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# "Stencil Options for Printing Solder Paste for .3 Mm CSP's and 01005 Chip Components"

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**Abstract:**
Printing solder paste for very small components like .3mm pitch CSP's and 01005 Chip Components is a challenge for the printing process when other larger components like RF shields, SMT Connectors, and large chip or resistor components are also present on the PCB. The smaller components require a stencil thickness typically of 3 mils (75u) to keep the Area Ratio greater than .55 for good paste transfer efficiency. The larger components require either more solder paste height or volume, thus a stencil thickness in the range of 4 to 5 mils (100 to 125u).

This paper will explore two stencil solutions to solve this dilemma. The first is a "Two Print Stencil" option where the small component apertures are printed with a thin stencil and the larger components with a thicker stencil with relief pockets for the first print. Successful prints with Keep-Outs as small as 15 mils (400u) will be demonstrated. The second solution is a stencil technology that will provide good paste transfer efficiency for Area Ratio's below .5. In this case a thicker stencil can be utilized to print all components. Paste transfer results for several different stencil types including Laser-Cut Fine Grain stainless steel, Laser-Cut stainless steel with and w/o PTFE Teflon coating, AMTX E-FAB with and w/o PTFE coating for Area Ratios ranging from .4 up to .69.

**Introduction:**
SMT assembly is faced with a common challenge. As components get smaller and smaller, it is difficult to print solder paste to satisfy both components. On the one hand the large components require more solder paste volume for sufficient solder fillets after reflow. If this same stencil is used to print paste for the small components the apertures are so small that poor paste release is encountered. This poor paste release is caused by a combination of factor's including the Area Ratio. The Area Ratio is defined as the area of the aperture opening divided by the area of the aperture wall. This is shown schematically in Figure 1.

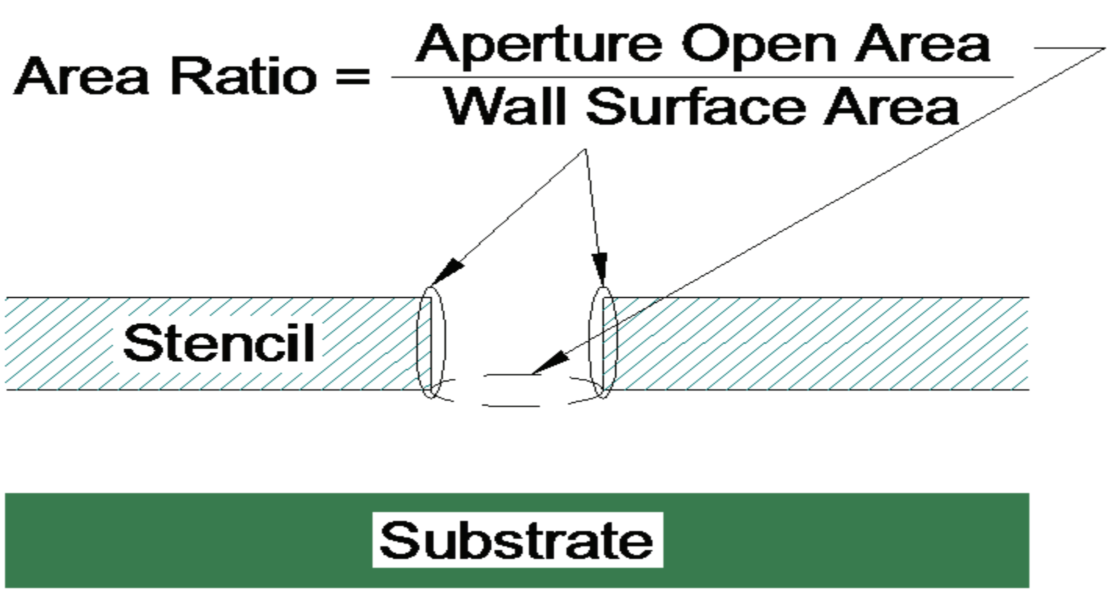



**Figure 1 Stencil showing Area Ratio**

The problem encountered when using a thick stencil for both small and large components is shown in Figure 2.

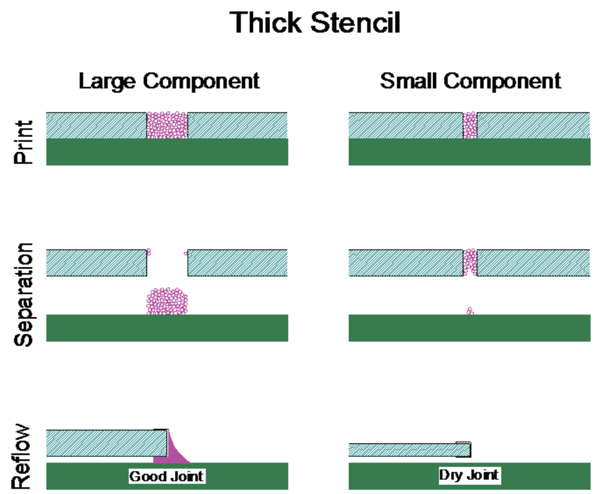



**Figure 2 Print sequence for Thick Stencil**

The thicker stencil gives sufficient paste for forming acceptable solder fillets after reflow. Poor paste release for the small components results in insufficient solder paste and dry solder joints. Figure 3 shows the problem encountered when using a thin stencil.

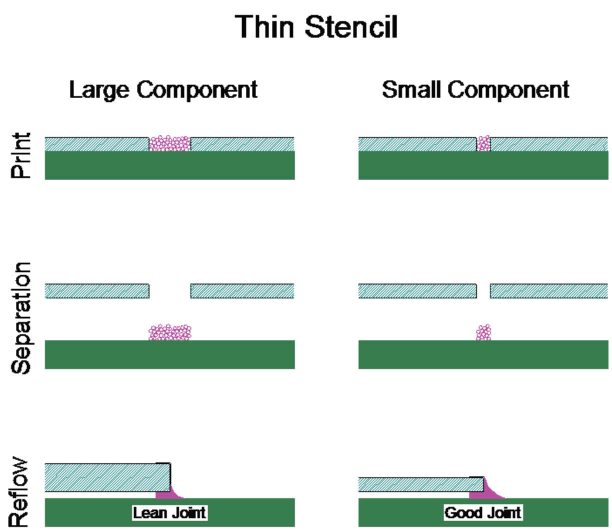



**Figure 3 Sequence for Thin Stencil**

There is good paste transfer for the small components resulting in good solder fillets. However, even though there is good paste transfer for the large components, there is insufficient solder paste volume to form a good solder joint fillet. The normal stencil aperture guideline is to keep the ratio >.66 (see IPC 7525). This is achieved by adjusting the aperture size and / or the stencil thickness. Stencil Technology also plays a role and Rev A of IPC 7525 changed the guideline to .5 for some stencil technologies including Electroform stencils. The Area Ratio Matrix, shown in Figure 4, illustrated the problem when printing .3 mm CSP's and 01005 chip components. As can be seen, even with a stencil 3 mils (75u) thick the Area Ratio is at the .5 limit.

| Component and typical Aperture Size | Stencil Thickness | | | | | |
|---|---|---|---|---|---|---|
| | 2 mil | 2.5 mil | 3 mil | 3.5 mil | 4 mil | 5 mil |
| | 50u | 62u | 75u | 87u | 100u | 125u |
| **01005** | | | | | | |
| 6 mil (150u) | 0.75 | 0.60 | 0.50 | 0.43 | 0.38 | 0.30 |
| 7 mil (175u) | 0.88 | 0.70 | 0.58 | 0.50 | 0.44 | 0.35 |
| **.4mm CSP** | | | | | | |
| 6 mil (150u) | 0.75 | 0.60 | 0.50 | 0.43 | 0.38 | 0.30 |
| 7 mil (175u) | 0.88 | 0.70 | 0.58 | 0.50 | 0.44 | 0.35 |
| 8 mil (200u) | 1.00 | 0.80 | 0.67 | 0.57 | 0.50 | 0.40 |

Green = OK Orange = Warning Red = Stop

**Figure 4 Area Ratio Matrix**

At a recent conference there were six technical papers all dealing with Optimizing the Miniature Component Solder Paste Printing Process[1-6]. Three solutions were discussed: (1) Step Stencils, (2) Two Print Stencils, (3) Improvement of Stencil Print Performance.

**Background:**

Step stencils have been in use for many years. Examples of step stencils are: Step-Up stencils for Ceramic BGA's and SMT connectors, Step-Down stencils for .5 and .4 mm pitch QFP's, and relief pocket step stencils for raised test via's or other raised areas on the PCB. The normal design guide for keep out area between apertures and the step area is 35 mils (875u) for every 1 mil (25u) of step. An example of a Step-Up stencil for a ceramic BGA is shown in Figure 5.

