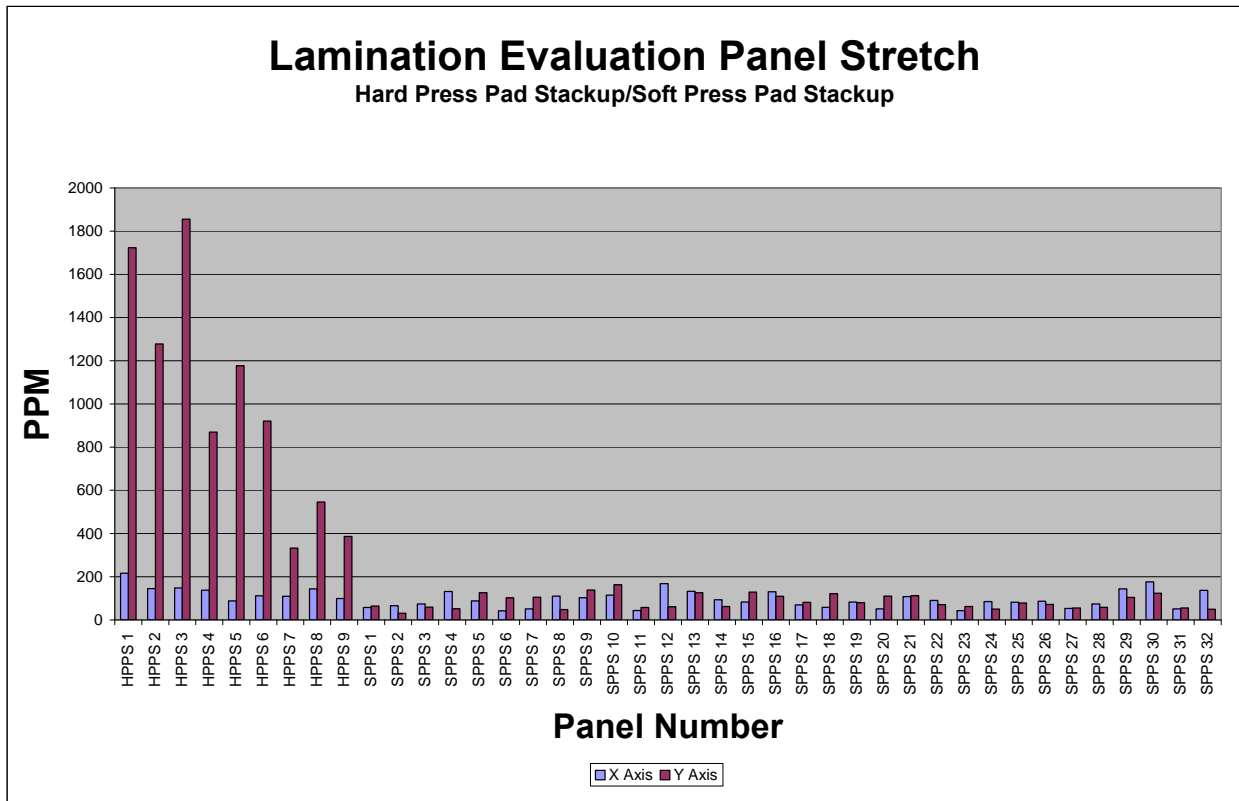
## Hole Location Analysis

The chart below illustrates parts per million stretch of sample panels in both the x and y axis. The .093 inch hole location measurements were used to generate the chart.



**Figure 19. Lamination Evaluation Panel Stretch (Soft Press Pad Stackup)**

Below is a chart comparing panel stretch between Phase Two hard press pad stackup sample panels and Phase Three soft press pad stackup sample panels. The chart illustrates an approximate factor of ten times more panel stretch between the 190 ton pressure used on hard press pad lamination stackup and the same pressure used on the soft press pad lamination stackup. When the hard press pad lamination stackup pressure is reduced to 90 tons, the panel stretch difference between the two press pad stackups is a factor of 2 with the hard press pad stackup having the most panel stretch.



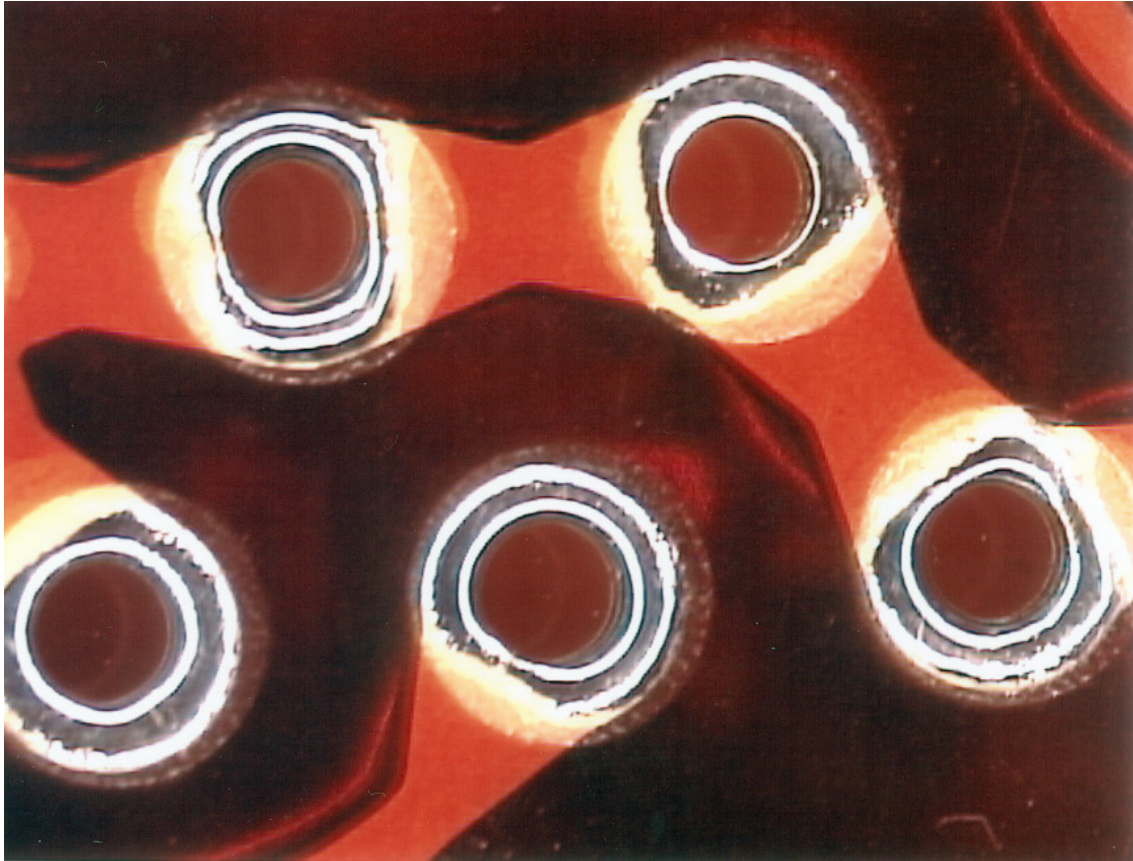
**Figure 20. Lamination Evaluation Panel Stretch (Hard Press Pad Stackup/Soft Press Pad Stackup)**

## Adhesion Quality Analysis

The table below summarizes each panels ranking as a sum of each parts ranking. The fill color highlights each pre-HASL bake temperature and time. When comparing solder wicking rank of each colored group highlighted, it is evident a higher pre-HASL bake could eliminate delamination/solder wicking when using a soft press pad stackup. The table below also illustrates how a higher bake temperature will cause a semi dark to very dark ‘halo’ under the coverlay around each circuit land as illustrated in Figures 23 and 24. See Appendix C for individual panel rankings (magnitude of discoloration/solder wicking).

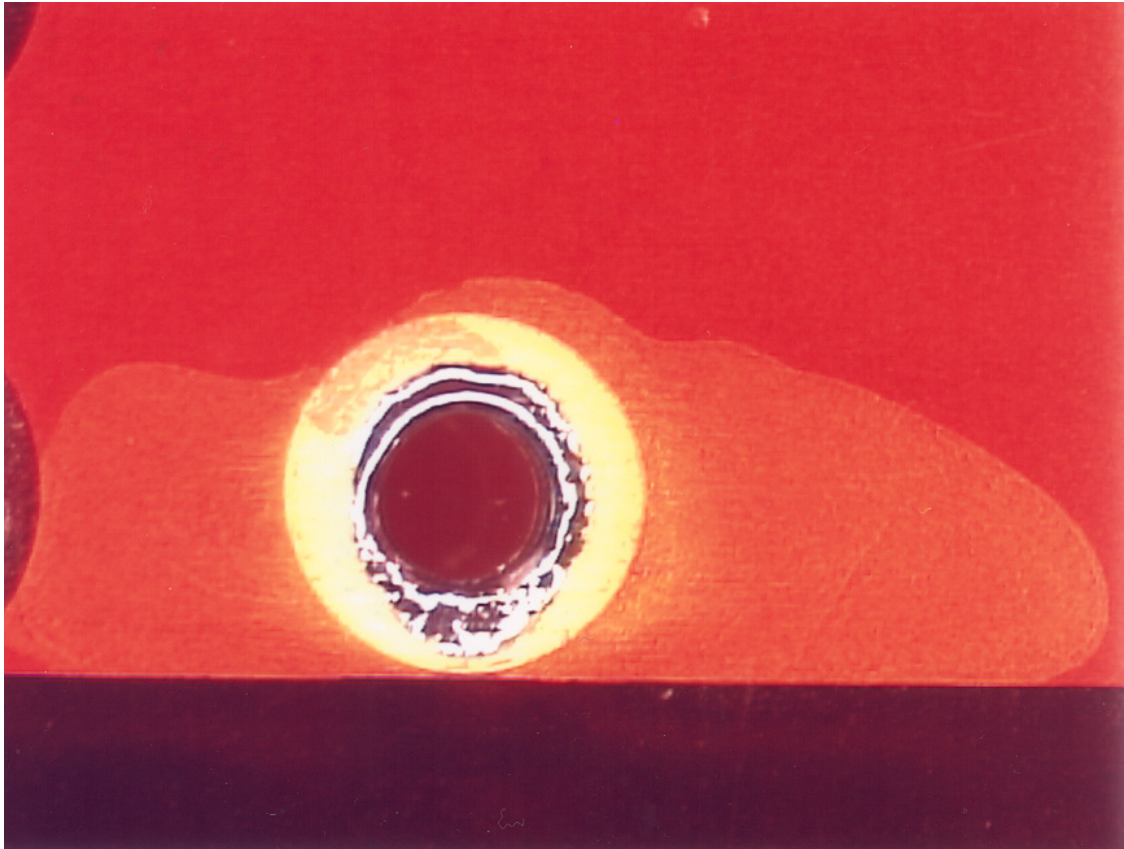
Panel Number	Extra 2mil Adhesive, Both Sides	Bake Temperature	Bake Time	Lamination			Solder Wicking Rank	Dark Halo/Annular Ring/Delamination
				Pressure	Temperature	Time		
3	Yes	275	1	300	385	60	28	/ULL/
12	Yes	275	1	300	385	80	36	/ULL/
19	Yes	275	1	300	385	60	20	/ULL/
28	No	275	1	300	365	80	40	
2	No	275	1	350	385	80	28	
15	No	275	1	350	365	60	45	
18	Yes	275	1	350	385	80	31	/ULL/
31	Yes	275	1	350	365	60	43	/ULL/
9	No	275	8	300	365	60	3	
13	No	275	8	300	385	80	1	
25	Yes	275	8	300	365	60	3	/ULL/
29	No	275	8	300	385	80	3	
4	No	275	8	350	385	60	2	
7	Yes	275	8	350	365	80	1	/ULL/
20	Yes	275	8	350	385	60	2	/ULL/
23	Yes	275	8	350	365	80	4	/ULL/
1	Yes	350	1	300	385	80	0	.005 light/ULL/
10	No	350	1	300	365	60	0	.005 light//
17	Yes	350	1	300	385	80	0	.005 light/ULL/
26	Yes	350	1	300	365	60	0	.005 light/ULL/
6	No	350	1	350	385	60	0	.005 light//
8	No	350	1	350	365	80	0	.005 light//
22	Yes	350	1	350	385	60	0	.005 light/ULL/
24	No	350	1	350	365	80	0	.005 light//
5	No	350	8	300	365	80	0	0.010 dark//
16	No	350	8	300	385	60	0	0.010 dark//
21	Yes	350	8	300	365	80	0	0.010 dark/ULL/Light spots
32	No	350	8	300	385	60	0	0.010 dark//Light spots
11	Yes	350	8	350	385	80	0	0.010 dark/ULL/Light spots
14	Yes	350	8	350	365	60	0	0.010 dark/ULL/Light spots
27	No	350	8	350	385	80	0	0.010 dark//Light spots
30	No	350	8	350	365	60	0	0.010 dark//Light spots

**Table 1. Panel Ranking**

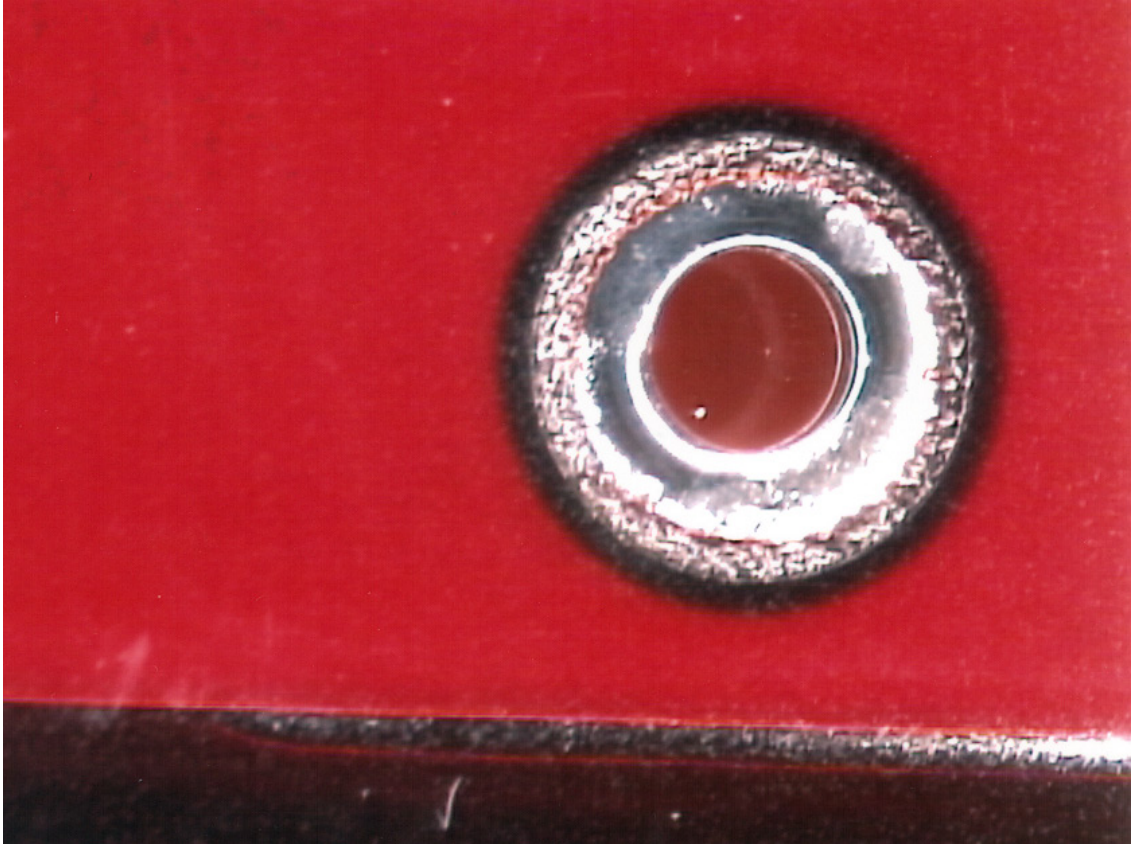


**Figure 21. Annular Rings**

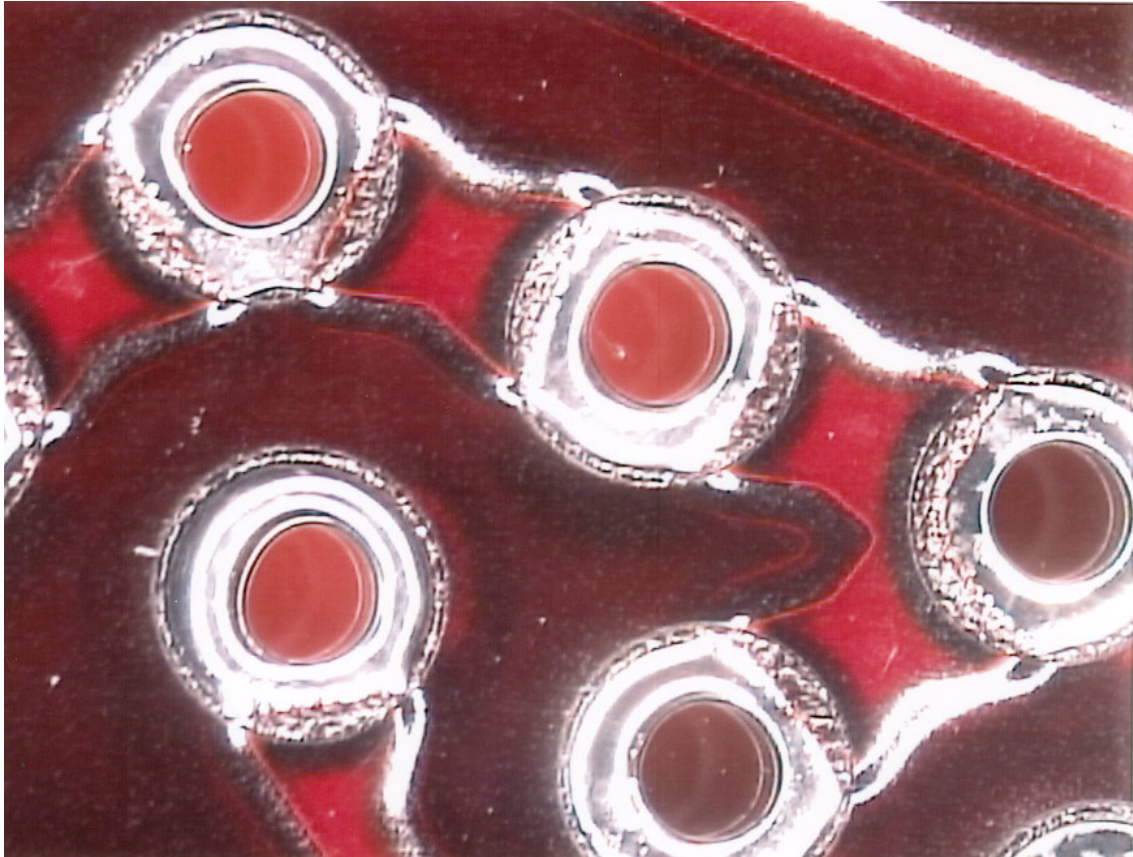




**Figure 22. Annular Ring**



**Figure 23. Annular Ring with Dark Halo**



**Figure 24. Annular Rings with Dark Halos**

## Statistical Analysis of Soft Press Pad Data

The data from the fractional factorial design was analyzed using Minitab for X and Y axis stretch, delamination/solder wicking and the dark 'halo' around the annular ring. The results are listed below.

### *Fractional Factorial Design*

Factors: 5 Base Design: 5, 16 Resolution: V  
Runs: 33 Replicates: 2 Fraction: 1/2  
Blocks: 1 Center pts (total): 1

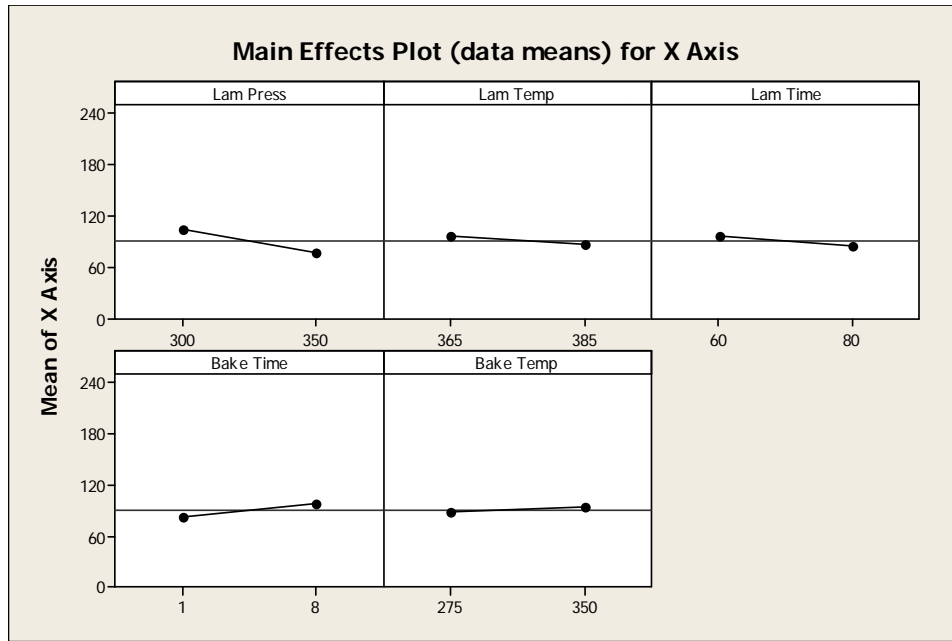
### *Factorial Fit: X Axis Stretch*

Any P value less than .100 is significant. In this case although several factors appear statistically significant, as with previous experiments, the distribution is so far below that required for processing no variables are practically significant.

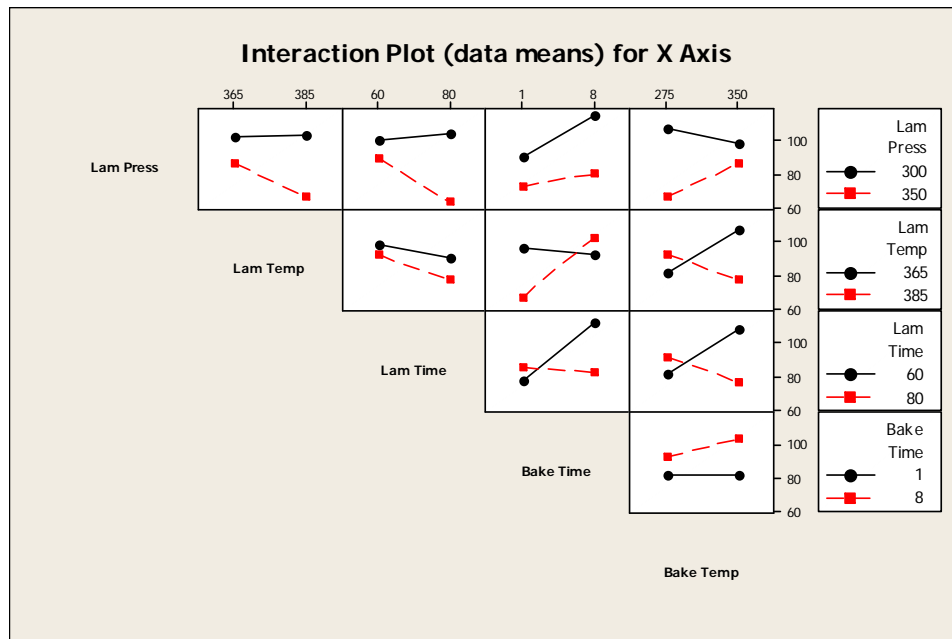
Estimated Effects and Coefficients for X Axis (coded units)

Term	Effect	Coef	SE Coef	T	P
Constant		89.97	5.286	17.02	0.000
Lam Press	-26.37	-13.18	5.286	-2.49	0.024
Lam Temp	-9.53	-4.76	5.286	-0.90	0.381
Lam Time	-11.01	-5.50	5.286	-1.04	0.313
Bake Time	16.00	8.00	5.286	1.51	0.150
Bake Temp	5.69	2.85	5.286	0.54	0.598
Lam Press*Lam Temp	-9.96	-4.98	5.286	-0.94	0.360
Lam Press*Lam Time	-15.11	-7.56	5.286	-1.43	0.172
Lam Press*Bake Time	-8.77	-4.38	5.286	-0.83	0.419
Lam Press*Bake Temp	14.10	7.05	5.286	1.33	0.201
Lam Temp*Lam Time	-3.24	-1.62	5.286	-0.31	0.763
Lam Temp*Bake Time	19.58	9.79	5.286	1.85	0.082
Lam Temp*Bake Temp	-20.49	-10.25	5.286	-1.94	0.070
Lam Time*Bake Time	-19.07	-9.54	5.286	-1.80	0.090
Lam Time*Bake Temp	-20.71	-10.36	5.286	-1.96	0.068
Bake Time*Bake Temp	5.65	2.83	5.286	0.53	0.600

S = 29.9019 R-Sq = 65.78% R-Sq(adj) = 33.70%



**Figure 25. Main Effects Plot for X Axis**



**Figure 26. Interaction Plot for X Axis**

### Factorial Fit: Y Axis Stretch

No variables were statistically or practically significant for Y axis stretch.

Estimated Effects and Coefficients for Y Axis (coded units)

Term	Effect	Coef	SE Coef	T	P
Constant		84.334	6.879	12.26	0.000
Lam Press	-8.089	-4.045	6.879	-0.59	0.565
Lam Temp	-7.316	-3.658	6.879	-0.53	0.602
Lam Time	-10.871	-5.435	6.879	-0.79	0.441
Bake Time	12.415	6.207	6.879	0.90	0.380
Bake Temp	-0.834	-0.417	6.879	-0.06	0.952
Lam Press*Lam Temp	7.842	3.921	6.879	0.57	0.577
Lam Press*Lam Time	-12.031	-6.015	6.879	-0.87	0.395
Lam Press*Bake Time	-10.170	-5.085	6.879	-0.74	0.470
Lam Press*Bake Temp	-11.745	-5.873	6.879	-0.85	0.406
Lam Temp*Lam Time	14.839	7.420	6.879	1.08	0.297
Lam Temp*Bake Time	-11.765	-5.882	6.879	-0.86	0.405
Lam Temp*Bake Temp	-3.043	-1.522	6.879	-0.22	0.828
Lam Time*Bake Time	14.708	7.354	6.879	1.07	0.301
Lam Time*Bake Temp	-8.148	-4.074	6.879	-0.59	0.562
Bake Time*Bake Temp	1.338	0.669	6.879	0.10	0.924

S = 38.9115    R-Sq = 33.01%    R-Sq(adj) = 0.00%

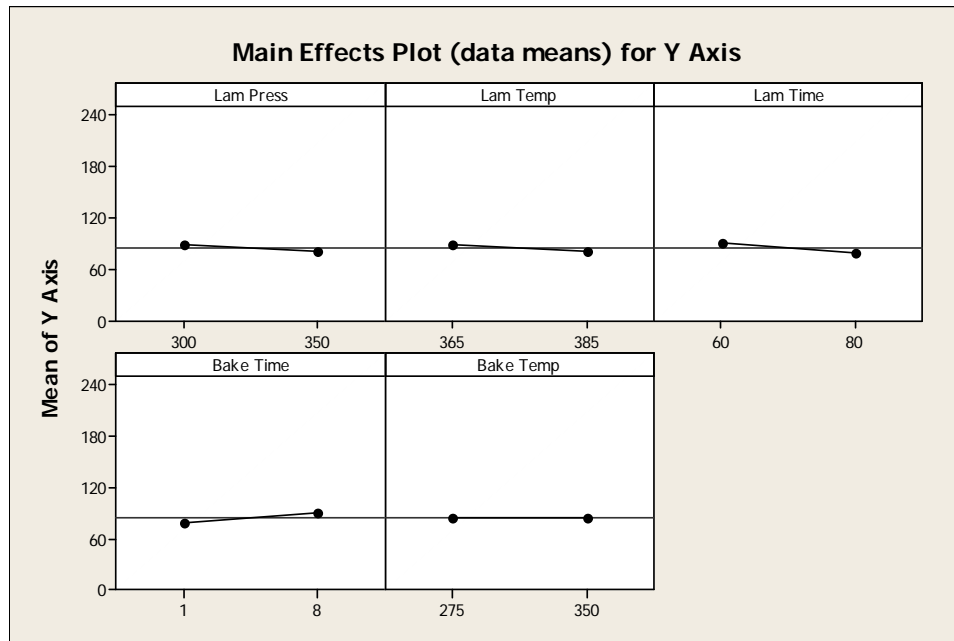


Figure 27. Main Effects Plot for Y Axis



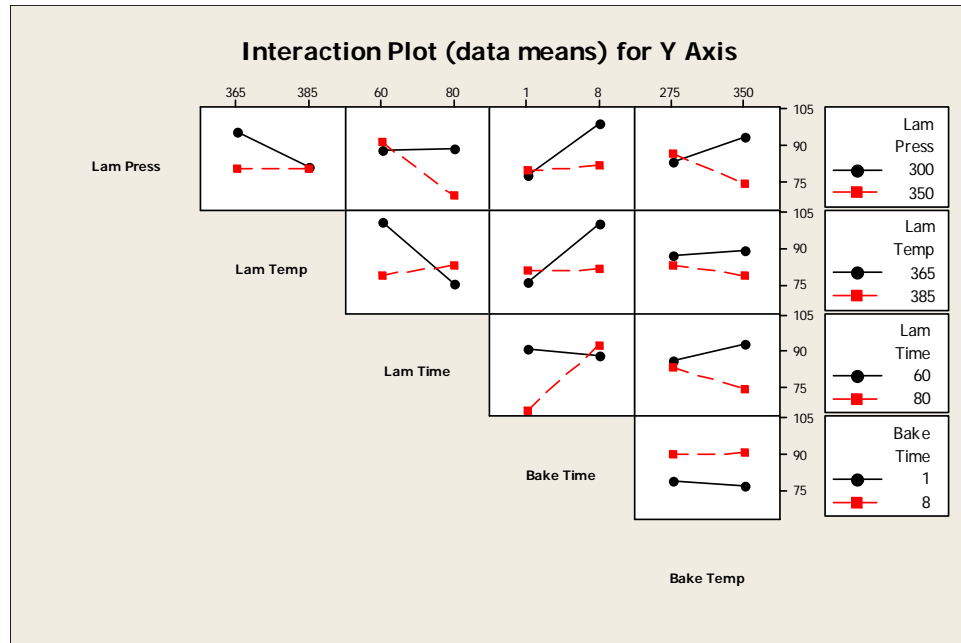


Figure 28. Interaction Plot for Y Axis

### Factorial Fit: Wicking

All delamination/solder wicking variables were statistically significant. However, the Main Effects plot illustrates the effects of bake time and temperature were significantly greater than the other variables.

Estimated Effects and Coefficients for Wicking (coded units)

Term	Effect	Coef	SE Coef	T	P
Constant		0.1366	0.003605	37.90	0.000
Lam Press	0.0277	0.0139	0.003605	3.85	0.001
Lam Temp	-0.1035	-0.0518	0.003605	-14.36	0.000
Lam Time	-0.0223	-0.0111	0.003605	-3.09	0.007
Bake Time	-0.2570	-0.1285	0.003605	-35.64	0.000
Bake Temp	-0.2733	-0.1366	0.003605	-37.90	0.000
Lam Press*Lam Temp	-0.0200	-0.0100	0.003605	-2.77	0.014
Lam Press*Lam Time	-0.1005	-0.0503	0.003605	-13.94	0.000
Lam Press*Bake Time	-0.0307	-0.0154	0.003605	-4.26	0.001
Lam Press*Bake Temp	-0.0277	-0.0139	0.003605	-3.85	0.001
Lam Temp*Lam Time	0.0307	0.0154	0.003605	4.26	0.001
Lam Temp*Bake Time	0.1005	0.0502	0.003605	13.94	0.000
Lam Temp*Bake Temp	0.1035	0.0517	0.003605	14.36	0.000
Lam Time*Bake Time	0.0200	0.0100	0.003605	2.77	0.014
Lam Time*Bake Temp	0.0222	0.0111	0.003605	3.09	0.007
Bake Time*Bake Temp	0.2570	0.1285	0.003605	35.64	0.000

S = 0.0203930    R-Sq = 99.67%    R-Sq(adj) = 99.37%

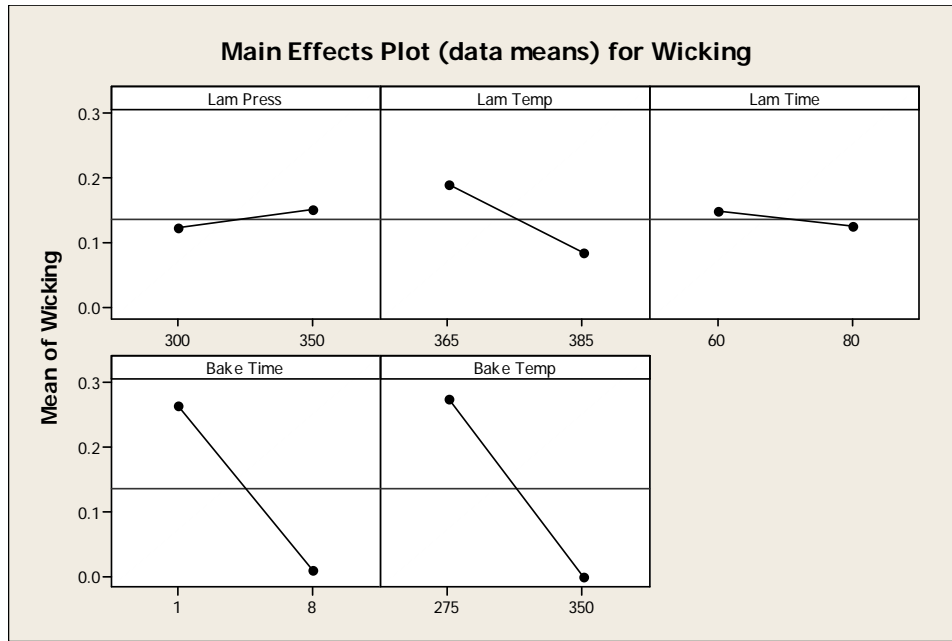


Figure 29. Main Effects Plot for Solder Wicking

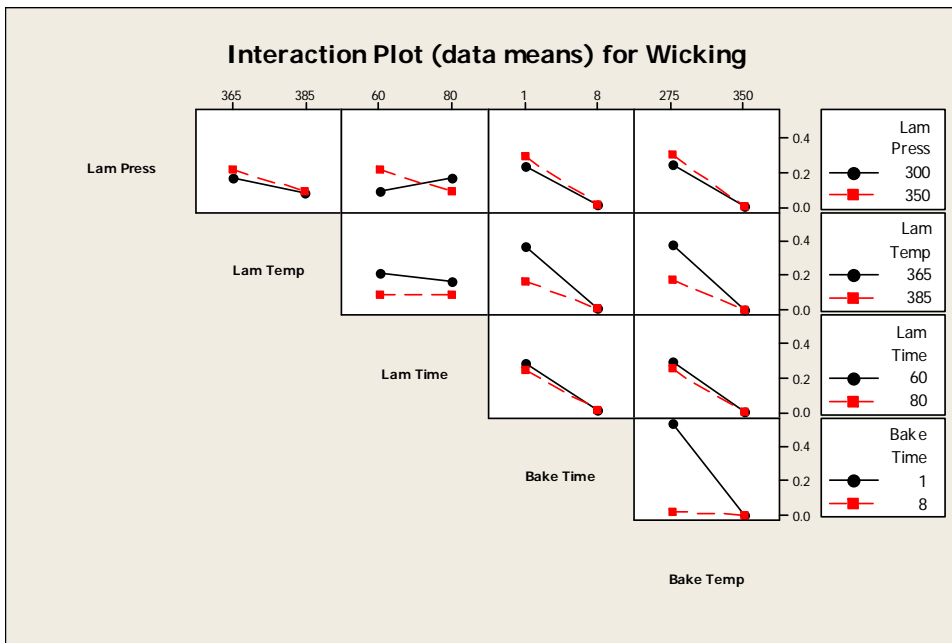


Figure 30. Interaction Plot for Solder Wicking



### Factorial Fit: Dark Halos

A dark 'halo' was observed under the coverlay around the annular rings during evaluation of the sample panels. Data analysis confirmed the dark 'halo' only occurred on sample panels baked at 350°F. The dark 'halos' are thought to be oxidation and are not necessarily a defect, but could be considered foreign material.

