Step Stencil design when 01005 and 0.3mm pitch uBGA's coexist with RF Shields

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Abstract
Some of the new handheld communication devices offer real challenges to the paste printing process. Normally, there are very small devices like 01005 chip components as well as 0.3 mm pitch uBGA along with other devices that require higher deposits of solder paste. Surface mount connectors or RF shields with coplanarity issues fall into this category. Aperture sizes for the small devices require a stencil thickness in the 50 to 75 um (2-3 mils) range for effective paste transfer whereas the RF shield and SMT connector would like at least 150 um (6 mils) paste height. Spacing is too small to use normal step stencils.

This paper will explore a different type of step stencil for this application; a "Two-Print Stencil Process" step stencil. Here is a brief description of a "Two-Print Stencil Process". A 50 to 75 um (2-3 mils) stencil is used to print solder paste for the 01005, 0.3 mm pitch uBGA and other fine pitch components. While this paste is still wet a second in-line stencil printer is used to print all other components using a second thicker stencil. This second stencil has relief pockets on the contact side of the stencil any paste was printed with the first stencil.

Design guidelines for minimum keep-out distances between the relief step, the fine pitch apertures, and the RF Shields apertures as well relief pocket height clearance of the paste printed by the first print stencil will be provided.

Introduction
A printing challenge exists when very small devices coexist on a PCB with components requiring either high volume or high paste height. When printing solder paste for 01005 and / or 0.3 mm pitch uBGA a thin stencil, normally (50 to 75 um) thick is preferable to achieve sufficient paste transfer efficiency and low paste volume dispersion. If a 100 um thick stencil is used to print these small devices, the area ratio is less than 0.5 which is lower than the recommended value for both Laser-Cut stencils and E-FAB Electroform stencils. It is very common to print solder paste for RF shields for hand-held devices. Normally, higher solder paste deposits are required because of coplanarity issues with RF shields. To achieve these higher solder paste deposits a thicker stencil is needed. A step stencil[(1)] is normally used to achieve different solder paste heights. However in many hand-held devices the spacing between the small pitch components and the RF shield is normally very small, in many cases as small as 500 um (20 mils). The design guideline[1] for a normal step-down stencil is that the aperture in the step-down region be positioned at least 890 um (35 mils) from the step-up wall for every 25um (1mil) of step-up thickness. Otherwise the squeegee blade (metal or rubber) does not do a very job of depositing paste into the lower level apertures. In the case of RF shields a stencil thickness of 150 to 175 um (6 to 7 mils) may be required to achieve the desired solder paste height. The height difference; 75um (3 mils) thick stencil for the small components and 150um (6 mils) thick stencil, prevents a normal step stencil to be used for this application.

However, a "Two-Print Stencil Process" allows for very small spacing between the apertures of the smaller components and apertures of the RF shield. The objective of this study is to determine the smallest spacing between small component apertures and RF shield apertures for the Two-Print stencil process. Another objective is to determine the minimum clearance between the relief pocket of the 2nd print stencil and the 1st print stencil without paste smearing in the relief pocket.

Two-Print Stencil Test Plan
The Two-Print stencil process consists of two stencils. The 1st print stencil is used to print 0.3 mm pitch uBGA (198 um circular apertures), 0.4 mm pitch uBGA (244 um circular apertures), 01005 chip components (178 um circular apertures), and 0201 chip component apertures (300 um square apertures). Two 1st print stencils were fabricated. Both were E-FAB Electroform stencils; one was 50 um (2 mils) thick and the other was 75 um (3 mils) thick. The 2nd print stencil is used to print RF shields and a SMT connector and some large capacitor apertures. Four 2nd print stencils were manufactured with four different stencil thicknesses; each stencil had a relief pocket etched in the area where solder paste was printed with the 1st stencil. The design is summarized in Table 1.

Table 1

Two-Print Stencil Test Plan:

1st print stencil is an E-FAB Electroform stencil and prints solder paste for 0.3 mm and 0.4 mm uBGA's, 01005 and 0201 chip components.

Two stencils were manufactured:

- 50 um (2 mil) thick E-FAB stencil
- 75 um (3 mil) thick E-FAB stencil.

2nd print stencil is a Laser-Cut / Chem-Etch stencil with apertures for RF Shields, capacitors, and a SMT connector. This 2nd print stencil has relief pockets anywhere paste is printed by the 1st print stencil.

Four 2nd print stencils were manufactured:

- 8 mil thick with a 6 mil deep relief pocket
- 7 mil thick with a 5 mil deep relief pocket
- 6 mil thick with a 4 mil deep relief pocket
- 5 mil thick with a 3 mil deep relief pocket

Design of the aperture spacing between 1st and 2nd print stencil and relief pocket (4 images in the stencil):

- Image 1 250 um (10 mil) spacing between apertures in 1st and 2nd stencil
- Image 2 500 um (20 mil) spacing between apertures in 1st and 2nd stencil
- Image 3 750 um (30 mil) spacing between apertures in 1st and 2nd stencil
- Image 4 1000 um (40 mil) spacing between apertures in 1st and 2nd stencil

The manufacturing process for the 2nd print stencils was to Chem-Etch the Relief pockets in the metal foil then to Laser-Cut the apertures for the RF shields and other devices in this stencil. The 2nd print stencil is designed to have different spacing's between the apertures in the 1st print stencil and the apertures in the 2nd print stencil. This design is shown in Figure 1.

