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Effect of Board Clamping System on Solder Paste Print Quality

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Abstract

Stencil printing technology has come a long way since the early 80's when SMT process gained importance in the electronics packaging industry. In those early days, components were fairly large, making the board design and printing process relatively simple. The current trend in product miniaturization has led to smaller and more complex board designs. This has resulted into designs with maximum area utilization of the board space. It is not uncommon, especially for hand held devices, to find components only a few millimeters from the edge of the board. The board clamping systems used in the printing process have become a significant area of concern based on the current board design trend.

The primary function of a clamping system is to hold the board tightly in place to provide optimum gasketing during the printing process. There are various types of clamping systems available in the market, including top clamp, snuggers, flippers, and vacuum hold down. Top clamp and snuggers, two primary clamping systems, operate slightly different in providing the mechanism to hold the board. Top clamp, as the name implies, holds the board in place by applying a clamping system (a thin metal foil) on the top of the board. While the snugger works by tightly snugging the board in the Y direction without any foil on top of the board.

The current study is designed to investigate the effect of top clamp and Y-snugger on both a specially designed test stencil and production quality cell phone boards. This study will use a 3D Solder Paste Inspection (SPI) system to determine the variation in paste volume and height based on the location of the pad on the board. Various statistical techniques will be used to analyze the SPI data to determine the effectiveness of the clamping system.

Introduction

For stencil printing, defects are typically caused by one or more of the following: poor alignment between the substrate and stencil, incorrect paste chemistry, or variations in the amount of paste deposited. Variation in the amount of paste deposited in turn depends on several factors. Some of the important factors are the following: paste chemistry, printer setup, squeegee blade type, stencil design, board support and board clamping. As most stencil printing experts know, board support is an integral part of developing a robust printing process. Without proper board support, the force applied to the board, across the entire width of the PCB, will vary and proper gasketing between the stencil and the board will not be achieved. Board support comes in two distinct forms; under board support and transport rail support. This study focuses on two commonly used transport rail board support systems known as "TopClamp" and "EdgeClamp". As the components are placed closer and closer to the edge, board clamping has become a significant factor in maintaining high print quality.

Experimental

A two-phase approach was used to understand the difference between the TopClamp and the EdgeClamp system on the overall solder paste print quality. Phase I focused on baselining the clamping system by using a special stencil design. Phase II focused on learning the effect of the clamping system on a production quality cell phone board.

Phase I

The stencil design for the Phase I study is presented in Figure 1. The stencil consisted of a 4mil laser cut, stainless steel foil with an image size of 8"x10". The aperture pattern starts 3mm from the edge of the board and increases by 0.5mm every 4 pads. As it is seen from Figure 1, the aperture patterns for the board were a "step & repeat" strategy for the top and bottom half of the board. This allowed investigation of both stroke directions using the same stencil. The test board for Phase I was a bare copper board. This allowed the study to focus on the clamping effect only, without the interference of board flatness due to pad/trace and board finish. Experimental detail is presented in Table 1.