Estimated Effects and Coefficients for Dark (coded units)

Term	Effect	Coef	SE Coef	T	P
Constant		0.0625	0.06250	1.00	0.332
Lam Press	0.1250	0.0625	0.06250	1.00	0.332
Lam Temp	-0.1250	-0.0625	0.06250	-1.00	0.332
Lam Time	-0.1250	-0.0625	0.06250	-1.00	0.332
Bake Time	0.1250	0.0625	0.06250	1.00	0.332
Bake Temp	-1.8750	-0.9375	0.06250	-15.00	0.000
Lam Press*Lam Temp	-0.1250	-0.0625	0.06250	-1.00	0.332
Lam Press*Lam Time	-0.1250	-0.0625	0.06250	-1.00	0.332
Lam Press*Bake Time	0.1250	0.0625	0.06250	1.00	0.332
Lam Press*Bake Temp	0.1250	0.0625	0.06250	1.00	0.332
Lam Temp*Lam Time	0.1250	0.0625	0.06250	1.00	0.332
Lam Temp*Bake Time	-0.1250	-0.0625	0.06250	-1.00	0.332
Lam Temp*Bake Temp	-0.1250	-0.0625	0.06250	-1.00	0.332
Lam Time*Bake Time	-0.1250	-0.0625	0.06250	-1.00	0.332
Lam Time*Bake Temp	-0.1250	-0.0625	0.06250	-1.00	0.332
Bake Time*Bake Temp	0.1250	0.0625	0.06250	1.00	0.332

S = 0.353553    R-Sq = 93.73%    R-Sq(adj) = 87.84%

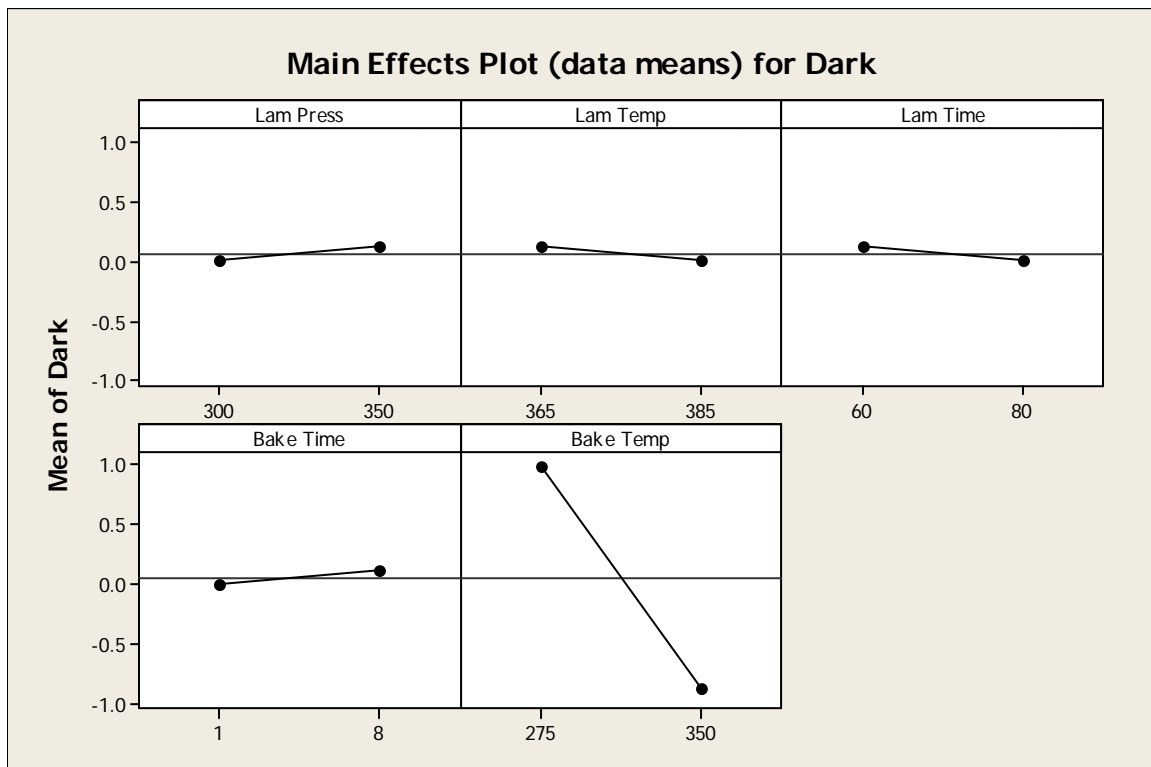


Figure 31. Main Effects Plot for Dark Halos

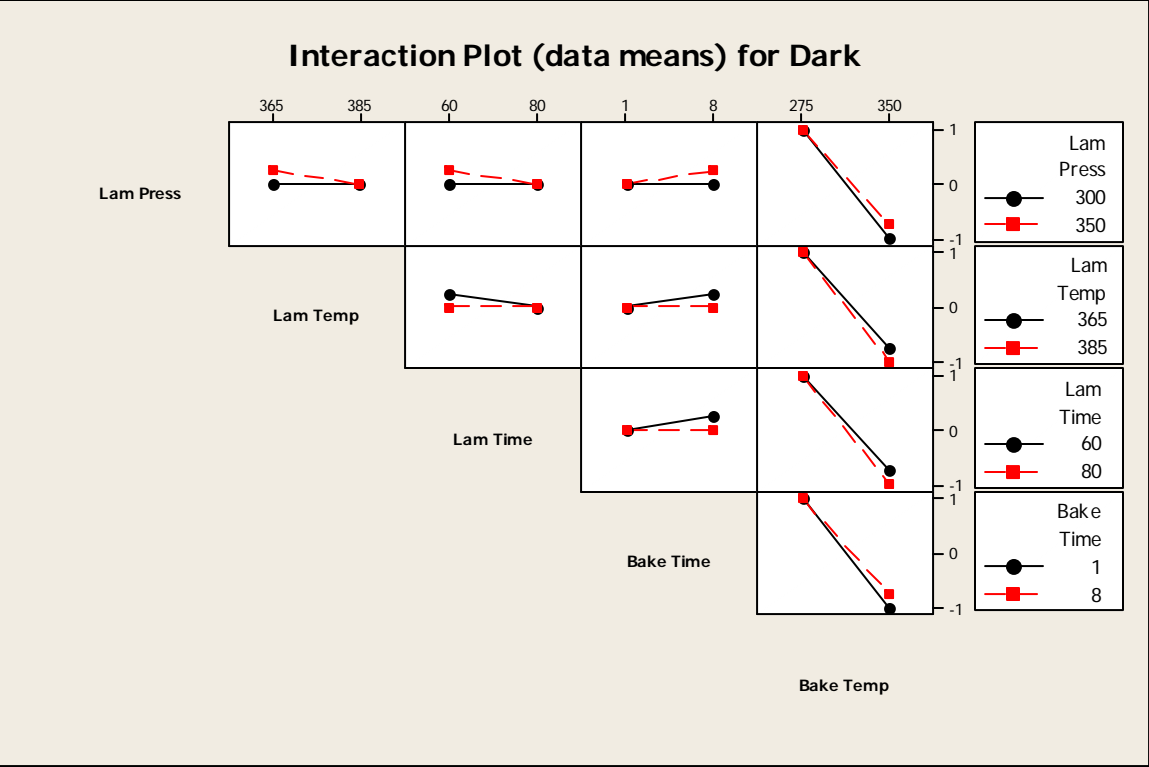


Figure 32. Interaction Plot for Dark Halos

StdOrder	RunOrder	CenterPt	Blocks	Lam Press	Lam Temp	Lam Time	Bake Time	Bake Temp	X Axis	Y Axis	Wicking
7	1	1	1	300	385	80	1	350	57.987	71.608	0
8	2	1	1	350	385	80	1	275	65.946	38.329	0.325
19	3	1	1	300	385	60	1	275	73.434	47.307	0.34
28	4	1	1	350	385	60	8	275	132.105	39.74	0.015
29	5	1	1	300	365	80	8	350	88.158	125.376	0
20	6	1	1	350	385	60	1	350	41.538	115.61	0
14	7	1	1	350	365	80	8	275	51.274	102.554	0.003
6	8	1	1	350	365	80	1	350	110.304	29.529	0
9	9	1	1	300	365	60	8	275	102.302	137.433	0.01
1	10	1	1	300	365	60	1	350	114.811	152.622	0
16	11	1	1	350	385	80	8	350	43.387	83.097	0
21	12	1	1	300	365	80	1	275	168.059	58.007	0.667
15	13	1	1	300	385	80	8	275	133.041	112.415	0.008
26	14	1	1	350	365	60	8	350	93.077	80.051	0
2	15	1	1	350	365	60	1	275	82.717	140.6	0.81
11	16	1	1	300	385	60	8	350	129.892	110.961	0
23	17	1	1	300	385	80	1	350	69.065	78.844	0
24	18	1	1	350	385	80	1	275	58.086	134.634	0.36
3	19	1	1	300	385	60	1	275	82.851	87.503	0.28
12	20	1	1	350	385	60	8	275	51.561	111.334	0.01
13	21	1	1	300	365	80	8	350	108.193	109.06	0
4	22	1	1	350	385	60	1	350	90.365	68.973	0
30	23	1	1	350	365	80	8	275	42.264	64.823	0.025
22	24	1	1	350	365	80	1	350	85.216	45.045	0
25	25	1	1	300	365	60	8	275	82.027	64.364	0.039
17	26	1	1	300	365	60	1	350	86.585	54.094	0
32	27	1	1	350	385	80	8	350	53.306	52.698	0
5	28	1	1	300	365	80	1	275	73.328	66.703	0.6
31	29	1	1	300	385	80	8	275	143.796	89.654	0.02
10	30	1	1	350	365	60	8	350	176.231	116.993	0
18	31	1	1	350	365	60	1	275	51.159	60.618	0.86
27	32	1	1	300	385	60	8	350	136.881	48.105	0

**Table 2. Phase Three DoE Results**

## Conclusions

A pre-HASL bake temperature higher than the current 275°F is required to potentially eliminate delamination/solder wicking when using the soft press pad stackup. A follow-on evaluation will be conducted to determine a temperature and time that will eliminate the wicking without the ‘halo’ effect.

As with previous evaluations, the amount of stretch in the X and Y axis is negligible when using the soft press pad stackup.

See Appendix D for results of environmental testing performed by Trace Laboratories.

## Sample (One Ounce Copper Laminate)

This experiment was performed to determine if flat flex cables containing one ounce copper laminate would have similar results as the two ounce copper laminates and to determine lamination and pre-HASL bake parameters that reduced or eliminated delamination/solder wicking. This was an effort to accomplish two goals with one experiment without diluting the experiment. But there was some concern the experiment contained too many variables since the results did not confirm earlier results from the two ounce laminate experiment.

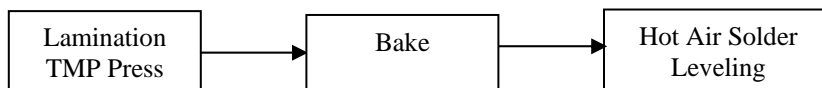
A twelve-by-twelve inch, one ounce copper, double-sided laminate sample was generated which contained the circuit patterns of five cables. The coverlay laminated to both sides of the laminate samples was two mil polyimide/one mil pyralux adhesive. Nine holes with a diameter of .060 inch were strategically located on the sample panel for CMM hole location measurements.

## Experiment

A fractional factorial experiment with two independent variables was developed. Six factors were selected for each variable as shown in the table below.

Variable (Pre HASL Bake)	Level	Level
Bake Temperature	300F	325F
Bake Time	1,2 & 4 hours	1, 2 & 4 hours

Six sample panels were processed for each variable and factor combination resulting in thirty-six panels total. All were laminated in the TMP lamination press over a period of three days using a pressure of 350 psi, a temperature of 385°F and a time of 60 minutes. Each lamination cycle’s actual temperature, pressure, and soak time were recorded at one minute intervals. After lamination each panel’s nine holes were measured for location by a department’s CMM and recorded. The pre-HASL bake was performed per the above variable/factor table. Below is a process map of lamination through HASL.



Measuring the depth of delamination/solder wicking on each land of all five cables per panel was determined to be an acceptable method of quantifying adhesion quality. The greater the solder wicking the more likely there is inadequate adhesion. The total number of lands per panel was seventy.

### **Adhesion Quality Analysis**

The table on the next page summarizes each panels ranking as a sum of each parts ranking. The fill color highlights each pre-HASL bake temperature and time. When comparing solder wicking rank of each colored group highlighted it is slightly evident a longer pre-HASL bake would reduce delamination/solder wicking when using a soft press pad stackup. See Appendix C for each individual panel ranking (magnitude of delamination/solder wicking).

### **Conclusions**

When performing this experiment with one ounce copper laminate cables, there was an increase in delamination/solder wicking with all variable combinations. Data analysis indicates longer HASL pre-bake times will produce less delamination/solder wicking. This data implies different processing for two and one ounce copper laminates.

As with previous evaluations the amount of stretch in the X and Y axis is negligible when using the soft press pad stackup.

See Appendix D for results of environmental testing performed by Trace Laboratories.

### **Future Work**

Future work will emphasize activities related to determining optimized lamination, pre-HASL bake and pre-HASL clean parameters:

- 1) Determining proper bake parameters when using the soft press pad stackup.
- 2) Evaluating the elimination of the bake process when using the hard press pad stackup.
- 3) Determining the interaction between lower lamination pressure and pre-HASL bake process when using the hard press pad stackup.

Future work will concentrate on determining process repeatability and part acceptability when changing process parameters.

Soft Press Pad System (10z)

Panel #	A	B	Total per Part	A	B	Total per Part	A	B	Total per Part	A	B	Total per Part	A	B	Total per Part	Total per Panel	DoE Parameters
9	0.000	0.000	0.000	0.000	0.000	0.000	0.015	0.000	0.015	0.018	0.018	0.036	0.013	0.014	0.027	0.078	300F 4 hours
12	0.004	0.000	0.004	0.000	0.000	0.000	0.019	0.010	0.029	0.013	0.018	0.031	0.016	0.018	0.034	0.098	325F 4 hours
2	0.000	0.000	0.000	0.000	0.000	0.000	0.027	0.009	0.036	0.028	0.006	0.034	0.017	0.014	0.031	0.101	300F 4 hours
4	0.004	0.000	0.004	0.005	0.000	0.005	0.028	0.006	0.034	0.035	0.007	0.042	0.015	0.011	0.026	0.111	325F 4 hours
8	0.000	0.004	0.004	0.000	0.004	0.004	0.025	0.006	0.031	0.050	0.007	0.057	0.020	0.004	0.024	0.120	325F 4 hours
17	0.000	0.000	0.000	0.000	0.000	0.000	0.020	0.018	0.038	0.021	0.034	0.055	0.040	0.007	0.047	0.140	325F 2 hours
10	0.000	0.000	0.000	0.005	0.002	0.007	0.025	0.032	0.057	0.026	0.031	0.057	0.022	0.011	0.033	0.154	325F 2 hours
14	0.000	0.000	0.000	0.007	0.000	0.007	0.035	0.014	0.049	0.036	0.024	0.060	0.030	0.010	0.040	0.156	300F 4 hours
21	0.000	0.000	0.000	0.002	0.000	0.002	0.019	0.038	0.057	0.053	0.038	0.091	0.031	0.015	0.046	0.196	300F 2 hours
6	0.000	0.005	0.005	0.000	0.000	0.000	0.033	0.024	0.057	0.066	0.023	0.089	0.027	0.019	0.046	0.197	325F 2 hours
27	0.008	0.008	0.016	0.006	0.000	0.006	0.035	0.028	0.063	0.056	0.028	0.084	0.024	0.016	0.040	0.209	300F 4 hours
15	0.000	0.000	0.000	0.017	0.000	0.017	0.051	0.010	0.061	0.064	0.013	0.077	0.034	0.025	0.059	0.214	325F 1 hour
18	0.000	0.000	0.000	0.024	0.000	0.024	0.030	0.030	0.060	0.050	0.035	0.085	0.032	0.015	0.047	0.216	300F 2 hours
11	0.000	0.009	0.009	0.004	0.000	0.004	0.032	0.035	0.067	0.042	0.041	0.083	0.029	0.027	0.056	0.219	300F 2 hours
22	0.005	0.005	0.010	0.019	0.000	0.019	0.057	0.021	0.078	0.064	0.011	0.075	0.036	0.003	0.039	0.221	325F 4 hours
16	0.000	0.000	0.000	0.014	0.000	0.014	0.037	0.027	0.064	0.055	0.039	0.094	0.044	0.013	0.057	0.229	325F 1 hour
26	0.005	0.010	0.015	0.023	0.000	0.023	0.033	0.032	0.065	0.063	0.028	0.091	0.024	0.012	0.036	0.230	325F 4 hours
30	0.005	0.005	0.010	0.019	0.000	0.019	0.039	0.033	0.072	0.048	0.047	0.095	0.027	0.013	0.040	0.236	325F 4 hours
28	0.000	0.009	0.009	0.002	0.004	0.006	0.032	0.038	0.070	0.061	0.050	0.111	0.022	0.022	0.044	0.240	325F 2 hours
20	0.007	0.015	0.022	0.018	0.005	0.023	0.036	0.029	0.065	0.060	0.034	0.094	0.026	0.014	0.040	0.244	300F 4 hours
32	0.010	0.008	0.018	0.014	0.016	0.030	0.012	0.032	0.044	0.069	0.048	0.117	0.025	0.018	0.043	0.252	300F 4 hours
35	0.009	0.008	0.017	0.000	0.004	0.004	0.032	0.045	0.077	0.062	0.050	0.112	0.026	0.019	0.045	0.255	325F 2 hours
24	0.000	0.008	0.008	0.010	0.002	0.012	0.033	0.039	0.072	0.069	0.047	0.116	0.029	0.019	0.048	0.256	325F 2 hours
3	0.000	0.000	0.000	0.006	0.000	0.006	0.045	0.034	0.079	0.072	0.034	0.106	0.079	0.022	0.101	0.292	300F 2 hours
36	0.011	0.005	0.016	0.008	0.000	0.008	0.064	0.041	0.105	0.067	0.067	0.134	0.047	0.029	0.076	0.339	300F 2 hours
34	0.006	0.017	0.023	0.020	0.012	0.032	0.041	0.050	0.091	0.075	0.062	0.137	0.039	0.020	0.059	0.342	325F 1 hour
29	0.009	0.014	0.023	0.020	0.016	0.036	0.058	0.058	0.116	0.070	0.067	0.137	0.042	0.040	0.082	0.394	300F 2 hours
13	0.018	0.012	0.030	0.026	0.000	0.026	0.048	0.034	0.082	0.102	0.079	0.181	0.071	0.055	0.126	0.445	300F 1 hour
23	0.000	0.003	0.003	0.017	0.002	0.019	0.034	0.050	0.084	0.060	0.069	0.129	0.228	0.025	0.253	0.488	325F 1 hour
5	0.004	0.006	0.010	0.010	0.000	0.010	0.047	0.034	0.081	0.078	0.035	0.113	0.282	0.026	0.308	0.522	325F 1 hour
19	0.004	0.017	0.021	0.025	0.000	0.025	0.061	0.031	0.092	0.112	0.067	0.179	0.144	0.070	0.214	0.531	300F 1 hour
1	0.000	0.013	0.013	0.027	0.000	0.027	0.049	0.059	0.108	0.106	0.040	0.146	0.212	0.044	0.256	0.550	300F 1 hour
7	0.015	0.015	0.030	0.010	0.022	0.032	0.051	0.077	0.128	0.122	0.092	0.214	0.120	0.047	0.167	0.571	300F 1 hour
31	0.019	0.013	0.032	0.032	0.019	0.051	0.078	0.066	0.144	0.118	0.079	0.197	0.114	0.083	0.197	0.621	300F 1 hour
25	0.010	0.020	0.030	0.022	0.000	0.022	0.057	0.029	0.086	0.123	0.089	0.212	0.280	0.069	0.349	0.699	300F 1 hour
33	0.012	0.022	0.034	0.031	0.000	0.031	0.069	0.050	0.119	0.124	0.098	0.222	0.478	0.808	1.286	1.692	325F 1 hour
Total			0.416			0.551			2.576			3.893			4.422	11.858	

Hard Press Pad System (10z)

Panel #	A	B	Total per Part	A	B	Total per Part	A	B	Total per Part	A	B	Total per Part	A	B	Total per Part	Total per Panel	DoE Parameters
1	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.004	0.002	0.000	0.002	0.007	0.000	0.007	0.013	190 ton
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.021	0.021	0.000	0.007	0.007	0.020	0.000	0.020	0.048	190 ton
3	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.003	0.000	0.000	0.000	0.010	0.000	0.010	0.013	190 ton
8	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.004	0.012	0.007	0.000	0.007	0.015	0.000	0.015	0.034	100 ton
9	0.000	0.000	0.000	0.004	0.000	0.004	0.002	0.011	0.013	0.006	0.000	0.006	0.011	0.000	0.011	0.034	100 ton

Table 3. Panel Ranking

# Appendix A

## Phase One Data

PNL #	Press Pad	Pre-Bake	As Measured on OGP											
			Upper Left			Upper Right			Lower Right			Lower Left		
			Dia.	X	Y	Dia.	X	Y	Dia.	X	Y	Dia.	X	Y
1	Hard	N	0.09256	0.00000	0.00000	0.09336	6.76706	-0.00017	0.09283	6.76696	-4.99075	0.09280	0.00181	-4.99437
2	Hard	N	0.09281	0.00000	0.00000	0.09311	6.76421	-0.00002	0.09298	6.76344	-4.99171	0.09300	-0.00121	-4.99061
3	Soft	N	0.09321	0.00000	0.00000	0.09305	6.76390	0.00003	0.09282	6.76428	-4.98473	0.09273	-0.00026	-4.98455
4	Hard	Y	0.09295	0.00000	0.00000	0.09259	6.76513	-0.00002	0.09278	6.76499	-4.99314	0.09243	-0.00097	-4.98930
5	Soft	Y	0.09293	0.00000	0.00000	0.09314	6.76403	-0.00006	0.09298	6.76394	-4.98506	0.09298	0.00007	-4.98414
6	Hard	Y	0.09313	0.00000	0.00000	0.09300	6.76296	0.00006	0.09294	6.76395	-4.99019	0.09265	0.00044	-4.99422
7	Hard	Y	0.09315	0.00000	0.00000	0.09322	6.76280	0.00008	0.09284	6.76270	-4.98924	0.09283	0.00000	-4.98856
8	Soft	Y	0.09291	0.00000	0.00000	0.09306	6.76365	0.00000	0.09308	6.76374	-4.98425	0.09289	-0.00012	-4.98383
9	Hard	N	0.09303	0.00000	0.00000	0.09327	6.76529	-0.00001	0.09291	6.76153	-4.99538	0.09273	-0.00325	-4.98858
10	Soft	N	0.09283	0.00000	0.00000	0.09319	6.76388	0.00001	0.09252	6.76504	-4.98510	0.09277	0.00092	-4.98475
11	Soft	N	0.09294	0.00000	0.00000	0.09309	6.76384	0.00003	0.09274	6.76414	-4.98508	0.09299	0.00055	-4.98426
12	Hard	Y	0.09275	0.00000	0.00000	0.09296	6.76552	0.00002	0.09288	6.76926	-4.99236	0.09336	0.00337	-4.99945
13	Hard	N	0.09346	0.00000	0.00000	0.09348	6.76347	-0.00027	0.09275	6.76425	-4.99519	0.09309	0.00055	-4.99282
14	Soft	Y	0.09306	0.00000	0.00000	0.09317	6.76454	0.00002	0.09276	6.76461	-4.98446	0.09316	0.00061	-4.98416
15	Soft	Y	0.09314	0.00000	0.00000	0.09278	6.76449	0.00007	0.09304	6.76472	-4.98458	0.09316	0.00073	-4.98398
16	Soft	N	0.09296	0.00000	0.00000	0.09317	6.76363	-0.00007	0.09309	6.76415	-4.98440	0.09305	0.00038	-4.98392
17	Hard	N	0.09300	0.00000	0.00000	0.09355	6.76733	0.00003	0.09241	6.76362	-5.00452	0.09236	-0.00255	-4.99360
18	Hard	N	0.09226	0.00000	0.00000	0.09295	6.76420	0.00000	0.09334	6.76658	-4.99280	0.09322	0.00174	-4.99989
19	Soft	N	0.09338	0.00000	0.00000	0.09300	6.76434	-0.00005	0.09297	6.76450	-4.98455	0.09288	-0.00008	-4.98374
20	Hard	Y	0.09337	0.00000	0.00000	0.09329	6.76407	-0.00001	0.09307	6.76461	-4.99120	0.09389	-0.00001	-4.99270
21	Soft	Y	0.09301	0.00000	0.00000	0.09305	6.76399	-0.00003	0.09271	6.76454	-4.98481	0.09285	0.00006	-4.98386
22	Hard	Y	0.09270	0.00000	0.00000	0.09251	6.76472	0.00015	0.09268	6.76366	-4.99727	0.09275	-0.00206	-4.99201
23	Hard	Y	0.09290	0.00000	0.00000	0.09205	6.76749	0.00004	0.09243	6.76508	-4.99397	0.09280	-0.00142	-4.98929
24	Soft	Y	0.09323	0.00000	0.00000	0.09329	6.76333	0.00001	0.09289	6.76332	-4.98425	0.09343	0.00044	-4.98379
25	Hard	N	0.09400	0.00000	0.00000	0.09299	6.76792	0.00003	0.09164	6.76444	-4.99502	0.09266	-0.00261	-4.99337
26	Soft	N	0.09286	0.00000	0.00000	0.09292	6.76438	0.00002	0.09298	6.76463	-4.98472	0.09304	0.00026	-4.98440
27	Soft	N	0.09292	0.00000	0.00000	0.09298	6.76400	-0.00005	0.09271	6.76453	-4.98420	0.09319	0.00052	-4.98372
28	Hard	Y	0.09403	0.00000	0.00000	0.09219	6.76610	0.00000	0.09307	6.76699	-4.99681	0.09291	0.00004	-4.99495
29	Hard	N	0.09326	0.00000	0.00000	0.09265	6.76508	-0.00001	0.09308	6.76376	-4.99609	0.09306	-0.00072	-4.99387
30	Soft	Y	0.09320	0.00000	0.00000	0.09297	6.76471	0.00002	0.09277	6.76492	-4.98401	0.09291	0.00029	-4.98360
31	Soft	Y	0.09284	0.00000	0.00000	0.09290	6.76486	0.00004	0.09261	6.76496	-4.98418	0.09313	0.00045	-4.98390
32	Soft	N	0.09293	0.00000	0.00000	0.09283	6.76483	0.00009	0.09268	6.76506	-4.98463	0.09040	0.00052	-4.98440

Table 4. Hole Location

Analysis											
Hole Diameter Deviations from Drilled					X axis PPM Distortion			Y axis PPM Distortion			
UL	UR	LR	LL	Avg.	UL→UR	LL→LR	Avg.	UL→LL	UR→LR	Avg.	
-0.00094	-0.00014	-0.00067	-0.00070	-0.00061	304.51	22.17	163.34	1153.46	1845.54	1499.50	
-0.00069	-0.00039	-0.00052	-0.00050	-0.00053	-116.78	-51.74	-84.26	1346.04	1121.36	1233.70	
-0.00029	-0.00045	-0.00068	-0.00077	-0.00055	-162.60	-68.00	-115.30	-54.16	-84.25	-69.21	
-0.00055	-0.00091	-0.00072	-0.00107	-0.00081	19.22	141.91	80.56	1632.90	858.58	1245.74	
-0.00057	-0.00036	-0.00052	-0.00052	-0.00049	-143.39	-167.04	-155.21	12.04	-184.55	-86.26	
-0.00037	-0.00050	-0.00056	-0.00085	-0.00057	-301.55	-220.25	-260.90	1041.12	1861.58	1451.35	
-0.00035	-0.00028	-0.00066	-0.00067	-0.00049	-325.20	-339.99	-332.59	850.55	730.19	790.37	
-0.00059	-0.00044	-0.00042	-0.00061	-0.00051	-199.56	-168.51	-184.04	-150.45	-234.70	-192.58	
-0.00047	-0.00023	-0.00059	-0.00077	-0.00051	42.87	-32.52	5.17	2082.25	716.15	1399.20	
-0.00067	-0.00031	-0.00098	-0.00073	-0.00067	-165.56	-130.08	-147.82	20.06	-48.14	-14.04	
-0.00056	-0.00041	-0.00076	-0.00051	-0.00056	-171.47	-208.43	-189.95	16.05	-142.43	-63.19	
-0.00075	-0.00054	-0.00062	-0.00014	-0.00051	76.87	131.56	104.21	1476.43	2902.71	2189.57	
-0.00004	-0.00002	-0.00075	-0.00041	-0.00031	-226.16	-192.17	-209.16	2044.13	1514.54	1779.34	
-0.00044	-0.00033	-0.00074	-0.00034	-0.00046	-68.00	-147.82	-107.91	-108.32	-164.49	-136.41	
-0.00036	-0.00072	-0.00046	-0.00034	-0.00047	-75.39	-149.30	-112.34	-84.25	-190.57	-137.41	
-0.00054	-0.00033	-0.00041	-0.00045	-0.00043	-202.51	-181.82	-192.17	-120.36	-230.69	-175.53	
-0.00050	0.00005	-0.00109	-0.00114	-0.00067	344.42	172.95	258.68	3915.75	1731.19	2823.47	
-0.00124	-0.00055	-0.00016	-0.00028	-0.00056	-118.26	-23.65	-70.95	1564.69	2986.96	2275.83	
-0.00012	-0.00050	-0.00053	-0.00062	-0.00044	-97.56	-62.08	-79.82	-90.27	-262.79	-176.53	
-0.00013	-0.00021	-0.00043	0.00039	-0.00010	-137.47	-56.17	-96.82	1243.73	1542.63	1393.18	
-0.00049	-0.00045	-0.00079	-0.00065	-0.00060	-149.30	-76.87	-113.08	-38.11	-234.70	-136.41	
-0.00080	-0.00099	-0.00082	-0.00075	-0.00084	-41.39	106.43	32.52	2461.38	1436.31	1948.85	
-0.00060	-0.00145	-0.00107	-0.00070	-0.00096	368.07	221.73	294.90	1799.40	868.61	1334.00	
-0.00027	-0.00021	-0.00061	-0.00007	-0.00029	-246.86	-313.38	-280.12	-150.45	-240.72	-195.59	
0.00050	-0.00051	-0.00186	-0.00084	-0.00068	431.63	303.03	367.33	2010.03	1685.06	1847.54	
-0.00064	-0.00058	-0.00052	-0.00046	-0.00055	-91.65	-93.13	-92.39	-56.17	-116.35	-86.26	
-0.00058	-0.00052	-0.00079	-0.00031	-0.00055	-147.82	-146.34	-147.08	-160.48	-266.80	-213.64	
0.00053	-0.00131	-0.00043	-0.00059	-0.00045	162.60	288.25	225.42	2369.11	1995.99	2182.55	
-0.00024	-0.00085	-0.00042	-0.00044	-0.00049	11.83	-76.87	-32.52	2224.67	1777.33	2001.00	
-0.00030	-0.00053	-0.00073	-0.00059	-0.00054	-42.87	-54.69	-48.78	-198.60	-276.83	-237.71	
-0.00066	-0.00060	-0.00089	-0.00037	-0.00063	-20.69	-72.43	-46.56	-164.49	-212.64	-188.57	
-0.00057	-0.00067	-0.00082	-0.000310	-0.00129	-25.13	-68.00	-46.56	-74.22	-102.31	-88.26	

Table 5. Hole Analysis

Std Order	Run Order	Pt Type	Blocks	Stackup	Bake	Clean	Dia	X Axis	Y Axis	Method 2A	Method 2B	Method 1
6	1	1	1	Rubber	No Bake	Clean	-0.0006	163.34	1499.5	1	0	8
7	2	1	1	Rubber	No Bake	No Clean	-0.0005	-84.26	1233.7	0	0	0
15	3	1	1	PacoPad	No Bake	No Clean	-0.0006	-115.3	-69.21	15	11	75
4	4	1	1	Rubber	Bake	No Clean	-0.0008	80.56	1245.74	1	0	21
11	5	1	1	PacoPad	Bake	No Clean	-0.0005	-155.21	-86.26	0	0	36
2	6	1	1	Rubber	Bake	Clean	-0.0006	-260.9	1451.35	4	0	24
3	7	1	1	Rubber	Bake	No Clean	-0.0005	-332.59	790.37	0	0	6
9	8	1	1	PacoPad	Bake	Clean	-0.0005	-184.04	-192.58	1	0	38
5	9	1	1	Rubber	No Bake	Clean	-0.0005	5.17	1399.2	0	0	0
16	10	1	1	PacoPad	No Bake	No Clean	-0.0007	-147.82	-14.04	14	11	75
13	11	1	1	PacoPad	No Bake	Clean	-0.0006	-189.95	-63.19	14	11	75
1	12	1	1	Rubber	Bake	Clean	-0.0005	104.21	2189.57	5	0	72
8	13	1	1	Rubber	No Bake	No Clean	-0.0003	-209.16	1779.34	0	0	8
10	14	1	1	PacoPad	Bake	Clean	-0.0005	-107.91	-136.41	1	0	17
12	15	1	1	PacoPad	Bake	No Clean	-0.0005	-112.34	-137.41	0	0	20
14	16	1	1	PacoPad	No Bake	Clean	-0.0004	-192.17	-175.53	13	8	75
22	17	1	2	Rubber	No Bake	Clean	-0.0007	258.68	2823.47	2	0	29
23	18	1	2	Rubber	No Bake	No Clean	-0.0006	-70.95	2275.83	1	0	12
31	19	1	2	PacoPad	No Bake	No Clean	-0.0004	-79.82	-176.53	14	9	75
20	20	1	2	Rubber	Bake	No Clean	-0.0001	-96.82	1393.18	0	0	8
27	21	1	2	PacoPad	Bake	No Clean	-0.0006	-113.08	-136.41	0	0	24
18	22	1	2	Rubber	Bake	Clean	-0.0008	32.52	1948.85	4	0	49
19	23	1	2	Rubber	Bake	No Clean	-0.001	294.9	1334	1	0	29
25	24	1	2	PacoPad	Bake	Clean	-0.0003	-280.12	-195.59	0	0	38
21	25	1	2	Rubber	No Bake	Clean	-0.0007	367.33	1847.54	1	0	15
32	26	1	2	PacoPad	No Bake	No Clean	-0.0006	-92.39	-86.26	13	11	75
29	27	1	2	PacoPad	No Bake	Clean	-0.0006	-147.08	-213.64	14	12	75
17	28	1	2	Rubber	Bake	Clean	-0.0005	225.42	2182.55	7	0	45
24	29	1	2	Rubber	No Bake	No Clean	-0.0005	-32.52	2001	0	0	8
26	30	1	2	PacoPad	Bake	Clean	-0.0005	-48.78	-237.71	0	0	28
28	31	1	2	PacoPad	Bake	No Clean	-0.0006	-46.56	-188.57	0	0	24
30	32	1	2	PacoPad	No Bake	Clean	-0.0013	-46.56	-88.26	15	11	75

**Table 6. DoE Variables and Results**



# Appendix B

## Phase Two Data

### Hole location data

A department's CMM hole location data is shown below. The post laminate measurements were taken after lamination.