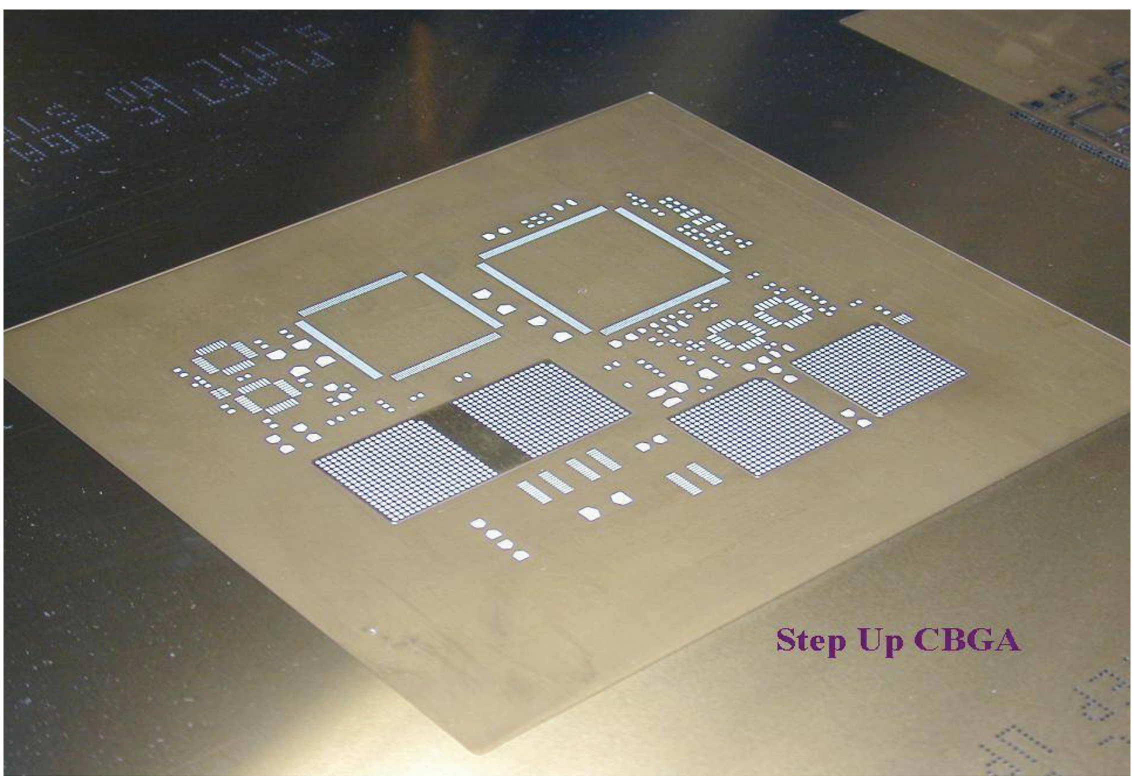


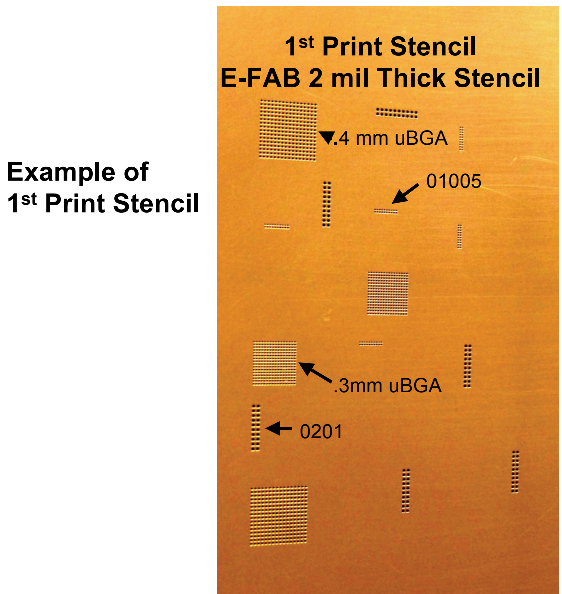

**Figure 5 Step-Up Stencil for Ceramic BGA**

In this example the step is 5 mils (125u) for normal SMT components step-up to 8 mils (200u) for the Ceramic BGA. In small handheld products the spacing between small and large components is too small to step-down the apertures of the small devices and still maintain the standard keep-out design guide of 35 mils per mil of step. Print results for designs with less than the standard Keep-out designs are discussed in detail in a paper by Zhang and Feng[6] of the iNEMI group.

Two Print stencils have also been in use for many years. They have been used for printing solder paste then glue for paste/ glue applications.

They have also been used to print SMT solder paste, and then solder paste for intrusive reflow of through-hole components. One such design was for a board having a fully populated Pin Grid Array which required a 20 mil (500u) thick stencil to achieve sufficient solder paste volume proper solder fillets.

A Two Print stencil for hand held electronics having .3 mm uBGA's and 01005's along with RF Shields and SMT connectors was described at APEX 2009[7]. The objective of this study was to determine the minimum spacing between the RF Shields and the small components. The 1st Print Stencil is shown in Figure 6. This stencil is an E-FAB stencil 2 mils (50u) thick. As seen from the area Ratio Matrix in Figure 4 a 2 mil (50u) thick stencil gives very acceptable Area Ratio's for both 01005's and .3 mm CSP's / uBGA's.



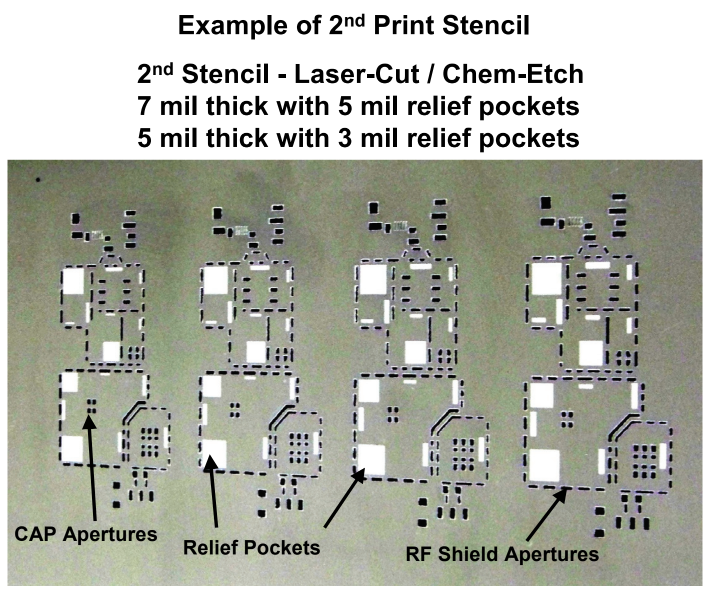




**Figure 6 1st Print E-FAB Stencil** **Figure 7 2nd Print Stencil Chem-Etch Relief / Laser-cut apertures**

Figure 7 shows the 2nd Print Stencil. This stencil is Chem-Etch to form the step relief pockets and Laser-cut to form the apertures. As seen, two versions of this stencil were made: (1) 7 mil (175u) thick with a 5 mil (125u) relief pocket and (2) 5 mil (125u) thick with a 3 mil (75u) relief pocket. Print results are shown in Figure 8. There is slight smearing of the paste printed with the 1st Print Stencil in the upper right hand corner close to the RF Shield. The spacing between the .3 mm ubGA and RF Shield aperture was 10 mils (250u).

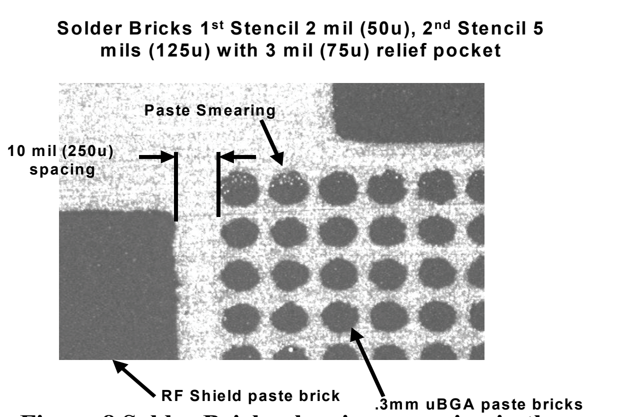



**Figure 8 Solder Bricks showing smearing in the corner**

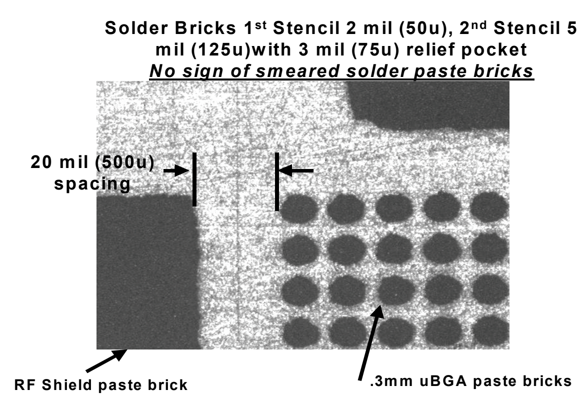



**Figure 9 Solder bricks showing no smearing**

Figure 9 shows print results when this spacing is increased to 20 mils (500u). As seen, there is no paste smearing. Some general design guidelines for Two Print Stencils are shown in Table 1. It is encouraging to observe that spacing between apertures on the 1st and 2nd print stencils can be as low as 15 mils (375u) without paste smearing and that the relief pocket clearance above the 1st print can be as low as 1 mil (25u) without paste smearing.