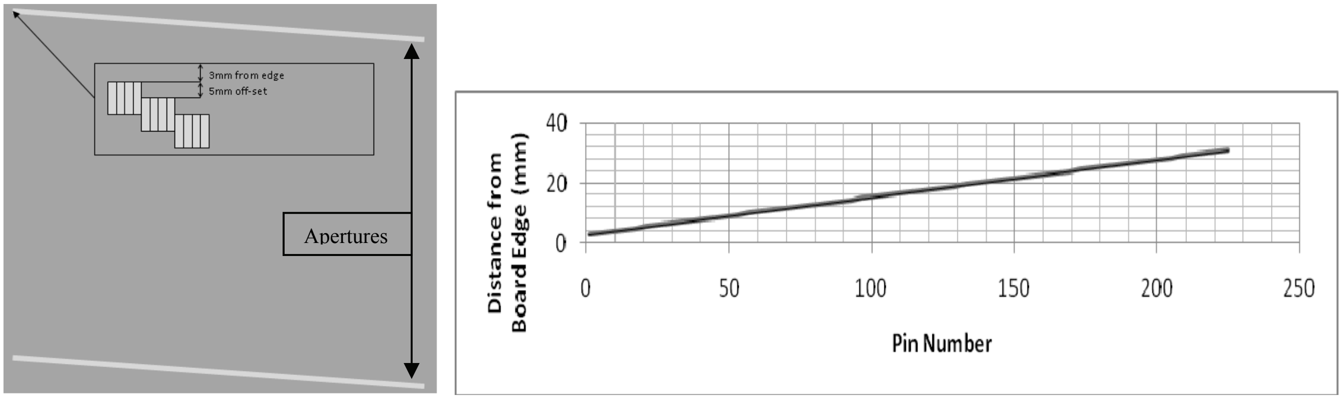

Figure 1. Baseline study Stencil Pattern

Table 1. Experimental detail

Printer	MPM Momentum Elite
Inspection tool	Koh Young - KY3020T with High res camera
Board type	Blank copper board
Image size	8” X 10”
Number of prints	20
Stroke direction	Both
Board Support	Dedicated holder
Paste	SCA 305, Type III
Clamp type	MPM TopClamp and EdgeLoc

Before the data collection began, a gage repeatability study was successfully conducted on the SPI machine as per the manufacturer’s recommendation to ensure the SPI was capable of detecting paste volume and height variation.

Phase I Results and Discussion

Figure 2 shows an optical image of a pasted board using the TopClamp. It is clearly seen from the image below that pads closer to the edge show a higher amount of paste as compared to the pads further away from the board edge. This effect is the result of poor gasketing near the edge of the board due to the presence of the top clamp foil. The right hand side of the drawing describes this effect.

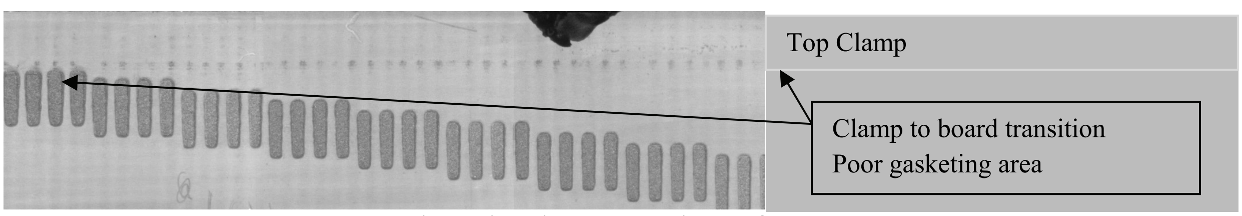

Figure 2. Printed board image for Phase I study

Figures 3-8 show the comparison of paste Transfer Efficiency (TE) and height result for both the clamping systems. The board to board repeatability of the experiment is shown in Figures 3 and 4. As the run chart of TE and paste height show, there is a good agreement between board to board repeatability. The box plot for TE for a single board is shown in Figure 5. A significantly higher TE close to the edge is seen for the TopClamp system. The TE stabilizes to a more constant value as prints move away from the edge. No such variation in TE is seen for the EdgeLoc system. The primary reason for the higher TE near the board edge is due to higher paste height. This is shown in Figure 6. This effect can be explained by the fact that when the squeegee blade moves over the stencil from the edge of the image to the center, the top clamp acts as a standoff height. This action prevents the stencil to provide necessary gasketing for consistent paste transfer. The “standoff” effect reduces and proper gasketing occurs between the board and the stencil for prints away from the edge. Since the EdgeLoc provides no such “standoff” effect, paste transfer seems to be uniform across the board.