$$\text{PPM} = \text{ABS}(A - (\text{ABS}(B - C))) / A \times 1000000$$

A = Delta of nominal data

B = hole location

C = hole location

B-C = distance between two holes

Panel	Post Laminate Measurement				PPM 11	PPM 12	PPM 21	PPM 22	PPM 31	PPM 32	Average PPM
HPPS 1	X Values	Column 1	Column 2	Column 3							
	Row 1	1.14819	5.47429	9.74209	439.0018	70.29877	136.3216	25.77622	404.3438	222.6128	216.3925065
	Row 2	1.14629	5.4737	9.74109							
	Row 3	1.14954	5.47579	9.74234							
HPPS 2	X Values	Column 1	Column 2	Column 3							
	Row 1	1.14582	5.47316	9.74011	152.4954	128.8811	131.7006	103.1049	134.0111	217.9262	144.6865251
	Row 2	1.14707	5.4745	9.74156							
	Row 3	1.14801	5.47543	9.742							
HPPS 3	X Values	Column 1	Column 2	Column 3							
	Row 1	1.14611	5.4732	9.74101	210.2588	72.64206	87.80037	56.23902	161.7375	297.5981	147.712646
	Row 2	1.14825	5.47663	9.74389							
	Row 3	1.14778	5.47508	9.74131							
HPPS 4	X Values	Column 1	Column 2	Column 3							
	Row 1	1.15049	5.47761	9.74497	203.3272	32.80609	284.1959	30.4628	182.5323	91.3884	137.4521244
	Row 2	1.14906	5.47829	9.74566							
	Row 3	1.15026	5.47747	9.74458							
HPPS 5	X Values	Column 1	Column 2	Column 3							
	Row 1	1.14865	5.47617	9.74349	110.9057	42.17926	23.10536	107.7914	157.1165	86.70182	87.96667775
	Row 2	1.14854	5.47664	9.74368							
	Row 3	1.14929	5.47661	9.74374							
HPPS 6	X Values	Column 1	Column 2	Column 3							
	Row 1	1.15087	5.47775	9.745	258.78	58.58231	69.31608	140.5975	41.58965	100.7616	111.6045308
	Row 2	1.14965	5.47795	9.74605							
	Row 3	1.14994	5.47776	9.74483							
HPPS 7	X Values	Column 1	Column 2	Column 3							
	Row 1	1.14847	5.47554	9.74291	214.8799	30.4628	62.38447	14.05975	173.2902	161.6872	109.4607089
	Row 2	1.14767	5.4754	9.74296							
	Row 3	1.14805	5.4753	9.74211							
HPPS 8	X Values	Column 1	Column 2	Column 3							
	Row 1	1.15	5.477	9.74424	231.0536	60.9256	120.1479	128.8811	138.6322	182.7768	143.7361869
	Row 2	1.14973	5.47721	9.74416							
	Row 3	1.1499	5.4773	9.74402							
HPPS 9	X Values	Column 1	Column 2	Column 3							
	Row 1	1.15171	5.47903	9.74619	157.1165	79.67194	99.35305	28.11951	87.80037	140.5975	98.77647619
	Row 2	1.15083	5.4784	9.74578							
	Row 3	1.1507	5.47832	9.74522							

Table 7. Post Laminate Hole Location X Values

Panel	Post Laminate Measurement				PPM Stretch from Nominal to Laminate						
	Y Values	Column 1	Column 2	Column 3	PPM 11	PPM 12	PPM 21	PPM 22	PPM 31	PPM 32	Average PPM
HPPS 1	Row 1	4.19043	4.1914	4.18623	2688.965	2294.13	1268.465	1563.141	1804.676	717.7688	1722.857572
	Row 2	-0.22832	-0.22561	-0.22626							
	Row 3	-4.62378	-4.62213	-4.61801							
HPPS 2	Y Values	Column 1	Column 2	Column 3							
	Row 1	4.18345	4.18764	4.18807	1055.163	1681.454	2049.059	416.9895	1424.144	1041.334	1278.024203
	Row 2	-0.2281	-0.22667	-0.22786							
HPPS 3	Row 3	-4.61853	-4.62152	-4.62103							
	Y Values	Column 1	Column 2	Column 3							
	Row 1	4.18571	4.1921	4.19239	1486.306	2414.396	2911.344	740.5551	1941.394	1640.614	1855.767959
HPPS 4	Row 2	-0.22774	-0.22544	-0.22734							
	Row 3	-4.61959	-4.62256	-4.62314							
	Y Values	Column 1	Column 2	Column 3							
HPPS 5	Row 1	4.18255	4.1856	4.18417	540.0622	1050.625	903.1292	353.1878	1449.209	920.5669	869.4634264
	Row 2	-0.22673	-0.22593	-0.22671							
	Row 3	-4.61688	-4.62089	-4.61935							
HPPS 6	Y Values	Column 1	Column 2	Column 3							
	Row 1	4.18281	4.18713	4.18563	719.3265	1261.658	1236.697	672.1961	2053.047	1118.808	1176.95531
	Row 2	-0.22726	-0.22533	-0.22672							
HPPS 7	Row 3	-4.61881	-4.62294	-4.62023							
	Y Values	Column 1	Column 2	Column 3							
	Row 1	4.1835	4.18526	4.18369	635.3673	937.1667	703.4423	845.3721	1476.553	927.4028	920.884019
HPPS 8	Row 2	-0.2262	-0.22577	-0.22631							
	Row 3	-4.61851	-4.62085	-4.61898							
	Y Values	Column 1	Column 2	Column 3							
HPPS 9	Row 1	4.18215	4.18526	4.18424	54.46005	737.4799	487.8713	109.3743	360.0237	248.3708	332.9299949
	Row 2	-0.22499	-0.22489	-0.22481							
	Row 3	-4.61407	-4.61507	-4.6145							
HPPS 10	Y Values	Column 1	Column 2	Column 3							
	Row 1	4.18334	4.18675	4.18513	431.1421	957.5892	696.6348	191.405	708.6542	291.6648	546.1816904
	Row 2	-0.22546	-0.22437	-0.22484							
HPPS 11	Row 3	-4.6149	-4.61608	-4.61472							
	Y Values	Column 1	Column 2	Column 3							
	Row 1	4.18294	4.18509	4.18356	270.0311	753.364	415.2579	205.0768	476.2339	198.2409	386.3674311
HPPS 12	Row 2	-0.22515	-0.22513	-0.22517							
	Row 3	-4.61465	-4.61582	-4.61464							

Table 8. Post Laminate Hole Location Y Values

## Adhesion Quality Data

The area around each land was evaluated for solder wicking/discoloration and if any was discovered the maximum ingress was measured and recorded. The measurement recorded was the linear distance under the coverlay not an attempt to quantify the total area covered by any solder wicking/discoloration. The data shown below signifies discoloration since solder wicking was found only on one panel four land and one panel five land.

The green column in the table below displays the additive total of land discoloration per part. This total was used to rank each part and then rank each panel.

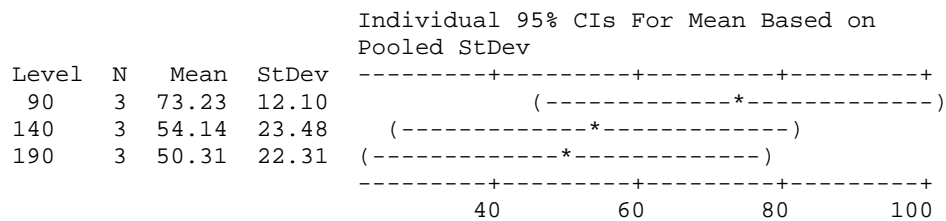
Cable	Hole	Panel 1 Discoloration	Panel 1 Total/ Part	Panel 2 Discoloration	Panel 2 Total/ Part	Panel 3 Discoloration	Panel 3 Total/ Part	Panel 4 Discoloration	Panel 4 Total/ Part	Panel 5 Discoloration	Panel 5 Total/ Part	Panel 6 Discoloration	Panel 6 Total/ Part	Panel 7 Discoloration	Panel 7 Total/ Part	Panel 8 Discoloration	Panel 8 Total/ Part	Panel 9 Discoloration	Panel 9 Total/ Part
	1	0.005	-	0.005	-	0.000	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	0.005	-	-	-	0.004	-	-	-	-	-	0.002	-	0.003	-	0.004	-
	3	0.007	-	0.010	-	0.005	-	0.005	-	0.011	-	0.009	-	0.006	-	0.007	-	0.006	-
	4	0.005	0.017	0.005	0.025	-	0.005	0.008	0.017	0.003	0.014	0.004	0.013	-	0.008	0.005	0.015	0.010	0.020
	5	-	-	-	-	-	-	-	-	-	-	-	-	0.005	-	-	-	0.002	-
	6	-	-	-	-	-	-	0.003	-	-	-	0.003	-	0.005	-	-	-	0.002	-
	7	0.005	-	0.005	-	-	-	-	-	0.007	-	0.005	-	-	-	0.005	-	0.007	-
	8	-	-	-	-	-	-	-	-	-	-	0.002	-	-	-	-	-	0.002	-
	9	-	-	0.005	0.005	-	-	-	-	-	-	0.005	-	-	-	0.005	-	-	-
	10	-	-	0.005	-	-	-	-	-	-	-	-	-	0.003	-	0.003	-	-	-
	11	-	-	0.007	-	-	-	-	-	-	-	-	-	0.004	-	0.002	-	-	-
	12	-	-	0.010	-	0.006	-	0.005	-	-	-	-	-	0.004	-	0.003	-	0.006	-
	13	-	-	-	-	0.004	-	-	-	0.003	-	0.003	-	0.003	-	-	-	0.003	-
	14	-	-	0.005	-	-	-	0.006	-	0.005	-	0.002	-	-	-	0.002	-	-	-
	15	-	0.005	0.010	0.047	-	0.015	0.002	0.016	0.006	0.021	0.002	0.022	-	0.024	0.002	0.022	0.007	0.029
	16	0.005	-	-	-	0.005	-	0.005	-	-	-	0.008	-	0.001	-	0.005	-	-	-
	17	0.005	0.010	-	0.000	0.006	0.011	0.005	0.010	-	0.000	0.007	0.015	-	0.001	0.003	0.008	-	0.000
	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	19	0.008	0.008	0.005	0.005	0.003	0.003	-	0.000	0.010	0.010	0.005	0.005	0.009	0.009	0.007	0.007	0.003	0.003
	20	0.002	-	0.005	-	0.003	-	0.003	-	-	-	0.003	-	0.002	-	0.002	-	0.005	-
	21	0.005	-	0.005	-	-	-	-	-	-	-	0.004	-	-	-	0.002	-	-	-
	22	0.005	-	-	-	-	-	-	-	-	-	0.003	-	-	-	-	-	-	-
	23	0.008	-	0.007	-	0.010	-	0.008	-	0.004	-	0.008	-	0.005	-	0.005	-	0.005	-
	24	0.005	-	-	-	0.005	-	0.003	-	-	-	0.008	-	0.005	-	0.010	-	0.002	-
	25	-	0.025	-	0.017	-	0.018	-	0.014	-	0.004	-	0.026	-	0.012	-	0.019	-	0.012
	26	-	-	-	-	-	-	-	-	-	-	0.004	-	0.004	-	-	-	-	-
	27	-	-	-	-	-	-	-	-	-	-	0.007	-	-	-	-	-	0.001	-
	28	0.005	-	-	-	0.005	-	0.004	-	0.003	-	0.005	-	0.002	-	0.003	-	-	-
	29	-	-	-	-	-	-	-	-	0.005	-	0.003	-	0.002	-	0.002	-	-	-
	30	-	-	-	-	-	-	-	-	-	-	-	-	0.002	-	-	-	-	-
	31	-	-	0.005	-	0.003	-	-	-	0.007	-	0.005	-	0.004	-	0.002	-	-	-
	32	-	-	-	-	-	-	0.004	-	-	-	0.006	-	-	-	0.002	-	-	-
	33	-	-	0.005	-	-	-	0.003	-	-	-	0.003	-	0.004	-	-	-	-	-
	34	0.005	-	0.004	-	-	-	0.005	-	0.004	-	0.002	-	0.003	-	-	-	-	-
	35	-	-	-	-	-	-	-	-	-	-	-	-	0.002	-	-	-	-	-
	36	-	0.010	-	0.014	-	0.008	-	0.016	-	0.019	-	0.035	-	0.023	-	0.009	0.002	0.003
	37	0.008	-	0.007	-	0.006	-	0.005	-	-	-	0.002	-	0.005	-	0.005	-	0.005	-
	38	-	-	0.002	-	0.003	-	0.005	-	0.012	-	0.008	-	0.005	-	0.003	-	0.004	-
	39	0.007	0.015	0.010	0.019	0.010	0.019	0.007	0.017	-	0.012	-	0.010	-	0.010	0.003	0.011	0.0075	0.017
	40	-	-	0.005	-	-	-	0.010	-	0.008	-	0.008	-	0.007	-	0.002	-	0.003	-
	41	-	-	-	-	-	-	0.014	-	0.007	-	0.006	-	0.006	-	0.004	-	0.002	-
	42	-	-	-	-	-	-	-	-	-	-	-	-	0.005	-	0.005	-	0.004	-
	43	-	0.000	0.010	0.015	-	0.000	0.002	0.026	0.005	0.020	-	0.014	0.002	0.020	0.003	0.014	0.007	0.016
	44	0.005	-	0.005	-	0.003	-	0.005	-	0.011	-	0.005	-	0.004	-	0.003	-	0.003	-
	45	-	-	-	-	0.002	-	-	-	-	-	-	-	-	-	-	-	-	-
	46	-	-	-	-	-	-	0.005	-	-	-	0.004	-	0.003	-	-	-	0.002	-
	47	-	-	-	-	-	-	-	-	-	-	-	-	0.003	-	-	-	0.002	-
	48	-	-	0.005	-	-	-	0.002	-	-	-	0.002	-	-	-	0.005	-	-	-
	49	-	-	0.002	-	-	-	-	-	-	-	0.007	-	0.002	-	0.002	-	-	-
	50	0.005	-	0.006	-	-	-	-	-	0.003	-	-	-	-	-	0.005	-	-	-
	51	-	-	-	-	0.002	-	-	-	-	-	-	-	-	-	-	-	-	-
	52	-	-	-	-	-	-	-	-	-	-	-	-	0.003	-	-	-	-	-
	53	-	-	0.002	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	54	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	55	0.002	-	-	-	-	-	-	-	-	-	0.003	-	0.002	-	-	-	-	-
	56	-	-	-	-	0.003	-	-	-	0.003	-	-	-	-	-	-	-	-	-
	57	-	0.012	-	0.020	-	0.010	-	0.012	-	0.017	-	0.021	0.002	0.019	0.003	0.018	-	0.007
	58	0.005	-	0.010	-	0.006	-	0.005	-	0.005	-	0.008	-	0.004	-	0.010	-	0.002	-
	59	0.005	0.005	0.005	0.015	-	0.006	0.004	0.009	-	0.005	-	0.008	0.004	0.008	0.010	0.010	-	0.002

Table 9. Adhesion Quality Data

## One-Way ANOVA: PPM X Versus Pressure

Source	DF	SS	MS	F	P
Pressure	2	904	452	1.13	0.382
Error	6	2392	399		
Total	8	3296			

S = 19.97    R-Sq = 27.44%    R-Sq(adj) = 3.25%

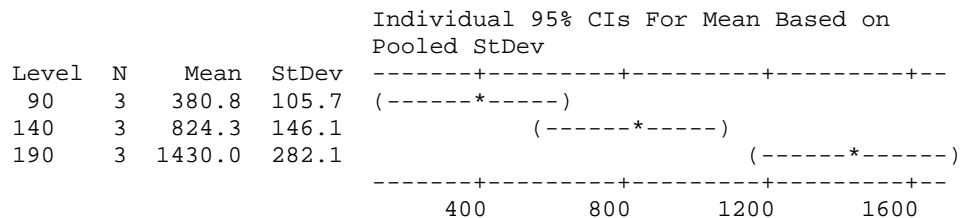


Pooled StDev = 19.97

## One-Way ANOVA: PPM Y Versus Pressure

Source	DF	SS	MS	F	P
Pressure	2	1664394	832197	22.27	0.002
Error	6	224243	37374		
Total	8	1888637			

S = 193.3    R-Sq = 88.13%    R-Sq(adj) = 84.17%

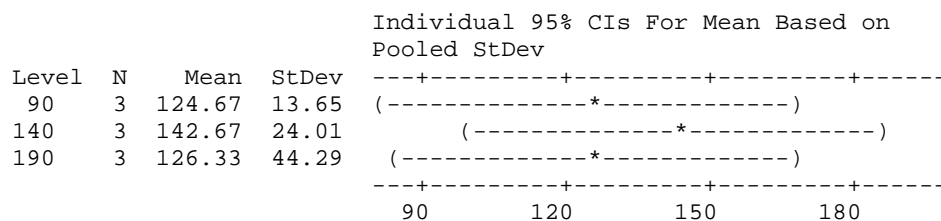


Pooled StDev = 193.3

## One-Way ANOVA: Discoloration Versus Pressure

Source	DF	SS	MS	F	P
Pressure	2	594	297	0.33	0.733
Error	6	5448	908		
Total	8	6042			

S = 30.13    R-Sq = 9.82%    R-Sq(adj) = 0.00%



Pooled StDev = 30.13

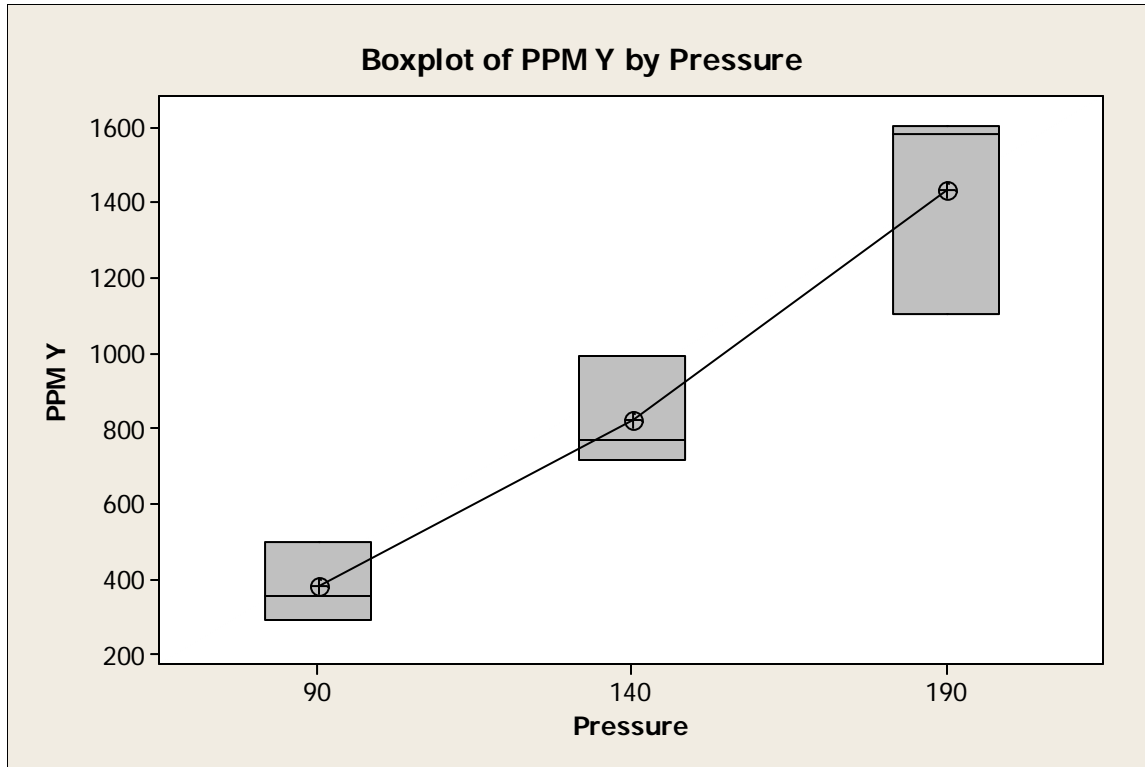


Figure 33. Boxplot of PPM Y by Pressure

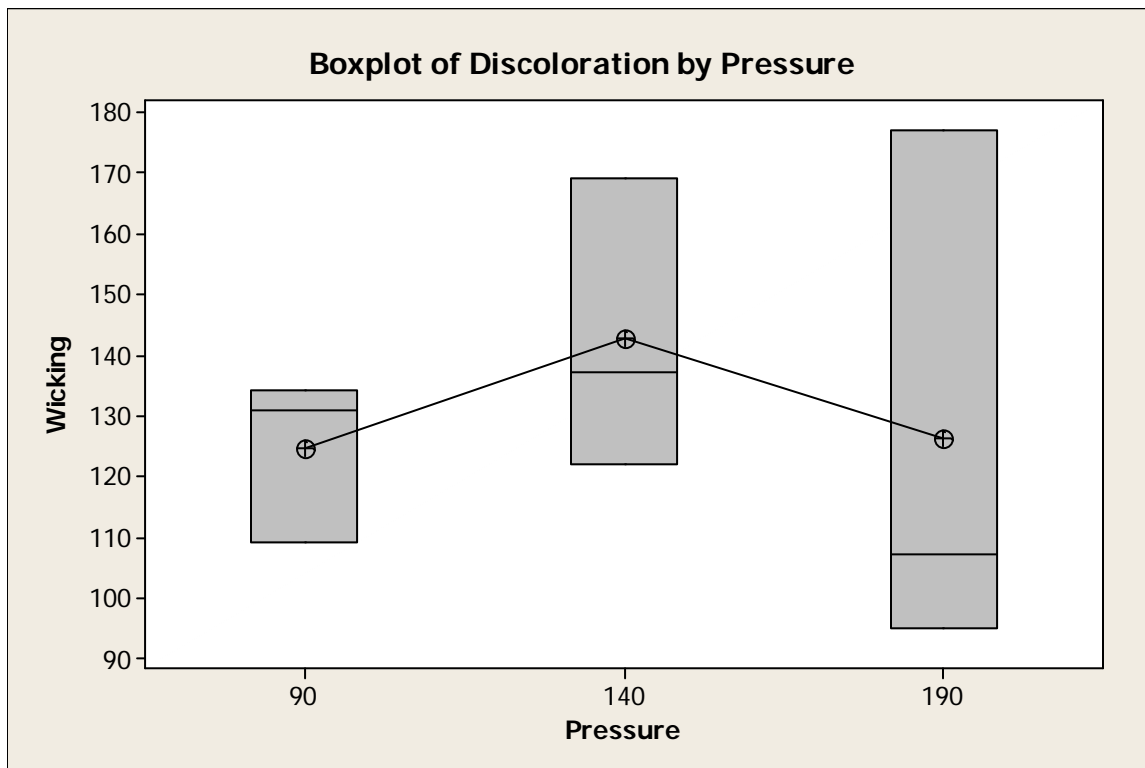


Figure 34. Boxplot of Discoloration by Pressure

# Appendix C

## Phase Three Data

### Sample (Two Ounce Copper Laminate)

Panel	Post Lamination Measurements					PPM 11	PPM 12	PPM 21	PPM 22	PPM 31	PPM 32	
	X Values	Column 1	Column 2	Column 3								Average PPM
SPPS 1	Row 1	1.14843	5.47607	9.74369		83.17930	28.11951	94.73198	7.02988	73.93715	60.92560	57.98724
	Row 2	1.14848	5.47607	9.7436								
	Row 3	1.14851	5.47619	9.74395								
SPPS 2	X Values	Column 1	Column 2	Column 3								
	Row 1	1.14883	5.4766	9.7439		53.14233	46.86585	115.52680	79.67194	20.79482	79.67194	65.94561
	Row 2	1.1481	5.4756	9.74276								
SPPS 3	Row 3	1.14667	5.47476	9.74192								
	X Values	Column 1	Column 2	Column 3								
	Row 1	1.14837	5.47576	9.74301		140.94270	58.58231	145.56377	35.14938	39.27911	21.08963	73.43448
SPPS 4	Row 2	1.148	5.47537	9.74272								
	Row 3	1.14719	5.47502	9.74243								
	X Values	Column 1	Column 2	Column 3								
SPPS 5	Row 1	1.14885	5.47619	9.74338		152.49538	72.64206	288.81701	35.14938	177.91128	65.61219	132.10455
	Row 2	1.14934	5.47609	9.74374								
	Row 3	1.14894	5.47617	9.74339								
SPPS 6	X Values	Column 1	Column 2	Column 3								
	Row 1	1.1497	5.47737	9.74437		76.24769	117.16462	73.93715	124.19449	60.07394	77.32865	88.15776
	Row 2	1.14981	5.47749	9.74446								
SPPS 7	Row 3	1.14928	5.47702	9.74419								
	X Values	Column 1	Column 2	Column 3								
	Row 1	1.15045	5.47811	9.74531		78.55823	70.29877	18.48429	67.95548	9.24214	4.68658	41.53758
SPPS 8	Row 2	1.14933	5.47725	9.74446								
	Row 3	1.14917	5.47721	9.74469								
	X Values	Column 1	Column 2	Column 3								
SPPS 9	Row 1	1.1498	5.47765	9.74463		34.65804	121.85120	34.65804	35.14938	48.52126	32.80609	51.27400
	Row 2	1.14903	5.47688	9.74423								
	Row 3	1.14778	5.47599	9.74363								
SPPS 10	X Values	Column 1	Column 2	Column 3								
	Row 1	1.14951	5.47695	9.74374		129.39002	166.37376	78.55823	171.06034	50.83179	65.61219	110.30439
	Row 2	1.14913	5.47679	9.74356								
SPPS 11	Row 3	1.14879	5.47657	9.74379								
	X Values	Column 1	Column 2	Column 3								
	Row 1	1.14876	5.47624	9.74352		120.14787	51.55243	203.32717	110.13474	16.17375	112.47803	102.30233
SPPS 12	Row 2	1.1494	5.47652	9.74355								
	Row 3	1.14846	5.47639	9.74341								
	X Values	Column 1	Column 2	Column 3								
SPPS 13	Row 1	1.14845	5.47575	9.74265		161.73752	140.59754	136.32163	149.97071	36.96858	63.26889	114.81081
	Row 2	1.14815	5.47556	9.74242								
	Row 3	1.14758	5.47542	9.74265								
SPPS 14	X Values	Column 1	Column 2	Column 3								
	Row 1	1.14939	5.47702	9.74454		85.48983	4.68658	6.93161	56.23902	57.76340	49.20914	43.38660
	Row 2	1.14902	5.47699	9.74425								
SPPS 15	Row 3	1.14847	5.47622	9.74393								
	X Values	Column 1	Column 2	Column 3								
	Row 1	1.14919	5.47643	9.74368		175.60074	58.58231	120.14787	126.53779	147.87431	379.61336	168.05940
SPPS 16	Row 2	1.14808	5.47556	9.74252								
	Row 3	1.14649	5.47385	9.74297								
	X Values	Column 1	Column 2	Column 3								
SPPS 17	Row 1	1.14893	5.47613	9.74259		184.84288	243.70240	103.97412	117.16462	99.35305	49.20914	133.04104
	Row 2	1.14811	5.47566	9.74266								
	Row 3	1.14808	5.47565	9.74294								
SPPS 18	X Values	Column 1	Column 2	Column 3								
	Row 1	1.14993	5.47681	9.74381		258.78004	117.16462	16.17375	157.00059	2.31054	7.02988	93.07657
	Row 2	1.14903	5.4771	9.74393								
SPPS 19	Row 3	1.14821	5.47622	9.74375								
	X Values	Column 1	Column 2	Column 3								
	Row 1	1.14692	5.47426	9.74143		152.49538	77.32865	46.21072	135.91095	0.00000	84.35852	82.71737
SPPS 20	Row 2	1.14769	5.47549	9.74241								
	Row 3	1.14871	5.47671	9.74385								
	X Values	Column 1	Column 2	Column 3								
SPPS 21	Row 1	1.14923	5.4764	9.7434		191.77449	117.16462	217.19039	86.70182	154.80591	11.71646	129.89228
	Row 2	1.14968	5.47674	9.74387								
	Row 3	1.1494	5.47673	9.74428								

Table 10. Panels 1-16 Rankings for X Values

	<b>X Values</b>	<b>Column 1</b>	<b>Column 2</b>	<b>Column 3</b>								
SPPS 17	<b>Row 1</b>	1.14917	5.4766	9.74367		131.70055	100.76157	23.10536	93.73169	36.96858	28.11951	69.06454
	<b>Row 2</b>	1.1488	5.4767	9.7438								
	<b>Row 3</b>	1.14868	5.47652	9.74414								
	<b>X Values</b>	<b>Column 1</b>	<b>Column 2</b>	<b>Column 3</b>								
SPPS 18	<b>Row 1</b>	1.15145	5.47893	9.74671		120.14787	65.61219	90.11091	23.43292	0.00000	49.20914	58.08550
	<b>Row 2</b>	1.15004	5.47765	9.74505								
	<b>Row 3</b>	1.1488	5.4768	9.74451								
	<b>X Values</b>	<b>Column 1</b>	<b>Column 2</b>	<b>Column 3</b>								
SPPS 19	<b>Row 1</b>	1.14852	5.47613	9.74343		90.11091	46.86585	140.94270	121.85120	76.24769	21.08963	82.85133
	<b>Row 2</b>	1.14826	5.47565	9.74263								
	<b>Row 3</b>	1.14738	5.47505	9.74246								
	<b>X Values</b>	<b>Column 1</b>	<b>Column 2</b>	<b>Column 3</b>								
SPPS 20	<b>Row 1</b>	1.14708	5.47473	9.7421		80.86876	30.46280	16.17375	28.11951	64.69501	89.04511	51.56082
	<b>Row 2</b>	1.14809	5.47602	9.7434								
	<b>Row 3</b>	1.14892	5.4772	9.74508								
	<b>X Values</b>	<b>Column 1</b>	<b>Column 2</b>	<b>Column 3</b>								
SPPS 21	<b>Row 1</b>	1.14711	5.47445	9.7413		152.49538	152.31400	124.76895	119.50791	48.52126	51.55243	108.19332
	<b>Row 2</b>	1.14745	5.47491	9.7419								
	<b>Row 3</b>	1.14786	5.47565	9.74337								
	<b>X Values</b>	<b>Column 1</b>	<b>Column 2</b>	<b>Column 3</b>								
SPPS 22	<b>Row 1</b>	1.14972	5.4772	9.74423		120.14787	110.13474	113.21627	91.38840	34.65804	72.64206	90.36456
	<b>Row 2</b>	1.14899	5.4765	9.74361								
	<b>Row 3</b>	1.14838	5.47623	9.74404								
	<b>X Values</b>	<b>Column 1</b>	<b>Column 2</b>	<b>Column 3</b>								
SPPS 23	<b>Row 1</b>	1.1487	5.47642	9.7438		64.69501	28.11951	13.86322	7.02988	50.83179	89.04511	42.26409
	<b>Row 2</b>	1.14765	5.47559	9.74306								
	<b>Row 3</b>	1.14705	5.47527	9.74315								
	<b>X Values</b>	<b>Column 1</b>	<b>Column 2</b>	<b>Column 3</b>								
SPPS 24	<b>Row 1</b>	1.14741	5.47483	9.74218		134.01109	35.14938	60.07394	98.41828	103.97412	79.67194	85.21646
	<b>Row 2</b>	1.14664	5.47438	9.74146								
	<b>Row 3</b>	1.14632	5.47387	9.74103								
	<b>X Values</b>	<b>Column 1</b>	<b>Column 2</b>	<b>Column 3</b>								
SPPS 25	<b>Row 1</b>	1.14809	5.47553	9.74283		129.39002	46.86585	103.97412	89.04511	92.42144	30.46280	82.02656
	<b>Row 2</b>	1.14873	5.47628	9.7434								
	<b>Row 3</b>	1.14917	5.47677	9.74414								
	<b>X Values</b>	<b>Column 1</b>	<b>Column 2</b>	<b>Column 3</b>								
SPPS 26	<b>Row 1</b>	1.14796	5.47574	9.74283		50.83179	96.07499	80.86876	112.47803	83.17930	96.07499	86.58464
	<b>Row 2</b>	1.14785	5.4755	9.74252								
	<b>Row 3</b>	1.14759	5.47523	9.74232								
	<b>X Values</b>	<b>Column 1</b>	<b>Column 2</b>	<b>Column 3</b>								
SPPS 27	<b>Row 1</b>	1.1499	5.4777	9.74511		46.21072	21.08963	85.48983	21.08963	117.83734	28.11951	53.30611
	<b>Row 2</b>	1.14915	5.47678	9.74419								
	<b>Row 3</b>	1.14841	5.4759	9.74328								
	<b>X Values</b>	<b>Column 1</b>	<b>Column 2</b>	<b>Column 3</b>								
SPPS 28	<b>Row 1</b>	1.14817	5.47589	9.74293		64.69501	107.79145	71.62662	89.04511	69.31608	37.49268	73.32782
	<b>Row 2</b>	1.14843	5.47612	9.74324								
	<b>Row 3</b>	1.14871	5.47641	9.74375								
	<b>X Values</b>	<b>Column 1</b>	<b>Column 2</b>	<b>Column 3</b>								
SPPS 29	<b>Row 1</b>	1.15002	5.4769	9.74365		258.78004	175.74692	161.73752	105.44815	43.90018	117.16462	143.79624
	<b>Row 2</b>	1.14872	5.47602	9.74307								
	<b>Row 3</b>	1.14823	5.47604	9.74304								
	<b>X Values</b>	<b>Column 1</b>	<b>Column 2</b>	<b>Column 3</b>								
SPPS 30	<b>Row 1</b>	1.14674	5.47361	9.7401		261.09057	236.67252	249.53789	82.01523	110.90573	117.16462	176.23109
	<b>Row 2</b>	1.14722	5.47414	9.74129								
	<b>Row 3</b>	1.14764	5.47516	9.74216								
	<b>X Values</b>	<b>Column 1</b>	<b>Column 2</b>	<b>Column 3</b>								
SPPS 31	<b>Row 1</b>	1.14682	5.47457	9.74174		57.76340	77.32865	64.69501	35.14938	43.90018	28.11951	51.15936
	<b>Row 2</b>	1.14674	5.47446	9.74211								
	<b>Row 3</b>	1.14722	5.47541	9.74279								
	<b>X Values</b>	<b>Column 1</b>	<b>Column 2</b>	<b>Column 3</b>								
SPPS 32	<b>Row 1</b>	1.1485	5.47593	9.74296		131.70055	110.13474	189.46396	147.62742	94.73198	147.62742	136.88101
	<b>Row 2</b>	1.14876	5.47594	9.74281								
	<b>Row 3</b>	1.14877	5.47636	9.74323								