**Table 1 General Design Guidelines for Two Print Stencil**

**General Design Guidelines for Two Print Stencils**

Minimum Spacing between apertures in 1st and 2nd stencil

- 15 mils (375um)

Minimum relief pocket height for clearance of 1st print paste brick

- 1st print stencil thickness + 1 mil (25um)

Thickness of 1st Stencil

- Determined by Area Ratio and Paste Transfer Efficiency

Thickness of 2nd Stencil

- Determined by height and volume of solder brick required
[5 mil (125um) to 10 mil (250 um)]

**Table 2 Stencils Tested**

**5 mil (125u) Thick Stencils**

| Aperture Size Circles mils | Aperture Size Circles microns | Area Ratio |
|---|---|---|
| 8 | 200 | 0.4 |
| | | |
| 10 | 250 | 0.5 |
| | | |
| 12 | 300 | 0.6 |

**4 mil Thick Stencils**

| Aperture Size Circles mils | Aperture Size Circles microns | Area Ratio |
|---|---|---|
| 6 | 150 | 0.38 |
| | | |
| 7 | 175 | 0.44 |
| | | |
| 8 | 200 | 0.5 |
| | | |
| 9 | 225 | 0.56 |
| | | |
| 10 | 250 | 0.63 |
| | | |
| 11 | 275 | 0.69 |

**Table 3 Aperture Sizes, and Area Ratios for both 5 mil (125u) and 4 mil (100u) Thick Stencils**

| Number | Type | Post processing | Thickness | |
|---|---|---|---|---|
| | | | mils | microns |
| 1 | Laser Datum FG (LPKF Micro-cut) | Sanding only | 5 | 125 |
| | | | | |
| 2 | Laser Datum FG (LPKF 6080 fiber optic) | Sanding only | 5 | 125 |
| | | | | |
| 3 | E-FAB | none | 5 | 125 |
| | | | | |
| 4 | E-FAB | Ni-TEF coating both sides | 5 | 125 |
| | | | | |
| 5 | Laser DurAlloy | Sanding only | 5 | 125 |
| | | | | |
| 6 | Laser DurAlloy | PTFE coating one side | 4 | 100 |
| | | | | |
| 7 | E-FAB | PTFE coating one side | 4 | 100 |
| | | | | |
| 8 | Laser DurAlloy | Sanding only | 4 | 100 |
| | | | | |
| 9 | E-FAB | none | 4 | 100 |
| | | | | |
| 10 | Premium Alloy 42 Laser cut | EP | 3.6 | 91 |
| | | | | |
| 11 | NicAlloy Laser cut Micro-cut | EP and NP | 4.2 | 106 |
| | | | | |
| 12 | E-FAB with Hard Nickel | none | 4 | 100 |
| | | | | |

**Improving the Stencil Printing Process:**
The third approach to resolve the dilemma of printing small and large devices is to improve the printing process. The measure of improvement is to be able to achieve acceptable paste transfer volumes and minimum paste volume variations for Area Ratio's less than .5. There are many processes involved in the paste printing process: Squeegee blades, Squeegee speed, Squeegee Angle, Separation Speed, Vibration while the paste is separating, Positive air pressure applied while paste is separating, Solder Paste, and finally the Stencil. I am going to consider only the stencil while holding all other parameters constant. The measurables are: Aperture Walls, Solder paste left in the apertures after printing, Appearance of the solder bricks printed, Solder paste volume, Solder paste volume variation. The last two measurables are key in determining the print performance of the stencil.

Twelve different stencils were manufactured for evaluation. These 12 stencils, along with a short description of their manufacturing process, are summarized in Table 2. The aperture sizes, thickness and Area Ratios are shown in Table 3. The five stencils that are 5 mils (125u) thick have circular 8 mil (200u), 10 mil (250u), and 12 mil (300u) apertures with Area Ratios ranging from .4 to .6. Two stencils, 1 and 2, were laser cut using two different LPKF lasers but both used the same stainless steel material, Datum FG (fine grain). Stencils 3 and 4 are both E-FAB Electroformed stencils, however stencil 4 was coated with Nickel Teflon plating after electroforming. Unfortunately, there were some process problems during the coating of stencil 4 that required it to be remade. Print tests on stencil 4 are delayed and will be reported at a later date. Stencil 5 is a Laser-cut DuraAlloy stencil. DuraAlloy is a proprietary stainless steel material. Stencils 6 through 12 are 4 mils (100u) thick and have circular apertures ranging from 6 mils (150u) to 11 mils (275u) with Area Ratio's ranging from .38 to .69. Stencils 6 and 8 are Laser-cut DuraAlloy stencils with 6 being coated with Teflon (PTFE). Stencils 7 and 9 are Electroformed E-FAB stencils with stencil 7 being coated with PTFE. Stencil 10 is Laser-cut Alloy 42 stencil with electropolish. Stencil 11 is Laser-cut NicaAlloy with Electropolish and Nickel plating. Finally stencil 12 is an Electroformed E-FAB stencil with additives that make the stencil foil harder. Area Ratio's as low as .4 for the 5 mil (125u) thick stencils and as low as .38 for the 4 mil (100u) thick stencils are a challenging test of the print performance for this collection of stencil types. The goal of testing this group of stencils is to determine which type is better suited to provide the best print performance for Area Ratio's below .5.

**Aperture Walls:**
A picture of the Aperture walls for the 5 mil (125u) thick stencils is shown in Figure 10. The picture is at 230 magnification at a 4.4$^{o}$ angle with backlight only. This picture shows that the E-FAB stencil has smoother walls than the other 3 laser-cut stencils. Figure 11 shows the 4 mil (100u) thick stencils. Magnification and angle are the same as in Figure 10. Here

DuraAlloy, which is a laser-cut stainless steel stencil, is shown with (6) and without (8) PTFE coating on the aperture walls. Also shown is an E-FAB stencil with (7) and without (9) PTFE coating. There appears to be no noticeable difference in the wall smoothness of the E-FAB stencil with and without coating. The same applies for the DuraAlloy stencil. However there is a difference, as before in Figure 10 between the E-FAB stencil and the DuraAlloy laser-cut stencil.