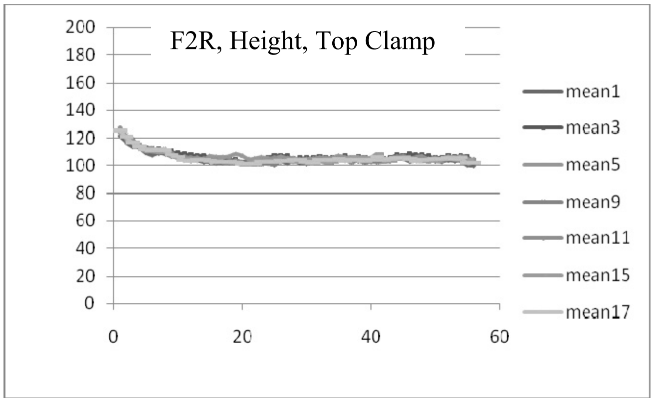

Figure 3. Run chart of TE for all F2R print directions

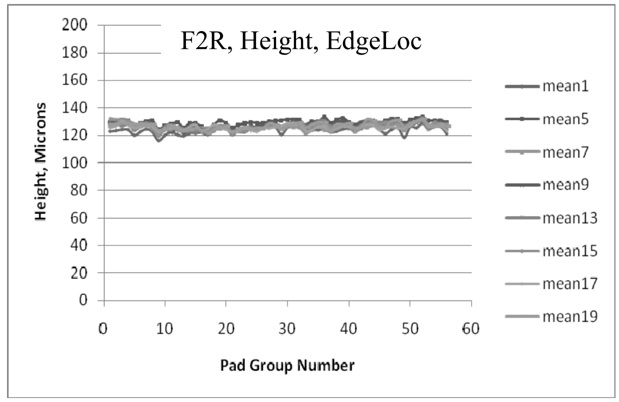

Figure 4. Run chart of height for all F2R print directions

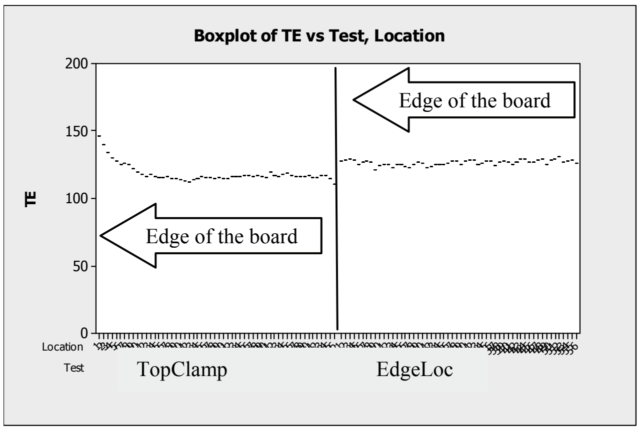

Figure 5. Paste TE for a single board

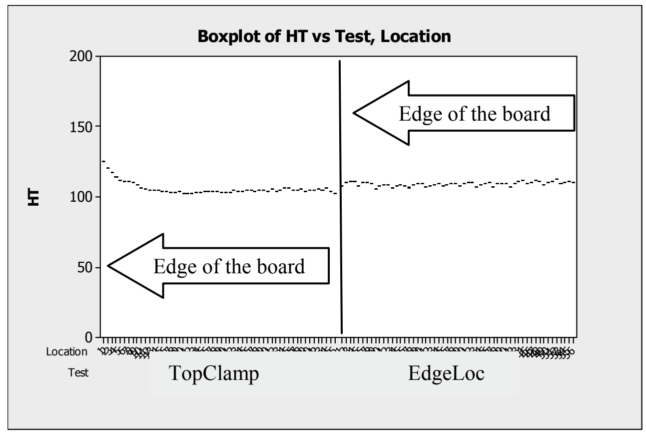

Figure 6. Paste Height for a single board

The results for all Front-to-Rear (F2R) stroke printed boards (8 boards) are presented in Figures 7 and 8. The most significant effect observed here is the variation in paste TE and height for the TopClamp system. The TE value for TopClamp ranges from ~110% to150% while the EdgeLoc system shows a much tighter distribution of ~120% to 130%. The same phenomenon is observed for the height value. This is a clear indication of the importance of the edge effect on the print quality.