**Table 11. Panels 17-32 Rankings for X Values**

Panel	Post Lamination Measurement				PPM 11	PPM 12	PPM 21	PPM 22	PPM 31	PPM 32	
	Y Values	Column 1	Column 2	Column 3							Average PPM
SPPS 1	Row 1	4.18085	4.18158	4.18083	104.38176	18.22905	15.88418	61.52304	122.53512	63.80167	64.39247
	Row 2	-0.22559	-0.22525	-0.22553							
	Row 3	-4.61411	-4.61412	-4.61385							
	Y Values	Column 1	Column 2	Column 3							
SPPS 2	Row 1	4.18104	4.18031	4.17888	9.07668	43.29399	11.34584	86.58798	20.42252	15.95042	31.11290
	Row 2	-0.22259	-0.22664	-0.22811							
	Row 3	-4.61431	-4.61562	-4.61678							
	Y Values	Column 1	Column 2	Column 3							
SPPS 3	Row 1	4.18099	4.18102	4.18006	86.22841	86.58798	52.19088	13.67179	97.57426	20.50768	59.46017
	Row 2	-0.22553	-0.22565	-0.22641							
	Row 3	-4.61375	-4.61419	-4.6151							
	Y Values	Column 1	Column 2	Column 3							
SPPS 4	Row 1	4.18085	4.18163	4.18102	22.69169	75.19482	99.84343	2.27863	72.61340	38.73673	51.89312
	Row 2	-0.22595	-0.22571	-0.22556							
	Row 3	-4.61422	-4.6143	-4.61433							
	Y Values	Column 1	Column 2	Column 3							
SPPS 5	Row 1	4.17966	4.18041	4.18013	310.87613	84.30935	83.95925	84.30935	77.15174	111.65292	125.37645
	Row 2	-0.22587	-0.22612	-0.22643							
	Row 3	-4.6141	-4.61435	-4.61454							
	Y Values	Column 1	Column 2	Column 3							
SPPS 6	Row 1	4.18008	4.18078	4.17983	179.26434	59.24441	93.03592	141.27512	45.38338	93.42387	101.93784
	Row 2	-0.22603	-0.22653	-0.22687							
	Row 3	-4.61437	-4.61451	-4.61506							
	Y Values	Column 1	Column 2	Column 3							
SPPS 7	Row 1	4.18095	4.18092	4.17981	322.22197	36.45810	74.88257	18.22905	127.07345	54.68714	105.59205
	Row 2	-0.22453	-0.22565	-0.22653							
	Row 3	-4.61329	-4.61417	-4.61489							
	Y Values	Column 1	Column 2	Column 3							
SPPS 8	Row 1	4.18115	4.18119	4.18072	22.69169	116.21018	9.07668	9.11452	102.11260	25.06494	47.37843
	Row 2	-0.22565	-0.22567	-0.22573							
	Row 3	-4.61374	-4.61423	-4.61422							
	Y Values	Column 1	Column 2	Column 3							
SPPS 9	Row 1	4.18014	4.18063	4.18015	231.45522	72.91619	147.49597	66.08030	231.45522	82.03072	138.57227
	Row 2	-0.22574	-0.22562	-0.22573							
	Row 3	-4.61402	-4.61393	-4.61397							
	Y Values	Column 1	Column 2	Column 3							
SPPS 10	Row 1	4.18045	4.1803	4.17945	206.49436	138.99649	167.91849	75.19482	238.26272	152.66828	163.25586
	Row 2	-0.22554	-0.22586	-0.2264							
	Row 3	-4.61353	-4.61413	-4.61433							
	Y Values	Column 1	Column 2	Column 3							
SPPS 11	Row 1	4.18096	4.18129	4.18063	2.26917	31.90083	81.69008	184.56911	20.42252	25.06494	57.65278
	Row 2	-0.22593	-0.22597	-0.22636							
	Row 3	-4.61439	-4.61538	-4.61507							
	Y Values	Column 1	Column 2	Column 3							
SPPS 12	Row 1	4.1821	4.18095	4.17926	11.34584	91.14524	40.84504	75.19482	88.49758	56.96577	60.66572
	Row 2	-0.22485	-0.22577	-0.22725							
	Row 3	-4.61305	-4.6147	-4.6161							
	Y Values	Column 1	Column 2	Column 3							
SPPS 13	Row 1	4.18008	4.1808	4.17934	229.18605	107.09566	29.49919	27.34357	283.64610	77.47345	125.70734
	Row 2	-0.22581	-0.22597	-0.22631							
	Row 3	-4.61394	-4.61445	-4.61457							
	Y Values	Column 1	Column 2	Column 3							
SPPS 14	Row 1	4.17974	4.18042	4.18	90.76675	47.85125	4.53834	157.22554	20.42252	50.12988	61.82238
	Row 2	-0.22676	-0.2265	-0.22681							
	Row 3	-4.61557	-4.61579	-4.61563							
	Y Values	Column 1	Column 2	Column 3							
SPPS 15	Row 1	4.17931	4.18059	4.18164	179.26434	75.19482	102.11260	150.38965	142.95763	118.48881	128.06797
	Row 2	-0.2268	-0.22586	-0.22463							
	Row 3	-4.61507	-4.6138	-4.61271							
	Y Values	Column 1	Column 2	Column 3							
SPPS 16	Row 1	4.17995	4.18053	4.1807	201.95602	70.63756	79.42091	79.75208	167.91849	56.96577	109.44181
	Row 2	-0.22606	-0.22602	-0.22546							
	Row 3	-4.61435	-4.61427	-4.61381							

Table 12. Panels 1-16 Rankings for Y Values



	Y Values	Column 1	Column 2	Column 3								
SPPS 17	Row 1	4.17956	4.17981	4.17938		27.23003	72.91619	83.95925	54.68714	102.11260	150.38965	81.88247
	Row 2	-0.22722	-0.22672	-0.22707								
	Row 3	-4.6155	-4.61556	-4.61501								
	Y Values	Column 1	Column 2	Column 3								
SPPS 18	Row 1	4.18241	4.18158	4.18003		136.15013	143.55375	106.65093	225.58447	22.69169	91.14524	120.96270
	Row 2	-0.22509	-0.22579	-0.22697								
	Row 3	-4.61432	-4.61538	-4.61597								
	Y Values	Column 1	Column 2	Column 3								
SPPS 19	Row 1	4.18072	4.18062	4.17988		115.72761	6.83589	18.15335	52.40851	188.34101	97.98113	79.90792
	Row 2	-0.22567	-0.2262	-0.22619								
	Row 3	-4.6143	-4.61457	-4.61436								
	Y Values	Column 1	Column 2	Column 3								
SPPS 20	Row 1	4.17884	4.18017	4.18092		161.11099	31.90083	145.22680	36.45810	152.03431	136.71786	110.57481
	Row 2	-0.22735	-0.22609	-0.22531								
	Row 3	-4.61581	-4.61453	-4.61331								
	Y Values	Column 1	Column 2	Column 3								
SPPS 21	Row 1	4.17899	4.18051	4.18069		222.37854	31.90083	72.61340	9.11452	156.57265	184.56911	112.85818
	Row 2	-0.22693	-0.22607	-0.22552								
	Row 3	-4.61539	-4.61463	-4.61331								
	Y Values	Column 1	Column 2	Column 3								
SPPS 22	Row 1	4.18081	4.1809	4.17976		45.38338	111.65292	54.46005	100.25976	108.92010	4.55726	70.87225
	Row 2	-0.22589	-0.22624	-0.22666								
	Row 3	-4.61498	-4.61528	-4.61524								
	Y Values	Column 1	Column 2	Column 3								
SPPS 23	Row 1	4.18097	4.18136	4.18076		68.07506	77.47345	24.96086	95.70250	77.15174	27.34357	61.78453
	Row 2	-0.22563	-0.22543	-0.2258								
	Row 3	-4.61389	-4.61445	-4.61428								
	Y Values	Column 1	Column 2	Column 3								
SPPS 24	Row 1	4.18238	4.18184	4.18119		34.03753	59.24441	86.22841	27.34357	93.03592	2.27863	50.36141
	Row 2	-0.22437	-0.22468	-0.2253								
	Row 3	-4.61271	-4.6134	-4.61391								
	Y Values	Column 1	Column 2	Column 3								
SPPS 25	Row 1	4.17965	4.18013	4.18048		68.07506	95.70250	129.34262	11.39315	86.22841	79.75208	78.41564
	Row 2	-0.22695	-0.2262	-0.22604								
	Row 3	-4.61513	-4.61485	-4.61429								
	Y Values	Column 1	Column 2	Column 3								
SPPS 26	Row 1	4.17982	4.18048	4.17936		81.69008	109.37429	77.15174	4.55726	147.49597	9.11452	71.56398
	Row 2	-0.22672	-0.22676	-0.22689								
	Row 3	-4.61484	-4.61538	-4.61545								
	Y Values	Column 1	Column 2	Column 3								
SPPS 27	Row 1	4.18137	4.18065	4.1794		4.53834	82.03072	11.34584	63.80167	113.45844	59.24441	55.73657
	Row 2	-0.22551	-0.2262	-0.227								
	Row 3	-4.61375	-4.61508	-4.61586								
	Y Values	Column 1	Column 2	Column 3								
SPPS 28	Row 1	4.18091	4.18143	4.18116		38.57587	31.90083	15.88418	82.03072	142.95763	38.73673	58.34766
	Row 2	-0.22582	-0.2254	-0.22511								
	Row 3	-4.61456	-4.61436	-4.61388								
	Y Values	Column 1	Column 2	Column 3								
SPPS 29	Row 1	4.18018	4.18065	4.17966		190.61018	88.86661	79.42091	4.55726	235.99356	22.78631	103.70580
	Row 2	-0.22588	-0.2259	-0.2262								
	Row 3	-4.61409	-4.61452	-4.6147								
	Y Values	Column 1	Column 2	Column 3								
SPPS 30	Row 1	4.18071	4.18238	4.1819		163.38015	72.91619	43.11421	36.45810	306.33779	116.21018	123.06944
	Row 2	-0.22547	-0.22471	-0.22365								
	Row 3	-4.61375	-4.61347	-4.61276								
	Y Values	Column 1	Column 2	Column 3								
SPPS 31	Row 1	4.17886	4.17999	4.17959		88.49758	29.62220	4.53834	59.24441	115.72761	36.45810	55.68137
	Row 2	-0.22765	-0.22689	-0.2268								
	Row 3	-4.61612	-4.61575	-4.61524								
	Y Values	Column 1	Column 2	Column 3								
SPPS 32	Row 1	4.18061	4.18097	4.18063		68.07506	61.52304	29.49919	50.12988	83.95925	6.83589	50.00372
	Row 2	-0.22599	-0.2258	-0.2259								
	Row 3	-4.61432	-4.61462	-4.61447								

Table 13. Panels 17-32 Rankings for Y Values

The following five tables contain the actual measured amount of delamination/solder wicking on each land on each panel.

Cable	Hole	Panel 1		Panel 2		Panel 3		Panel 4		Panel 5		Panel 6		Panel 7		Panel 8	
		Discoloration	Total/ Part	Discoloration	Total/ Part	Discoloration	Total/ Part	Discoloration	Total/ Part	Discoloration	Total/ Part	Discoloration	Total/ Part	Discoloration	Total/ Part	Discoloration	Total/ Part
	1	-		-		-		-		-		-		-		-	
	2	-		0.007		-		-		-		-		-		-	
	3	-		0.017		0.030		-		-		-		-		-	
	4	-	0.000	-	0.024	-	0.030	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000
	5	-		-		0.005		-		-		-		-		-	
	6	-		0.006		0.005		-		-		-		-		-	
	7	-		-		-		-		-		-		-		-	
	8	-		-		0.005		0.002		-		-		-		-	
	9	-		-		0.004		-		-		-		-		-	
	10	-		-		-		0.002		-		-		-		-	
	11	-		-		0.003		-		-		-		-		-	
	12	-		0.006		0.004		0.002		-		-		-		-	
	13	-		-		0.002		-		-		-		-		-	
	14	-		-		0.007		-		-		-		-		-	
	15	-	0.000	-	0.012	0.007	0.042	-	0.006	-	0.000	-	0.000	-	0.000	-	0.000
	16	-		0.008		0.006		-		-		-		-		-	
	17	-	0.000	-	0.008	0.006	0.012	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000
	18	-		0.007		-		-		-		-		-		-	
	19	-	0.000	0.015	0.022	0.007	0.007	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000
	20	-		0.025		0.012		0.003		-		-		-		-	
	21	-		0.035		0.035		-		-		-		-		-	
	22	-		0.033		-		-		-		-		-		-	
	23	-		0.035		0.030		-		-		-		-		-	
	24	-		0.033		0.025		-		-		-		-		-	
	25	-	0.000	-	0.161	-	0.102	-	0.003	-	0.000	-	0.000	-	0.000	-	0.000
	26	-		-		0.007		-		-		-		-		-	
	27	-		-		0.007		-		-		-		-		-	
	28	-		0.008		0.002		-		-		-		-		-	
	29	-		0.009		-		-		-		-		-		-	
	30	-		-		0.004		-		-		-		-		-	
	31	-		0.010		-		-		-		-		-		-	
	32	-		-		0.003		-		-		-		-		-	
	33	-		-		-		-		-		-		-		-	
	34	-		0.004		0.004		-		-		-		-		-	
	35	-		0.006		-		-		-		-		-		-	
	36	-	0.000	0.005	0.042	0.003	0.030	0.004	0.004	-	0.000	-	0.000	-	0.000	-	0.000
	37	-		0.002		0.006		-		-		-		-		-	
	38	-		0.005		0.003		-		-		-		-		-	
	39	-	0.000	0.007	0.014	-	0.009	-	0.000	-	0.000	-	0.000	0.003	0.003	-	0.000
	40	-		-		-		-		-		-		-		-	
	41	-		-		-		-		-		-		-		-	
	42	-		0.010		0.006		-		-		-		-		-	
	43	-	0.000	0.010	0.020	0.007	0.013	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000
	44	-		0.005		0.012		-		-		-		-		-	
	45	-		-		0.007		-		-		-		-		-	
	46	-		-		0.008		-		-		-		-		-	
	47	-		-		0.009		-		-		-		-		-	
	48	-		-		0.008		-		-		-		-		-	
	49	-		-		-		-		-		-		-		-	
	50	-		0.003		0.025		-		-		-		-		-	
	51	-		-		-		0.002		-		-		-		-	
	52	-		-		-		-		-		-		-		-	
	53	-		-		-		-		-		-		-		-	
	54	-		-		-		-		-		-		-		-	
	55	-		-		0.006		-		-		-		-		-	
	56	-		-		-		-		-		-		-		-	
	57	-	0.000	-	0.008	-	0.075	-	0.002	-	0.000	-	0.000	-	0.000	-	0.000
	58	-		0.005		0.01		-		-		-		-		-	
	59	-	0.000	0.009	0.014	0.010	0.020	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000
		Dark .005 in halo around each land - annular ring failures due to adhesive squeeze out								Larger .010 dark halo around lands. Very dark, black even back along conductors. Burnt adhesive		Dark .005 in halo around each land - annular ring failures due to adhesive squeeze out		Annular ring ULL, due to adhesive squeeze out		Dark .005 in halo around each land - annular ring failures due to adhesive squeeze out	

Table 14. Panel 1-8 Delamination/Solder Wicking Results

Panel 9	Total/ Part	Panel 10	Total/ Part	Panel 11	Total/ Part	Panel 12	Total/ Part	Panel 13	Total/ Part	Panel 14	Total/ Part	Panel 15	Total/ Part	Panel 16	Total/ Part
Discoloration		Discoloration		Discoloration		Discoloration		Discoloration		Discoloration		Discoloration		Discoloration	
-		-		-		-		-		-		-		-	
-		-		-		0.045		-		-		0.006		-	
-		-		-		0.085		-		-		0.060		-	
-	0.000	-	0.000	-	0.000	-	0.130	-	0.000	-	0.000	-	0.066	-	0.000
-		-		-		-		-		-		-		-	
-		-		-		-		-		-		0.017		-	
-		-		-		-		-		-		0.010		-	
-		-		-		-		-		-		0.010		-	
-		-		-		0.007		-		-		0.012		-	
-		-		-		0.012		-		-		0.010		-	
-		-		-		-		-		-		0.013		-	
-		-		-		0.004		-		-		0.008		-	
-		-		-		0.005		-		-		0.010		-	
-		-		-		-		-		-		0.007		-	
-	0.000	-	0.000	-	0.000	0.006	0.034	-	0.000	-	0.000	0.012	0.109	-	0.000
-		-		-		0.006		-		-		0.021		-	
0.003	0.003	-	0.000	-	0.000	0.010	0.016	-	0.000	-	0.000	0.014	0.035	-	0.000
-		-		-		-		-		-		0.011		-	
-	0.000	-	0.000	-	0.000	0.037	0.037	-	0.000	-	0.000	0.063	0.074	-	0.000
0.004		-		-		0.006		0.008		-		0.060		-	
-		-		-		0.006		-		-		0.036		-	
-		-		-		0.015		-		-		0.070		-	
-		-		-		0.020		-		-		0.035		-	
-		-		-		0.040		-		-		0.040		-	
-	0.004	-	0.000	-	0.000	-	0.087	-	0.008	-	0.000	0.005	0.246	-	0.000
-		-		-		-		-		-		-		-	
-		-		-		0.005		-		-		0.013		-	
-		-		-		0.003		-		-		0.017		-	
-		-		-		0.007		-		-		0.018		-	
-		-		-		-		-		-		-		-	
-		-		-		0.008		-		-		0.015		-	
-		-		-		-		-		-		0.008		-	
-		-		-		-		-		-		0.007		-	
-		-		-		0.009		-		-		0.010		-	
-		-		-		-		-		-		-		-	
-	0.000	-	0.000	-	0.000	0.003	0.035	-	0.000	-	0.000	0.009	0.097	-	0.000
-		-		-		0.010		-		-		0.010		-	
-		-		-		0.005		-		-		0.012		-	
0.003	0.003	-	0.000	-	0.000	0.215	0.230	-	0.000	-	0.000	0.005	0.027	-	0.000
-		-		-		-		-		-		0.005		-	
-		-		-		-		-		-		0.004		-	
-		-		-		0.005		-		-		0.005		-	
-	0.000	-	0.000	-	0.000	0.005	0.010	-	0.000	-	0.000	0.011	0.025	-	0.000
-		-		-		0.012		-		-		0.010		-	
-		-		-		0.007		-		-		0.011		-	
-		-		-		0.007		-		-		0.005		-	
-		-		-		0.010		-		-		0.010		-	
-		-		-		-		-		-		-		-	
-		-		-		-		-		-		-		-	
-		-		-		-		-		-		0.022		-	
-		-		-		-		-		-		0.030		-	
-		-		-		0.025		-		-		0.003		-	
-		-		-		0.005		-		-		0.007		-	
-		-		-		0.006		-		-		0.008		-	
-		-		-		-		-		-		0.010		-	
-		-		-		-		-		-		0.002		-	
-	0.000	-	0.000	-	0.000	-	0.072	-	0.000	-	0.000	-	0.118	-	0.000
-		-		-		0.005		-		-		0.008		-	
-	0.000	-	0.000	-	0.000	0.011	0.016	-	0.000	-	0.000	0.005	0.013	-	0.000
		Dark .005 in halo around each land - annular ring failures due to adhesive squeeze out		Larger .010 dark halo around lands. Very dark, black even back along conductors. Burnt adhesive Possible non adhered areas around land. Light colored										Larger .010 dark halo around lands. Very dark, black even back along conductors. Burnt adhesive	

Table 15. Panel 9-16 Delamination/Solder Wicking Results

Panel 17	Total/ Part	Panel 18	Total/ Part	Panel 19	Total/ Part	Panel 20	Total/ Part	Panel 21	Total/ Part	Panel 22	Total/ Part	Panel 23	Total/ Part	Panel 24	Total/ Part
Discoloration		Discoloration		Discoloration		Discoloration		Discoloration		Discoloration		Discoloration		Discoloration	
-		-		-		-		-		-		-		-	
-		-		-		-		-		-		-		-	
-		0.068		0.010		-		-		-		0.012		-	
-	0.000	-	0.068	-	0.010	-	0.000	-	0.000	-	0.000	-	0.012	-	0.000
-		0.008		-		-		-		-		-		-	
-		0.009		-		-		-		-		-		-	
-		0.007		-		-		-		-		-		-	
-		0.005		-		-		-		-		-		-	
-		0.002		-		-		-		-		-		-	
-		-		0.004		-		-		-		-		-	
-		0.005		0.008		-		-		-		-		-	
-		0.007		-		-		-		-		-		-	
-		0.006		0.006		-		-		-		-		-	
-		0.005		0.005		-		-		-		-		-	
-	0.000	0.005	0.059	0.005	0.028	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000
-		0.006		0.004		-		-		-		0.002		-	
-	0.000	0.007	0.013	0.007	0.011	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000
-		-		-		-		-		-		-		-	
-	0.000	-	0.000	0.007	0.007	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000
-		0.023		-		0.006		-		-		0.005		-	
-		0.010		0.038		-		-		-		-		-	
-		0.012		-		-		-		-		-		-	
-		0.005		0.015		-		-		-		-		-	
-		-		0.040		-		-		-		-		-	
-	0.000	0.011	0.061	0.038	0.131	-	0.006	-	0.000	-	0.000	-	0.005	-	0.000
-		-		-		-		-		-		-		-	
-		-		-		-		-		-		-		-	
-		-		0.002		-		-		-		-		-	
-		-		-		-		-		-		-		-	
-		-		-		-		-		-		-		-	
-		-		-		-		-		-		-		-	
-		-		-		-		-		-		-		-	
-		-		-		-		-		-		-		-	
-		0.005		-		-		-		-		-		-	
-		-		-		-		-		-		-		-	
-	0.000	-	0.005	-	0.002	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000
-		0.008		0.004		0.006		-		-		0.003		-	
-		0.005		0.002		-		-		-		-		-	
-	0.000	0.055	0.068	-	0.006	-	0.006	-	0.000	-	0.000	0.003	0.006	-	0.000
-		-		-		-		-		-		-		-	
-		-		-		-		-		-		-		-	
-		0.005		0.004		-		-		-		-		-	
-	0.000	0.005	0.010	0.004	0.008	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000
-		0.022		0.037		-		-		-		-		-	
-		0.008		0.006		-		-		-		-		-	
-		0.005		0.007		-		-		-		-		-	
-		-		0.006		-		-		-		-		-	
-		-		0.004		-		-		-		-		-	
-		0.002		-		-		-		-		-		-	
-		0.013		0.005		-		-		-		-		-	
-		-		-		-		-		-		-		-	
-		-		-		-		-		-		-		-	
-		-		-		-		-		-		-		-	
-		0.008		-		-		-		-		-		-	
-		-		-		-		-		-		-		-	
-	0.000	-	0.058	-	0.065	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000
-		0.005		0.005		-		-		-		-		-	
-	0.000	0.011	0.016	0.010	0.015	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000
Dark .005 in halo around each land - annular ring failures due to adhesive squeeze out						Annular ring ULL due to adhesive squeeze out		Larger .010 dark halo around lands. Very dark, black even back along conductors. Burnt adhesive Possible non adhered areas around land. Light colored		Dark .005 in halo around each land - annular ring failures due to adhesive squeeze out		Annular ring ULL due to adhesive squeeze out		Dark .005 in halo around each land - annular ring failures due to adhesive squeeze out	

**Table 16. Panel 17-24 Delamination/Solder Wicking Results**

Panel 25	Total/ Part	Panel 26	Total/ Part	Panel 27	Total/ Part	Panel 28	Total/ Part	Panel 29	Total/ Part	Panel 30	Total/ Part	Panel 31	Total/ Part	Panel 32	Total/ Part
Discoloration		Discoloration		Discoloration		Discoloration		Discoloration		Discoloration		Discoloration		Discoloration	
-		-		-		0.007		-		-		-		-	
-		-		-		0.005		0.010		-		0.010		-	
0.022		-		-		0.027		-		-		0.120		-	
-	0.022	-	0.000	-	0.000	0.004	0.043	-	0.010	-	0.000	0.004	0.134	-	0.000
-		-		-		0.003		-		-		0.008		-	
-		-		-		0.005		-		-		0.013		-	
-		-		-		-		-		-		0.005		-	
-		-		-		-		-		-		0.003		-	
-		-		-		-		-		-		0.006		-	
-		-		-		-		-		-		0.005		-	
-		-		-		0.013		-		-		0.005		-	
-		-		-		0.006		-		-		0.005		-	
-		-		-		0.009		-		-		0.004		-	
-		-		-		-		-		-		0.005		-	
-	0.000	-	0.000	-	0.000	0.008	0.044	-	0.000	-	0.000	0.005	0.064	-	0.000
-		-		-		0.005		-		-		0.025		-	
-	0.000	-	0.000	-	0.000	0.017	0.022	0.005	0.005	-	0.000	0.016	0.041	-	0.000
-		-		-		0.017		-		-		-		-	
-	0.000	-	0.000	-	0.000	0.060	0.077	-	0.000	-	0.000	0.015	0.015	-	0.000
0.005		-		-		0.075		-		-		0.153		-	
-		-		-		0.040		-		-		0.018		-	
-		-		-		0.038		-		-		0.014		-	
-		-		-		0.035		-		-		0.028		-	
-		-		-		0.038		-		-		0.030		-	
-	0.005	-	0.000	-	0.000	0.025	0.251	-	0.000	-	0.000	-	0.243	-	0.000
-		-		-		0.006		-		-		0.008		-	
-		-		-		0.010		-		-		0.008		-	
-		-		-		0.01		-		-		0.010		-	
-		-		-		0.007		-		-		0.008		-	
-		-		-		-		-		-		-		-	
-		-		-		0.009		-		-		0.010		-	
-		-		-		-		-		-		0.015		-	
-		-		-		0.002		-		-		0.010		-	
-		-		-		0.007		-		-		0.016		-	
-		-		-		-		-		-		0.007		-	
-	0.000	-	0.000	-	0.000	0.009	0.060	-	0.000	-	0.000	0.005	0.097	-	0.000
0.002		-		-		-		-		-		0.007		-	
-		-		-		0.004		-		-		0.007		-	
0.010	0.012	-	0.000	-	0.000	0.011	0.015	0.003	0.003	-	0.000	0.054	0.068	-	0.000
-		-		-		-		-		-		0.015		-	
-		-		-		-		-		-		0.003		-	
-		-		-		0.008		-		-		0.008		-	
-	0.000	-	0.000	-	0.000	0.008	0.016	-	0.000	-	0.000	0.010	0.036	-	0.000
-		-		-		0.016		-		-		0.048		-	
-		-		-		-		-		-		0.012		-	
-		-		-		-		-		-		0.011		-	
-		-		-		-		-		-		0.013		-	
-		-		-		-		-		-		-		-	
-		-		-		-		-		-		0.018		-	
-		-		-		-		-		-		0.012		-	
-		-		-		0.008		-		-		-		-	
-		-		-		0.002		-		-		-		-	
-		-		-		0.009		-		-		-		-	
-		-		-		0.009		-		-		-		-	
-		-		-		0.011		-		-		0.007		-	
-		-		-		-		-		-		0.007		-	
-	0.000	-	0.000	-	0.000	0.003	0.058	-	0.000	-	0.000	0.004	0.132	-	0.000
-		-		-		0.003		-		-		0.008		-	
-	0.000	-	0.000	-	0.000	0.010	0.013	-	0.000	-	0.000	0.020	0.028	-	0.000
Annular ring ULL due to adhesive squeeze out		Dark .005 in halo around each land - annular ring failures due to adhesive squeeze out		Larger .010 dark halo around lands. Very dark, black even back along conductors. Burnt adhesive Possible non adhered areas around land. Light colored						Larger .010 dark halo around lands. Very dark, black even back along conductors. Burnt adhesive Possible non adhered areas around land. Light colored				Larger .010 dark halo around lands. Very dark, black even back along conductors. Burnt adhesive Possible non adhered areas around land. Light colored	

Table 17. Panel 25-32 Delamination/Solder Wicking Results

Panel			Total	Rank			Total	Rank			Total	Rank			Total	Rank			Total	Rank	
1	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0
5	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0
6	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0
8	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0
10	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0
11	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0
14	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0
16	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0
17	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0
21	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0
22	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0
24	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0
26	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0
27	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0
30	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0
32	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0
7	0.000	0.003	0.003	1	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	1
13	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.008	0.000	0.008	1	1
4	0.000	0.000	0.000	0	0.006	0.004	0.010	1	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.003	0.002	0.005	1	2
20	0.000	0.006	0.006	1	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.006	0.000	0.006	1	2
9	0.000	0.003	0.003	1	0.000	0.000	0.000	0	0.003	0.000	0.003	1	0.000	0.000	0.000	0	0.004	0.000	0.004	1	3
25	0.022	0.012	0.034	3	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.000	0.000	0.000	0	0.005	0.000	0.000	0	3
29	0.010	0.003	0.013	2	0.000	0.000	0.000	0	0.005	0.000	0.005	1	0.000	0.000	0.000	0	0.000	0.000	0.000	0	3
23	0.012	0.006	0.018	2	0.000	0.000	0.000	0	0.002	0.000	0.002	1	0.000	0.000	0.000	0	0.005	0.000	0.005	1	4
19	0.010	0.006	0.016	2	0.028	0.002	0.030	3	0.011	0.015	0.026	3	0.007	0.008	0.015	2	0.131	0.065	0.196	10	20
2	0.024	0.014	0.038	4	0.012	0.042	0.054	6	0.008	0.014	0.022	3	0.022	0.020	0.042	5	0.161	0.008	0.169	10	28
3	0.030	0.009	0.039	4	0.042	0.030	0.072	8	0.012	0.020	0.032	4	0.007	0.013	0.020	2	0.102	0.075	0.177	10	28
18	0.068	0.068	0.136	10	0.059	0.005	0.064	7	0.013	0.016	0.029	3	0.000	0.010	0.010	1	0.061	0.058	0.119	10	31
12	0.130	0.230	0.360	10	0.034	0.035	0.069	7	0.016	0.016	0.032	4	0.037	0.010	0.047	5	0.087	0.072	0.159	10	36
28	0.043	0.015	0.058	6	0.044	0.060	0.104	10	0.022	0.013	0.035	4	0.077	0.016	0.093	10	0.251	0.058	0.309	10	40
31	0.134	0.068	0.202	10	0.064	0.097	0.161	10	0.041	0.028	0.069	7	0.015	0.036	0.051	6	0.243	0.132	0.375	10	43
15	0.066	0.027	0.093	10	0.109	0.097	0.206	10	0.035	0.013	0.048	5	0.074	0.025	0.099	10	0.246	0.118	0.364	10	45

Table 18. Panel Rankings

## Sample (One Ounce Copper Laminate)

The following five tables contain the actual measured amount of delamination/solder wicking on each land on each panel, soft press pad stackup panels 1 through 36 and hard press pad stackup panels 1 through 9.

		Panel 1		Panel 2		Panel 3		Panel 4		Panel 5		Panel 6		Panel 7		Panel 8		Panel 9	
Cable	Hole	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part
	1	-		-		-		-		-		-		-		-		-	
	2	-		-		-		-		-		-		0.010		-		-	
	3	-		-		-		0.004		0.004		-		0.005		-		-	
	4	-	0.000	-	0.000	-	0.000	-	0.004	-	0.004	-	0.000	-	0.015	-	0.000	-	0.000
	5	0.005		-		0.006		-		-		-		-		-		-	
	6	0.005		-		-		0.005		0.010		-		0.010		-		-	
	7	0.010		-		-		-		-		-		-		-		-	
	8	0.007	0.027	-	0.000	-	0.006	-	0.005	-	0.010	-	0.000	-	0.010	-	0.000	-	0.000
	9	-		-		-		-		-		-		-		-		-	
	10	-		-		-		0.003		-		0.006		0.003		0.005		0.004	
	11	0.010		-		0.009		0.005		-		-		0.007		-		-	
	12	-		-		-		-		-		-		-		-		-	
	13	0.005		-		0.005		0.002		0.005		0.003		0.004		0.002		-	
	14	0.012		0.010		0.014		0.007		0.015		0.010		0.014		0.005		-	
	15	-		0.004		-		0.001		0.005		0.004		0.005		0.003		0.002	
	16	0.010		0.005		0.01		0.004		0.010		0.003		0.008		0.005		0.002	
	17	0.012		0.005		0.007		0.004		0.010		0.004		0.010		0.005		0.005	
	18	-	0.049	0.003	0.027	-	0.045	0.002	0.028	0.002	0.047	0.003	0.033	-	0.051	-	0.025	0.002	0.015
	19	-		-		-		-		-		-		-		0.005		-	
	20	0.008		-		0.008		0.004		0.007		-		0.010		0.005		0.004	
	21	0.012		0.005		0.008		-		0.010		0.007		0.015		0.005		-	
	22	0.012		0.005		-		-		0.010		0.005		0.012		0.005		-	
	23	0.006		-		0.01		-		0.007		0.008		0.011		0.005		-	
	24	-		0.006		0.009		-		0.007		0.007		0.012		0.005		-	
	25	0.014		-		0.006		0.005		0.003		0.007		0.010		-		0.007	
	26	0.012		0.002		-		0.005		0.008		0.007		0.015		0.006		-	
	27	0.012		-		0.007		0.005		0.007		0.006		0.012		0.005		-	
	28	0.008		-		0.014		0.007		0.007		0.005		0.010		0.004		0.007	
	29	0.012		0.005		0.005		0.004		0.005		0.008		0.005		-		-	
	30	0.010	0.106	0.005	0.028	0.005	0.072	0.005	0.035	0.007	0.078	0.006	0.066	0.010	0.122	0.005	0.050	-	0.018
	31	-		-		-		-		-		-		-		-		-	
	32	0.006		-		0.008		0.003		0.007		0.002		0.005		0.002		0.003	
	33	0.078		-		0.037		0.004		0.085		0.005		0.043		0.005		-	
	34	0.053		0.010		0.020		-		0.170		0.010		0.020		0.005		0.005	
	35	0.075	0.212	0.007	0.017	0.014	0.079	0.008	0.015	0.020	0.282	0.010	0.027	0.052	0.120	0.008	0.020	0.005	0.013
	36	0.005		-		-		-		-		0.002		0.010		-		-	
	37	0.005		-		-		-		-		0.002		0.010		-		-	
	38	0.005		-		-		-		-		0.002		0.010		-		-	
	39	0.007		-		-		-		-		-		0.010		-		-	
	40	0.008		-		0.007		-		0.004		-		0.007		-		-	
	41	0.007		0.005		0.007		-		0.008		0.005		0.006		0.003		-	
	42	0.009		-		0.008		0.002		0.005		0.003		0.010		-		-	
	43	0.007		-		0.004		-		0.005		0.002		0.007		-		-	
	44	0.006		0.004		0.008		-		0.005		0.004		0.007		-		-	
	45	-	0.059	-	0.009	-	0.034	0.004	0.006	0.007	0.034	0.004	0.024	-	0.077	0.003	0.006	-	0.000
	46	-		-		-		-		-		-		0.007		0.004		-	
	47	-		-		-		-		-		-		0.005		-		-	
	48	-		-		-		-		-		-		0.005		-		-	
	49	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	0.005	0.022	-	0.004	-	0.000
	50	-		-		0.010		-		-		-		0.007		0.002		-	
	51	0.003		-		-		-		-		-		-		-		-	
	52	0.010		-		-		-		0.006		0.005		0.008		-		-	
	53	-	0.013	-	0.000	-	0.010	-	0.000	-	0.006	-	0.005	-	0.015	0.002	0.004	-	0.000
	54	-		0.005		0.005		-		0.014		-		0.012		0.004		-	
	55	0.032		0.007		0.012		0.007		0.012		0.010		0.017		-		0.007	
	56	0.010		-		0.005		-		-		0.004		0.010		-		0.007	
	57	-		-		-		-		-		-		-		-		-	
	58	0.002	0.044	0.002	0.014	-	0.022	0.004	0.011	-	0.026	0.005	0.019	0.008	0.047	-	0.004	-	0.014
	59	-		-		0.007		0.004		-		0.007		0.008		0.005		0.008	
	60	-		-		-		-		-		-		-		-		-	
	61	-		-		-		-		-		-		0.005		-		-	
	62	-		-		-		-		-		-		0.005		-		-	
	63	-		-		-		-		-		-		0.005		-		-	
	64	-		-		-		-		-		-		0.005		-		-	
	65	0.008		-		0.002		-		0.010		0.004		0.010		-		0.005	
	66	0.007		0.003		0.002		-		-		-		0.010		-		-	
	67	0.003		-		0.008		0.003		0.005		0.003		0.010		0.002		-	
	68	0.005		-		0.008		-		0.007		0.005		0.010		-		-	
	69	0.007		-		0.009		-		0.007		0.004		0.012		-		0.005	
	70	0.010	0.040	0.003	0.006	0.010	0.046	0.007	0.006	0.035	-	0.023	0.012	0.092	-	0.007	-	-	0.018
	Total		0.550		0.101		0.314		0.111		0.522		0.197		0.571		0.120		0.078