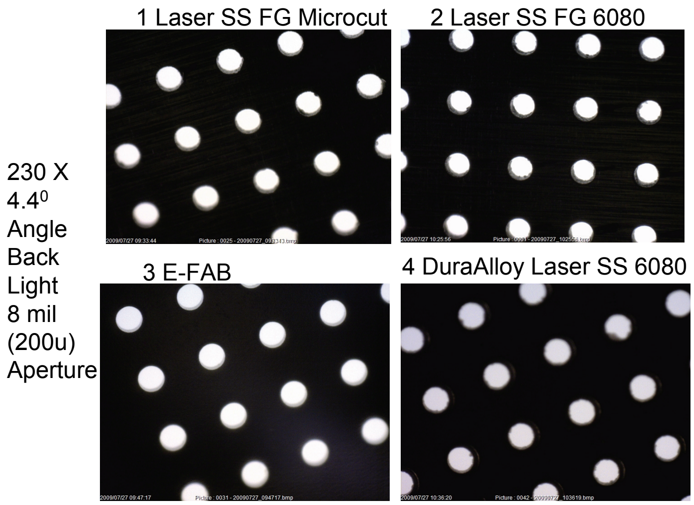



**Figure 10 Aperture Walls of 5 mil (125u) Stencils**

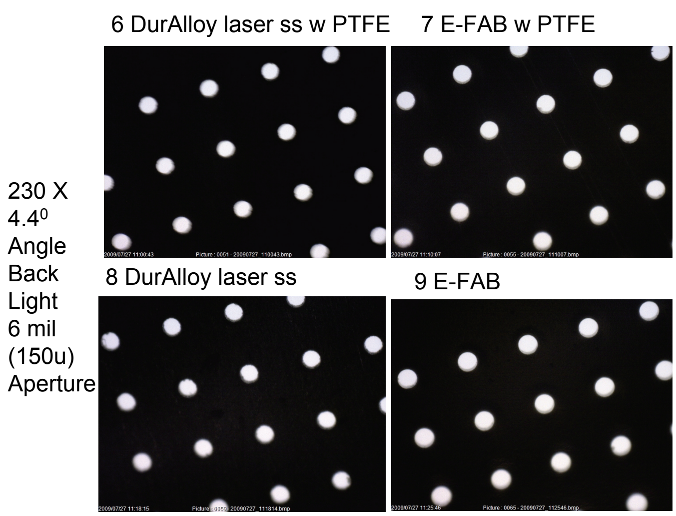



**Figure 11 Aperture Walls of 4 mil (100u) Stencils**

**Solder Paste Print Tests:**

Two separate print tests were performed. A Speedline Momentum printer was used to print solder paste on two Benchmarker boards in order to observe: (1) paste left in the apertures and (2) appearance of the solder paste brick printed. Indium 8.9 HF No-Clean type 4 paste was used. Print speed was 1 inch (2.54cm) per second. Squeegee blade was an Electroform E-Blade.
Figures 12 through 14 show the paste remaining in the stencil aperture for 8 mil (200u), 10 mil (250u), and 12 mil (300u) circular apertures for stencils 1 through 4. The 8 mil (200u) aperture shows blockage in all the laser-cut stencils and blockage in the E-FAB stencil except for a couple of apertures. The 10 mil (250u) aperture shows blockage in all apertures of the DuraAlloy stencil and blockage in almost all apertures in stencils 1 and 2, the Datum FG laser-cut stencils. Stencil 3, the E-FAB stencils, has the majority of apertures unblocked. The 12 mil (300u) aperture, with an Area Ratio of .6, shows all apertures unblocked for stencil3, the E-FAB stencil. Stencil 2 has the next fewest blocked apertures followed by stencil 1 then stencil 4.