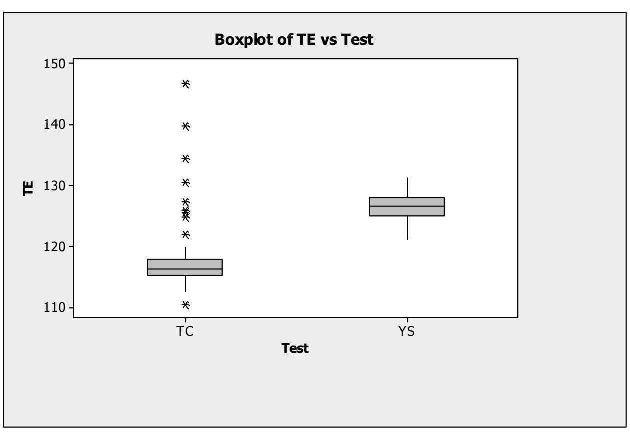

Figure 7. Box plot of TE for 8 boards

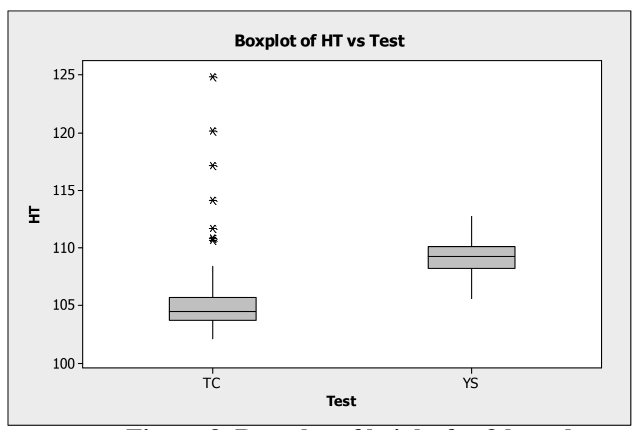

Figure 8. Box plot of height for 8 boards

Phase II

Phase II of the experimental study focused on a production quality cell phone board to determine the effect of clamping system on the print quality. Figure 9 shows the schematic of the cell phone board used in this study. Four components per panel were inspected that covered both edges and the center of the board. As seen from Figure 9, Panels 1 and 3 have the same orientation while Panels 2 and 4 have the opposite orientation. Analysis presented here is restricted to the F2R stroke and P1, P3 only. Further analysis and the remainder of the data will be presented at a future time.

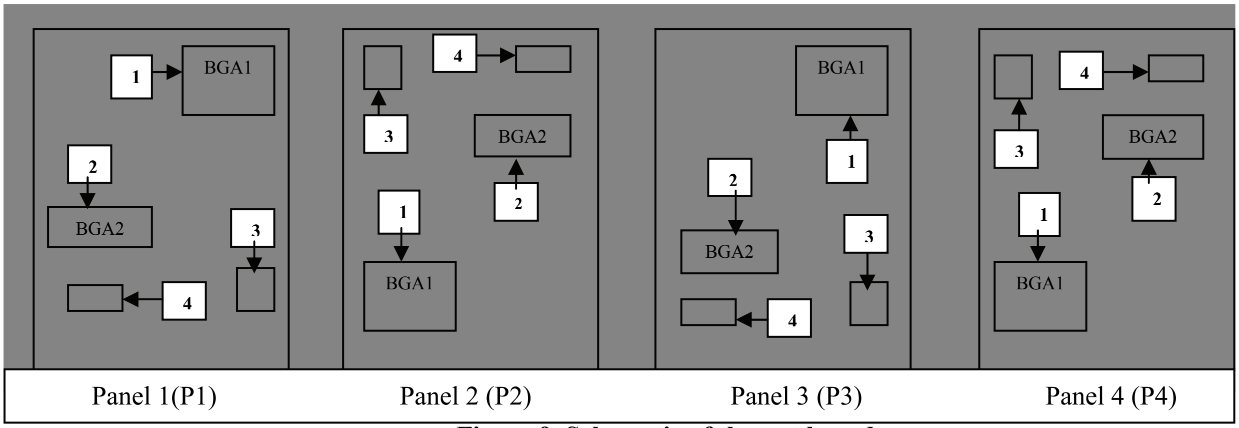

Figure 9. Schematic of the test board

Before the data collection began, print parameters were optimized based on the stencil, board and paste type. Specifics of the experimental setup are given in Table 2, below.