Table 19. Panel 1-9 Delamination/Solder Wicking Results (One Ounce Copper)

		Panel 10		Panel 11		Panel 12		13		Panel 14		Panel 15		Panel 16		Panel 17		Panel 18	
Cable	Hole	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part
	1	-		-		-		-		-		-		-		-		-	
	2	-		-		-		0.008		-		-		-		-		-	
	3	-		-		0.004		0.010		-		-		-		-		-	
	4	-	0.000	-	0.000	-	0.004	-	0.018	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000
	5	0.002		-		-		0.009		-		0.005		0.004		-		0.005	
	6	0.003		0.004		-		0.007		-		0.005		-		-		-	
	7	-		-		-		0.010		0.003		0.007		0.010		-		0.015	
	8	-	0.005	-	0.004	-	0.000	-	0.026	0.004	0.007	-	0.017	-	0.014	-	0.000	0.004	0.024
	9	-		-		-		-		-		-		0.002		-		-	
	10	0.004		-		-		0.010		0.003		0.005		-		0.005		0.003	
	11	-		0.002		0.004		0.005		-		0.004		-		-		0.004	
Voids	12	-		-		-		-		-		-		0.005		-		-	
	13	0.002		0.005		-		0.007		0.008		0.003		0.005		-		0.003	
	14	0.007		-		0.005		-		0.013		0.014		0.012		0.006		0.015	
	15	0.003		0.002		0.002		-		0.004		0.003		-		0.002		-	
	16	0.004		0.010		0.003		0.008		0.005		0.008		0.008		0.002		0.002	
	17	0.002		0.010		0.005		0.012		-		0.010		-		0.003		0.003	
	18	0.003	0.025	0.003	0.032	-	0.019	0.006	0.048	0.002	0.035	0.004	0.051	0.005	0.037	0.002	0.020	-	0.030
	19	-		-		-		-		-		-		-		-		-	
	20	0.005		0.005		-		0.007		0.005		-		-		-		0.008	
	21	-		0.005		0.003		0.012		0.003		0.010		0.005		0.005		0.007	
	22	-		0.005		-		0.012		0.004		0.002		0.005		0.003		0.005	
	23	0.005		-		0.005		0.002		0.005		0.007		0.006		-		0.005	
	24	-		-		-		-		0.007		0.007		0.006		0.002		0.005	
	25	0.005		0.004		-		0.010		-		0.007		-		-		-	
	26	0.005		0.008		-		0.012		-		0.006		0.007		0.006		0.004	
	27	0.006		0.005		-		0.011		-		0.005		0.008		-		0.005	
	28	-		0.005		-		0.015		-		0.015		0.005		-		0.005	
	29	-		-		-		0.010		0.007		-		0.006		-		0.004	
	30	-	0.026	0.005	0.042	0.005	0.013	0.011	0.102	0.005	0.036	0.005	0.064	0.007	0.055	0.005	0.021	0.002	0.050
	31	-		-		-		-		-		-		-		-		-	
	32	0.002		-		-		0.012		0.005		0.003		0.007		0.012		0.005	
	33	0.007		0.010		0.006		0.030		0.010		0.012		0.015		0.005		0.012	
	34	0.006		0.012		-		0.020		0.015		0.013		0.015		0.015		0.012	
	35	0.007	0.022	0.007	0.029	0.010	0.016	0.009	0.071	-	0.030	0.006	0.034	0.007	0.044	0.008	0.040	0.003	0.032
	36	-		0.002		0.002		-		-		-		-		-		-	
	37	0.002		-		-		-		-		-		-		-		-	
	38	0.002		0.002		-		-		-		-		-		-		-	
	39	0.002		-		-		0.007		-		-		-		-		-	
	40	0.005		-		0.003		0.008		0.006		-		0.004		0.003		-	
	41	0.003		0.007		0.002		0.007		0.003		0.005		0.005		0.004		0.007	
	42	0.005		0.007		-		0.007		-		0.004		0.005		0.003		0.008	
	43	0.005		0.005		0.003		-		0.003		-		0.003		0.005		0.004	
	44	0.004		0.007		-		0.005		0.002		0.001		0.006		0.003		0.008	
	45	0.004	0.032	0.005	0.035	-	0.010	-	0.034	-	0.014	-	0.010	0.004	0.027	-	0.018	0.003	0.030
	46	-		-		-		-		-		-		-		-		-	
	47	0.002		-		-		-		-		-		-		-		-	
	48	-		-		-		-		-		-		-		-		-	
	49	-	0.002	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000
	50	-		0.004		-		0.012		-		-		-		-		-	
	51	-		-		-		-		-		-		-		-		-	
	52	-		0.005		-		-		-		-		-		-		-	
	53	-	0.000	-	0.009	-	0.000	-	0.012	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000
	54	0.007		0.007		0.007		0.025		0.007		0.010		-		-		0.005	
	55	0.004		0.010		0.005		0.030		0.003		0.010		0.008		0.007		0.008	
	56	-		0.010		0.006		-		-		0.005		0.005		-		0.002	
	57	-		-		-		-		-		-		-		-		-	
	58	-	0.011	-	0.027	-	0.018	-	0.055	-	0.010	-	0.025	-	0.013	-	0.007	-	0.015
	59	0.006		-		-		0.005		-		-		-		-		-	
	60	-		0.008		0.003		-		-		-		-		0.005		0.004	
	61	-		-		-		0.005		-		-		-		-		-	
	62	-		-		-		0.005		-		-		-		-		-	
	63	-		-		-		0.005		-		-		-		-		-	
	64	-		-		-		0.005		-		-		-		-		-	
	65	0.008		0.005		0.008		0.012		0.007		0.003		0.015		0.005		0.006	
	66	0.003		-		0.003		0.007		-		-		-		0.003		0.003	
	67	-		0.009		-		0.008		0.003		-		-		0.003		0.003	
	68	0.005		0.005		-		0.008		0.004		-		-		0.007		0.007	
	69	0.004		0.010		-		0.009		0.005		0.008		0.012		0.006		0.008	
	70	0.005	0.031	0.004	0.041	0.004	0.018	0.010	0.079	0.005	0.024	0.002	0.013	0.012	0.039	0.005	0.034	0.004	0.035
	Total		0.154		0.219		0.098		0.445		0.156		0.214		0.229		0.140		0.216

Table 20. Panel 10-18 Delamination/Solder Wicking Results (One Ounce Copper)



Cable	Hole	Panel 19		Panel 20		Panel 21		Panel 22		Panel 23		Panel 24		Panel 25		Panel 26		Panel 27	
		Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part
	1	-		-		-		-		-		-		-		-		-	
	2	0.004		-		-		-		-		-		0.010		-		0.002	
	3	-		0.007		-		0.005		-		-		-		0.005		0.006	
	4	-	0.004	-	0.007	-	0.000	-	0.005	-	0.000	-	0.000	-	0.010	-	0.005	-	0.008
	5	0.005		0.006		0.002		0.005		0.007		-		0.007		0.006		0.006	
	6	0.010		0.005		-		0.004		0.007		0.005		0.008		0.004		-	
	7	0.010		0.007		-		0.005		0.003		0.005		0.007		0.007		-	
	8	-	0.025	-	0.018	-	0.002	0.005	0.019	-	0.017	-	0.010	-	0.022	0.006	0.023	-	0.006
	9	-		-		-		0.005		0.003		-		-		-		-	
	10	0.005		0.005		0.002		0.003		-		0.002		0.010		-		-	
	11	0.010		0.005		-		0.005		0.003		0.003		0.010		-		0.003	
	12	-		-		-		0.006		0.003		-		-		-		-	
	13	0.005		0.006		0.005		0.008		-		0.006		0.007		0.006		0.006	
	14	0.015		0.008		-		0.008		-		0.007		0.013		0.010		0.010	
	15	0.004		0.005		0.003		0.008		0.005		0.003		-		0.005		0.003	
	16	0.010		0.007		0.002		0.006		0.006		0.004		0.005		0.007		0.005	
	17	0.010		-		0.004		0.003		0.008		0.005		0.007		-		0.005	
	18	0.002	0.061	-	0.036	0.003	0.019	0.005	0.057	0.006	0.034	0.003	0.033	0.005	0.057	0.005	0.033	0.003	0.035
	19	-		-		-		-		-		-		-		0.002		-	
	20	0.010		-		0.005		0.006		0.004		0.006		0.010		0.005		-	
	21	0.012		0.005		0.006		0.005		0.006		0.007		0.013		0.005		0.006	
	22	0.012		0.007		0.006		0.007		0.003		0.006		0.012		0.006		0.004	
	23	0.011		0.006		0.005		0.005		0.003		0.005		0.010		0.007		0.007	
	24	0.012		0.006		0.002		0.005		0.006		0.007		0.013		0.004		0.007	
	25	0.007		0.006		0.005		0.005		0.005		0.005		0.005		0.006		0.002	
	26	0.012		0.004		0.005		0.006		0.005		0.005		0.013		0.007		0.006	
	27	0.006		0.010		0.004		0.007		0.006		0.006		0.012		0.003		0.007	
	28	0.012		0.006		0.004		0.007		0.008		0.007		0.015		0.005		0.006	
	29	0.007		0.003		0.005		0.005		0.008		0.007		0.010		0.007		0.003	
	30	0.011	0.112	0.007	0.060	0.006	0.053	0.006	0.064	0.006	0.060	0.008	0.069	0.010	0.123	0.006	0.063	0.008	0.056
	31	-		-		-		0.010		-		-		-		-		-	
	32	0.005		0.005		0.007		0.007		0.009		0.004		0.007		0.004		0.004	
	33	0.037		0.006		0.008		0.008		0.185		0.007		0.141		0.007		0.004	
	34	0.017		0.005		0.010		0.006		0.023		0.008		0.030		0.006		0.008	
	35	0.085	0.144	0.010	0.026	0.006	0.031	0.005	0.036	0.011	0.228	0.010	0.029	0.102	0.280	0.007	0.024	0.008	0.024
	36	-		-		-		-		0.002		0.003		-		0.005		0.002	
	37	-		-		-		-		0.002		0.004		-		-		-	
	38	-		-		0.005		-		0.002		-		-		-		-	
	39	0.005		0.004		-		0.004		-		0.003		0.005		0.003		0.001	
	40	0.003		0.007		0.006		0.005		0.008		0.005		0.006		0.005		0.006	
	41	0.006		0.009		0.005		0.003		0.010		0.005		0.007		0.004		-	
	42	0.007		0.004		0.005		0.003		0.005		0.006		-		0.003		0.005	
	43	0.005		0.005		0.003		0.004		0.006		0.006		0.004		0.006		0.004	
	44	-		-		0.005		-		0.010		-		0.007		0.003		0.003	
	45	0.005	0.031	-	0.029	0.009	0.038	0.002	0.021	0.005	0.050	0.007	0.039	-	0.029	0.003	0.032	0.007	0.028
	46	-		-		-		-		-		0.002		-		-		-	
	47	-		-		-		-		-		-		-		-		-	
	48	-		0.005		-		-		0.002		-		-		-		-	
	49	-	0.000	-	0.005	-	0.000	-	0.000	-	0.002	-	0.002	-	0.000	-	0.000	-	0.000
	50	0.010		0.005		-		0.002		0.003		0.005		0.012		0.005		0.005	
	51	-		0.003		-		-		-		-		-		-		-	
	52	0.007		0.004		-		0.003		-		0.003		0.008		0.005		0.003	
	53	-	0.017	0.003	0.015	-	0.000	-	0.005	-	0.003	-	0.008	-	0.020	-	0.010	-	0.008
	54	0.020		-		0.002		-		0.010		0.007		0.033		0.008		0.006	
	55	0.042		0.011		0.008		0.003		0.010		0.005		0.023		0.004		0.005	
	56	0.008		0.003		-		-		0.005		0.001		0.013		-		0.002	
	57	-		-		-		-		-		-		-		-		-	
	58	-	0.070	-	0.014	0.005	0.015	-	0.003	-	0.025	0.006	0.019	-	0.069	-	0.012	0.003	0.016
	59	0.004		0.008		-		-		0.005		0.006		0.013		0.004		0.005	
	60	-		-		-		-		-		0.001		-		-		-	
	61	0.003		-		0.002		-		0.005		0.003		0.007		-		0.005	
	62	0.003		-		0.001		-		0.003		0.004		-		-		-	
	63	0.007		0.007		0.003		-		0.004		0.003		0.007		-		0.004	
	64	0.005		0.005		-		-		0.003		0.003		0.005		-		0.002	
	65	0.005		-		0.005		0.004		0.009		0.003		0.013		0.005		0.003	
	66	0.006		0.005		0.005		0.004		0.010		0.004		0.009		0.004		0.006	
	67	0.007		0.004		0.005		0.003		0.006		0.004		0.007		0.002		0.003	
	68	0.008		0.005		0.006		-		0.010		0.006		0.010		0.005		0.005	
	69	0.009		-		0.005		-		0.008		0.004		0.008		0.005		0.006	
	70	0.010	0.067	-	0.034	0.010	0.042	-	0.011	0.006	0.069	0.006	0.047	0.010	0.089	0.003	0.028	0.002	0.041
	Total		0.531		0.244		0.200		0.221		0.488		0.256		0.699		0.230		0.222

Table 21. Panel 19-27 Delamination/Solder Wicking Results (One Ounce Copper)

Cable	Hole	Panel 28	Total/	Panel 29	Total/	Panel 30	Total/	Panel 31	Total/	Panel 32	Total/	Panel 33	Total/	Panel 34	Total/	Panel 35	Total/	Panel 36	Total/
		Discoloration/D elamination	Part	Discoloration/D elamination	Part	Discoloration/D elamination	Part	Discoloration/D elamination	Part	Discoloration/D elamination	Part	Discoloration/D elamination	Part	Discoloration/D elamination	Part	Discoloration/D elamination	Part	Discoloration/D elamination	Part
	1	-		-		-		-		-		-		-		-		-	
	2	-		0.005		-		0.008		0.004		0.007		0.001		-		0.006	
	3	-		0.004		0.005		0.011		0.006		0.005		0.005		0.009		0.005	
	4	-	0.000	-	0.009	-	0.005	-	0.019	-	0.010	-	0.012	-	0.006	0.009	-	-	0.011
	5	-		0.009		0.005		0.009		-		0.004		0.005		-		0.002	
	6	-		0.006		-		0.010		-		0.007		0.005		-		0.004	
	7	0.002		-		0.007		0.010		0.007		0.015		0.005		-		-	
	8	-	0.002	0.005	0.020	0.007	0.019	0.003	0.032	0.007	0.014	0.005	0.031	0.005	0.020	-	0.000	0.002	0.008
	9	-		0.001		-		0.003		-		-		-		-		0.007	
	10	0.005		0.005		0.005		0.005		-		0.007		0.004		-		0.006	
	11	-		0.003		0.005		0.013		0.006		0.011		0.005		-		0.005	
	12	-		0.002		-		0.003		-		-		-		-		0.004	
	13	0.007		0.007		0.004		0.008		-		0.005		0.003		0.005		0.005	
	14	0.004		0.013		0.009		0.013		-		0.016		0.010		0.010		0.011	
	15	0.004		0.005		0.003		0.006		0.003		0.003		0.004		0.002		0.005	
	16	0.002		0.007		0.005		0.012		0.003		0.013		0.007		0.005		0.007	
	17	0.005		0.010		0.006		0.008		-		0.011		0.005		0.007		0.008	
	18	0.005	0.032	0.005	0.058	0.002	0.039	0.007	0.078	-	0.012	0.003	0.069	0.003	0.041	0.003	0.032	0.006	0.064
	19	-		-		-		-		0.003		-		-		-		-	
	20	0.002		0.005		0.003		0.007		0.006		0.010		0.005		0.004		0.010	
	21	0.006		0.006		0.004		0.012		0.008		0.013		0.007		0.007		0.005	
	22	0.007		0.011		0.003		0.013		0.006		0.008		0.013		0.007		0.005	
	23	0.007		0.007		0.006		0.009		0.006		0.012		0.006		0.006		0.002	
	24	0.006		0.003		0.007		0.011		0.005		0.013		0.007		0.004		0.003	
	25	0.003		0.006		0.003		0.009		0.007		0.008		0.006		0.006		0.003	
	26	0.003		0.007		0.004		0.013		0.004		0.013		0.006		0.006		0.007	
	27	0.007		0.006		0.007		0.011		0.006		0.011		0.006		0.006		0.006	
	28	0.005		0.007		0.004		0.015		0.007		0.016		0.007		0.005		0.006	
	29	0.007		0.004		0.003		0.007		0.003		0.010		0.006		0.005		0.010	
	30	0.008	0.061	0.008	0.070	0.004	0.048	0.011	0.118	0.008	0.069	0.010	0.124	0.006	0.075	0.006	0.062	0.010	0.067
	31	-		-		-		-		-		-		-		-		-	
	32	-		0.006		0.006		0.008		0.003		0.005		0.003		0.004		0.012	
	33	0.010		0.020		0.008		0.081		0.010		0.210		0.010		0.011		0.015	
	34	0.005		0.010		0.003		0.010		0.005		0.020		0.015		0.004		0.011	
	35	0.007	0.022	0.006	0.042	0.010	0.027	0.015	0.114	0.007	0.025	0.243	0.478	0.011	0.039	0.007	0.026	0.009	0.047
	36	0.004		0.005		0.007		0.001		-		0.003		0.003		0.002		-	
	37	0.002		0.007		-		0.005		-		-		0.003		-		-	
	38	0.002		0.005		-		0.007		-		-		0.004		0.002		0.002	
	39	0.003		0.003		0.005		0.007		-		0.008		0.003		0.002		0.002	
	40	0.006		0.009		0.005		0.011		0.004		0.007		0.005		0.005		0.006	
	41	0.005		0.006		0.003		0.007		0.005		0.010		0.009		0.010		0.007	
	42	0.003		0.006		0.004		0.009		0.005		0.008		0.003		0.007		0.006	
	43	0.006		0.005		0.004		0.006		0.003		0.003		0.007		0.005		0.007	
	44	0.003		0.006		0.003		0.007		0.006		0.007		0.010		0.007		0.006	
	45	0.004	0.038	0.006	0.058	0.002	0.033	0.006	0.066	0.006	0.032	0.004	0.050	0.003	0.050	0.005	0.045	0.005	0.041
	46	-		0.004		-		0.005		0.005		-		0.002		-		-	
	47	0.002		0.004		-		0.003		0.004		-		0.002		-		-	
	48	0.002		0.004		-		0.002		0.003		-		0.004		0.002		-	
	49	-	0.004	0.004	0.016	-	0.000	0.003	0.013	0.004	0.016	-	0.000	0.004	0.012	0.002	0.004	-	0.000
	50	0.006		0.007		0.003		0.011		0.006		0.018		0.007		0.002		0.002	
	51	-		0.002		-		0.001		0.001		-		0.004		-		-	
	52	0.003		0.002		0.002		0.001		0.001		0.004		0.003		0.003		0.003	
	53	-	0.009	0.003	0.014	-	0.005	-	0.013	-	0.008	-	0.022	0.003	0.017	0.003	0.008	-	0.005
	54	0.006		0.011		0.006		0.015		0.006		0.190		0.006		0.007		0.011	
	55	0.006		0.010		0.004		0.033		0.004		0.600		0.010		0.007		0.014	
	56	0.008		0.007		0.003		0.015		0.003		0.018		0.001		0.002		0.004	
	57	-		-		-		0.012		-		-		-		-		-	
	58	0.002	0.022	0.012	0.040	-	0.013	0.008	0.083	0.005	0.018	-	0.808	0.003	0.020	0.003	0.019	-	0.029
	59	0.007		0.004		0.008		0.008		0.009		0.011		0.006		0.005		0.004	
	60	0.004		-		-		-		0.001		0.002		-		-		-	
	61	0.003		0.006		0.003		0.004		0.003		0.007		0.006		0.003		0.005	
	62	0.002		0.004		0.002		0.003		0.003		0.003		0.002		0.002		0.002	
	63	0.003		0.006		0.004		-		0.003		0.003		0.005		0.004		0.005	
	64	0.002		0.003		0.004		0.004		0.003		0.007		0.004		0.003		0.003	
	65	0.005		0.008		0.006		0.012		0.004		0.015		0.005		0.006		0.010	
	66	0.003		0.005		0.004		0.010		0.002		0.010		0.007		0.004		0.006	
	67	0.003		0.007		0.003		0.010		0.006		0.010		0.007		0.003		0.007	
	68	0.006		0.007		0.003		0.007		0.003		0.008		0.007		0.007		0.008	
	69	0.005		0.012		0.005		0.011		0.007		0.012		0.009		0.006		0.008	
	70	0.007	0.050	0.005	0.067	0.005	0.047	0.010	0.079	0.004	0.048	0.010	0.098	0.004	0.062	0.007	0.050	0.009	0.067
	Total		0.240		0.394		0.236		0.615		0.252		1.692		0.342		0.255		0.339

**Table 22. Panel 28-36 Delamination/Solder Wicking Results (One Ounce Copper)**

Cable	Hole	Panel 1		Panel 2		Panel 3		Panel 4		Panel 5		Panel 6		Panel 7		Panel 8		Panel 9	
		Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part	Discoloration/D elamination	Total/ Part
	1	-		-		-										-		-	
	2	-		-		-										-		-	
	3	-		-		-										-		-	
	4	-	0.000	-	0.000	-	0.000		0.000		0.000		0.000		0.000	-	0.000	-	0.000
	5	-		-		-										-		0.004	
	6	-		-		-										-		-	
	7	-		-		-										-		-	
	8	-	0.000	-	0.000	-	0.000		0.000		0.000		0.000		0.000	-	0.000	-	0.004
	9	-		-		-										-		-	
	10	-		-		-										-		-	
	11	-		-		-										-		-	
Voids	12	-		-		-										-		-	
	13	0.002		-		-										-		-	
	14	-		-		-										-		-	
	15	-		-		-										-		-	
	16	-		-		-										0.003		0.002	
	17	-		-		0.003										0.005		-	
	18	-	0.002	-	0.000	-	0.003		0.000		0.000		0.000		0.000	-	0.008	-	0.002
	19	-		-		-										-		-	
	20	-		-		-										-		-	
	21	-		-		-										-		-	
	22	-		-		-										-		-	
	23	-		-		-										-		-	
	24	-		-		-										0.007		-	
	25	-		-		-										-		-	
	26	0.002		-		-										-		0.003	
	27	-		-		-										-		-	
	28	-		-		-										-		-	
	29	-		-		-										-		-	
	30	-	0.002	-	0.000	-	0.000		0.000		0.000		0.000		0.000	-	0.007	0.003	0.006
	31	-		-		-										-		-	
	32	-		-		0.002										-		-	
	33	-		0.007		-										0.003		0.006	
	34	0.005		0.006		0.008										0.010		0.005	
	35	0.002	0.007	0.007	0.020	-	0.010		0.000		0.000		0.000		0.000	0.002	0.015	-	0.011
	36	-		-		-										-		-	
	37	-		-		-										-		-	
	38	-		-		-										-		-	
	39	-		-		-										-		-	
	40	-		-		-										-		-	
	41	-		0.006		-										0.002		0.006	
	42	0.002		0.008		-										0.002		0.005	
	43	-		0.003		-										-		-	
	44	-		0.004		-										-		-	
	45	-	0.002	-	0.021	-	0.000		0.000		0.000		0.000		0.000	-	0.004	-	0.011
	46	-		-		-										-		-	
	47	-		-		-										-		-	
	48	-		-		-										-		-	
	49	-	0.000	-	0.000	-	0.000		0.000		0.000		0.000		0.000	-	0.000	-	0.000
	50	-		-		-										-		-	
	51	-		-		-										-		-	
	52	-		-		-										-		-	
	53	-	0.000	-	0.000	-	0.000		0.000		0.000		0.000		0.000	-	0.000	-	0.000
	54	-		-		-										-		-	
	55	-		-		-										-		-	
	56	-		-		-										-		-	
	57	-		-		-										-		-	
	58	-	0.000	-	0.000	-	0.000		0.000		0.000		0.000		0.000	-	0.000	-	0.000
	59	-		-		-										-		-	
	60	-		-		-										-		-	
	61	-		-		-										-		-	
	62	-		-		-										-		-	
	63	-		-		-										-		-	
	64	-		-		-										-		-	
	65	-		-		-										-		-	
	66	-		-		-										-		-	
	67	-		0.002		-										-		-	
	68	-		-		-										-		-	
	69	-		-		-										-		-	
	70	-	0.000	0.005	0.007	-	0.000		0.000		0.000		0.000		0.000	-	0.000	-	0.000
	Total		0.013		0.048		0.013		0.000		0.000		0.000		0.000		0.034		0.034

Table 23. Panel Rankings

# Appendix D

## Manufacturing Instructions

Engineer: 2 oz. Copper Panels Customer: HPPS/SPPS Experiment Charge Number:

Due Date: 8/10/07

### Material Setup

- 41 panels 12x12 Laminate
- 82 panels 12x12 Coverlay
- 32 panels 12x12 Adhesive
- 2 panels 12 x 12 (Processing Aide)

### Stamp

Impression stamp on 12" side "HPPS", and a panel numbers "1" through "9" in laminate material  
Impression stamp on a 12" side "SPPS", and a panel numbers "1" through "32" in laminate material

**Panel Numbers are important for recording the data at the end of the experiment.**  
Mark one processing aide with "Top" and the other with "Bottom".

### Punch U/V Tooling holes in all material

#### Processing Aides

Butt against tooling pins and drill U/V (X0.Y-.625) & (X11Y-.625) tooling holes in Processing aide material on the marked side. Ream as necessary.

#### Setup of \_\_\_\_\_ for drilling – Processing Aides

- 12x12 panels. Normal Stackup.
- Load material on U/V – bottom piece/marking down, top piece/marking up
- Run program

#### Setup of \_\_\_\_\_ for drilling – Laminate

- 12x12 panels. Normal Stackup.
- Load material on U/V – Stamp side UP
- Run program

#### Setup of \_\_\_\_\_ for drilling – Top/Bottom Coverlay and Adhesive

- 12x12 panels. Normal Stackup.  
TOP COVERLAY – LABEL 41 PIECES OF -952 MATERIAL
- Load material on U/V – release sheet DOWN  
Run program
- ADHESIVE – LABEL 16 PIECES OF -044 MATERIAL
- Load material on U/V – release sheet DOWN  
Run program
- BOTTOM COVERLAY – LABEL 41 PIECES OF -952 MATERIAL
- Load material on U/V – release sheet UP  
Run program
- ADHESIVE – LABEL 16 PIECES OF -044 MATERIAL
- Load material on U/V – release sheet UP  
Run program

FLEX CABLE

## 2 oz. Copper Panels

Engineer: ' .

Customer: HPPS/SPPS Experiment

Charge Number: ' .

**Due Date: 8/10/07**

### OGP Laminate

OGP each laminate panel.

6-1-07 6-1-07 Plasma Desmear 6-1-07  
Plasma per

### Wet Blast Laminate

Wet blast hole walls per 1 using processing aides provided. Pin from auxiliary tooling holes -O- and -P-. Blast both sides of panels

### OGP Laminate

OGP a sample of panels.

6-1-07 6-1-07 Direct Deposit 6-1-07  
Direct Deposit per

6-1-07 6-1-07 Panel Plate  
Panel plate panel for 80 minutes @ 20 amp/ft<sup>2</sup> per  
Use the Flex program  
DO NOT deform M/N tooling holes!

### Cleaning

Clean using FabTech per PES

### Dry film lamination

Laminate with MM120i per

### Expose on Scanex or ORC

Expose with Adhesion Sample – 2oz tools per

- Stamped side: AXX
- Unstamped side: BXX

### Develop

Develop per Temp: 85 F, Speed – 2.00 fpm for MM120i

### Touchup

Touchup as required

### Etch

Etch per 110 °F, 35 oscillations/min. 2 oz copper + 80 min. plate

### Resist Strip

Strip resist per

### OGP Laminate

OGP a sample of panles.

FLEX CABLE

## 2 oz. Copper Panels

Engineer:

Customer: HPPS/SPPS Experiment

Charge Number:

### Layup

- Place laminate with impression stamp DOWN.
- Put tooling pins in M & N to help with registration.
- Place Bottom coverlay on back side of panel. This is marked UP; taking the release sheet off will take the marking off.
- Add the 2 mil Adhesive to half the SPPS panels.
- Heat Tack just the corners and take out the tooling pins.
- Place panel with impression stamp UP
- Place tooling pins in M & N to help with registration.
- Place Top coverlay on top side of panel. This is marked DOWN.
- Add the 2 mil Adhesive to half the SPPS panels.
- Heat Tack just the corners

FLEX CABLE

2 oz. Copper Panels

Engineer:

Customer: HPPS/SPPS Experiment

Charge Number:

**Due Date: 8/10/07**

**Do not process any parts for this page, unless  
are present!**

Laminate

1. Plate / Rubber / Teflon / Part / Teflon / Rubber / Plate
  - a. Panel numbers – 1, 2, 3 at 190 ton
  - b. Panel numbers – 4, 5, 6 at 140 ton *139 Ton*
  - c. Panel numbers – 7, 8, 9 at 90 ton
2. Plate/ Paco Pad / Pacothane / Part / Pacothane / Paco Pad / Plate
  - ~~a.~~ Pressure – 300 Temperature – 365 Time – 80
    - i. Panel numbers – 5, 12, 21, 28
  - ~~b.~~ Pressure – 300 Temperature – 365 Time – 60
    - i. Panel numbers – 9, 10, 25, 26
  - ~~c.~~ Pressure – 300 Temperature – 385 Time – 80
    - i. Panel numbers – 1, 13, 17, 29
  - ~~d.~~ Pressure – 300 Temperature – 385 Time – 60
    - i. Panel numbers – 3, 16, 19, 32
  - ~~e.~~ Pressure – 350 Temperature – 365 Time – 80
    - i. Panel numbers – 7, 8, 23, 24
  - ~~f.~~ Pressure – 350 Temperature – 365 Time – 60
    - i. Panel numbers – 14, 15, 30, 31
  - ~~g.~~ Pressure – 350 Temperature – 385 Time – 80
    - i. Panel numbers – 2, 11, 18, 27
  - ~~h.~~ Pressure – 350 Temperature – 385 Time – 60
    - i. Panel numbers – 4, 6, 20, 22

*O = laminate extra  
adhesive*

**Please record which press was used and the location of the panels in the presses on the following  
sheet.**

FLEX CABLE

2 oz. Copper Panels  
Customer: HPPS/SPPS Experiment

Charge Number:

Engineer:

OGP Laminate

OGP each laminate panel.

Panel Bake Use program LAM - Study from Hard Drive.

1. Bake the SPPS panels per the following:

a. Bake panel at 275°F for 8 hours

i. Panel numbers - 4, 9, 7, 13, 20, 23, 25, 29

b. Bake panel at 275°F for 1 hours

i. Panel numbers - 2, 3, 12, 15, 18, 19, 28, 31

c. Bake panel at 350°F for 8 hours

i. Panel numbers - 5, 11, 14, 16, 21, 27, 30, 32

d. Bake panel at 350°F for 1 hours

i. Panel numbers - 1, 6, 8, 10, 17, 22, 24, 26

2. Bake the HPPS panels per the following:

a. Bake All panels at 275°F for 8 hours

Remove Panel from Oven

- Remove panels from oven, panels will be hot so use appropriate PPE

Hot Air Solder

1. Use PES
2. Record time from oven/lamination to out of post-cleaner on last sheet.

Evaluate Parts

FLEX CABLE



## 2 oz. Copper Panels

Engineer:

Customer: HPPS/SPPS Experiment

Charge Number:

### Hard Press Pad Panels

Panel Number	Press/Date	Location
1	TMP - 7/17/07	D
2	TMP - 7/17/07	E
3	TMP - 7/17/07	F
4	TMP - 7/17/07	D
5	TMP - 7/17/07	E
6	TMP - 7/17/07	F
7	TMP - 7/17/07	D
8	TMP - 7/17/07	E
9	TMP - 7/17/07	F

As you are looking at the Presses, all impression stamps towards ~~clean benches~~ <sup>↑</sup> ~~clean benches~~.

#### TMP

TOP (going left to right)

A B C

BOTTOM (going left to right)

D E F

back of press  
for SPPS

I loaded the stackups  
myself, LHW

FLEX CABLE

# 2 oz. Copper Panels

Engineer:

Customer: HPPS/SPPS Experiment

Charge Number:

## Soft Press Pad Panels

Panel Number	Press/Date	Location
1	TMP 7/27/07	D
2	TMP 8/2/07	A
3	TMP 7/27/07	D
4	TMP 7/3/07	D
5	TMP 7/29/07	D
6	TMP 8/3/07	F
7	TMP 7/31/07	D
8	TMP 7/31/07	A
9	TMP 7/26/07	D
10	TMP 7/26/07	F
11	TMP 8/2/07	D
12	TMP 7/26/07	A
13	TMP 7/27/07	A
14	TMP 8/1/07	D
15	TMP 8/1/07	A
16	TMP 7/27/07	A
17	TMP 7/27/07	F
18	TMP 8/2/07	F
19	TMP 7/27/07	F
20	TMP 8/3/07	A
21	TMP 7/29/07	C
22	TMP 8/3/07	C
23	TMP 7/31/07	F
24	TMP 7/31/07	C
25	TMP 7/26/07	A
26	TMP 7/26/07	C
27	TMP 8/2/07	C
28	TMP 7/26/07	F
29	TMP 7/27/07	C
30	TMP 8/1/07	C
31	TMP 8/1/07	F
32	TMP 7/27/07	C

FLEX CABLE

## 2 oz. Copper Panels

Engineer: '

Customer: HPPS/SPPS Experiment

Charge Number:

As you are looking at the Presses, all impression stamps towards clean benches.

### TMP

TOP (going left to right)

A      B      C

BOTTOM (going left to right)

D      E      F

FLEX CABLE

# 2 oz. Copper Panels

Engineer:

Customer: HPPS/SPPS Experiment

Charge Number:

Group	Order of Serial #s	Out of Oven	Started Gyrex Process	Ended Gyrex Process	KNIFE PRESS.
9/16 DRA	1 hr @ 350°F 1, 6, 8, 10, 17 22, 24, 26	2:55	3:00	3:11	28 24R
9/16 DRA	1 hr @ 275°F 2, 3, 12, 15 18, 19, 23, 31	4:00	4:05	4:17	28F 24R
9/19 DRA	8 hr @ 350°F 5, 11, 14, 16 21, 27, 30, 32	1:00 *	2:00	2:10	28 24
9/19 DRA	8 hr @ 275°F 4, 7, 9, 13 20, 23, 25, 29	1:00 *	1:50	2:00	28 24

ALL PANELS RUN STAMP SIDE FRONT/TOP.  
PANELS RUN THROUGH GYREX IN REV. ORDER

\* STORED IN N<sub>2</sub> CABINET FROM  
1:00 PM TO GYREX OPERATION

FLEX CABLE

Engineer:

1 oz. Copper Panels  
Customer: HPPS/SPPS Experiment

Charge Number:

**Due Date: 8/10/07**

### Material Setup

- 41 panels 12x12 Laminate
- 82 panels 12x12 Coverlay
- 32 panels 12x12 Adhesive
- 2 panels 12 x 12 (Processing Aide)

### Stamp

Impression stamp on 12" side "HPPS", and a panel numbers "1" through "9" in laminate material

Impression stamp on a 12" side "SPPS", and a panel numbers "1" through "32" in laminate material

**Panel Numbers are important for recording the data at the end of the experiment.**

Mark one processing aide with "Top" and the other with "Bottom".

### Punch U/V Tooling holes in all material

### Processing Aides

Butt against tooling pins and drill U/V (X0.Y-.625) & (X11Y-.625) tooling holes in

- Processing aide material on the marked side. Ream as necessary.