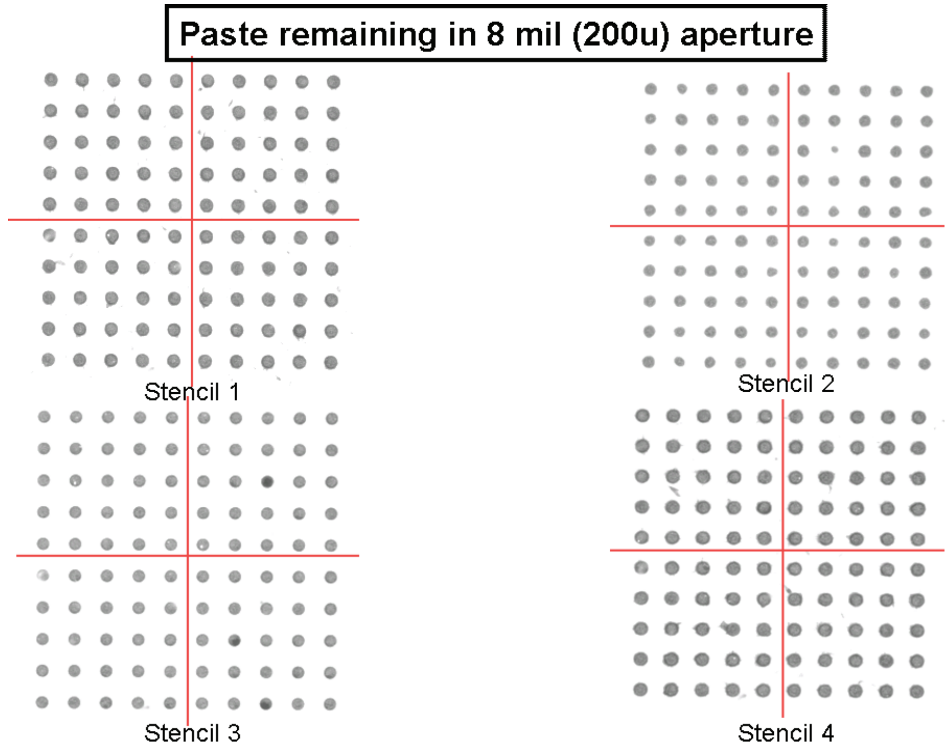



**Figure 12 Solder Paste Remaining in Apertures of 5 mil (125u) Thick Stencil: 8 mil (200u) Apertures**

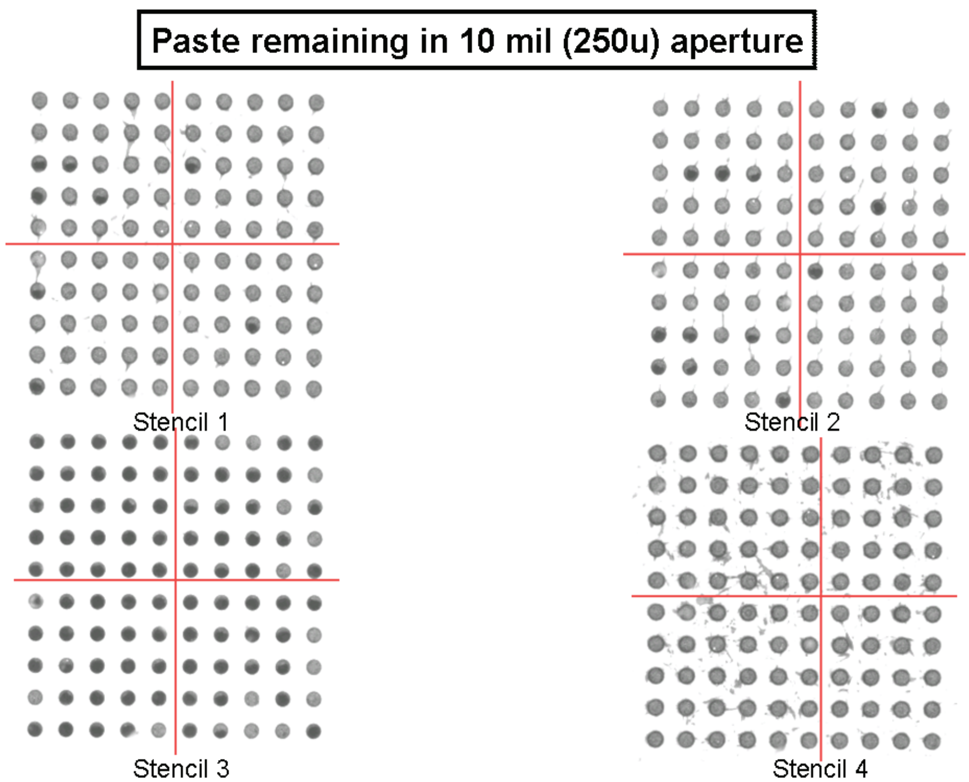



**Figure 13 Solder Paste Remaining in Apertures of 5 mil (125u) Thick Stencil: 10 mil (250u) Apertures**

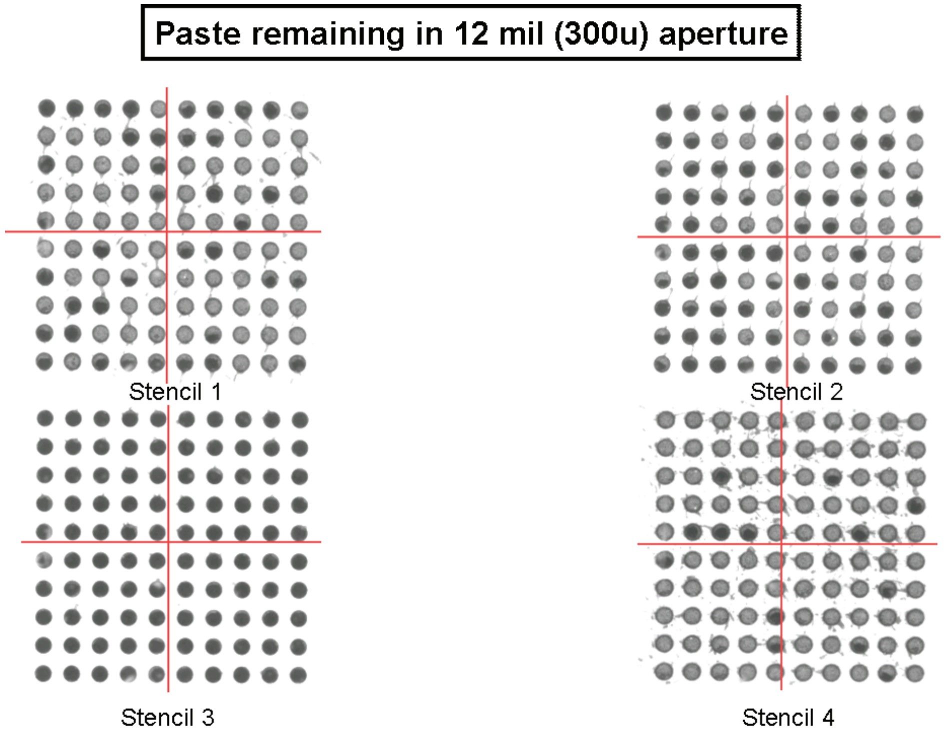



**Figure 14 Solder Paste Remaining in Apertures of 5 mil (125u) Thick Stencil: 12 mil (300u) Apertures**

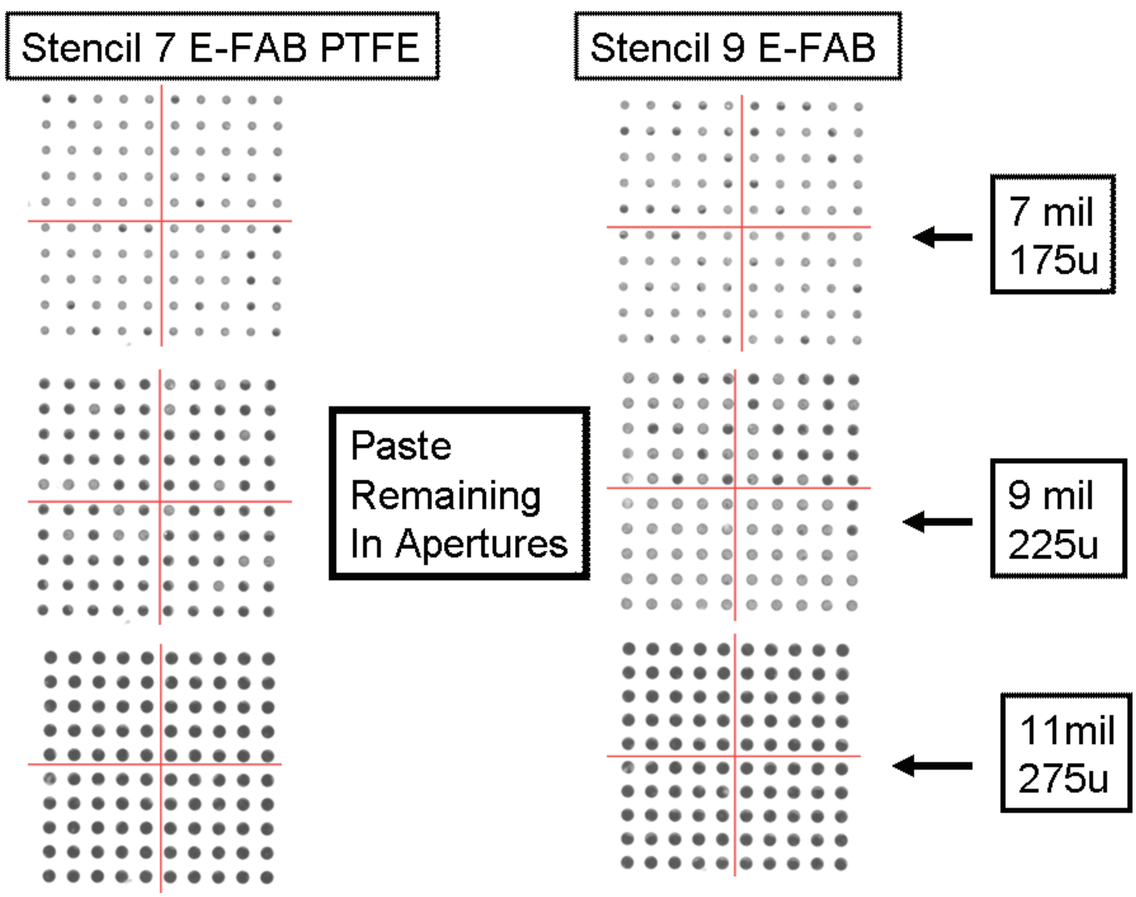



**Figure 15 Solder Paste Remaining in Apertures of 4 mil (100u) thick stencil: 7 (175u), 9 (225u), and 11mil 275u) Apertures**

Figure 15 shows a comparison of aperture blockage for 7 mil (175u), 9 mil (225u), and 11 mil (275u) circular apertures for the Electroform E-FAB stencils with (stencil 7) and w/o (stencil9) PTFE coating. There appears to be little difference in aperture blockage in this picture. Figure 16 shows the comparison for a 10 mil (250u) circular aperture. Here it is seen that the E-FAB with PTFE coating has less blocked apertures than the normal E-FAB w/o PTFE coating. Figure 17, DuraAlloy Laser-cut stencils with and w/o PTFE coating, show considerable more blockage than the E-FAB stencils. There also appears to be little difference in blockage for coated or non-coated DuraAlloy stencils.

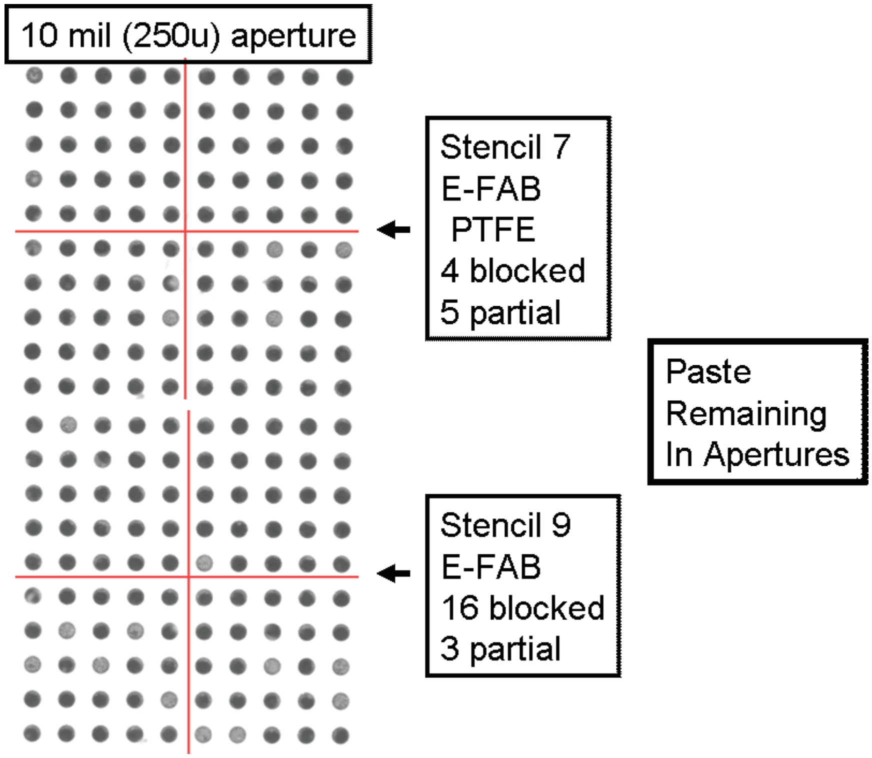



**Figure 16 Comparison of Paste left in apertures or a 4 mil (100u) thick stencil for 10 mil (250u) aperture: E-FAB with and E-FAB w/o with PTFE coating**

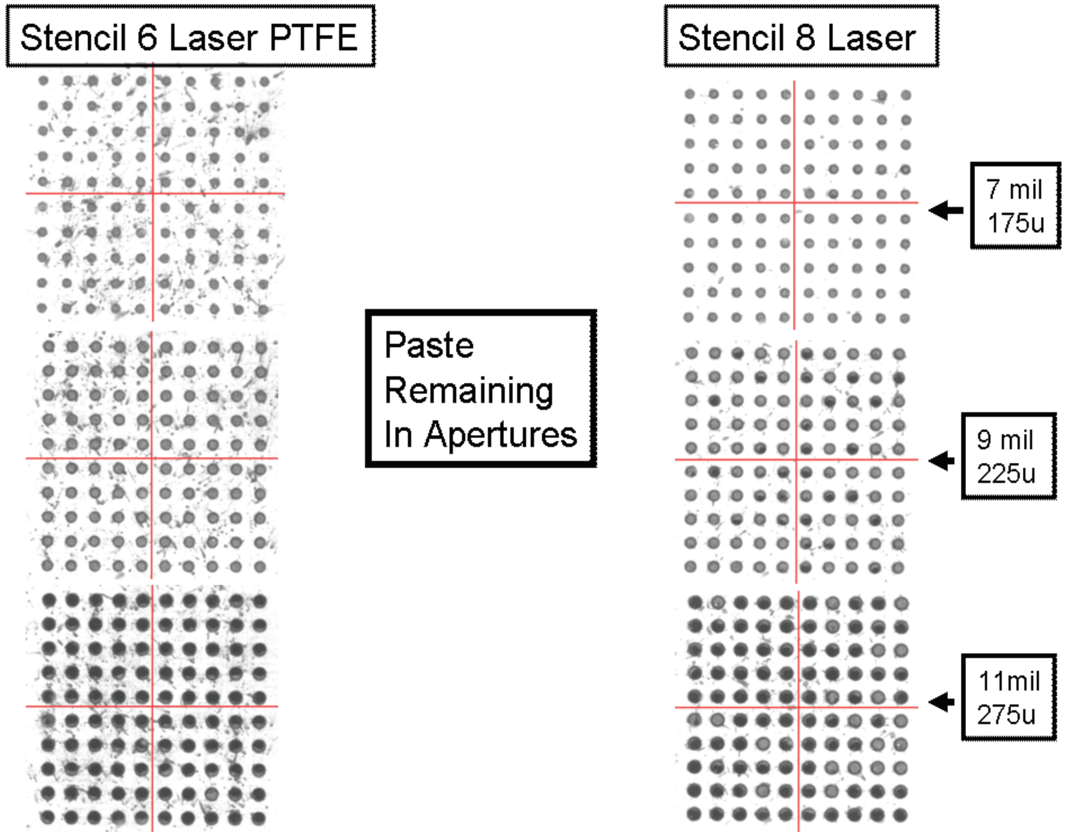



**Figure 17 Comparison of Paste left in apertures or a 4 mil (100u) thick stencil for 7 (175u), 9 (225u) and 11 mil (275u) apertures: Laser-cut w/o and Laser-cut with PTFE coating**