Table 2. Phase II Experiment Parameters

Printer	MPM Momentum Elite
SPI system	Koh Young (KY3020T with hi-res camera)
Test board	FR4 with ENIG pad finish
Components inspected	1 – Large BGA
	2 – Small BGA
	3 – QFN
	4 – SOP
Stencil	4 mil Laser cut Electropolish
Board support	Dedicated work holder
Paste Type	Commercial grade, SAC 305, Type IV
Stroke direction	Both (F2R & R2F)
Number of boards/stroke	9
Print Pressure	15lb
Print Speed	1.00 in/sec
Separation speed	0.05 in/sec
Stencil wipe	Heavy wipe after each board

Phase II Results and Discussion

Presenting the detailed results and analysis for the current study is beyond the scope and size limitations of this paper. Hence, results from selected areas, representing the critical components are presented here. Figure 10 shows the board to board repeatability for the 9 boards tested with the F2R stroke. This graph shows average TE for a large BGA (1) over Panels 1 and 3. Both clamping systems show good agreement between each board in regards to trend. TopClamp shows slightly higher variability and lower TE as compared to EdgeLoc. This is not unexpected as the baseline result showed similar phenomena. Figures 11 and 12 show results from various statistical analyses conducted using Minitab.

The box plot for all four components, which is shown in Figure 11a, shows that clamping system has a significant effect on BGA1 and BGA2. However, QFN and SOP are less affected by the clamping system. Both BGA's show much higher variation in TE for TopClamp as compared to EdgeLoc. In addition, BGA2 appears to have higher variation than BGA1 regardless of the clamping system. One explanation for this behavior is the smaller pad size and tighter pitch for BGA2. As QFN and SOP have a smaller number of pads and larger sized pads, the effect of clamping system is negligible. The same data, when presented in histogram form, Figure 12, shows TopClamp has higher spread and a lower mean as compared to the EdgeLoc system.