2nd Print Stencil showing apertures and Relief Pockets

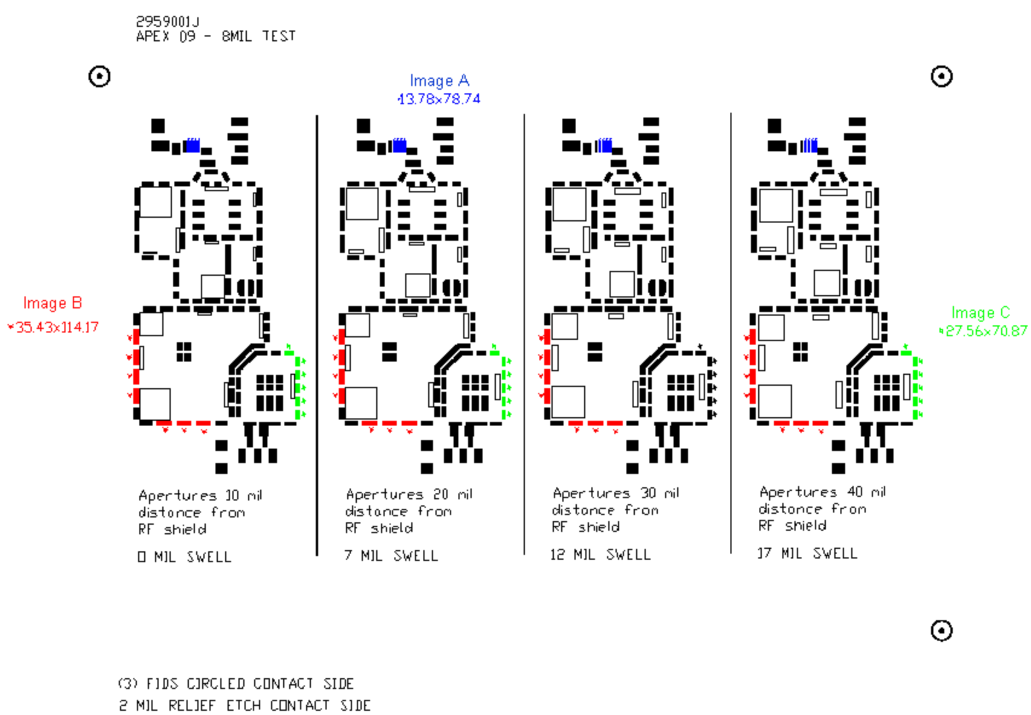

Figure 1. Schematic Layout of 2nd Print Stencil

As seen the spacing is 250 um (10 mils) for Image 1, 500 um (20 mils) for Image 2, 750 um (30 mils) for Image 3 and 100 um (40 mils) for Image 4. Figure 1 is a schematic drawing of the aperture layout and relief pockets for the 2nd print stencil.

As seen in Figure 1 there is 0 swell for Image 1. This means that the relief etch pocket edge was designed to line up with the edge of the apertures in the 1st stencil. No etch compensation was used for this relief pocket. When the pocket is etched it not only etches down but it also etches out making the pocket larger. The increase in pocket size depends on how deep the pocket is etched. The increase in pocket size is about ½ of the depth of the relief pocket. As an example in the case of the 175 um (7 mil) thick stencil with a relief pocket 125 um (5 mils) deep the increase in size of the relief pocket is 64 um (2.5 mils). The layout of the 1st print stencil is shown Figure 2.