Figures 18-20 shows solder paste bricks after printing with the 5 mil (125u) thick stencils 1-4. The solder bricks printed with the 8 mil (200u) aperture (.4AR) show significant more paste volume for stencil 3 (E-FAB stencil than the other 3 Laser-cut stencils. Figures 19 and 20 show solder bricks for the 10 mil (250u) (.5AR) and 12 mil (300u) (.6AR) apertures. Stencil 3 (E-FAB) still has more paste volume but the gap between it and the Laser-cut stencils is reduced.

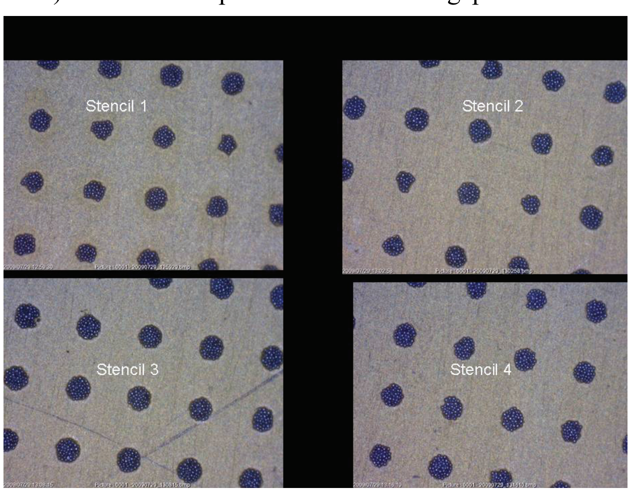



**Figure 18 Solder Bricks: 5 mil stencil, 8 mil aperture**

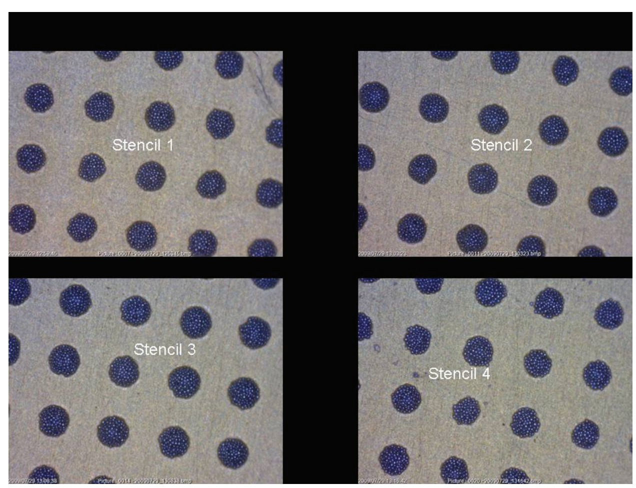



**Figure 19 Solder Bricks: 5 mil stencil, 10 mil aperture**

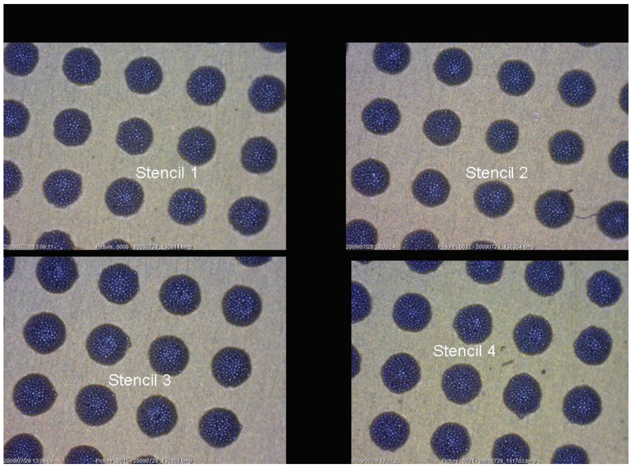



**Figure 20 Solder Bricks: 5 mil stencil, 12 mil aperture**

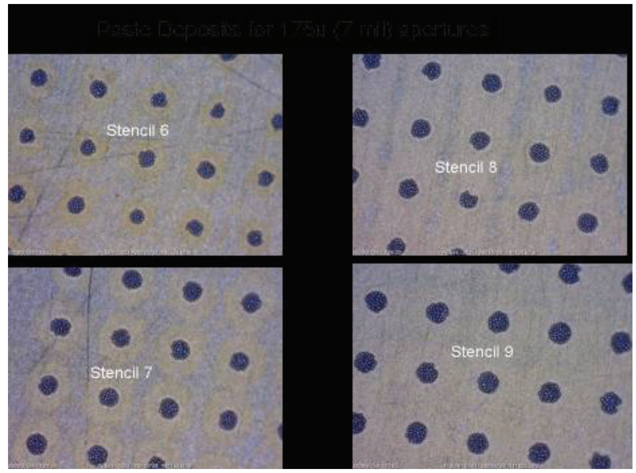



**Figure 21 Solder Bricks 4 mil stencil, 7 mil aperture**

Figures 21 and 22 shows solder paste bricks after printing with the 4 mil (100u) thick stencils 6-9. Both E-FAB stencils (7 and 9) show more solder paste volume than the Laser-cut stencils (6 and 8) for both the 7 mil (175u) apertures (.44AR) and 10 mil (250u) apertures (.63AR). It appears that the uncoated E-FAB stencil (9) has bricks with slightly more volume than the PTFE coated E-FAB stencil (7).