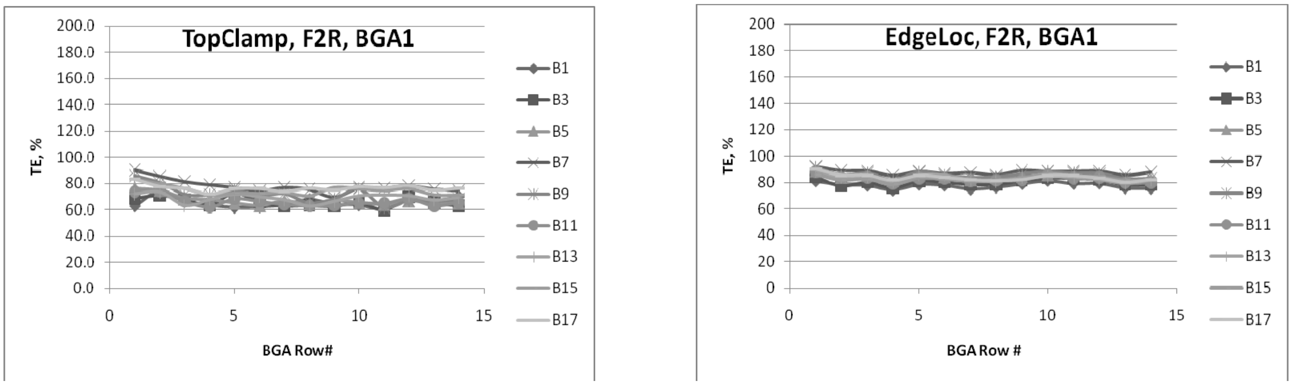

Figure 10. Board to board repeatability for BGA 1, P1 and P2

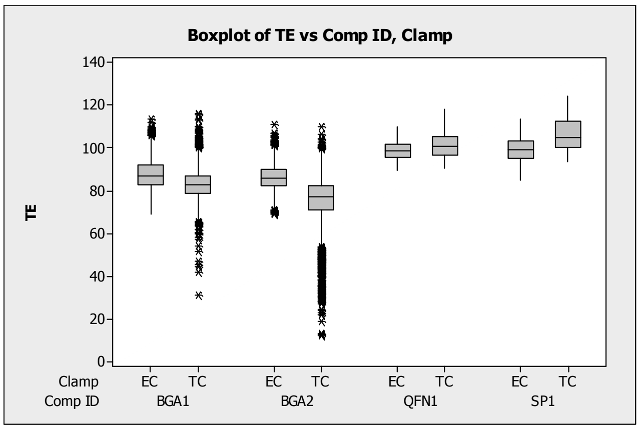

Figure 11a. Box plot showing TE for all 4 components, Individually

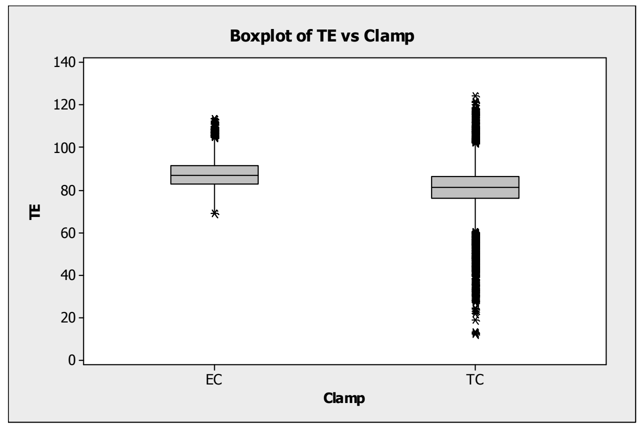

Figure 11b. Box plot showing average TE for all 4 components, Combined

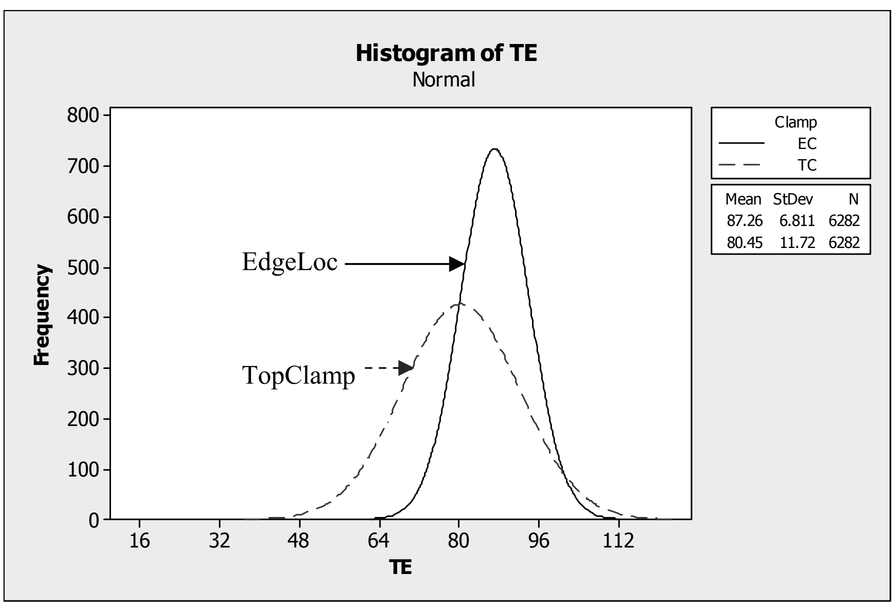

Figure 12. Histogram of TE for TopClamp and EdgeLoc

Figures 13 and 14 represent optical images from Phase II experimental work. Figure 13 refers to TopClamp, BGA1, Panel 1 and Figure 14 refers to EdgeLoc, BGA1, Panel 1. The EdgeLoc clamping image shows the print to be of higher quality than TopClamp. EdgeLoc shows the solder deposit to be uniform across the component while TopClamp shows bare copper pads, indicating poor print quality. This is in agreement with the statistical analysis.