### Setup of for drilling – Processing Aides

- 12x12 panels. Normal Stackup.
- Load material on U/V – bottom piece/marking down, top piece/marking up  
Run program

### Setup of for drilling – Laminate

- 12x12 panels. Normal Stackup.
- Load material on U/V – Stamp side UP  
Run program

### Setup of for drilling – Top/Bottom Coverlay and Adhesive

- 12x12 panels. Normal Stackup.  
TOP COVERLAY – LABEL 41 PIECES OF -922 MATERIAL
- Load material on U/V – release sheet DOWN  
Run program

- ADHESIVE – LABEL 16 PIECES OF -044 MATERIAL
- Load material on U/V – release sheet DOWN  
Run program

BOTTOM COVERLAY – LABEL 41 PIECES OF -922 MATERIAL

- Load material on U/V – release sheet UP  
Run program

ADHESIVE – LABEL 16 PIECES OF -044 MATERIAL

- Load material on U/V – release sheet UP  
Run program

Completed 10-29-2007

**Due Date: 8/10/07**

**OGP Laminate**

OGP each laminate panel.

Use program from hard drive

**Plasma Desmear**

Plasma per PES

**Wet Blast Laminate**

Wet blast hole walls per using processing aides provided. Pin from auxiliary tooling holes -O- and -P-. Blast both sides of panels

**OGP Laminate**

OGP a sample of panels.

**Direct Deposit**

**Completed 2-11-2008**

Direct Deposit per

**Panel Plate**

**Completed 2-19-2008**

Panel plate panel for 80 minutes @ 20 amp/ft<sup>2</sup> per

Use the Flex program

DO NOT deform M/N tooling holes!

**Cleaning**

**Completed 3-17-2008**

Clean using FabTech per PES

**Dry film lamination**

**Completed 3-17-2008**

Laminate with MM120i per

**Expose on Scanex or ORC**

**Completed 3-18-2008**

Expose with Adhesion Sample – 1oz tools per

- Stamped side: AXX
- Unstamped side: BXX

**Develop**

**Completed 3-18-2008 (61-4)**

Develop per PES Temp: 85 F, Speed – 2.00 fpm for MM120i

**Touchup**

**Completed 3-18-2008**

Touchup as required

**Etch**

**Completed 3-20-2008 (61-4)**

Etch per, 110 °F, 35 oscillations/min. 1 oz copper + 80 min. plate

**Resist Strip**

Strip resist per

**OGP Laminate**

**Completed 4-18-2008**

OGP a sample of panels.

Use program from hard drive

### Layup

- Place laminate with impression stamp DOWN.
- Put tooling pins in M & N to help with registration.
- Place Bottom coverlay on back side of panel. This is marked UP; taking the release sheet off will take the marking off.
- Heat Tack just the corners and take out the tooling pins.
- Place panel with impression stamp UP
- Place tooling pins in M & N to help with registration.
- Place Top coverlay on top side of panel. This is marked DOWN.
- Heat Tack just the corners

**Due Date: 8/10/07**

**Do not process any parts for this page, unless are present!**

### Laminate

1. Plate / Rubber / Teflon / Part / Teflon / Rubber / Plate
  - a. Panel numbers – 1, 2, 3 at 190 ton
  - ~~b. Panel numbers – 4, 5, 6 at 140 ton~~
  - c. Panel numbers – ~~7~~, 8, 9 at 100 ton (227psi)
2. Plate/ Paco Pad / Pacothane / Part / Pacothane / Paco Pad / Plate
  - a. Pressure – 350psi Temperature – 385F Time – 60minAll SPPS panels

**Please record which press was used and the location of the panels in the presses on the following sheet.**

### OGP Laminate

Completed 5-1-2008

OGP each laminate panel.

Use program from hard drive

### Panel Bake

1. Bake the SPPS panels per the following:
  - a. Bake panel at 300°F for 1 hour
    - i. Panel numbers – 1, 7, 13, 19, 25, 31 **(Trace Labs Group 1)**
  - b. Bake panel at 300°F for 2 hours
    - i. Panel numbers – 3, 11, 18, 21, 29, 36(HPPS4) **(Trace Labs Group 2)**
  - c. Bake panel at 300°F for 4 hours
    - i. Panel numbers – 2, 9, 14, 20, 27, 32 **(Trace Labs Group 3)**
  - d. Bake panel at 325°F for 1 hour
    - i. Panel numbers – 5, 15, 16, 23, 33(HPPS5), 34(HPPS7) **(Trace Labs Group 4)**
  - e. Bake panel at 325°F for 2 hours
    - i. Panel numbers – 6, 10, 17, 24, 28, 35(HPPS6) **(Trace Labs Group 5)**
  - f. Bake panel at 325°F for 4 hours
    - i. Panel numbers – 4, 8, 12, 22, 26, 30 **(Trace Labs Group 6)**
2. Bake the HPPS panels per the following:
  - a. Bake ONLY HPPS1, HPPS2, HPPS3, HPPS8, and HPPS9 at 275°F for 8 hours **(Trace Labs Group 7)**

### Remove Panel from Oven

- Remove panels from oven, panels will be hot so use appropriate PPE

### Hot Air Solder

1. Use PES.



2. ~~Record time from oven/lamination to out of post cleaner on last sheet.~~

### Evaluate Parts

#### Hard Press Pad Panels

Panel Number	Press/Date	Location
1	TMP 4-28-08	D
2	TMP 4-28-08	E
3	TMP 4-28-08	F
4		
5		
6		
7		
8	TMP 4-28-08	D
9	TMP 4-28-08	F

As you are looking at the Presses, all impression stamps towards clean benches.

#### TMP

TOP (going left to right)

A      B      C

BOTTOM (going left to right)

D      E      F

## Soft Press Pad Panels

Panel Number	Press/Date	Location
1	Wabash 4-25-08	A
2	TMP 4-24-08	D
3	Wabash 4-24-08	D
4	Wabash 4-25-08	F
5	TMP 4-24-08	E
6	TMP 4-25-08	A
7	Wabash 4-25-08	C
8	Wabash 4-24-08	A
9	Wabash 4-24-08	F
10	TMP 4-25-08	D
11	Wabash 4-24-08	C
12	Wabash 4-24-08	E
13	Wabash 4-24-08	B
14	TMP 4-24-08	E
15	Wabash 4-25-08	F
16	Wabash 4-25-08	D
17	Wabash 4-25-08	E
18	Wabash 4-25-08	B
19	TMP 4-25-08	B
20	Wabash 4-25-08	B
21	TMP 4-24-08	A
22	TMP 4-25-08	C
23	TMP 4-24-08	B
24	TMP 4-25-08	A
25	Wabash 4-25-08	C
26	TMP 4-25-08	B
27	Wabash 4-25-08	E
28	Wabash 4-25-08	A
29	TMP 4-25-08	F

30	TMP 4-25-08	E
31	TMP 4-25-08	E
32	TMP 4-25-08	F
<b>33</b> HPPS5	Wabash 4-25-08	D
<b>34</b> HPPS7	TMP 4-25-08	D
<b>35</b> HPPS6	TMP 4-25-08	C
<b>36</b> HPPS4	TMP 4-24-08	C

As you are looking at the Presses, all impression stamps towards clean benches.

#### TMP

TOP (going left to right)

A      B      C

BOTTOM (going left to right)

D      E      F

		HPPS Panels	Bake Temperature	Bake Time
Tuesday 5/13/08	2:30 PM	Bake all HPPS Panels except for 4, 5, 6, and 7	275	8 hours
Wednesday 5/14/08	6:30 AM	Gyrex all HPPS Panels except for 4, 5, 6, and 7		
		SPPS Panels	Bake Temperature	Bake Time
Wednesday 5/14/08	7:00 AM	Panel #'s: 1, 7, 13, 19, 25, 31	300	1 hour
	8:00 AM	Gyrex Panels: 1, 7, 13, 19, 25, 31		
	8:00 AM	Panel #'s: 3, 11, 18, 21, 29, HPPS4	300	2 hours
	10:00 AM	Gyrex Panels: 3, 11, 18, 21, 29, HPPS4		
	10:00 AM	Panel #'s: 2, 9, 14, 20, 27, 32	300	4 hours
	2:00 PM	Gyrex Panels: 2, 9, 14, 20, 27, 32		
			Bake Temperature	Bake Time
Thursday 5/15/08	7:00 AM	Panel #'s: 5, 15, 16, 23, HPPS5, HPPS7	325	1 hour
	8:00 AM	Gyrex Panels: 5, 15, 16, 23, HPPS5, HPPS7		
	8:00 AM	Panel #'s: 6, 10, 17, 24, 28, HPPS6	325	2 hours
	10:00 AM	Gyrex Panels: 6, 10, 17, 24, 28, HPPS6		
	10:00 AM	Panel #'s: 4, 8, 12, 22, 26, 30	325	4 hours
	2:00 PM	Gyrex Panels: 4, 8, 12, 22, 26, 30		

# Appendix E

Trace Laboratories Test Reports

Phase Three Two Ounce Copper Laminate Environmental Test Report .....	85-111
Phase Three One Ounce Copper Laminate Environmental Test Report.....	112-139



**TEST REPORT FOR:**  
HONEYWELL, FM&T

Attn:

**DATE IN:**

November 8, 2007

**P/O #:**

**SUBMISSION IDENTIFICATION:**

Four (4) lots of flexible printed circuit boards were submitted for Bending Test, MIR and Thermal Shock in accordance with IPC-6013A, Amendment 2, Class 3. The boards were identified as follows:


**SUMMARY:**

The boards met the requirements of IPC-6013A, Amendment 2, Class 3, for Bending Test, MIR and Thermal Shock

**APPROVED:**

**SAMPLE DISPOSITION:** Samples returned to the customer



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## BENDING TEST

### TEST SPECIMENS:

Four (4) lots of flexible printed circuit boards.

### REFERENCE:

IPC-6013A, Amendment 2, Class 3, paragraphs 3.6.1, 3.9 and 3.3.

### REQUIREMENT:

After completion of the bending test in both directions, the flexible or rigid flexible printed wiring board shall be tested for electrical defects in accordance with 3.9 and shall meet the visual requirements of 3.3

### METHOD:

The bending test shall conform to Figure 3-8, unless otherwise agreed to by the user. The bending test requirements shall be as specifies on the appropriate document / drawing. See IPC 2223 for guidance on the minimum bend radii. The following parameters shall be specified as minimum:

- Direction of bend (a).
- Degree of bend (b)
- Number of bend cycles (c)
- Diameter of mandrel (d)
- Points of application to be supplied by user.

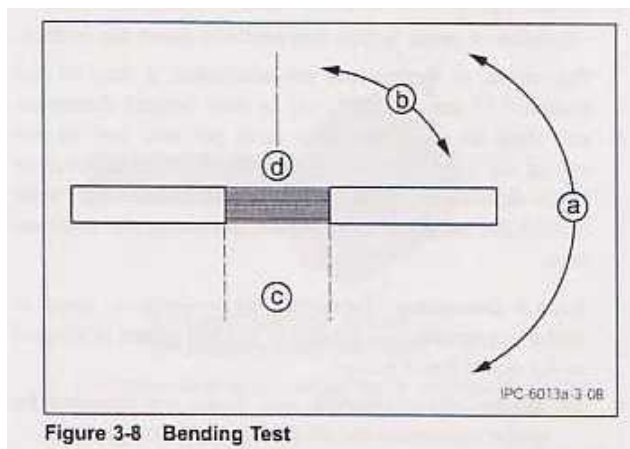
A bend cycle is defined as taking one end of the specimen and bending it around a mandrel and then bending back to the original starting point, traveling 180° in one direction and 180° in the opposite direction. A bend cycle may also be defined as bending (using opposite ends) the ends towards each other (bend the same direction) and then bending them back to the original starting position, with each end traveling 90° in the opposite direction.



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The direction of the bend was 90° upward and 90° downward.

The degree of the bends was 90°.

The number of bend cycles was 25.

Mandrel Diameter:

Part Number	10 times the thickness	Mandrel size
	mils	7/32"
	mils	3/16"
	mils	3/16"
	mils	3/16"

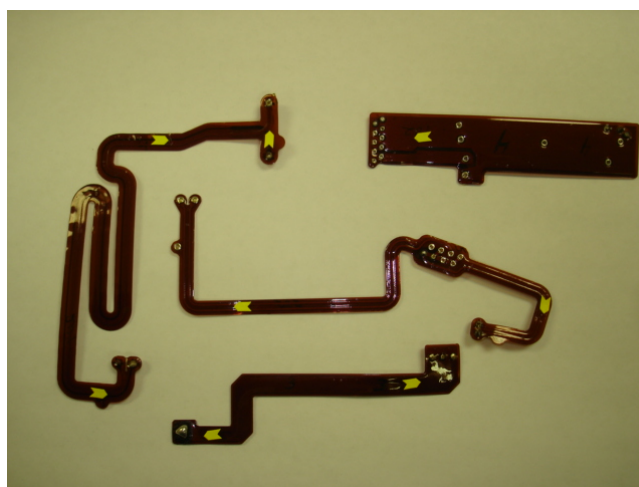


Photo 1: Bend Locations

After completing the bending test the boards were tested per electrical requirements 3.9.



## ELECTRICAL REQUIREMENTS

### DIELECTRIC WITHSTANDING VOLTAGE

#### TEST SPECIMENS:

Four (4) lots of flexible printed circuit boards.

#### REFERENCE:

IPC-6013A, Amendment 2, Class 3, paragraph 3.9.1

#### REQUIREMENT:

Applicable test coupons or production boards shall meet the requirements of Table 3-12, without flashover, sparkover, or breakdown between conductor, or conductors and lands. The dielectric withstanding voltage test shall be performed in accordance with IPC-TM-650, method 2.5.7D. The dielectric withstanding voltage shall be applied between all common portions of each conductor pattern and adjacent common portions of each conductor pattern. The voltage shall be applied between conductor patterns of each layer and the electrically isolated pattern of each adjacent layer.

Table 3-12 Dielectric Withstanding Voltage

	Class 2	Class 3
Voltage	500VDC +15, -0	1000VDC +25, -0
Time 30	seconds +3, -0	30 seconds +3, -0

#### METHOD:

Insulated wires were soldered to a set of adjacent parallel conductors. The electrodes of the hi-pot tester were connected to the insulated wires. Five hundred VDC were applied for 30 seconds. The results were recorded.

#### RESULTS:

There was no flashover, or breakdown between conductor, or conductors and lands between all common portions of each conductor pattern and adjacent common portions of each conductor pattern.



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## CONTINUITY

### TEST SPECIMENS:

Four (4) lots of flexible printed circuit boards.

### REFERENCE:

IPC-6013A, Amendment 2, Class 3, paragraph 3.9.2.1.

### REQUIREMENT:

Flexible printed boards and qualification testing of flexible printed wiring boards shall be tested in accordance with the procedure outlined below. There shall be no circuits whose resistance exceeds the values established in the procurement documentation. The presence of long runs of very narrow conductors, or high resistance metals may increase these values. When required by the user, interconnect shorts and continuity coupon D shall be used for evaluation of the interconnection resistance and circuit continuity.

A current shall be passed through each conductor or group of interconnected conductors by applying electrodes on the terminals at each end of the conductor or group of conductors. The current passing through the conductors shall not exceed that specified in IPC-2221 for the smallest conductor in the circuit. For qualification, the test current shall not exceed one ampere. Flexible printed wiring with designed resistive patterns shall meet the resistance requirements specified on the procurement documentation.

### METHOD:

Insulated wires were soldered to the plated through holes at the ends of a selected conductor. The wires were placed in the grips of a multimeter. A resistance measurement was observed.

### RESULTS:

The boards met the requirements for continuity between the conductor and land patterns.



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## ISOLATION (CIRCUIT SHORTS)

### TEST SPECIMENS:

Four (4) lots of flexible printed circuit boards.

### REFERENCE:

IPC-6013A, Amendment 2, Class 3, paragraph 3.9.2.2.

### REQUIREMENT:

Flexible printed wiring shall be tested in accordance with the following procedure. The isolation resistance between conductors shall meet the values established in the procurement documentation. The voltage applied between the networks must be high enough to provide sufficient current resolution for the measurement. At the same time, it must be low enough to prevent arc-over between adjacent networks, which could induce defects within the product. For manual testing, the voltage shall be 200 volts minimum and shall be applied for a minimum of 5 seconds. When automatic test equipment is used, the minimum applied voltage shall be the maximum rated voltage of the flexible printed wiring. When not specified, the default value of 40 volts shall be used.

### METHOD:

Insulated wires were soldered to the plated through holes at the ends of a selected conductor. The wires were placed in the grips of a multimeter. The resistance measurement was obtained.

### RESULTS:

The boards met the requirements for isolation (circuit shorts).

#### Part Number

	Layer 103-1	303-3	503-5	803-8		
Continuity	1-1	Pass	Pass	Pass	Pass	
	2-2	Pass	Pass	Pass	Pass	
	3-3	Pass	Pass	Pass	Pass	
Isolation	1-1	Pass	Pass	Pass	Pass	
	2-3	Pass	Pass	Pass	Pass	



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**Part Number**

	Layer 202-2	402-4 602-6 902-9		
Continuity	1-1	Pass Pass Pass Pass		
	2-2	Pass Pass Pass Pass		
	3-3	Pass Pass Pass Pass		
Isolation	1-2	Pass Pass Pass Pass		
	2-3	Pass Pass Pass Pass		

**Part Number**

	Layer 305-3	505-5 705-7 805-8		
Continuity	1-1	Pass Pass Pass Pass		
	2-2	Pass Pass Pass Pass		
Isolation	1-2	Pass Pass Pass Pass		

**Part Number**

	Layer 204-2	604-6 704-7		
Continuity 1-1		Pass	Pass	Pass
2-2		Pass	Pass	Pass
Isolation 1-2		Pass	Pass	Pass

## MOISTURE AND INSULATION RESISTANCE

### TEST SPECIMENS:

Four (4) lots of flexible printed circuit boards.

### REFERENCE:

IPC-6013A, Amendment 2, Class 3, paragraph 3.10.1.

### REQUIREMENT:

The flexible wiring boards shall not exhibit measling, blistering, or delamination in excess of that allowed in 3.3.2. Insulation resistance shall meet the requirements shown in table 3-13. Noncomponent flush wiring shall have a minimum requirement of 50M $\Omega$  [5.0E+9] for all classes. Moisture and insulation resistance testing for flexible printed wiring shall be performed in accordance with IPC-TM-650, Method 2.6.3F.



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## METHOD:

Insulated single stranded wires were soldered to each of the connection points of the test specimen. These wires were used to connect the test patterns of the test specimen in order to obtain the insulation resistance measurements and to allow a connection with the outside power supply. The test leads were cleaned with isopropyl alcohol and scrubbed with a soft bristle brush for a minimum of 30 seconds. The test specimen was rinsed thoroughly with fresh isopropyl alcohol from top to bottom. The cleaned area was rinsed thoroughly with fresh deionized water holding the test specimen at an approximate 30° angle and sprayed from top to bottom. The test specimen was dried in an oven for a minimum of three hours at an oven temperature of 50±5°C (122±9°F). The test specimen was then coated with conformal coating in accordance with IPC-CC-830 and cured as specified by the coating supplier. After curing the test specimens were then stabilized to ambient temperature. Initial insulation resistance measurements were taken by applying five hundred (500) volts direct current for one minute using a high resistance meter.

The test specimen was placed in the vertical position in a moisture chamber and the wires were connected to a power supply throughout the entire test. A polarizing voltage of 100 volts direct current was applied. The test sample was exposed to 20 cycles of temperature and humidity. The humidity chamber was cycled from 25°C, +5°C, -2°C at 85% to 93% relative humidity, to 65°C, ±2°C at 85% to 93% relative humidity.

Note: The humidity may drop to a minimum of 80% relative humidity when going from high to low temperature.

Insulation resistance measurements were made within two hours after removal from the chamber. Following 24 hours stabilization period, the test samples were visually examined.

Table 3-13 Insulation Resistance

	Class 2	Class 3
As Received	500 MΩ 500	MΩ
After exposure to moisture	100 MΩ 500	MΩ

## RESULTS:

Visual Results:

There was no evidence of mealing of the conformal coating.



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Insulation Resistance Measurements (in megohms):

Part Number

S/n	Layer	Before Conditioning	After Conditioning
103 1-1		$>10^7$	1.77E+07
103 1-2		$>10^7$ 5.50E+06	
303 1-1		$>10^7$ 1.74E+07	
303 1-2		$>10^7$ 1.90E+07	
503 1-1		$>10^7$ 1.51E+07	
503 1-2		$>10^7$ 2.71E+07	
803 1-1		$>10^7$ 1.49E+07	
803 1-2		$>10^7$ 2.66E+07	

Part Number

S/n	Layer	Before Conditioning	After Conditioning
202 1-1		$>10^7$ 1.64E+07	
202 1-2		$>10^7$ 1.24E+07	
402 1-1		$>10^7$ 4.09E+07	
402 1-2		$>10^7$ 2.06E+07	
602 1-1		$>10^7$ 2.69E+07	
602 1-2		$>10^7$ 1.51E+07	
902 1-1		$>10^7$ 3.33E+07	
902 1-2		$>10^7$ 2.74E+07	

Part Number

S/n	Layer	Before Conditioning	After Conditioning
305 1-1		$>10^7$ 1.41E+07	
505 1-1		$>10^7$ 1.19E+07	
705 1-1		$>10^7$ 1.25E+07	
805 1-1		$>10^7$ 7.75E+06	

Part Number

S/n	Layer	Before Conditioning	After Conditioning
204 1-1		$>10^7$ 1.34E+07	
604 1-1		$>10^7$ 3.85E+06	
704 1-1		$>10^7$ 5.24E+06	



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## VISUAL

### TEST SPECIMENS:

Four (4) lots of flexible printed circuit boards

### REFERENCE:

IPC-6013A, Amendment 2, Class 3 paragraphs 3.3.1.2, 3.3.2 – 3.3.2.10.

### REQUIREMENT:

The finished flexible printed wiring shall be examined in accordance with the following procedure. They shall be of uniform quality and shall conform to sections 3.3.1 and 3.3.9.

Visual examination for applicable attributes shall be conducted at 3 diopters (approx. 1.75X). If the acceptable condition of a suspected defect is not apparent, it should be verified at progressively higher magnifications (up to 40X) to confirm that it is a defect. Dimensional requirements such as spacing or conductor width measurements require other magnification and devices with reticles or scales in the instrument which allow accurate measurements of the specified dimensions. Contract or specification may require other magnifications.

**3.3.1.1 Edges, Rigid Section** Nicks, Crazing or haloing along the edges of the flexible printed wiring, cutouts, and nonplated-through holes are acceptable, provided the penetration does not exceed 50% of the distance from the edge of the nearest conductor or 2.5mm [0.0984 in], whichever is less. Edges shall be clean cut and without metallic burrs. Nonmetallic burrs are acceptable as long as they are not loose and/or do not affect fit and function. Panels that are scored or routed with a breakaway tab shall meet the depanalization requirements of the assembled flexible printed wiring.

**3.3.1.2 Edges, Flexible Section** The trimmed edges of the flexible printed wiring or the flexible section of finished rigid-flex printed wiring shall be free of burrs, nicks or delamination in excess of that allowed in the procurement documentation. Tears shall not be allowed in Type 1 or Type 2 flexible printed wiring or within flexible sections of Type 3 or Type 4. When nicks and tears occur as a result of tie-in tabs to facilitate circuit removal, the extent of these imperfections shall be agreed upon between user and supplier. Minimum edge to conductor spacing shall be specified in the procurement documentation.

**3.3.1.3 Transition Zone, Rigid Area to Flexible Area** The transition zone is the area centered on the edge of the rigid portion from which the flex portion extends. The inspection range is limited to 3 mm [0.118 in], centered on the transition, which is the edge of the rigid portion. Visual imperfections inherent to the fabrication technique (i.e., adhesive squeeze-out, localized deformation of the dielectric and conductors,



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protruding dielectric materials, crazing, or haloing) shall not be cause for rejection. Imperfections in excess of that allowed shall be agreed upon between the fabricator and user, or as so stated on the procurement documentation.

**3.3.2 Construction    Imperfections** Laminate imperfections include those characteristics that are both internal and external within the printed board but are visible from the surface.

**3.3.2.1    Measling** Measling is acceptable for all classes of end product, with the exception of high-voltage applications. Refer to IPC-A-600 for more information.

**3.3.2.2    Crazing** Crazing is acceptable for all classes of end product provided the imperfection does not reduce the conductor spacing below the minimum and there is no propagation of the imperfection as a result of thermal testing that replicates the manufacturing process. For Class 2 and 3, the distance of crazing shall not span more than 50% of the distance between adjacent conductors.

**3.3.2.3    Delamination/ Blister** Delamination and blistering is acceptable for all classes of end product provided the area affected imperfections does not exceed 1% of the board area on each side and does not reduce the spacing between conductive patterns below the minimum conductor spacing. There shall be no propagation of imperfections as a result of thermal testing that replicates the manufacturing process. For Class 2 and 3, the blister or delamination shall not span more than 25% of the distance between adjacent conductive patterns.

**3.3.2.4    Foreign    Inclusions** Translucent particles trapped within the board shall be acceptable. Other particles trapped within the board shall be acceptable, provided the particle does not reduce the spacing between adjacent conductors to below the minimum spacing specified in 3.5.2.

**3.3.2.5    Weave Exposure** Weave exposure or exposed/disrupted fibers are acceptable for all Classes provided the imperfection does not reduce the remaining conductor spacing (excluding the area(s) with weave exposure) below the minimum. Refer to IPC-A-600 for more information.

**3.3.2.6    Scratches, Dents, and Tool Marks** Scratches, dents and tool marks are acceptable provided they do not expose conductors or expose/disrupt fibers greater than allowed in 3.3.2.4 and 3.3.2.5 and do not reduce the dielectric spacing below the minimum specified. Dents or tool marks that cause delamination, changes physical size of the conductor, or reduces condor width or spacing shall be rejected.

**3.3.2.7    Surface    Microvoids** Surface microvoids are acceptable provided they do not exceed 0.8 mm [0.0315 in] in the longest dimension, bridge conductors, or exceed 5% of the total flexible printed wiring area.



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3.3.2.8 Color Variations in Bond Enhancement Treatment Mottled appearance or color variation in bond enhancement treatment is acceptable. Random missing areas of treatment shall not exceed 10% of the total conductor surface area of the affected layer.

3.3.2.9 Pink Ring There is no existing evidence that pink ring affects functionality. The presence of pink ring may be considered an indicator of process or design variation but is not a cause for rejection. The focus of concern should be the quality of the lamination bond.

3.3.2.10 Coverfilm Separations The coverfilm shall be uniform and free of coverfilm separations, such as wrinkles, creases, and soda strawing. Nonlamination shall be acceptable, provided such imperfections do not violate 3.3.2.4 and all of the following:

- a. At random locations away from conductors, if each separation is no larger than 0.80 mm x 0.80 mm [0.0315 in x 0.0315 in] and is not within 1.0 mm [0.0394 in] of the board edge or the coverfilm opening. The total number of separations shall not exceed three in any 25 mm x 25 mm [0.984 in x 0.984 in] of coverfilm surface area.
- b. The total separation shall not exceed 25% of the spacing between adjacent conductors.
- c. There shall be no coverfilm nonlamination along the outer edges or covercoat openings of the coverfilm that reduces the seal below minimum edge to conductor spacing.

3.3.2.11.1 Covercoat Coverage Covercoat coverage manufacturing variations resulting in skips, voids, and misregistration are subject to the following restrictions:

- a. Metal conductors shall not be exposed or bridged by blisters in areas where covercoat is required. Touch up, if required to cover these areas with covercoat, shall be of a material that is compatible and of equal resistance to soldering and cleaning as the originally applied covercoat.
- b. In areas containing parallel conductors, covercoat variations shall not expose adjacent conductors unless the area between the conductors is purposely left blank as for a test point or for some surface mount devices.
- c. Covercoat need not be flush with the surface of the land. Misregistration of a covercoat-defined feature shall not expose adjacent isolated lands or conductors.
- d. Covercoat is allowed on lands for plated through holes to which solder connections are to be made, provided the external annular ring requirements for that class of products are not violated. Resist shall not encroach upon the barrel of this type of plated through holes.



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- Other surfaces, such as edge flexible printed wiring connector fingers and surface mount lands, shall be free of covercoat, except as specified. Covercoat allowed in plated through holes and vias into which no component lead is soldered, unless the procurement documentation requires that the holes be completely solder filled. Covercoat may tent or plug via holes as specified by the procurement documentation. Test points that are intended for assembly testing must be free of covercoat unless coverage is specified.
- e. When a land contains no plated through holes, as in the case of surface mount or ball grid array (BGA) lands, misregistration shall not cause encroachment of the covercoat on the land or lack of solder resist definition in excess of the following:
    - 1) On surface mount lands, misregistration shall not cause encroachment of the covercoat over the land area greater than 0.050 mm [0.00197 in] for a pitch  $\geq 1.25$  mm [0.04921 in]. Encroachment shall not exceed 0.025 mm [0.00098 in] for a pitch  $\leq 1.25$  mm [0.04921 in] and encroachment may occur on adjacent sides, but not on opposite sides of a surface mount land.
    - 2) On BGA lands, if the land is solder resist defined misregistration may allow a 90° breakout of the covercoat on the land. If clearance is specified, no encroachment of the covercoat on the land is allowed, except at the conductor attachment.
    - 3) On BGA lands connected to via holes, which have coverlayer dams required, the dam shall be continuous without missing peeling or cracked coverlayer, allowing a bare metal path between the BGA land and the via.
  - f. Blistering shall be allowed to the following extent:
    - 1) Class 1: Does not bridge between conductors.
    - 2) Class 2 and 3: Two per side, maximum 0.25mm [0.00984 in] in longest dimension, does not reduce electrical spacing between conductors by more than 25%.
  - g. Pits and voids are allowed in nonconductor areas, provided they have adherent edges and do not exhibit lifting or blistering in excess of allowance in 3.3.2.11.1(f).
  - h. Coverage between closely spaced surface mount lands shall be as required by procurement documentation.

- i. When design requires coverage to the flexible printed wiring edge, chipping or lifting of covercoat along the flexible printed wiring edge after fabrication shall not penetrate more than 1.25mm [0.04291 in] or 50% of the distance to the closest conductor, whichever is less.

3.3.2.11.2 Covercoat Cure and Adhesion The cured covercoat shall not exhibit tackiness or blistering in excess of that permitted in 3.3.2.11.1(f). When tested in accordance with IPC-TM-650, Method 2.4.28.1, the maximum percentage of cured covercoat lifting from Coupon G identified in IPC-2221 shall be in accordance with Table 3-1.

Table 3-1 Covercoat Adhesion

Surface	Maximum Percentage Loss Allowed		
	Class 1	Class 2	Class 3
Bare Copper	10	5	0
Gold Nickel	25	10	5
Base Laminate	10	5	0
Melting Metals (Tin-lead, fused tin-lead, and bright acid-tin)	50	25	10

3.3.2.11.3 Covercoat Thickness Covercoat thickness is not measured, unless specified on the procurement documentation. If a thickness measurement is required, instrumental methods may be used or an assessment may be made using a microsection of the parallel conductors on Coupon E identified in IPC-2221.

3.3.2.12 Solder Wicking/Plating Penetration Solder wicking or other plating penetration shall not extend into a bend or flex transition area and shall meet the conductor spacing requirements. Solder wicking or other plating penetration shall not exceed the limits specified in Table 3-2.

Table 3-2 Solder Wicking/Plating Penetration Limits

Class 1	Class 2	Class 3
As agreed upon between user and supplier	0.5mm (0.020") maximum	0.3 mm (0.012") maximum

3.3.2.13 Stiffener A stiffener will be evaluated only as a mechanical support. Void free bonding of the stiffener to the flexible printed wiring is not required. Specific requirements shall be as agreed upon between user and supplier.



3.3.1 Plating and Coating Voids in the Hole Plating and coating voids shall not exceed that allowed by Table 3-3.

Table 3-3 Plating and Coating Voids Visual Examination

Material	Class 1	Class 2	Class 3
Copper <sup>1</sup>	Three voids allowed per hole in not more than 10% of the holes.	One void allowed per hole in not more than 5% of the holes.	None
Finish Coating <sup>2</sup>	Five voids allowed per hole in not more than 15% of the holes.	Three voids allowed per hole in not more than 5% of the holes.	One void allowed per hole in not more than 5% of the holes.

<sup>1</sup>For class 2 flexible printed wiring product, copper voids shall not exceed 5% of the hole length. For class 1 flexible printed wiring product, copper voids shall not exceed 10% of the hole length. Circumferential voids shall not extend beyond 90° of the circumference.

<sup>2</sup>For class 2 and 3 product, finished coating voids shall not exceed 5% of the hole length. For class 1, finished coating voids shall not exceed 10% of the hole length. Circumferential voids shall not extend beyond 90° for class 1, 2, or 3.

3.3.4 Markings If required, each individual flexible printed board, qualification flexible printed board, and set of quality conformance test circuit strips (as opposed to each individual test coupon) shall be marked. This marking is required in order to insure traceability between the flexible printed wiring/test strips and the manufacturing history and to identify the supplier (logo, etc.). If size or space does not permit marking individual flexible printed wiring, bagging or tagging is permitted.

The marking shall be produced by the same process as used in producing the conductive pattern, or by use of a permanent fungistatic ink or paint (see 3.2.10), LASER marker or by vibrating pencil marking on a metallic area provided for marking purposes.

Conductive markings, either etched copper or conductive ink (see 3.2.10) shall be considered as electrical elements of the circuit and shall not reduce the electrical spacing requirements. All markings shall be compatible with materials and parts, legible for all tests, and in no case affect flexible printed wiring performance.

Marking shall not cover areas of lands that are to be soldered. (see IPC-A-600 for legibility requirements). In addition to this marking, the use of bar code marking is permissible. When used, date code shall be formatted per the supplier's discretion in order to establish traceability as to when the manufacturing operations were performed.

3.3.5 Solderability Only those flexible printed boards that require soldering in a subsequent assembly operation require solderability testing. Solderability testing is not necessary for flexible printed wiring that does not require soldering. This shall be specified on the master drawing, as in the case where press-



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fit components are used. Flexible printed wiring to be used for surface mount does not require hole solderability testing.

When required by the procurement documentation, accelerated aging for coating durability shall be in accordance with J-STD-003. The Category of durability shall be specified on the master drawing; however, if not specified, Category 2 shall be used. Specimens to be tested shall be conditioned, if required, and evaluated for surface and hole solderability using J-STD-003.

When solderability testing is required, consideration should be given to flexible printed wiring thickness and copper thickness. As both increase, the amount of time to properly wet the sides of the holes and the tops of the lands increases proportionately.

Note: Accelerated aging (steam aging) is intended for use on coatings of tin/lead solder or tin, but not other final finishes.

**3.3.6 Plating Adhesion** The adhesion of the plating shall be tested in accordance with IPC-TM-650, method 2.4.1. There shall be no evidence of any portion of the protective plating or the conductor pattern foil being removed, as shown by particles of the plating or pattern foil adhering to the tape. If overhanging metal (slivers) breaks off and adheres to the tape, it is evidence of overhang or slivers, but not of plating adhesion failure.

**3.3.7 Edge Board Contact, Junction of Gold Plate to Solder Finish** Exposed copper/plating overlap between the solder finish and gold plate shall meet the requirements of Table 3-4. The exposed copper/plating or gold overlap may exhibit a discolored or gray-black area which is acceptable (see 3.5.3.3).

Table 3-4 Edge Board Contact Gap

Class	Maximum Exposed Copper Gap	Maximum Gold Overlap
1	2.5 mm [0.0984 in]	2.5 mm [0.0984 in]
2	1.25 mm [0.04921 in]	1.25 mm [0.04921 in]
3	0.8 mm [0.031 in]	0.8 mm [0.031 in]

**3.3.8 Lifted Lands** When visually examined in accordance with 3.3, there shall be no lifted lands on the delivered (nonstressed) printed circuit board.