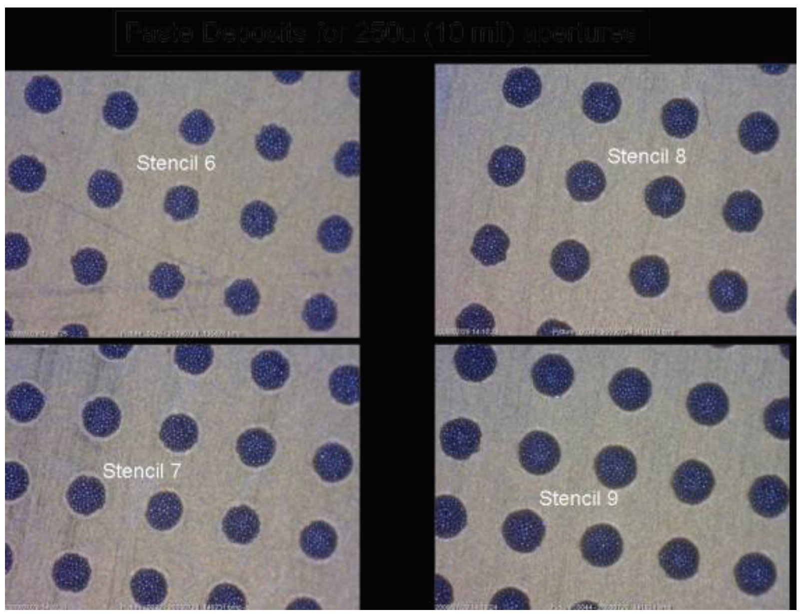



**Figure 22 Solder bricks 4 mil stencil, 10 mil aperture**

**Solder Paste Volume and Volume Variation:**

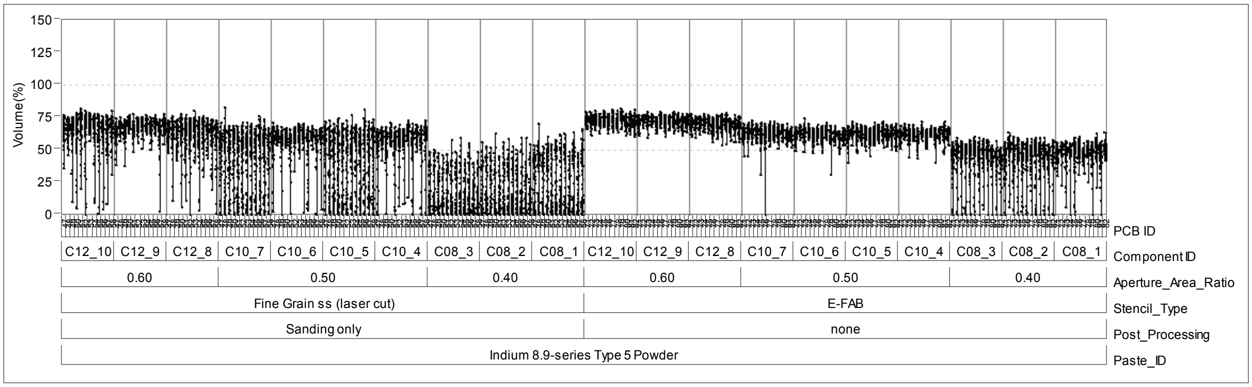
Pictures of clogged apertures and solder paste bricks are good for a visual comparison of different stencil technologies but the true comparative test is solder paste volume and especially solder paste volume dispersion. The volume measurements were performed at Indium Corporation in Clinton NY. The printer was a DEK 265 using a standard stainless steel squeegee blade. Indium 8.9 LF type 5 solder paste was used. Print speed was 1 inch (25mm) per second, pressure 4.6 kgm, and separation speed was .5mm/sec. A modified Benchmarker II PCB was used and paste was printed onto a large copper area w/o pad definition. Twelve boards were printed and solder paste volume was measured on a Koh Young paste volume machine. Ten 1000 solder bricks per board were measured giving a total of 12,000 solder bricks measured for each stencil. A layout of the Benchmarker board showing location and size of the stencil apertures is shown in Figure 23 for the 4 mil (100u) stencils.


**Figure 23 Benchmarker II Board showing test sites for 4 mil (100u) thick stencils: 1,000 total sites per board**

For ease in looking at the volume data a single stencil was compared to another single stencil. For the 5 mil (125u) thick stencils Stencil 2 (Datum FG Laser-cut) was compared to Stencil 3 (E-FAB) as one set and Stencil 5 (DuraAlloy Laser-cut) was compared to Stencil 3 (E-FAB) as a second set.

Figure 24 shows the Volume Variability and Standard Deviation charts for stencil 3 (E-FAB) compared to Stencil 2 (Datum FG Laser-cut). Figure 25 shows the average Volume and Standard Deviation for these same two stencils. The E-FAB shows good behavior down to .5 AR with good volume (> 60%) and low Standard deviation (<5%). On the other Hand the Datum FG Laser-cut has lower volume and Standard Deviations of 10% for AR of .6 and 20% for AR of .5.

# Volume Variability and Standard Deviation Charts for #2 Datum FG Laser-cut ss vs. #3 E-FAB



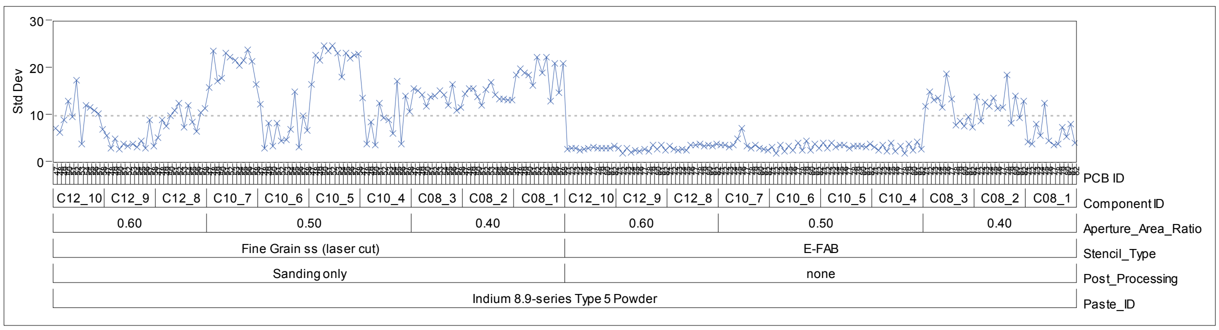




**Figure 24 Comparison of Solder paste Volume Variability and Standard Deviation for 5 mil (125u) thick stencil: Comparing Datum FG Stainless Steel Laser-cut on the left and E-FAB on the right**

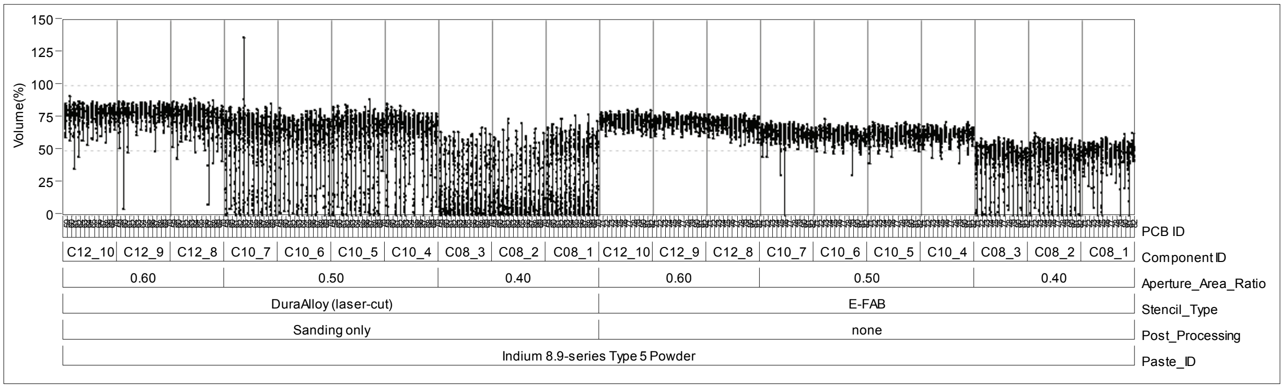
## Average Volume and Standard Deviation for #2 Datum FG Laser-cut ss vs. #3 E-FAB

| | | 02_5-mil - Fine Grain ss (laser cut) | | 03_5-mil E-FAB | |
|---|---|---|---|---|---|
| | Area Ratio | Avg Vol% | Std Dev | Avg Vol% | Std Dev |
| C12_10 | 0.60 | 66 | 11 | 73 | 3 |
| C12_9 | | 68 | 5 | 72 | 3 |
| C12_8 | | 63 | 10 | 70 | 4 |
| C10_7 | 0.50 | 45 | 21 | 62 | 4 |
| C10_6 | | 59 | 9 | 61 | 4 |
| C10_5 | | 44 | 23 | 62 | 4 |
| C10_4 | | 58 | 11 | 62 | 4 |
| C08_3 | 0.40 | 10 | 14 | 44 | 12 |
| C08_2 | | 10 | 14 | 44 | 13 |
| C08_1 | | 22 | 21 | 48 | 7 |

**Figure 25 Average Volume and Standard Deviation for 5 mil (125u) thick stencil: Comparing Datum FG Stainless Steel Laser-cut on the left and E-FAB on the right**

Figure 26 and 27 show the same parameters when comparing Stencil 3 (E-FAB) vs. Stencil 5 (DuraAlloy Laser-cut). Results are similar to the Datum FG Laser-cut although DuraAlloy has more volume for the 12 mil (300u) aperture (.6AR) but the E-FAB has much lower Standard Deviation for all three AR tested (.4, .5, .6).

## Volume Variability and Standard Deviation Charts for #5 DuraAlloy Laser-cut ss vs. #3 E-FAB



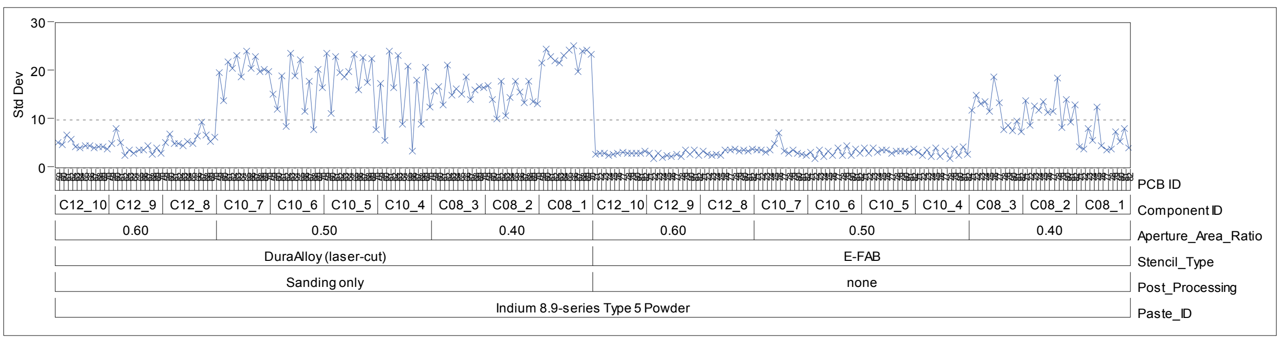




**Figure 26 A Comparison of Solder paste Volume Variability and Standard Deviation for 5 mil (125u) thick stencil: Comparing Dura Alloy Stainless Steel Laser-cut on the left and E-FAB on the right**