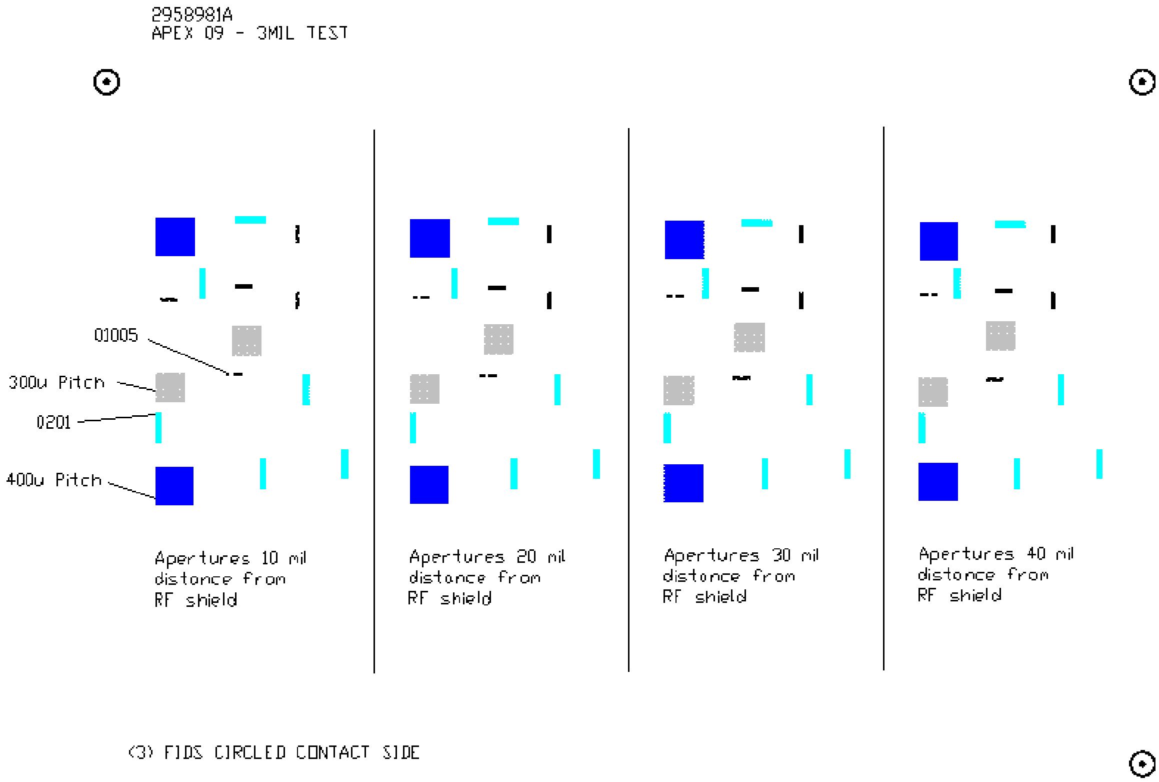

Figure. 1st Print Stencil showing aperture sizes and aperture position

A photograph of the 1st print E-FAB stencil is shown in Figure 3.

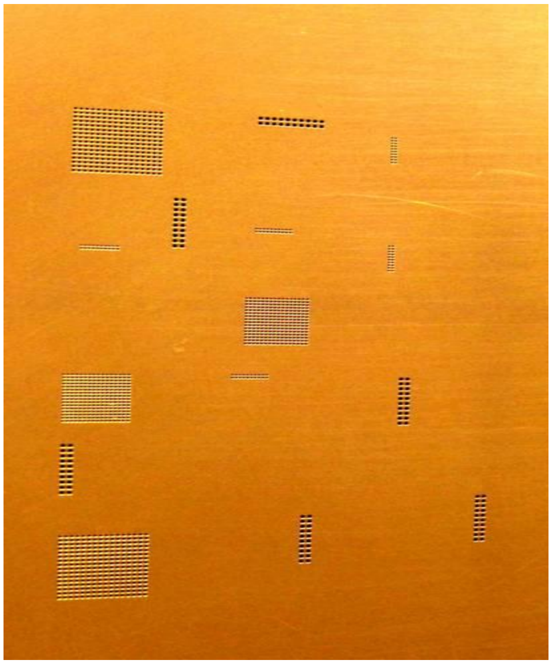

Figure 3. 1st Print E-FAB Stencil

Figure 4 shows a picture of the 2nd print stencil, a Laser-Cut / Chem-Etch stencil, showing the apertures along with the relief pockets.

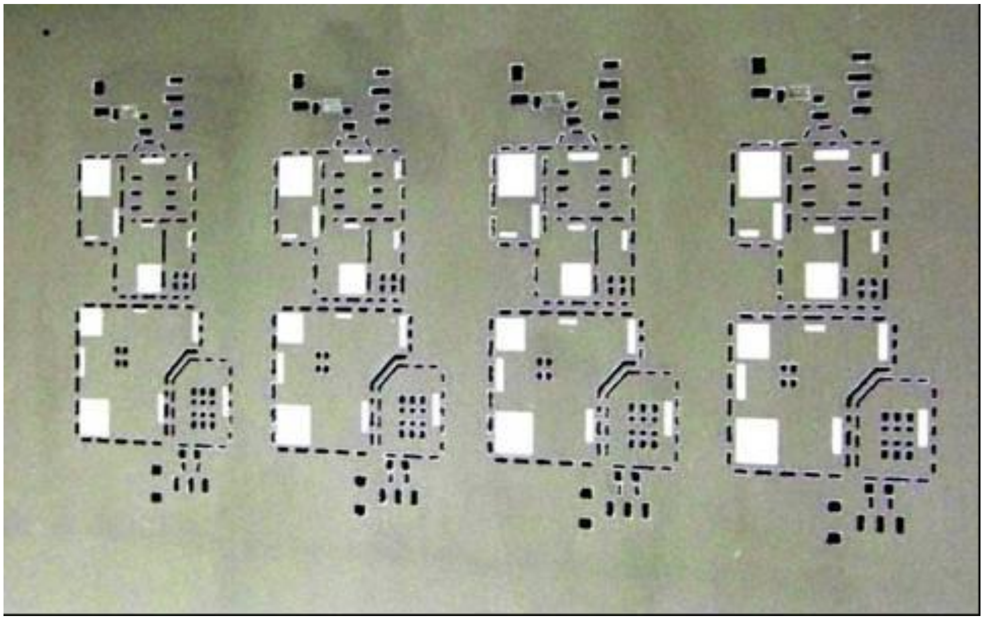

Figure 4. 2nd Print Laser-Cut Chem-Etch Stencil

Print Results

The test boards used in this experiment were bare copper clad FR4 with 3 fiducials for registration between the 1st print and 2nd print stencil.

Table 2 Printer Set-Up

Printer:	Speedline Momentum
Squeegee:	E-Blade Electroformed blade
Board:	Blank Copper Clad FR4 with Fids
Print Speed:	1 inch / sec
Print Pressure:	11 lbs.
Paste:	Type 5 Heraeus BD72 SAC 305
Print Sequence:	Print 1st print stencil then immediately print 2nd print stencil while 1st print still wet

A Speedline Momentum printer, along with E-Blade Electroformed squeegee blades was used. The printer set-up and Printing test procedure are shown in Table 2.