**3.3.9 Workmanship** Flexible printed boards shall be processed in such a manner as to be uniform in quality and show no visual evidence of dirt, foreign matter, oil, fingerprints, tin/lead or solder smear transfer to the dielectric surface, flux residue and other contaminants that affect life, ability to assemble and serviceability. Visually dark appearances in non-plated holes, which are seen when a metallic or non-



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metallic semiconductive coating is used, are not foreign material and do not affect life or function. Flexible printed wiring shall be free of defects in excess of those allowed in this specification. There shall be no evidence of any lifting or separation of platings from the surface of the conductive pattern, or of the conductor from the base laminate in excess of that allowed. There shall be no loose plating slivers on the surface of the printed board.

#### **METHOD:**

The boards were visually examined with approximately 1.75X using various light sources. Progressively higher magnifications, up to 40X, were used for referee evaluation.

#### **RESULTS:**

The boards met the requirements of IPC-6013A, Amendment 2, Class 3, paragraph 3.3.

### **THERMAL SHOCK**

#### **TEST SPECIMENS:**

Four (4) lots of flexible printed circuit boards.

#### **REFERENCE:**

IPC-6013A, Amendment 2, Class 3, paragraph 3.10.2.

#### **REQUIREMENT:**

When specified on the procurement documentation, flexible printed wiring or test coupons shall be tested in accordance with the procedure outlined below.

The specimen shall be tested for thermal shock in accordance with IPC-TM-650, method 2.6.7.2B, except the temperature range shall be  $-65^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  [ $-85^{\circ}\text{F}$  to  $257^{\circ}\text{F}$ ]. Microsection evaluation in accordance with IPC-TM-650, Method 2.6.7.2 is not required. Following removal from the test chamber, the specimen shall meet the circuitry requirements of 3.9.2. The resistance value shall not vary by more than  $\pm 10\%$ .

#### **METHOD:**

Insulated wires were soldered to the terminals of the test specimen. The initial resistance measurement was obtained using a multimeter. The samples were placed in Thermal Shock



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Chamber. The cold chamber was set at -65°C, and the hot portion of the chamber was set at 125°C. The dwell time was set at 15 minutes. The transfer to temperature extremes was approximately 15 seconds. During the first hot cycle, the resistance measurement was obtained with a multimeter.

The chamber was set for 100 cycles. During the last hot cycle the resistance measurement was again measured and recorded. The percent change was then calculated.

## RESULTS:

### Resistance Measurements:

Part Number

S/n	Layer	Before Conditioning (ohms)	After Conditioning (ohms)	% Change
		0.017	0.018	5.88
		0.022	0.023	4.55
		0.016	0.016	0.00
		0.010	0.010	0.00
		0.005	0.005	0.00
		0.027	0.028	3.70
		0.009	0.009	0.00
		0.010	0.010	0.00

Part Number

S/n	Layer	Before Conditioning (ohms)	After Conditioning (ohms)	% Change
		0.041	0.044	7.32
		0.040	0.041	2.50
		0.039	0.041	5.13
		0.043	0.043	0.00
		0.044	0.043	-2.27
		0.053	0.055	3.77
		0.030	0.031	3.33
		0.035	0.036	2.86



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Part Number

S/n	Layer	Before Conditioning (ohms)	After Conditioning (ohms)	% Change
		0.006	0.006	0.00
		0.019	0.018	-5.26
		0.008	0.008	0.00
		0.013	0.014	7.69

Part Number

S/n	Layer	Before Conditioning (ohms)	After Conditioning (ohms)	% Change
		0.380	0.386	1.58
		0.350	0.365	4.29
		0.350	0.355	1.43

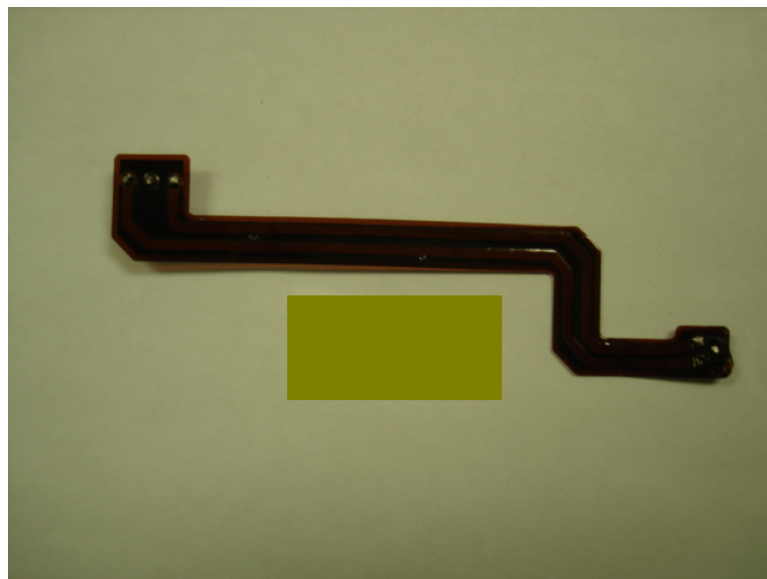


Photo 2:





Photo 3:

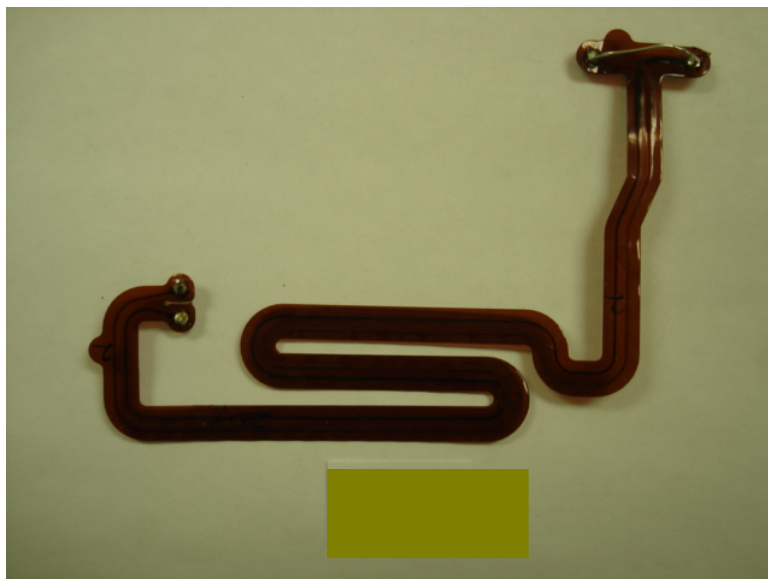


Photo 4:



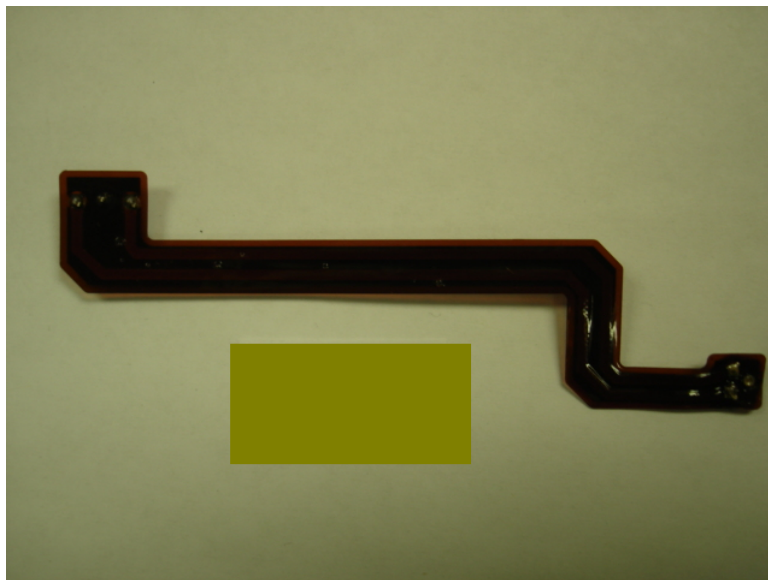


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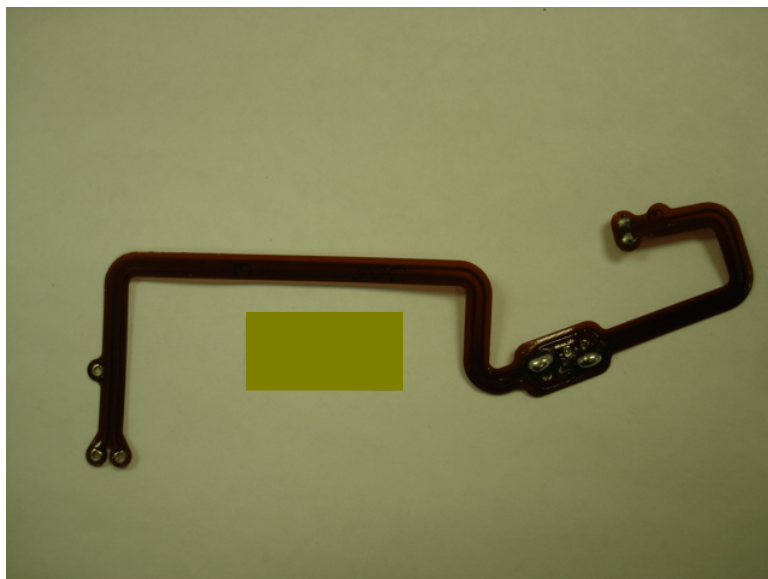


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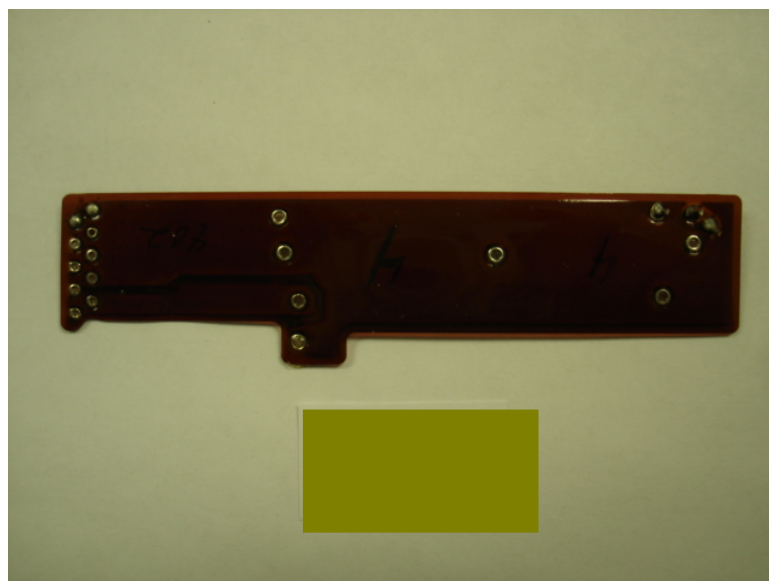


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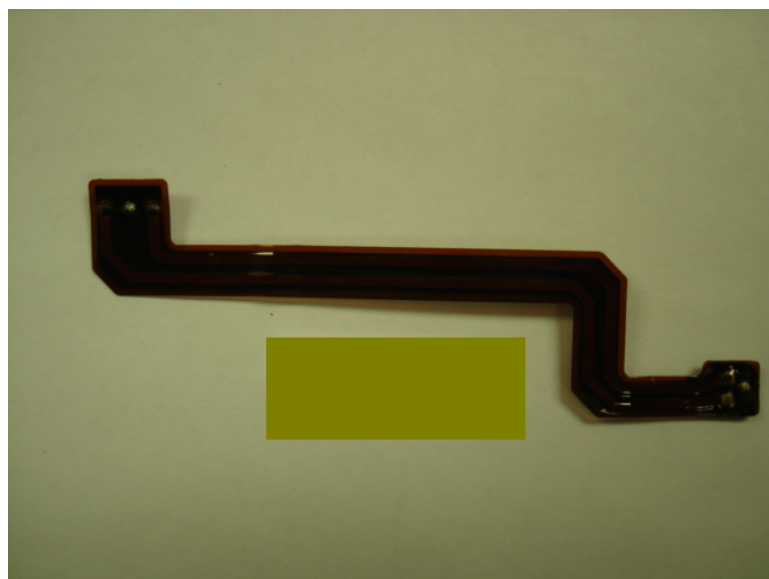


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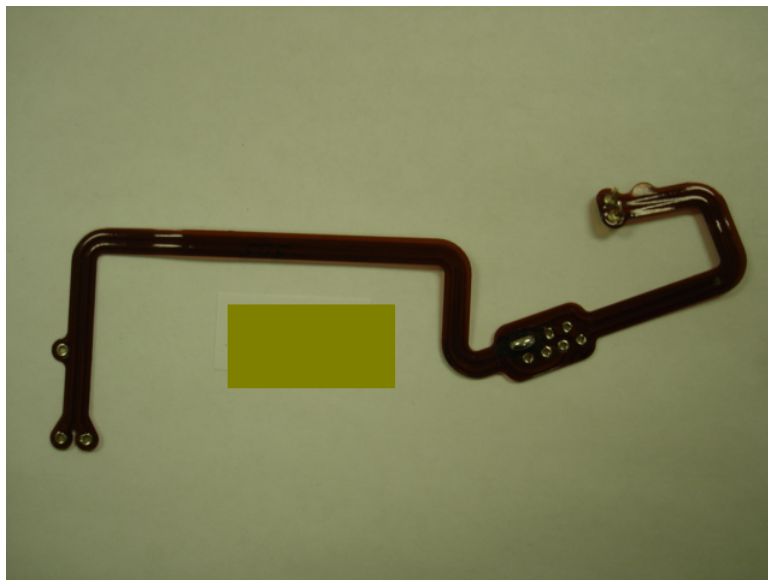


Photo 9:



Photo 10:

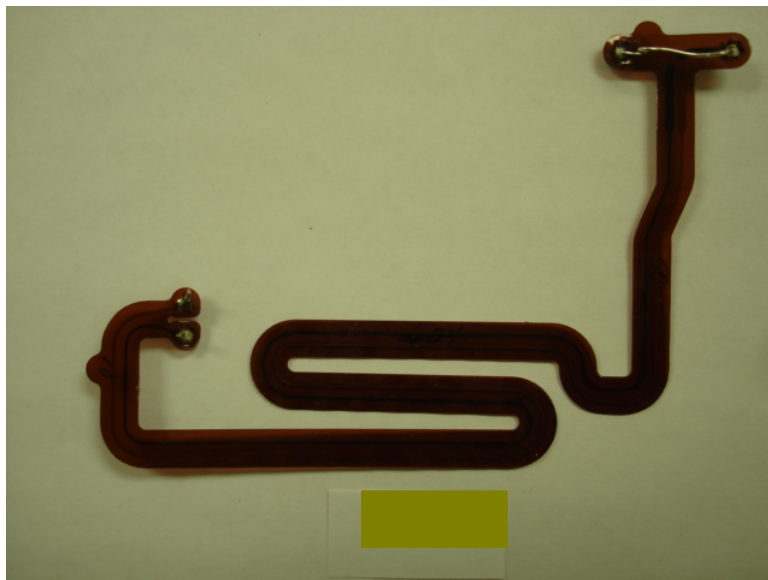


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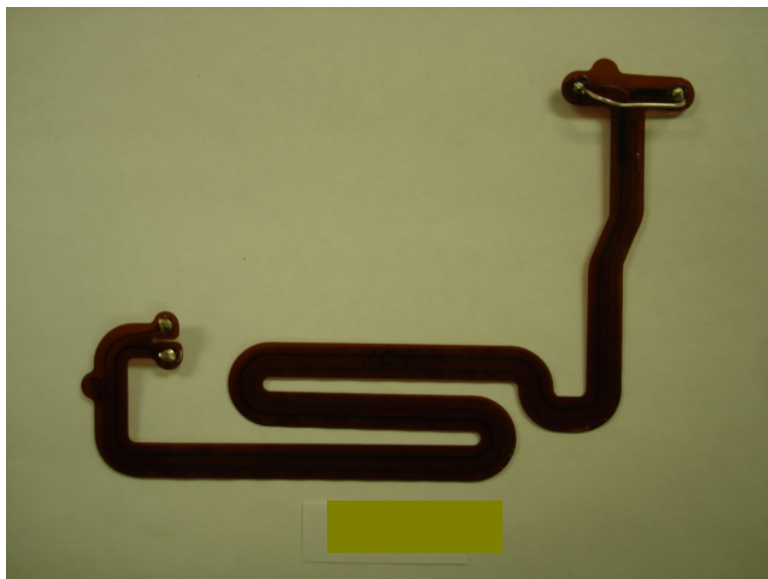


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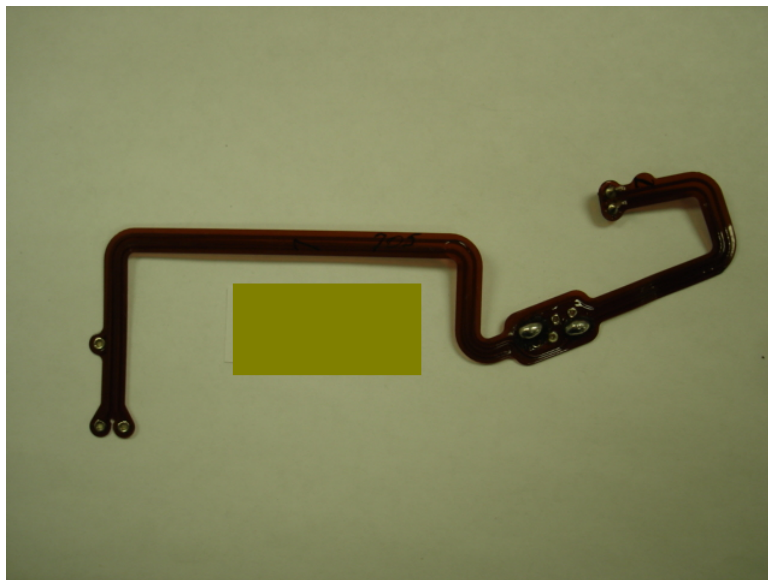


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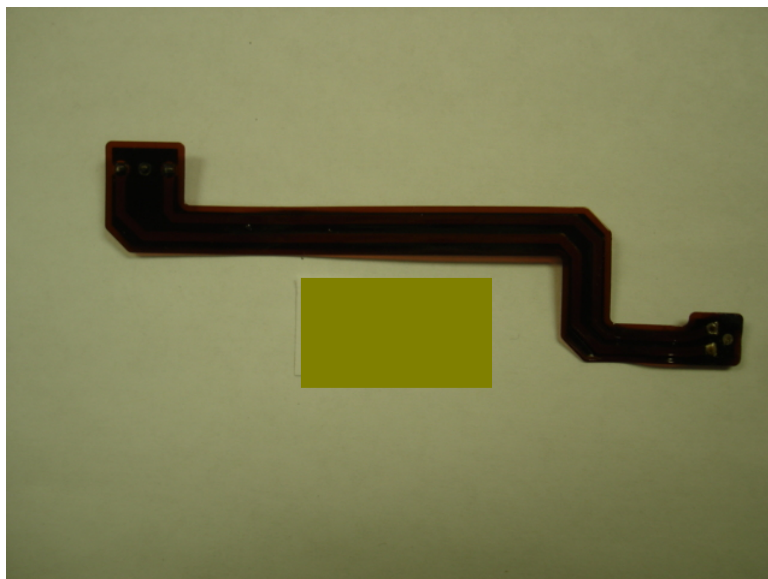


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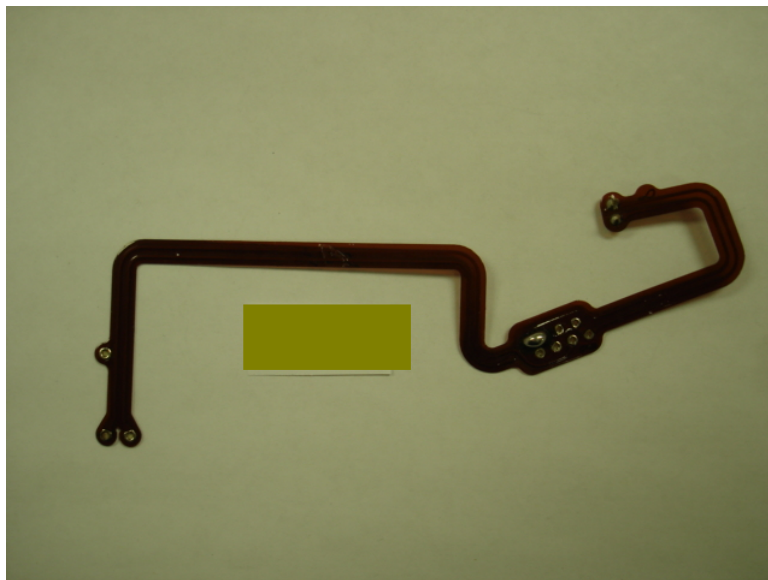


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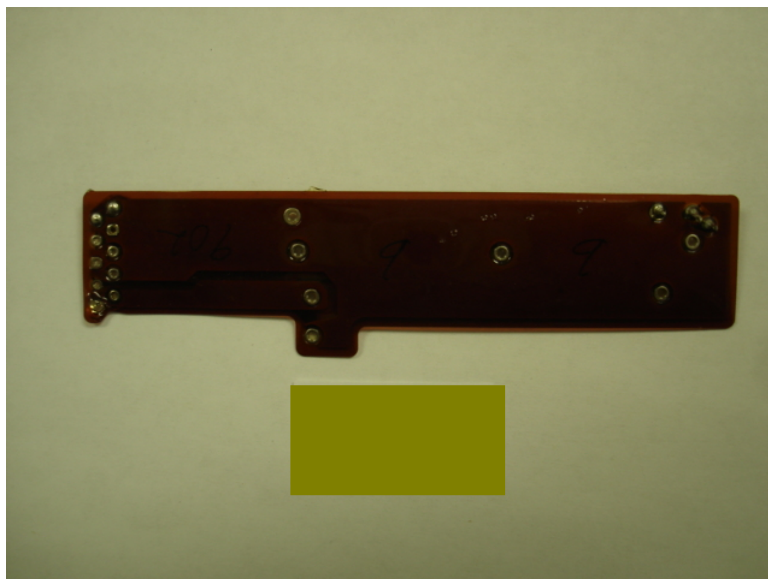


Photo 16:



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Trace Laboratories, Inc. certifies that the test equipment used complies with the calibration test purposes of ISO 10012-1, ANSI/NCSL Z540-1-1994, and MIL-STD-45662A and that the data contained in this report is accurate within the tolerance limitation of this equipment.

All test procedures detailed within this report are complete. The results in this report relate only to those items tested. If any additional information or clarification of this report is required, please contact us. This test report shall not be reproduced except in full, without the written approval of Trace Laboratories, Inc.

Thank you for selecting Trace Laboratories, Inc. for your testing requirements. Testing was subcontracted to an A2LA-approved laboratory.

**Lead Engineer:**

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Senior Engineer



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S/O 66024



**TEST REPORT FOR:**  
HONEYWELL, FM&T

Attn:

**DATE IN:**

July 15, 2008

**P/O #:**

**SUBMISSION IDENTIFICATION:**

Seven (7) groups of flexible printed circuit boards were submitted for Bending Test, MIR and Thermal Shock in accordance with IPC-6013A, Amendment 2, Class 3. The boards were identified as follows:

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
1-1	2-1	3-1	4-1	5-1	6-1	7-1
1-2	2-2	3-2	4-2	5-2	6-2	7-2
1-3	2-3	3-3	4-3	5-3	6-3	7-3

**SUMMARY:**

The boards met the requirements of IPC-6013A, Amendment 2, Class 3, for Bending Test, MIR and Thermal Shock.

**APPROVED:**

\_\_\_\_\_  
Laboratory Director

**SAMPLE DISPOSITION:** Samples returned to the customer



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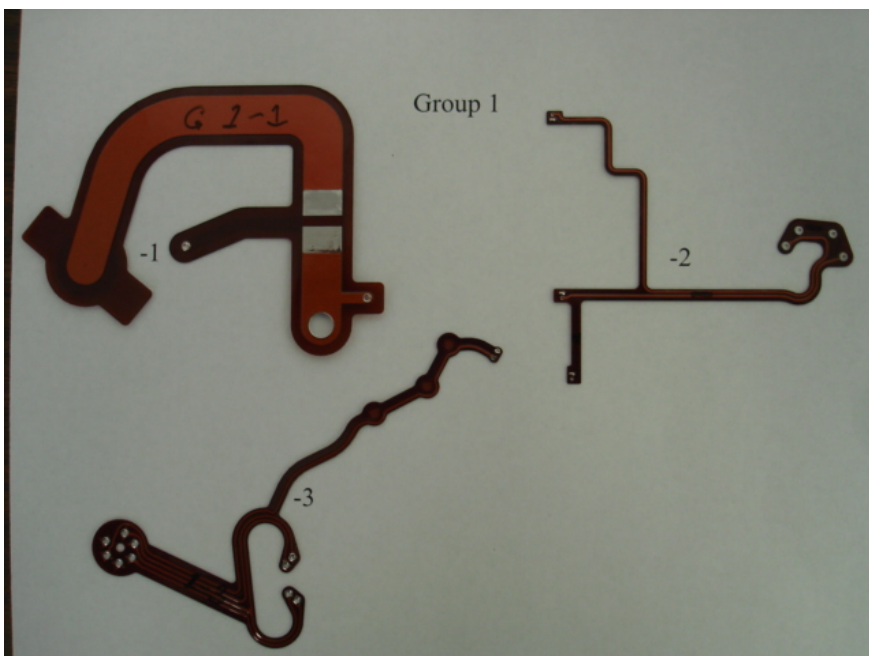


Photo 2: Group 1

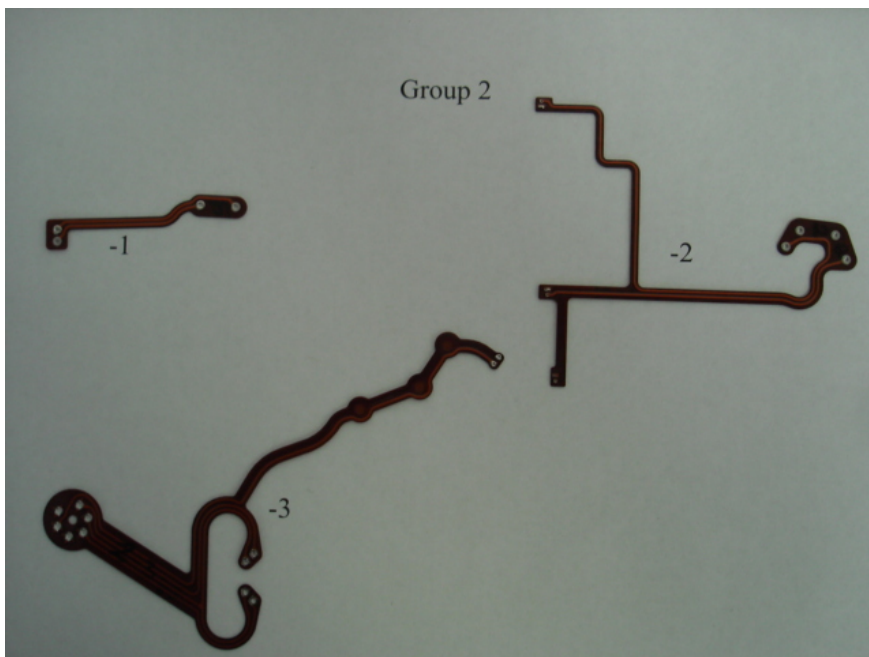


Photo 3: Group 2

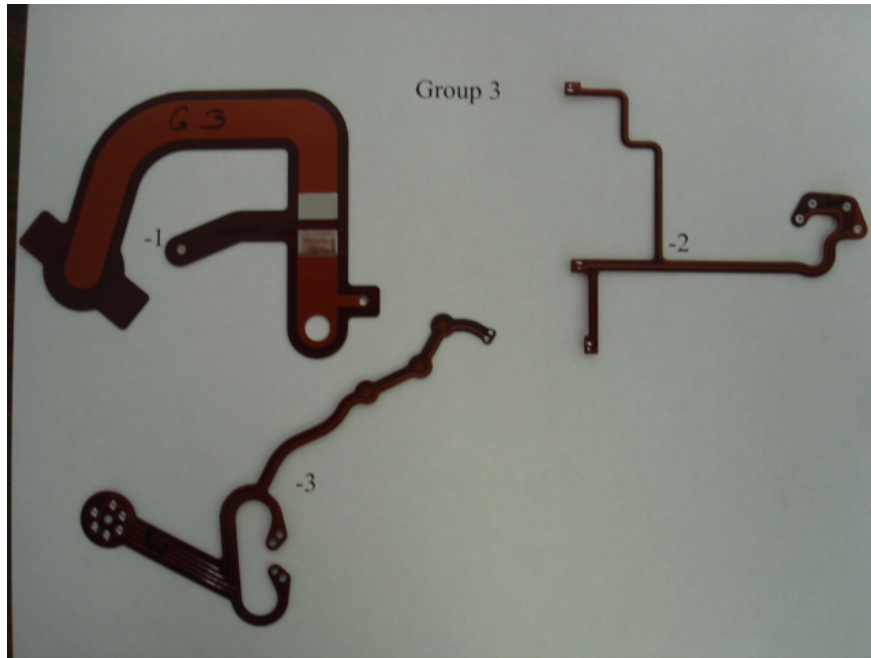


Photo 4: Group 3

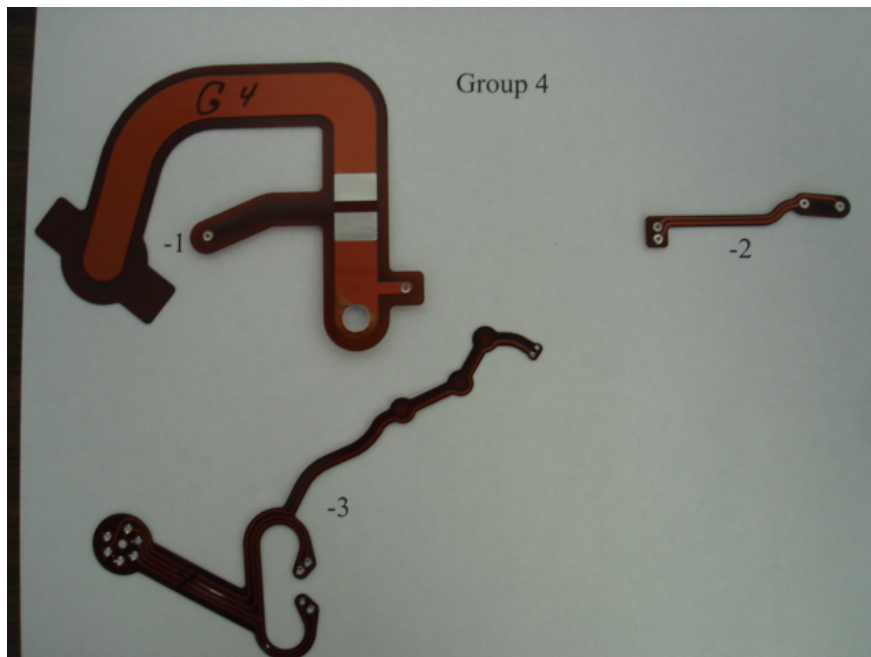


Photo 5: Group 4

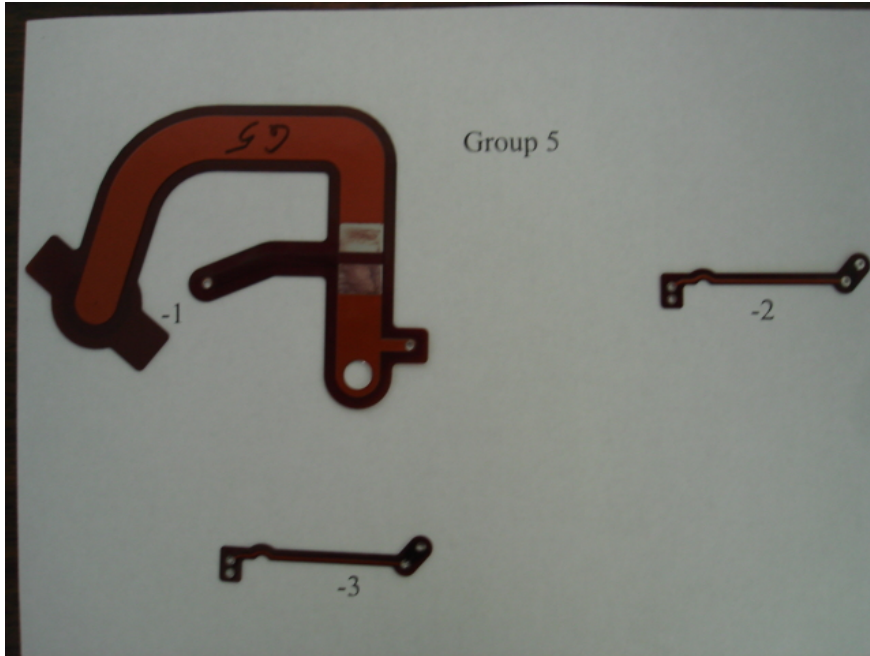


Photo 6: Group 5

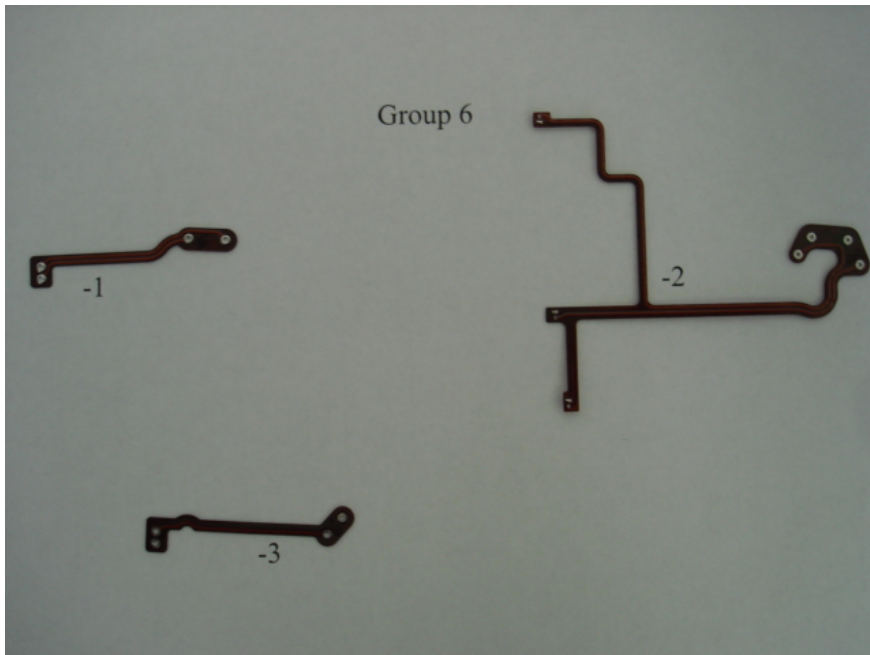


Photo 7: Group 6



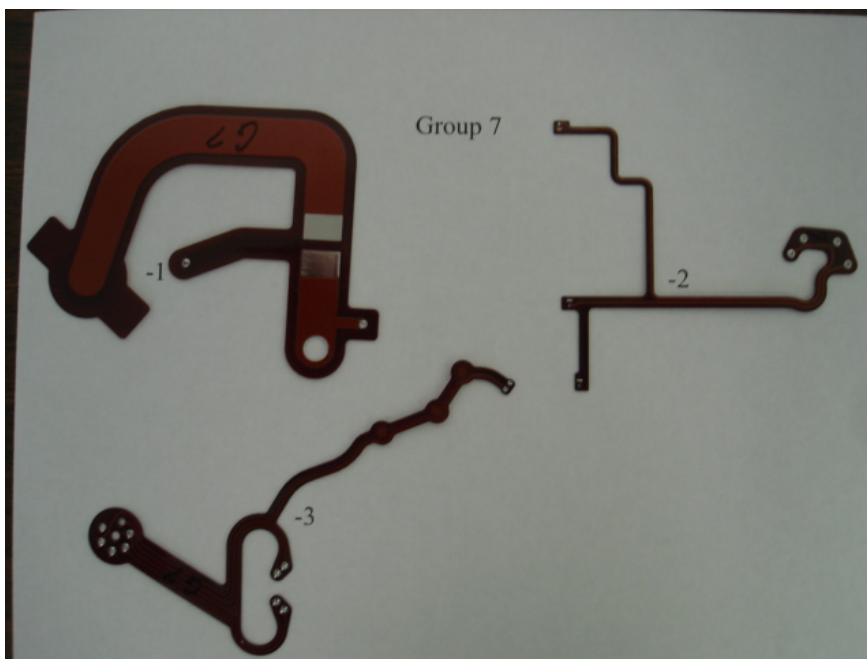


Photo 8: Group 7



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## BENDING TEST

### TEST SPECIMENS:

Seven (7) groups of flexible printed circuit boards.