## Average Volume and Standard Deviation for #5 DuraAlloy Laser-cut ss vs. #3 E-FAB

| | | 05_5-mil - DuraAlloy (laser-cut) | | 03_5-mil E-FAB | |
|---|---|---|---|---|---|
| | Area Ratio | Avg Vol% | Std Dev | Avg Vol% | Std Dev |
| C12_10 | 0.60 | 78 | 5 | 73 | 3 |
| C12_9 | | 79 | 5 | 72 | 3 |
| C12_8 | | 76 | 6 | 70 | 4 |
| C10_7 | 0.50 | 59 | 21 | 62 | 4 |
| C10_6 | | 61 | 18 | 61 | 4 |
| C10_5 | | 61 | 20 | 62 | 4 |
| C10_4 | | 64 | 17 | 62 | 4 |
| C08_3 | 0.40 | 12 | 17 | 44 | 12 |
| C08_2 | | 9 | 15 | 44 | 13 |
| C08_1 | | 29 | 25 | 48 | 7 |

**Figure 27 Average Volume and Standard Deviation for 5 mil (125u) thick stencil: Comparing Dura Alloy Stainless Steel Laser-cut on the left and E-FAB on the right**

Figure 28 shows Volume Variability and Standard Deviation charts for Stencil 7 (E-FAB with PTFE coating) and Stencil 9 (E-FAB w/o coating). Figure 29 shows the average Volume and Standard Deviation for these same two stencils. Both stencils are 4 mils (100u) thick. The volume variability and standard deviation of Stencil 7 (E-FAB with PTFE coating) is excellent. The standard deviation is less than 5% all the way down to a .44 AR. The solder paste volume for stencil 9 is slightly higher than stencil 7 but the Standard Deviation is also higher. These results indicate that with special PTFE coatings on Electroform (E-FAB) stencils Area Ratios of .44 may be achievable with suitable print performance.

## Volume Variability and Standard Deviation Charts for #7 E-FAB with PTFE vs. #9 E-FAB w/o PTFE

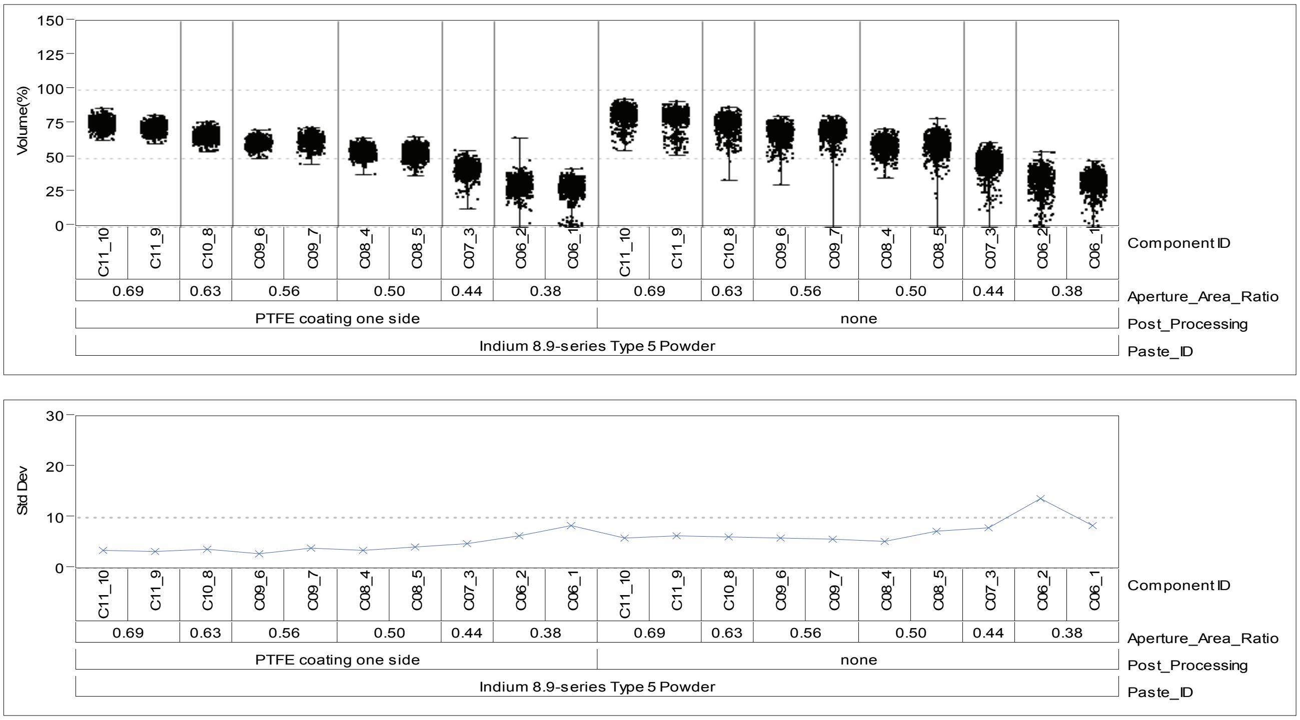



**Figure 28 A Comparison of Solder paste Volume Variability and Standard Deviation for 4mil (100u) thick stencil: Comparing E-FAB with PTFE coating on the left and E-FAB w/o PTFE coating on the right**

**Average Volume and Standard Deviation for #7 E-FAB with PTFE vs. #9 E-FAB w/o PTFE**

| | PTFE coating | | none | |
|---|---|---|---|---|
| | Avg Vol% | Std Dev | Avg Vol% | Std Dev |
| C11_10 [0.69] | 75 | 4 | 82 | 6 |
| C11_9 [0.69] | 72 | 3 | 80 | 6 |
| C10_8 [0.63] | 67 | 4 | 74 | 6 |
| C09_6 [0.56] | 61 | 3 | 67 | 6 |
| C09_7 [0.56] | 62 | 4 | 69 | 6 |
| C08_4 [0.50] | 54 | 4 | 59 | 5 |
| C08_5 [0.50] | 54 | 4 | 59 | 7 |
| C07_3 [0.44] | 41 | 5 | 46 | 8 |
| C06_2 [0.38] | 30 | 6 | 29 | 14 |
| C06_1 [0.38] | 26 | 8 | 31 | 8 |

**Figure 29 Average Volume and Standard Deviation for 5 mil (125u) thick stencil: Comparing E-FAB with PTFE coating on the left and E-FAB w/o PTFE coating on the right**

**Conclusion:**
Three different stencil options have been discussed to deal with the same challenge: inclusion of very small components with standard or large components in the same PCB.

Step stencils have limitation when the small components are placed too close to the larger components. In this case there is insufficient keep-out area to allow squeegee blade access to the step down area. This is particularly a problem for the apertures positioned to the step walls oriented East or West to the squeegee stroke where the squeegee stroke is north to South.

Two Print Stencils have the disadvantage of requiring two in-line screen printers. However, there are also some advantages including different solder paste for the 1st and 2nd print. For example, a type 5 solder paste could be used for the 1st print and a type 3 solder paste for the 2nd print. Small keep-out areas are available with this stencil option. This paper reports keep-out areas as small as 15 mils (600u), which is normally suitable for most hand-held electronic devices.

The third stencil option to deal with this challenge is to improve the stencil print performance. The objective was to increase the performance to allow Area Ratio's less than .5 to be utilized. Several Stencil types were evaluated and compared. High magnification pictures revealed that the Electroform (E-FAB) stencil walls were the smoothest compared to Laser-cut stencils. Comparison of aperture clogging after printing was shown for Laser-cut and E-FAB stencils. Solder brick comparisons were also shown for the different stencil types. The most important parameter (measurable) was the solder paste volume and solder paste volume variability. Several comparisons were made. The E-FAB stencil showed low variation and good volume down to an Area Ratio of .5, where the Laser-cut Datum FG stencil had major variability in the .5 and .6 Area Ratio region. In comparing DuraAlloy Laser-cut with Datum FG Laser-cut, the performance was similar, however DuraAlloy had lower variation in the .6 Area Ratio region. The comparison of E-FAB with and without PTFE coating was very interesting. Although the E-FAB stencil without PTFE coating showed slightly higher solder paste volume the variation of the E-FAB stencil with PTFE coating was less than the standard E-FAB stencil. In fact the E-FAB stencil with PTFE coating had an average standard deviation of 5% at an Area Ratio of .44 while still yielding an average volume of 41% of theoretical volume. This is very encouraging and more work is planned to further develop PTFE coated E-FAB stencils.

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