Figure 5 shows solder bricks printed with the 1st and 2nd stencil for Image 1 with 250 um (10 mils) spacing between the 1st and 2nd print. This print sequence used a 50 um (2mil) thick E-FAB 1st print stencil and a 175 um (7 mil) Laser-Cut / Chem-Etch with a 125 um (5 mil) relief pocket 2nd print stencil.

Note that the spacing between the .3 mm uBGA and the RF shield is 250 um (10 mils). Figure 6 shows the same print sequence but for the 01005 chip component solder bricks next to the FR shield solder brick. Spacing is 250 um (10 mils) but a slight smearing of the 01005 solder brick can be seen.

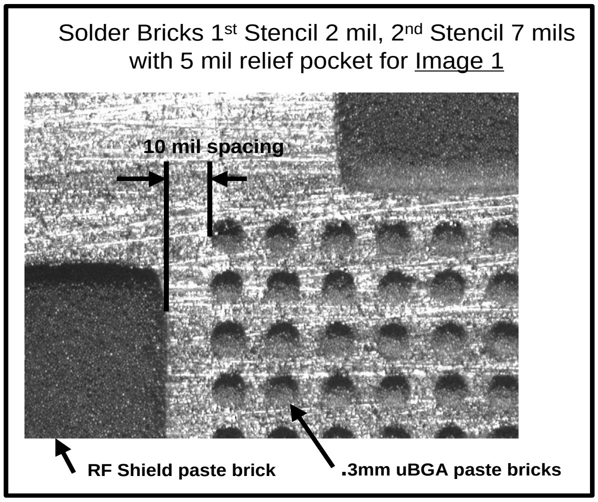

Figure 5. Solder Bricks .3 mm uBGA Image 1

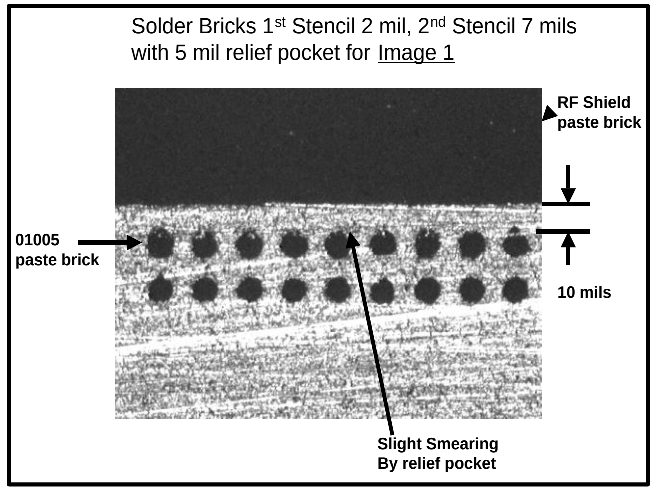

Figure 6. Solder Bricks 01005 Image 1

Figure 7 shows a close up of the 2nd print stencil which is 175 um (7 mils) thick with a 125 um (5 mil) deep relief pocket. Notice that the spacing from the wall of the relief pocket is 175 um (7 mils) to the RF shield aperture. This is as expected for the Image 1 since the relief pocket increased about 64 um (2.5 mils) from the original starting position of 250 um (10 mils) from the RF shield aperture.

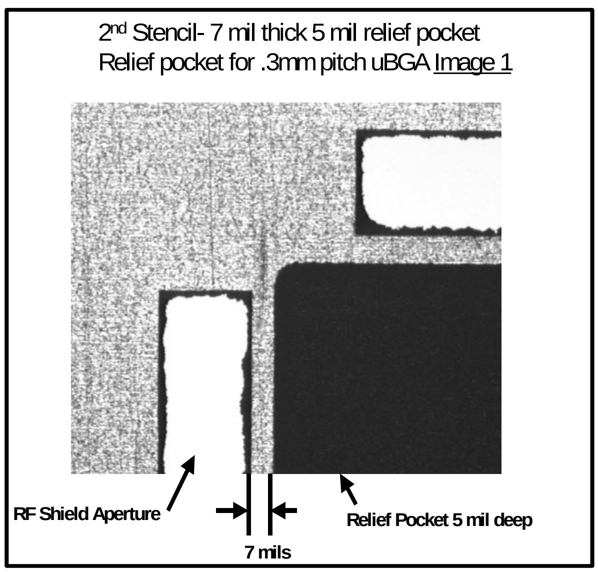

Figure 7. Relief Pocket for .3 mm uBGA Image 1

Figure 8 shows the same print sequence for Image 2, where the 0.3 mm uBGA apertures were spaced 500 um (20 mils) from the RF shield aperture. There is no hint of smearing for this configuration.