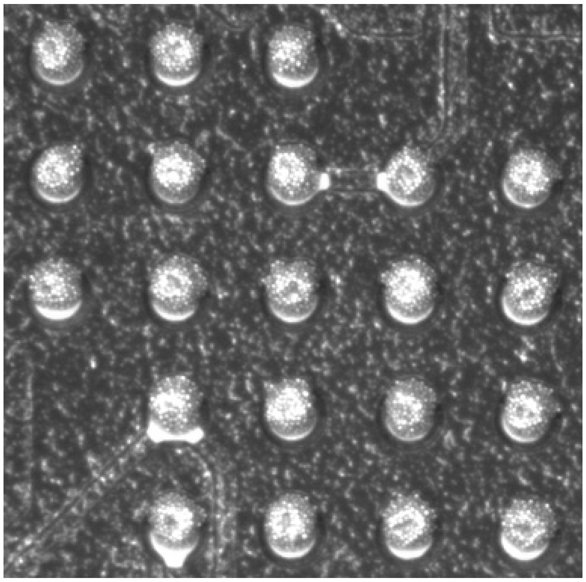

Figure 13. BGA1 for TopClamp

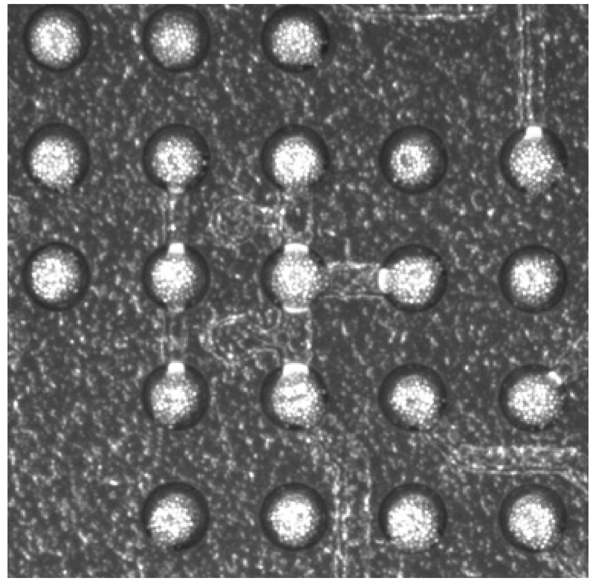

Figure 14. BGA1 EdgeLoc

Conclusion

Two sets of experiment were conducted to understand the effect of rail clamping systems on overall print quality of solder paste printing. Two different types of clamping systems were used herein, MPM's TopClamp and EdgeLoc. The baseline test, which used a special stencil design, showed that the EdgeLoc system has less variation in TE than the TopClamp system. This is due to the smoother transition of squeegee blade over the clamping system during a print stroke. The second test, which used a production quality cell phone board, confirmed that the EdgeLoc system provides better gasketing and hence better overall print quality. In addition, it is observed that for fine pitch components, the effect of clamping system is even more critical. The EdgeLoc clamping system provided higher TE with lower standard deviation. Based on this study, it can be concluded that the EdgeLoc clamping system is a more desirable clamping mechanism, especially when using fine pitch components.

Future Work

The current work was strictly restricted to smaller board size with standard board thickness (0.062"). In order for us to access the wider benefit of EdgeLoc clamping system, additional experimental work is necessary. This work will includes thinner and larger board with mix-size components.