### REFERENCE:

IPC-6013A, Amendment 2, Class 3, paragraphs 3.6.1, 3.9 and 3.3.

### REQUIREMENT:

After completion of the bending test in both directions, the flexible or rigid flexible printed wiring board shall be tested for electrical defects in accordance with 3.9 and shall meet the visual requirements of 3.3

### METHOD:

The bending test shall conform to Figure 3-8, unless otherwise agreed to by the user. The bending test requirements shall be as specifies on the appropriate document / drawing. See IPC 2223 for guidance on the minimum bend radii. The following parameters shall be specified as minimum:

- Direction of bend (a).
- Degree of bend (b)
- Number of bend cycles (c)
- Diameter of mandrel (d)
- Points of application to be supplied by user.

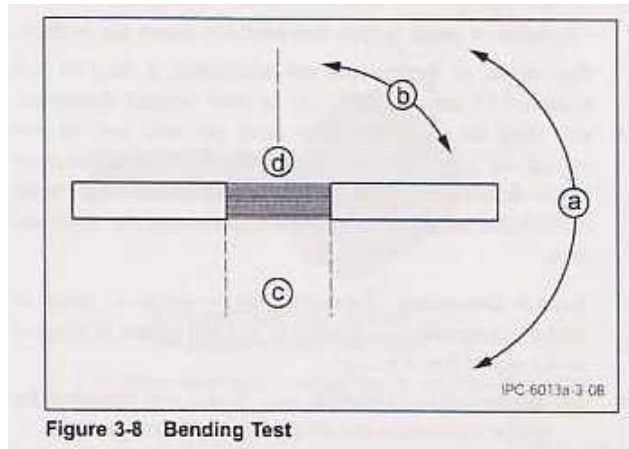
A bend cycle is defined as taking one end of the specimen and bending it around a mandrel and then bending back to the original starting point, traveling 180° in one direction and 180° in the opposite direction. A bend cycle may also be defined as bending (using opposite ends) the ends towards each other (bend the same direction) and then bending them back to the original starting position, with each end traveling 90° in the opposite direction.



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The direction of the bend was 90° upward and 90° downward.  
The degree of the bends was 90°.  
The number of bend cycles was 25.  
Mandrel Diameter:

Groups	10 times the thickness	Mandrel size
1 thru 7	160 mils	.323"

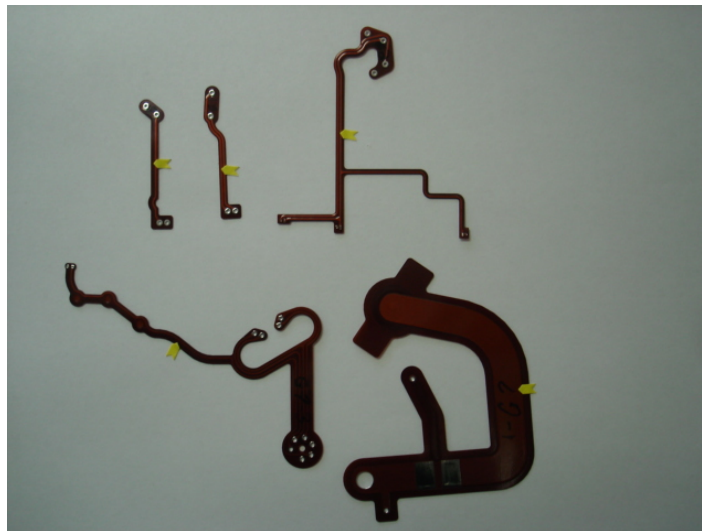


Photo 1: Bend Locations

After completing the bending test the boards were tested per electrical requirements 3.9.



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## ELECTRICAL REQUIREMENTS

### CONTINUITY

#### TEST SPECIMENS:

Seven (7) groups of flexible printed circuit boards.

#### REFERENCE:

IPC-6013A, Amendment 2, Class 3, paragraph 3.9.2.1.

#### REQUIREMENT:

Flexible printed boards and qualification testing of flexible printed wiring boards shall be tested in accordance with the procedure outlined below. There shall be no circuits whose resistance exceeds the values established in the procurement documentation. The presence of long runs of very narrow conductors, or high resistance metals may increase these values. When required by the user, interconnect shorts and continuity coupon D shall be used for evaluation of the interconnection resistance and circuit continuity.

A current shall be passed through each conductor or group of interconnected conductors by applying electrodes on the terminals at each end of the conductor or group of conductors. The current passing through the conductors shall not exceed that specified in IPC-2221 for the smallest conductor in the circuit. For qualification, the test current shall not exceed one ampere. Flexible printed wiring with designed resistive patterns shall meet the resistance requirements specified on the procurement documentation.

#### METHOD:

Insulated wires were soldered to the plated through holes at the ends of a selected conductor. The wires were placed in the grips of a multimeter. A resistance measurement was observed.

#### RESULTS:

The boards met the requirements for continuity between the conductor and land patterns.



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## ISOLATION (CIRCUIT SHORTS)

### TEST SPECIMENS:

Seven (7) groups of flexible printed circuit boards.

### REFERENCE:

IPC-6013A, Amendment 2, Class 3, paragraph 3.9.2.2.

### REQUIREMENT:

Flexible printed wiring shall be tested in accordance with the following procedure. The isolation resistance between conductors shall meet the values established in the procurement documentation. The voltage applied between the networks must be high enough to provide sufficient current resolution for the measurement. At the same time, it must be low enough to prevent arc-over between adjacent networks, which could induce defects within the product. For manual testing, the voltage shall be 200 volts minimum and shall be applied for a minimum of 5 seconds. When automatic test equipment is used, the minimum applied voltage shall be the maximum rated voltage of the flexible printed wiring. When not specified, the default value of 40 volts shall be used.

### METHOD:

Insulated wires were soldered to the plated through holes at the ends of a selected conductor. The wires were placed in the grips of a multimeter. The resistance measurement was obtained.

### RESULTS:

The boards met the requirements for isolation (circuit shorts).



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#### Group 1

	Layer	1-1	1-2	1-3
Continuity	1	Pass	Pass	Pass
	2	Pass	Pass	Pass
Isolation	1	Pass	Pass	Pass
	2	Pass	Pass	Pass

#### Group 2

	Layer	2-1	2-2	2-3
Continuity	1	Pass	Pass	Pass
	2	Pass	Pass	Pass
Isolation	1	Pass	Pass	Pass
	2	Pass	Pass	Pass

#### Group 3

	Layer	3-1	3-2	3-3
Continuity	1	Pass	Pass	Pass
	2	Pass	Pass	Pass
Isolation	1	Pass	Pass	Pass
	2	Pass	Pass	Pass

#### Group 4

	Layer	4-1	4-2	4-3
Continuity	1	Pass	Pass	Pass
	2	Pass	Pass	Pass
Isolation	1	Pass	Pass	Pass
	2	Pass	Pass	Pass



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Group 5

	Layer	5-1	5-2	5-3
Continuity	1	Pass	Pass	Pass
	2	Pass	Pass	Pass
Isolation	1	Pass	Pass	Pass
	2	Pass	Pass	Pass

Group 6

	Layer	6-1	6-2	6-3
Continuity	1	Pass	Pass	Pass
	2	Pass	Pass	Pass
Isolation	1	Pass	Pass	Pass
	2	Pass	Pass	Pass

Group 7

	Layer	7-1	7-2	7-3
Continuity	1	Pass	Pass	Pass
	2	Pass	Pass	Pass
Isolation	1	Pass	Pass	Pass
	2	Pass	Pass	Pass



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## MOISTURE AND INSULATION RESISTANCE

### TEST SPECIMENS:

Seven (7) groups of flexible printed circuit boards.

### REFERENCE:

IPC-6013A, Amendment 2, Class 3, paragraph 3.10.1.

### REQUIREMENT:

The flexible wiring boards shall not exhibit measling, blistering, or delamination in excess of that allowed in 3.3.2. Insulation resistance shall meet the requirements shown in table 3-13. Noncomponent flush wiring shall have a minimum requirement of  $50\text{M}\Omega$  [ $5.0\text{E}+7$ ] for class 3. Moisture and insulation resistance testing for flexible printed wiring shall be performed in accordance with IPC-TM-650, Method 2.6.3F.

### METHOD:

Insulated single stranded wires were soldered to each of the connection points of the test specimen. These wires were used to connect the test patterns of the test specimen in order to obtain the insulation resistance measurements and to allow a connection with the outside power supply. The test leads were cleaned with isopropyl alcohol and scrubbed with a soft bristle brush for a minimum of 30 seconds. The test specimen was rinsed thoroughly with fresh isopropyl alcohol from top to bottom. The cleaned area was rinsed thoroughly with fresh deionized water holding the test specimen at an approximate  $30^\circ$  angle and sprayed from top to bottom. The test specimen was dried in an oven for a minimum of three hours at an oven temperature of  $50\pm 5^\circ\text{C}$  ( $122\pm 9^\circ\text{F}$ ). The test specimen was then coated with conformal coating in accordance with IPC-CC-830 and cured as specified by the coating supplier. After curing the test specimens were then stabilized to ambient temperature. Initial insulation resistance measurements were taken by applying five hundred (500) volts direct current for one minute using a high resistance meter.

The test specimen was placed in the vertical position in a moisture chamber and the wires were connected to a power supply throughout the entire test. A polarizing voltage of 100 volts direct current was applied. The test sample was exposed to 20 cycles of temperature and humidity. The humidity chamber was cycled from  $25^\circ\text{C}$ ,  $+5^\circ\text{C}$ ,  $-2^\circ\text{C}$  at 85% to 93% relative humidity, to  $65^\circ\text{C}$ ,  $\pm 2^\circ\text{C}$  at 85% to 93% relative humidity.

Note: The humidity may drop to a minimum of 80% relative humidity when going from high to low temperature.



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Insulation resistance measurements were made within two hours after removal from the chamber. Following 24 hours stabilization period, the test samples were visually examined.

Table 3-13 Insulation Resistance

	Class 2	Class 3
As Received	500 MΩ	500 MΩ
After exposure to moisture	100 MΩ	500 MΩ

## RESULTS:

### Visual Results:

There was no evidence of mealing of the conformal coating.

### Insulation Resistance Measurements (in megohms):

Group 1	Layer	Before Conditioning	After Conditioning
-1	1	$1.11 \times 10^5$	$1.46 \times 10^6$
-1	1	$5.16 \times 10^5$	$3.20 \times 10^6$
-1	2	$2.70 \times 10^5$	$1.89 \times 10^5$
-2	1	$6.98 \times 10^6$	$1.82 \times 10^6$
-2	1	$3.42 \times 10^6$	$1.07 \times 10^5$
-2	2	$3.96 \times 10^6$	$1.62 \times 10^6$
-3	1	$7.05 \times 10^6$	$1.33 \times 10^6$
-3	1	$8.87 \times 10^6$	$1.64 \times 10^6$

Group 2	Layer	Before Conditioning	After Conditioning
-1	1	$5.75 \times 10^6$	$5.21 \times 10^6$
-2	1	$6.27 \times 10^5$	$3.22 \times 10^6$
-2	1	$7.50 \times 10^5$	$1.40 \times 10^6$
-2	2	$1.11 \times 10^5$	$1.18 \times 10^6$
-3	1	$2.59 \times 10^4$	$1.43 \times 10^6$
-3	1	$7.54 \times 10^4$	$1.13 \times 10^5$



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Group 3	Layer	Before Conditioning	After Conditioning
-1	1	$4.55 \times 10^6$	$2.31 \times 10^6$
-1	1	$5.02 \times 10^5$	$1.16 \times 10^6$
-1	2	$4.21 \times 10^6$	$4.50 \times 10^5$
-2	1	$2.83 \times 10^6$	$1.19 \times 10^6$
-2	1	$2.62 \times 10^6$	$8.91 \times 10^6$
-2	2	$2.38 \times 10^6$	$8.57 \times 10^5$
-3	1	$6.86 \times 10^5$	$2.00 \times 10^6$
-3		$1.06 \times 10^5$	$1.31 \times 10^6$

Group 4	Layer	Before Conditioning	After Conditioning
-1	1	$9.01 \times 10^6$	$2.18 \times 10^6$
-1	1	$4.29 \times 10^6$	$8.98 \times 10^5$
-1	2	$4.23 \times 10^6$	$4.28 \times 10^5$
-2	1	$4.52 \times 10^6$	$4.35 \times 10^6$
-3	1	$7.59 \times 10^5$	$2.13 \times 10^6$
-3	1	$7.72 \times 10^5$	$1.28 \times 10^6$

Group 5	Layer	Before Conditioning	After Conditioning
-1	1	$2.75 \times 10^5$	$1.95 \times 10^6$
-1	1	$4.88 \times 10^5$	$2.57 \times 10^6$
-1	2	$1.65 \times 10^5$	$3.42 \times 10^5$
-2	1	$2.76 \times 10^6$	$2.62 \times 10^6$
-3	1	$7.72 \times 10^4$	$3.14 \times 10^6$

Group 6	Layer	Before Conditioning	After Conditioning
-1	1	$4.73 \times 10^6$	$2.65 \times 10^6$
-2	1	$3.15 \times 10^6$	$1.44 \times 10^6$
-2	1	$2.94 \times 10^6$	$8.93 \times 10^5$
-2	2	$3.18 \times 10^6$	$9.97 \times 10^5$
-3	1	$4.01 \times 10^6$	$2.50 \times 10^6$

Group 7	Layer	Before Conditioning	After Conditioning
-1	1	$3.66 \times 10^5$	$2.15 \times 10^6$
-1	1	$7.30 \times 10^5$	$2.28 \times 10^6$
-1	2	$2.97 \times 10^5$	$5.12 \times 10^5$
-2	1	$4.19 \times 10^6$	$1.39 \times 10^6$
-2	1	$2.91 \times 10^6$	$1.36 \times 10^6$
-2	2	$2.87 \times 10^6$	$2.61 \times 10^6$
-3	1	$3.50 \times 10^5$	$1.06 \times 10^6$
-3	1	$2.70 \times 10^6$	$8.09 \times 10^5$

## DIELECTRIC WITHSTANDING VOLTAGE

### TEST SPECIMENS:

Seven (7) groups of flexible printed circuit boards.

### REFERENCE:

IPC-6013A, Amendment 2, Class 3, paragraph 3.9.1

### REQUIREMENT:

Applicable test coupons or production boards shall meet the requirements of Table 3-12, without flashover, sparkover, or breakdown between conductor, or conductors and lands. The dielectric withstanding voltage test shall be performed in accordance with IPC-TM-650, method 2.5.7D. The dielectric withstanding voltage shall be applied between all common portions of each conductor pattern and adjacent common portions of each conductor pattern. The voltage shall be applied between conductor patterns of each layer and the electrically isolated pattern of each adjacent layer.

Table 3-12 Dielectric Withstanding Voltage

	Class 2	Class 3
Voltage	500VDC +15, -0	1000VDC +25, -0
Time	30 seconds +3, -0	30 seconds +3, -0



---

#### METHOD:

Insulated wires were soldered to a set of adjacent parallel conductors. The electrodes of the hi-pot tester were connected to the insulated wires. Five hundred VDC were applied for 30 seconds. The results were recorded.

#### RESULTS:

**There was no flashover, or breakdown between conductor, or conductors and lands between all common portions of each conductor pattern and adjacent common portions of each conductor pattern.**



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## VISUAL

### TEST SPECIMENS:

Seven (7) groups of flexible printed circuit boards

### REFERENCE:

IPC-6013A, Amendment 2, Class 3 paragraphs 3.3.1.2, 3.3.2 – 3.3.2.10.

### REQUIREMENT:

The finished flexible printed wiring shall be examined in accordance with the following procedure. They shall be of uniform quality and shall conform to sections 3.3.1 and 3.3.9.

Visual examination for applicable attributes shall be conducted at 3 diopters (approx. 1.75X). If the acceptable condition of a suspected defect is not apparent, it should be verified at progressively higher magnifications (up to 40X) to confirm that it is a defect. Dimensional requirements such as spacing or conductor width measurements require other magnification and devices with reticles or scales in the instrument which allow accurate measurements of the specified dimensions. Contract or specification may require other magnifications.

**3.3.1.1 Edges, Rigid Section** Nicks, Cracking or haloing along the edges of the flexible printed wiring, cutouts, and nonplated-through holes are acceptable, provided the penetration does not exceed 50% of the distance from the edge of the nearest conductor or 2.5mm [0.0984 in], whichever is less. Edges shall be clean cut and without metallic burrs. Nonmetallic burrs are acceptable as long as they are not loose and/or do not affect fit and function. Panels that are scored or routed with a breakaway tab shall meet the depanelization requirements of the assembled flexible printed wiring.

**3.3.1.2 Edges, Flexible Section** The trimmed edges of the flexible printed wiring or the flexible section of finished rigid-flex printed wiring shall be free of burrs, nicks or delamination in excess of that allowed in the procurement documentation. Tears shall not be allowed in Type 1 or Type 2 flexible printed wiring or within flexible sections of Type 3 or Type 4. When nicks and tears occur as a result of tie-in tabs to facilitate circuit removal, the extent of these imperfections shall be agreed upon between user and supplier. Minimum edge to conductor spacing shall be specified in the procurement documentation.

**3.3.1.3 Transition Zone, Rigid Area to Flexible Area** The transition zone is the area centered on the edge of the rigid portion from which the flex portion extends. The inspection range is limited to 3 mm [0.118 in], centered on the transition, which is the edge of the rigid portion. Visual imperfections inherent to the fabrication technique (i.e., adhesive squeeze-out, localized deformation of the dielectric and conductors,



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protruding dielectric materials, crazing, or haloing) shall not be cause for rejection. Imperfections in excess of that allowed shall be agreed upon between the fabricator and user, or as so stated on the procurement documentation.

3.3.2 Construction Imperfections Laminate imperfections include those characteristics that are both internal and external within the printed board but are visible from the surface.

3.3.2.1 Measling Measling is acceptable for all classes of end product, with the exception of high-voltage applications. Refer to IPC-A-600 for more information.

3.3.2.2 Crazing Crazing is acceptable for all classes of end product provided the imperfection does not reduce the conductor spacing below the minimum and there is no propagation of the imperfection as a result of thermal testing that replicates the manufacturing process. For Class 2 and 3, the distance of crazing shall not span more than 50% of the distance between adjacent conductors.

3.3.2.3 Delamination/ Blister Delamination and blistering is acceptable for all classes of end product provided the area affected imperfections does not exceed 1% of the board area on each side and does not reduce the spacing between conductive patterns below the minimum conductor spacing. There shall be no propagation of imperfections as a result of thermal testing that replicates the manufacturing process. For Class 2 and 3, the blister or delamination shall not span more than 25% of the distance between adjacent conductive patterns.

3.3.2.4 Foreign Inclusions Translucent particles trapped within the board shall be acceptable. Other particles trapped within the board shall be acceptable, provided the particle does not reduce the spacing between adjacent conductors to below the minimum spacing specified in 3.5.2.

3.3.2.5 Weave Exposure Weave exposure or exposed/disrupted fibers are acceptable for all Classes provided the imperfection does not reduce the remaining conductor spacing (excluding the area(s) with weave exposure) below the minimum. Refer to IPC-A-600 for more information.

3.3.2.6 Scratches, Dents, and Tool Marks Scratches, dents and tool marks are acceptable provided they do not expose conductors or expose/disrupt fibers greater than allowed in 3.3.2.4 and 3.3.2.5 and do not reduce the dielectric spacing below the minimum specified. Dents or tool marks that cause delamination, changes physical size of the conductor, or reduces condor width or spacing shall be rejected.

3.3.2.7 Surface Microvoids Surface microvoids are acceptable provided they do not exceed 0.8 mm [0.0315 in] in the longest dimension, bridge conductors, or exceed 5% of the total flexible printed wiring area.



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3.3.2.8 Color Variations in Bond Enhancement Treatment Mottled appearance or color variation in bond enhancement treatment is acceptable. Random missing areas of treatment shall not exceed 10% of the total conductor surface area of the affected layer.

3.3.2.9 Pink Ring There is no existing evidence that pink ring affects functionality. The presence of pink ring may be considered an indicator of process or design variation but is not a cause for rejection. The focus of concern should be the quality of the lamination bond.

3.3.2.10 Coverfilm Separations The coverfilm shall be uniform and free of coverfilm separations, such as wrinkles, creases, and soda strawing. Nonlamination shall be acceptable, provided such imperfections do not violate 3.3.2.4 and all of the following:

- a. At random locations away from conductors, if each separation is no larger than 0.80 mm x 0.80 mm [0.0315 in x 0.0315 in] and is not within 1.0 mm [0.0394 in] of the board edge or the coverfilm opening. The total number of separations shall not exceed three in any 25 mm x 25 mm [0.984 in x 0.984 in] of coverfilm surface area.
- b. The total separation shall not exceed 25% of the spacing between adjacent conductors.
- c. There shall be no coverfilm nonlamination along the outer edges or covercoat openings of the coverfilm that reduces the seal below minimum edge to conductor spacing.

3.3.2.11.1 Covercoat Coverage Covercoat coverage manufacturing variations resulting in skips, voids, and misregistration are subject to the following restrictions:

- a. Metal conductors shall not be exposed or bridged by blisters in areas where covercoat is required. Touch up, if required to cover these areas with covercoat, shall be of a material that is compatible and of equal resistance to soldering and cleaning as the originally applied covercoat.
- b. In areas containing parallel conductors, covercoat variations shall not expose adjacent conductors unless the area between the conductors is purposely left blank as for a test point or for some surface mount devices.
- c. Covercoat need not be flush with the surface of the land. Misregistration of a covercoat-defined feature shall not expose adjacent isolated lands or conductors.
- d. Covercoat is allowed on lands for plated through holes to which solder connections are to be made, provided the external annular ring requirements for that class of products are not violated. Resist shall not encroach upon the barrel of this type of plated through holes.



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- Other surfaces, such as edge flexible printed wiring connector fingers and surface mount lands, shall be free of covercoat, except as specified. Covercoat allowed in plated through holes and vias into which no component lead is soldered, unless the procurement documentation requires that the holes be completely solder filled. Covercoat may tent or plug via holes as specified by the procurement documentation. Test points that are intended for assembly testing must be free of covercoat unless coverage is specified.
- e. When a land contains no plated through holes, as in the case of surface mount or ball grid array (BGA) lands, misregistration shall not cause encroachment of the covercoat on the land or lack of solder resist definition in excess of the following:
    - 1) On surface mount lands, misregistration shall not cause encroachment of the covercoat over the land area greater than 0.050 mm [0.00197 in] for a pitch  $\geq 1.25$  mm [0.04921 in]. Encroachment shall not exceed 0.025 mm [0.00098 in] for a pitch  $\leq 1.25$  mm [0.04921 in] and encroachment may occur on adjacent sides, but not on opposite sides of a surface mount land.
    - 2) On BGA lands, if the land is solder resist defined misregistration may allow a 90° breakout of the covercoat on the land. If clearance is specified, no encroachment of the covercoat on the land is allowed, except at the conductor attachment.
    - 3) On BGA lands connected to via holes, which have coverlayer dams required, the dam shall be continuous without missing peeling or cracked coverlayer, allowing a bare metal path between the BGA land and the via.
  - f. Blistering shall be allowed to the following extent:
    - 1) Class 1: Does not bridge between conductors.
    - 2) Class 2 and 3: Two per side, maximum 0.25mm [0.00984 in] in longest dimension, does not reduce electrical spacing between conductors by more than 25%.
  - g. Pits and voids are allowed in nonconductor areas, provided they have adherent edges and do not exhibit lifting or blistering in excess of allowance in 3.3.2.11.1(f).
  - h. Coverage between closely spaced surface mount lands shall be as required by procurement documentation.

- i. When design requires coverage to the flexible printed wiring edge, chipping or lifting of covercoat along the flexible printed wiring edge after fabrication shall not penetrate more than 1.25mm [0.04291 in] or 50% of the distance to the closest conductor, whichever is less.

3.3.2.11.2 Covercoat Cure and Adhesion The cured covercoat shall not exhibit tackiness or blistering in excess of that permitted in 3.3.2.11.1(f). When tested in accordance with IPC-TM-650, Method 2.4.28.1, the maximum percentage of cured covercoat lifting from Coupon G identified in IPC-2221 shall be in accordance with Table 3-1.

Table 3-1 Covercoat Adhesion

Surface	Maximum Percentage Loss Allowed		
	Class 1	Class 2	Class 3
Bare Copper	10	5	0
Gold Nickel	25	10	5
Base Laminate	10	5	0
Melting Metals (Tin-lead, fused tin-lead, and bright acid-tin)	50	25	10

3.3.2.11.3 Covercoat Thickness Covercoat thickness is not measured, unless specified on the procurement documentation. If a thickness measurement is required, instrumental methods may be used or an assessment may be made using a microsection of the parallel conductors on Coupon E identified in IPC-2221.

3.3.2.12 Solder Wicking/Plating Penetration Solder wicking or other plating penetration shall not extend into a bend or flex transition area and shall meet the conductor spacing requirements. Solder wicking or other plating penetration shall not exceed the limits specified in Table 3-2.

Table 3-2 Solder Wicking/Plating Penetration Limits

Class 1	Class 2	Class 3
As agreed upon between user and supplier	0.5mm (0.020") maximum	0.3 mm (0.012") maximum

3.3.2.13 Stiffener A stiffener will be evaluated only as a mechanical support. Void free bonding of the stiffener to the flexible printed wiring is not required. Specific requirements shall be as agreed upon between user and supplier.



3.3.1 Plating and Coating Voids in the Hole Plating and coating voids shall not exceed that allowed by Table 3-3.

Table 3-3 Plating and Coating Voids Visual Examination

Material	Class 1	Class 2	Class 3
Copper <sup>1</sup>	Three voids allowed per hole in not more than 10% of the holes.	One void allowed per hole in not more than 5% of the holes.	None
Finish Coating <sup>2</sup>	Five voids allowed per hole in not more than 15% of the holes.	Three voids allowed per hole in not more than 5% of the holes.	One void allowed per hole in not more than 5% of the holes.

<sup>1</sup>For class 2 flexible printed wiring product, copper voids shall not exceed 5% of the hole length. For class 1 flexible printed wiring product, copper voids shall not exceed 10% of the hole length. Circumferential voids shall not extend beyond 90° of the circumference.

<sup>2</sup>For class 2 and 3 product, finished coating voids shall not exceed 5% of the hole length. For class 1, finished coating voids shall not exceed 10% of the hole length. Circumferential voids shall not extend beyond 90° for class 1, 2, or 3.

3.3.4 Markings If required, each individual flexible printed board, qualification flexible printed board, and set of quality conformance test circuit strips (as opposed to each individual test coupon) shall be marked. This marking is required in order to insure traceability between the flexible printed wiring/test strips and the manufacturing history and to identify the supplier (logo, etc.). If size or space does not permit marking individual flexible printed wiring, bagging or tagging is permitted.

The marking shall be produced by the same process as used in producing the conductive pattern, or by use of a permanent fungistatic ink or paint (see 3.2.10), LASER marker or by vibrating pencil marking on a metallic area provided for marking purposes.

Conductive markings, either etched copper or conductive ink (see 3.2.10) shall be considered as electrical elements of the circuit and shall not reduce the electrical spacing requirements. All markings shall be compatible with materials and parts, legible for all tests, and in no case affect flexible printed wiring performance.

Marking shall not cover areas of lands that are to be soldered. (see IPC-A-600 for legibility requirements). In addition to this marking, the use of bar code marking is permissible. When used, date code shall be formatted per the supplier's discretion in order to establish traceability as to when the manufacturing operations were performed.

3.3.5 Solderability Only those flexible printed boards that require soldering in a subsequent assembly operation require solderability testing. Solderability testing is not necessary for flexible printed wiring that does not require soldering. This shall be specified on the master drawing, as in the case where press-



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fit components are used. Flexible printed wiring to be used for surface mount does not require hole solderability testing.

When required by the procurement documentation, accelerated aging for coating durability shall be in accordance with J-STD-003. The Category of durability shall be specified on the master drawing; however, if not specified, Category 2 shall be used. Specimens to be tested shall be conditioned, if required, and evaluated for surface and hole solderability using J-STD-003.

When solderability testing is required, consideration should be given to flexible printed wiring thickness and copper thickness. As both increase, the amount of time to properly wet the sides of the holes and the tops of the lands increases proportionately.

Note: Accelerated aging (steam aging) is intended for use on coatings of tin/lead solder or tin, but not other final finishes.

**3.3.6 Plating Adhesion** The adhesion of the plating shall be tested in accordance with IPC-TM-650, method 2.4.1. There shall be no evidence of any portion of the protective plating or the conductor pattern foil being removed, as shown by particles of the plating or pattern foil adhering to the tape. If overhanging metal (slivers) breaks off and adheres to the tape, it is evidence of overhang or slivers, but not of plating adhesion failure.

**3.3.7 Edge Board Contact, Junction of Gold Plate to Solder Finish** Exposed copper/plating overlap between the solder finish and gold plate shall meet the requirements of Table 3-4. The exposed copper /plating or gold overlap may exhibit a discolored or gray-black area which is acceptable (see 3.5.3.3).

Table 3-4 Edge Board Contact Gap

Class	Maximum Exposed Copper Gap	Maximum Gold Overlap
1	2.5 mm [0.0984 in]	2.5 mm [0.0984 in]
2	1.25 mm [0.04921 in]	1.25 mm [0.04921 in]
3	0.8 mm [0.031 in]	0.8 mm [0.031 in]

**3.3.8 Lifted Lands** When visually examined in accordance with 3.3, there shall be no lifted lands on the delivered (nonstressed) printed circuit board.



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3.3.9 Workmanship Flexible printed boards shall be processed in such a manner as to be uniform in quality and show no visual evidence of dirt, foreign matter, oil, fingerprints, tin/lead or solder smear transfer to the dielectric surface, flux residue and other contaminants that affect life, ability to assemble and serviceability. Visually dark appearances in non-plated holes, which are seen when a metallic or non-metallic semiconductive coating is used, are not foreign material and do not affect life or function. Flexible printed wiring shall be free of defects in excess of those allowed in this specification. There shall be no evidence of any lifting or separation of platings from the surface of the conductive pattern, or of the conductor from the base laminate in excess of that allowed. There shall be no loose plating slivers on the surface of the printed board.

**METHOD:**

The boards were visually examined with approximately 1.75X using various light sources. Progressively higher magnifications, up to 40X, were used for referee evaluation.

**RESULTS:**

The boards met the requirements of IPC-6013A, Amendment 2, Class 3, paragraph 3.3.



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## THERMAL SHOCK

### TEST SPECIMENS:

Seven (7) groups of flexible printed circuit boards.

### REFERENCE:

IPC-6013A, Amendment 2, Class 3, paragraph 3.10.2.

### REQUIREMENT:

When specified on the procurement documentation, flexible printed wiring or test coupons shall be tested in accordance with the procedure outlined below.

The specimen shall be tested for thermal shock in accordance with IPC-TM-650, method 2.6.7.2B, except the temperature range shall be  $-65^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  [ $-85^{\circ}\text{F}$  to  $257^{\circ}\text{F}$ ]. Microsection evaluation in accordance with IPC-TM-650, Method 2.6.7.2 is not required. Following removal from the test chamber, the specimen shall meet the circuitry requirements of 3.9.2. The resistance value shall not vary by more than  $\pm 10\%$ .

### METHOD:

Insulated wires were soldered to the terminals of the test specimen. The initial resistance measurement was obtained using a multimeter. The samples were placed in Thermal Shock Chamber. The cold chamber was set at  $-65^{\circ}\text{C}$ , and the hot portion of the chamber was set at  $125^{\circ}\text{C}$ . The dwell time was set at 15 minutes. The transfer to temperature extremes was approximately 15 seconds. During the first hot cycle, the resistance measurement was obtained with a multimeter.

The chamber was set for 100 cycles. During the last hot cycle the resistance measurement was again measured and recorded. The percent change was then calculated.

### RESULTS:

Resistance Measurements:



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Group 1	Layer	Before Conditioning (milliohms)	After Conditioning (milliohms)	% Change
-1	1	1.98	1.90	4.04
-1	2	8.65	8.54	1.27
-2	1	99.43	98.43	1.01
-2	2	85.00	84.36	0.75
-3	1	60.38	59.95	0.71
-3	2	112.00	111.00	0.89

Group 2	Layer	Before Conditioning (milliohms)	After Conditioning (milliohms)	% Change
-1	1	25.52	25.11	1.61
-2	1	98.92	98.01	0.92
-2	2	83.77	83.07	0.84
-3	1	61.69	61.27	0.68
-3	2	104.17	102.78	1.33

Group 3	Layer	Before Conditioning (milliohms)	After Conditioning (milliohms)	% Change
-1	1	2.17	2.08	4.15
-1	2	9.92	9.80	1.21
-2	1	106.92	105.88	0.97
-2	2	80.66	80.16	0.62
-3	1	58.42	57.84	0.99
-3	2	110.00	109.00	0.91

Group 4	Layer	Before Conditioning (milliohms)	After Conditioning (milliohms)	% Change
-1	1	2.01	1.95	2.99
-1	2	9.69	9.56	1.34
-2	1	21.52	21.18	1.58
-3	1	60.54	59.98	0.93
-3	2	106.78	105.14	1.54

Group 5	Layer	Before Conditioning (milliohms)	After Conditioning (milliohms)	% Change
-1	1	2.04	1.96	3.92
-1	2	9.72	9.67	0.51
-2	1	26.58	26.21	1.39
-2	2	29.35	28.90	1.53
-3	1	23.78	23.43	1.47
-3	2	29.82	29.31	1.71

Group 6	Layer	Before Conditioning (milliohms)	After Conditioning (milliohms)	% Change
-1	1	23.61	23.28	1.40
-2	1	106.05	104.80	1.18
-2	2	80.66	79.85	1.00
-3	1	23.97	23.61	1.50
-3	2	30.32	29.73	1.95

Group 7	Layer	Before Conditioning (milliohms)	After Conditioning (milliohms)	% Change
-1	1	2.13	2.06	3.29
-1	2	9.79	9.68	1.12
-2	1	103.26	102.10	1.12
-2	2	*	*	*
-3	1	60.80	60.17	1.04
-3	2	107.00	105.40	1.50

\* Board was shorted during the soldering process, prior to resistance readings.



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Trace Laboratories, Inc. certifies that the test equipment used complies with the calibration test purposes of ISO 10012-1, ANSI/NCSL Z540-1-1994, and MIL-STD-45662A and that the data contained in this report is accurate within the tolerance limitation of this equipment.

All test procedures detailed within this report are complete. The results in this report relate only to those items tested. If any additional information or clarification of this report is required, please contact us. This test report shall not be reproduced except in full, without the written approval of Trace Laboratories, Inc. Thank you for selecting Trace Laboratories, Inc. for your testing requirements.

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Laboratory Technician

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Laboratory Technician



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