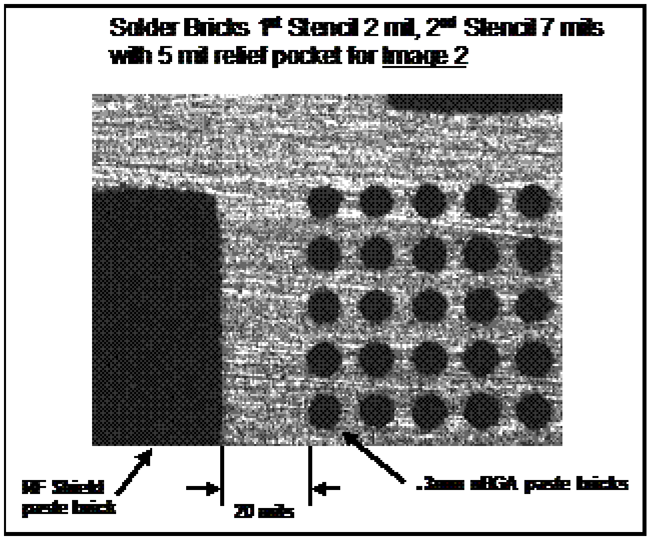

Figure 8. Solder Bricks .3 mm uBGA Image 2

Solder Paste Volume Results

The solder paste volume measurements were performed at Speedline using a Koh Young paste volume-measuring machine. The author wished to extend a special thanks to Vatsah Shah for making the measurements.

Table 3
Paste Volume Measurement Summary

1st Print Stencil

Component	Number of Solder Bricks Measured
01005	406
0.3 mm pitch uBGA	2048
0.4 mm pitch uBGA	2048
0201	480

2nd Print Stencil

Component	Number of Solder Bricks Measured
5 pin Connector	16
RF Shield 1	24
RF Shield 2	28

Table 3 summarizes the solder bricks measured for each component type in the 1st print stencil and the 2nd print stencil. Figures 8 through Figure 11 show a comparison of the 50 um (2mil) thick E-FAB stencil and the 75 um (3 mil) thick E-FAB stencil for total solder paste volume, % solder paste volume compared to theoretical volume of the stencil aperture, % standard deviation of the solder paste volume from the mean value, and solder paste height. It is noteworthy, as seen in Figure 9, that for the smallest component, 01005 chip components with 178 um (7 mil) apertures, the volume of solder paste for the 50 um (2 mil) thick stencil is almost as much as for the 75 um (3 mil) thick stencil.

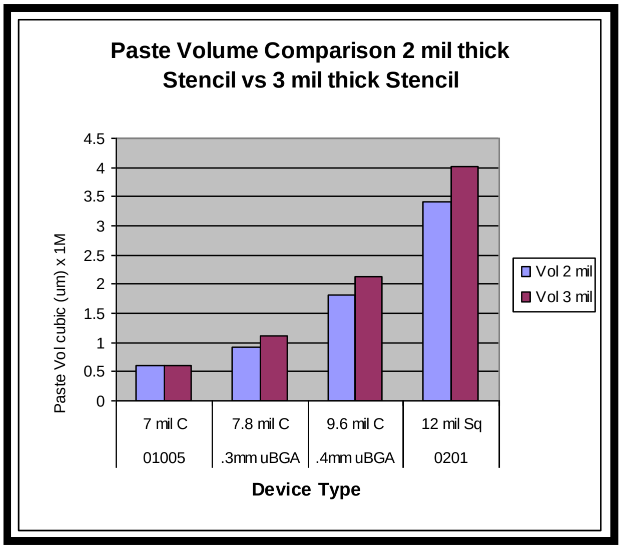

Figure 9. Paste Volume Comparison 2 vs. 3

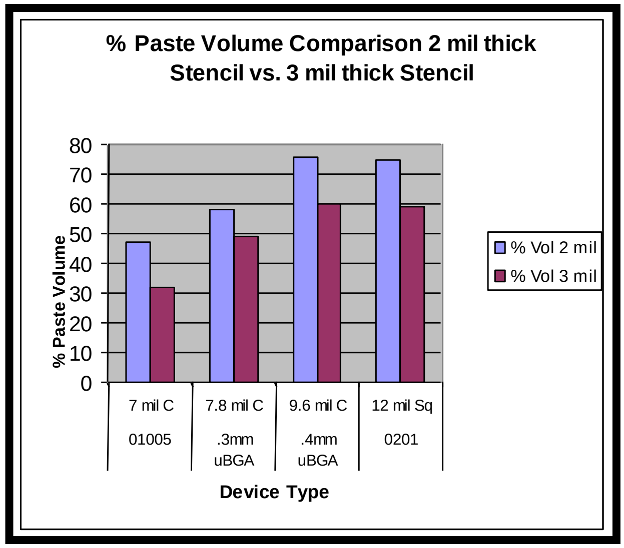

Figure 10. % Paste Volume Comparisons 2 vs. 3

Figure 10 shows that the % paste release is greater for all four components for the 50 um (2 mil) thick stencil compared to the 75 um (3 mil) thick stencil. As seen in Figure 11, the % standard deviation is also smaller for the 50 um (2 mil) stencil than for the 75 um (3 mil) stencil; especially for the 01005 chip component solder paste. Figure 12 shows the solder paste height comparison.

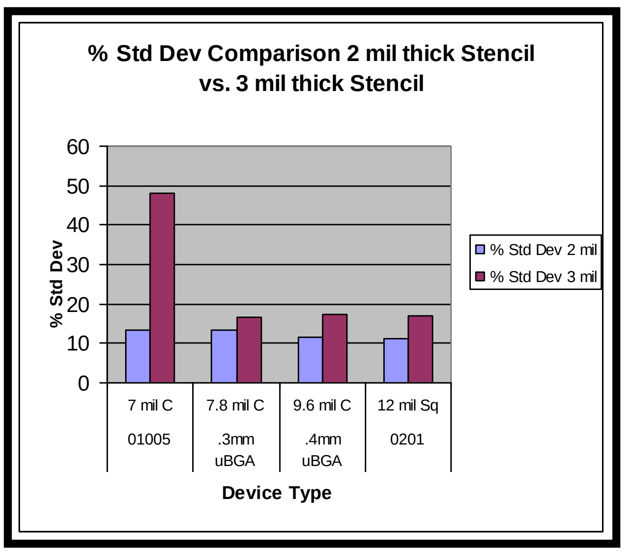

Figure 11. % Standard Deviation Comparison 2 vs. 3

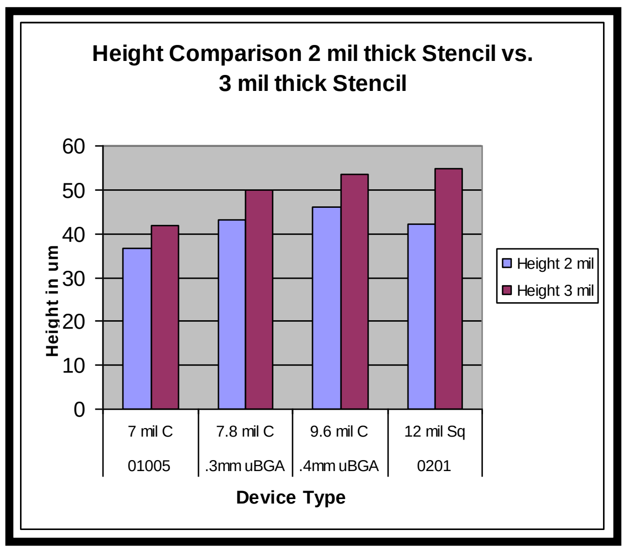

Figure 12. Paste Height Comparison 2 vs. 3

Similar solder paste volume measurements were recorded for the 175 um (7 mil) thick stencil and the 200 um (8 mil) thick stencil. These results are shown in Figures 13 through Figure 16.

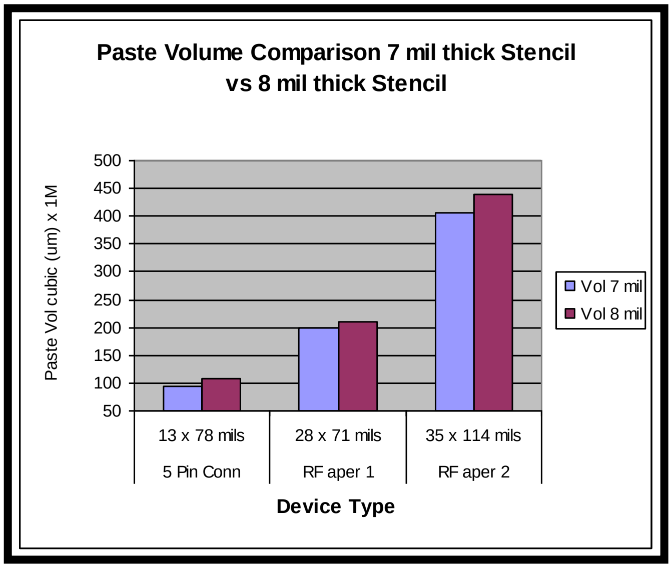

Figure 13. Paste Volume Comparison 7 vs. 8

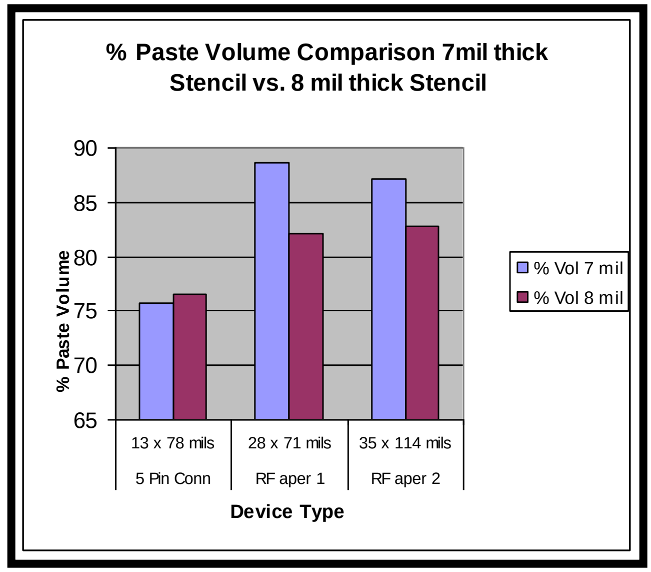

Figure 14. % Paste Volume Comparisons 7 vs. 8

As seen from Table 3, the number of data points was much smaller for these two stencils compared to the thinner stencils. As seen in Figure 14, the % standard deviation is much smaller for these larger apertures compared to the smaller apertures in the thinner stencils.

Additional Testing

The prior "Two-Print Stencil Process" dealt with two sets of stencils; (1) a 50 um (2mil) thick 1st print stencil used with a 175 um (7 mil) thick 2nd print stencil having a 125 um (5 mil) deep relief pocket and (2) a 75 um (3 mil) thick 1st print stencil used with a 200 um (8 mil) thick 2nd print stencil having a 150 um (6 mil) deep relief pocket. In order to establish the minimum clearance height required between the 1st print stencil and the thickness of the relief pocket of the 2nd print stencil a third set of stencils was tested. A 50 um (2 mil) thick 1st print stencil was used with a 125 um (5 mil) 2nd thick 2nd print stencil having a 75 um (3 mil) deep relief pocket. Print results for this test are shown in Figures 17 to Figures 19 for the Image 1 configuration [250 um (10 mils) spacing between apertures in the 1st and 2nd print stencils]. Figure 17 shows the position of the 0.3 mm uBGA solder paste bricks with respect to the RF shield solder paste bricks.

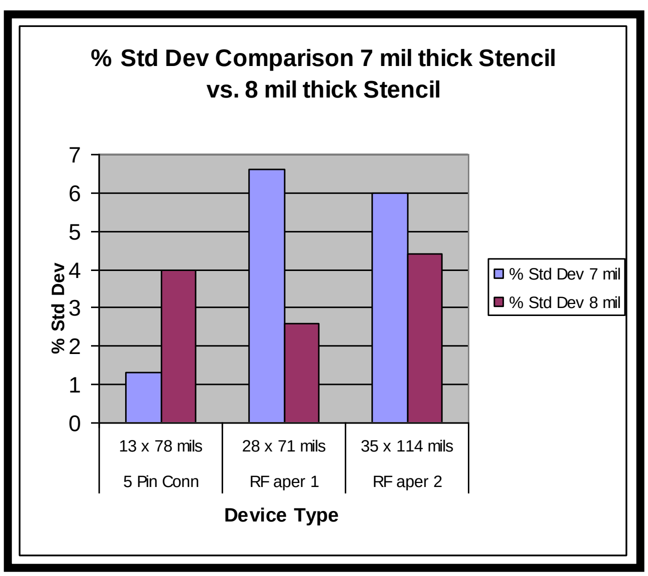

Figure 15. % Standard Deviation Comparison 7 vs. 8

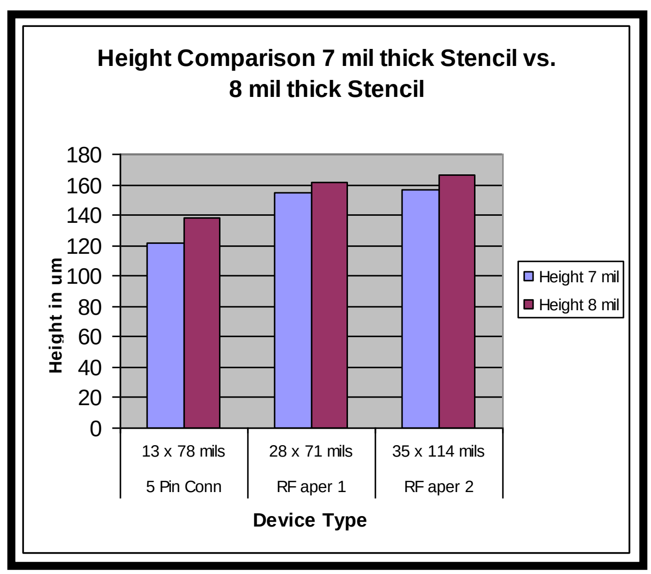

Figure 16. Paste Height Comparison 7 vs. 8

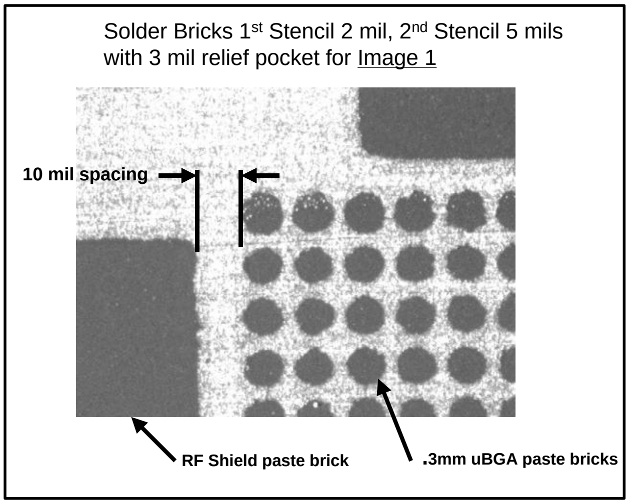

Figure 17. .3 mm uBGA solder bricks 2 mil with 5 mil

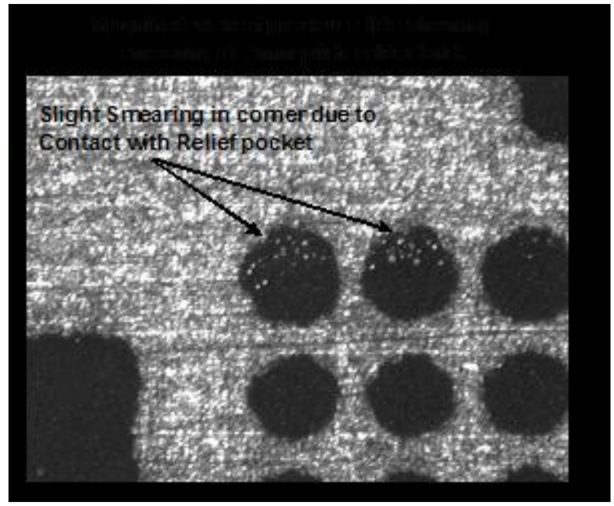

Figure 18. Magnified view of 17 showing smearing

Figure 18 is a close-up of the same image. This image shows slight smearing in the corner of the uBGA array caused by contact with the corner of the relief pocket. Figure 19 shows solder bricks for the 01005 chip component with respect to the RF shield solder brick. Again slight smearing is observed on the solder brick closest to the relief pocket. Figure 20 demonstrates that no smearing was observed when the spacing between apertures in the 1st stencil and 2nd stencil was increased to 500 um (20 mils). It can be concluded that with a spacing as low as 25 um (1 mil) between the 1st print stencil thickness and the depth of the relief pocket on the 2nd stencil no paste smearing occurred during the 2nd print as long as the clearance between apertures is between 250 um (10 mils) and 500 um (20 mils). Although not specifically confirmed by tests, I believe a safe keep-out spacing between apertures in the 1st print stencil and the 2nd print stencil is 380 um (15 mils). This is based on the fact that only the outer halves of the 0.3 mm uBGA solder brick touched the relief pocket at a spacing of 250 um (10 mils) as seen in Figure 18.

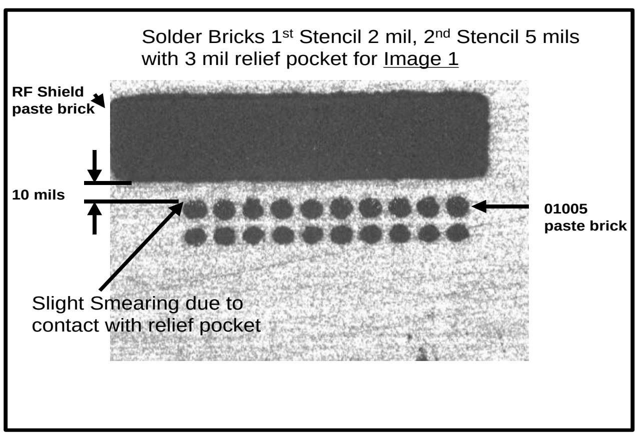

Figure 19. 01005 solder bricks, slight smearing

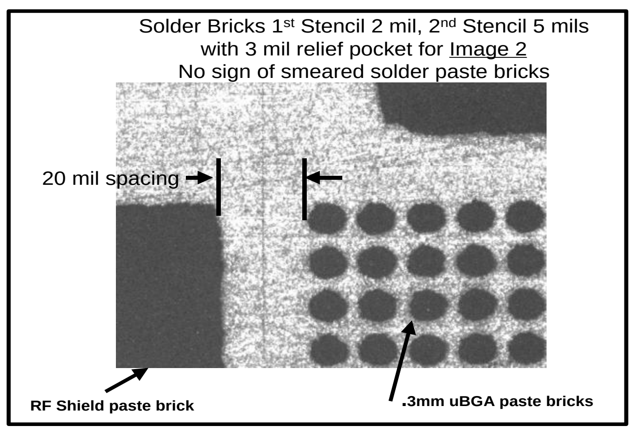

Figure 20. 0.3mm uBGA solder bricks with 20 mil spacing

Conclusion

It has been demonstrated that "A Two-Print Stencil Process" is an effective solution to print solder paste when different paste heights are required. The spacing between apertures requiring different heights can be as small as 380 um (15 mils). It has also been demonstrated that the depth of the relief pocket in the 2nd print stencil can be as low as 25 um (1 mil) more than the thickness of the 1st print stencil. It should also be noted that aperture spacing between apertures in the 1st and 2nd print stencil is independent of the thickness of the 2nd print stencil. This is very useful when very thick paste heights are required from the 2nd print stencil. The "Two-Print Stencil Process" offers a new solution to cell phone and hand-held SMT assemblers. Thick solder paste for RF shields can be printed very close to solder paste bricks for very small devices like 0.3 mm uBGA and 01005 chip components. A design decision must be made as to which apertures are to be included in the 1st print stencil and which apertures are to be included in the 2nd print stencil. As a secondary outcome of this testing it is seen, for the particular print set-up, the standard deviation of the 50 um (2 mil) thick 1st print stencil is significantly lower that the thicker 75 um (3 mil) 1st print stencil. It is also observed that generally, the standard deviation for the 1st print stencils is lower for the larger apertures and the thinner stencil.

Design Guidelines
General design guidelines are shown in Table 3.

Future Work
The work presented here had relief pockets positioned in close proximity to apertures in the 1st and 2nd print stencils. The relief pockets encompassed the entire area of the device printed in the 1st print stencil. The largest relief pocket was 6.8 mm x 6.8 mm (0.270" x 0.270"). There was no support issue regarding the 2nd print stencil flexing down to touching solder bricks printed by the 1st stencil, even when there was only 25 um (1 mil) clearance.

As a future project it should be determined how large the relief pocket could be designed without flexing to touch 1st print solder bricks. The future project should also address the size and spacing of support pillars between apertures when the 1st print stencil has a high density of apertures.

Acknowledgements
The author would like to extend his appreciation and thanks of Vatsal Shah of Speedline for his contribution in measuring the solder paste volume.

References
(1) William Coleman and Michael Burgess "Step Stencils", Global SMT and Packaging, October 2006