Paste Jetting Within a Solder Paste Inspection Process

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ABSTRACT
In the electronics industry, consumer demand drives a large portion of product innovations. Consumers want greater functionality and power, while maintaining a small footprint. Due to this demand, printed circuit board (PCB) manufacture and the related solder paste screen printing process become increasingly complex.

Generally speaking, in high volume surface mount technology (SMT) assembly; consistent solder paste print volume and deposition are required to insure a high yield rate. With new product designs adopting finer pitch, smaller components, and greater density, stencil designs violating typical recommendations for area ratio are being evaluated.

Using a stencil nearing or exceeding boundaries of known good performance challenges consistent screen print volumes and deposition throughout an entire PCB. This paper will review a solder paste developed for use with a combined solder paste inspection (SPI) and jetting tool. The paper will consider the viability of this process to prevent defects related to insufficient solder paste prints.

Key words: Printed Circuit Board (PCB), Surface Mount Technology (SMT), Solder Paste Inspection (SPI).

INTRODUCTION
Design guidelines for stencil apertures with acceptable solder paste release historically carry a greater than 0.66 area ratio and greater than 1.5 aspect ratio, anything below typically causes issues with paste release from the stencil. For example, ball grid array (BGA) packages with 0.25mm bumps using a stencil with 4mil thickness and round apertures smaller than 10mil diameter, violate these historical criteria and can become problematic in high volume production.

When complying with traditional design rules and maintaining area ratios greater than 0.66 [1], then it becomes near impossible to design a print process for a wide mix of fine and large pitch components. [2]

The adoption of large, unique components and heatsinks, combined with uBGA's, 0402 components (or 01005 for imperial coding) in high volumes as well as high densities throughout the entire PCB, are making it exceedingly difficult to maintain a stable printing process. Insufficient prints are very common in these types of situations, and can lead to increased costs, decreased productivity, lower product reliability and an increase in overall defects (if gone unnoticed).

For example, these new components (01005) are extremely challenging to incorporate into the manufacturing process, as their size drives the need for very small stencil apertures that generally require violating typical recommendations for area aspect ratios. [3]

Furthermore, some OEM's are adopting "no touch" requirements restricting human contact of PCB's or rework; meaning boards with insufficient prints are discarded, which is extremely costly. Eliminating insufficient prints can drastically improve your overall process and reduce your overall costs.

This paper will review the performance of a solder paste developed for use in combination with a solder print inspection (SPI) machine's dispensing tool, as a viable solution to prevent defects related to insufficient solder paste printing.

TEST VEHICLE & MATERIAL

A 10inch X 8inch FR4, non-solder mask defined (NSMD), printed circuit board (PCB), with various test pads was chosen for this study. An example of this test vehicle can be seen in Figure 1. The area of the PCB with a 10x10 array and 250um pads, along with 0402 and 0201 pads of varying pad shapes, sizes and configurations were used for this testing. An illustration of the PCB and test pads are shown below in figures 1 and 2.

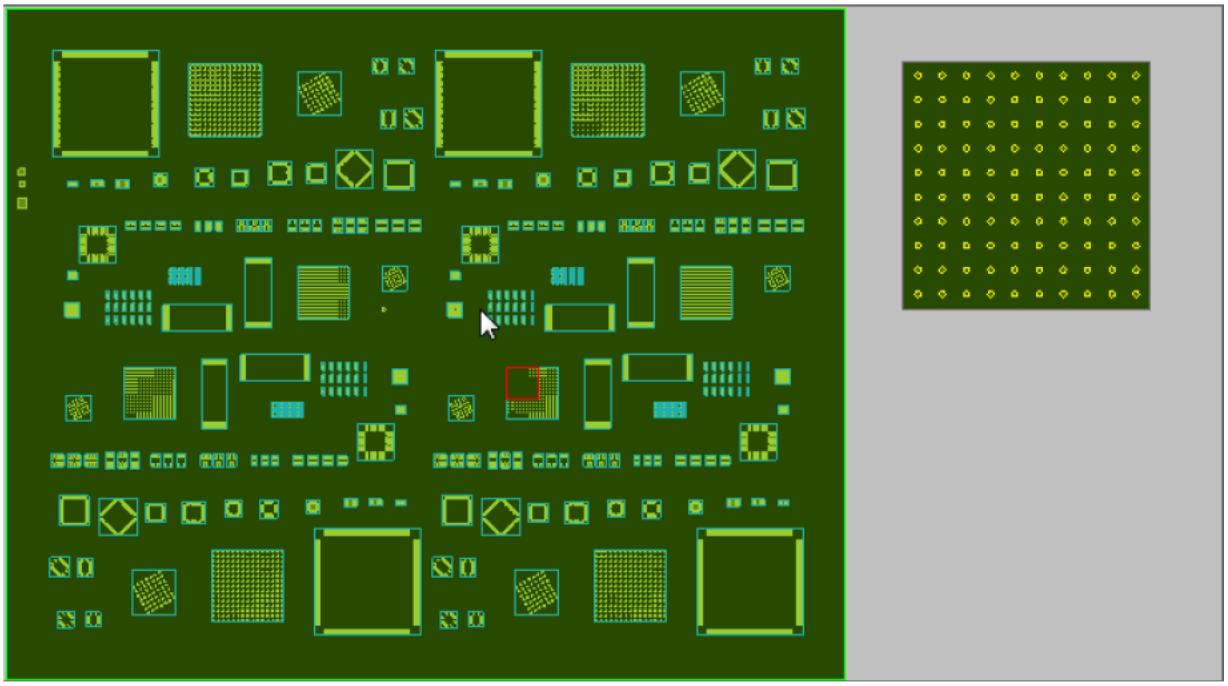

Figure 1. 10in X 8in FR4 Test Vehicle board and illustration of 10 X 10 array with 250um pads.

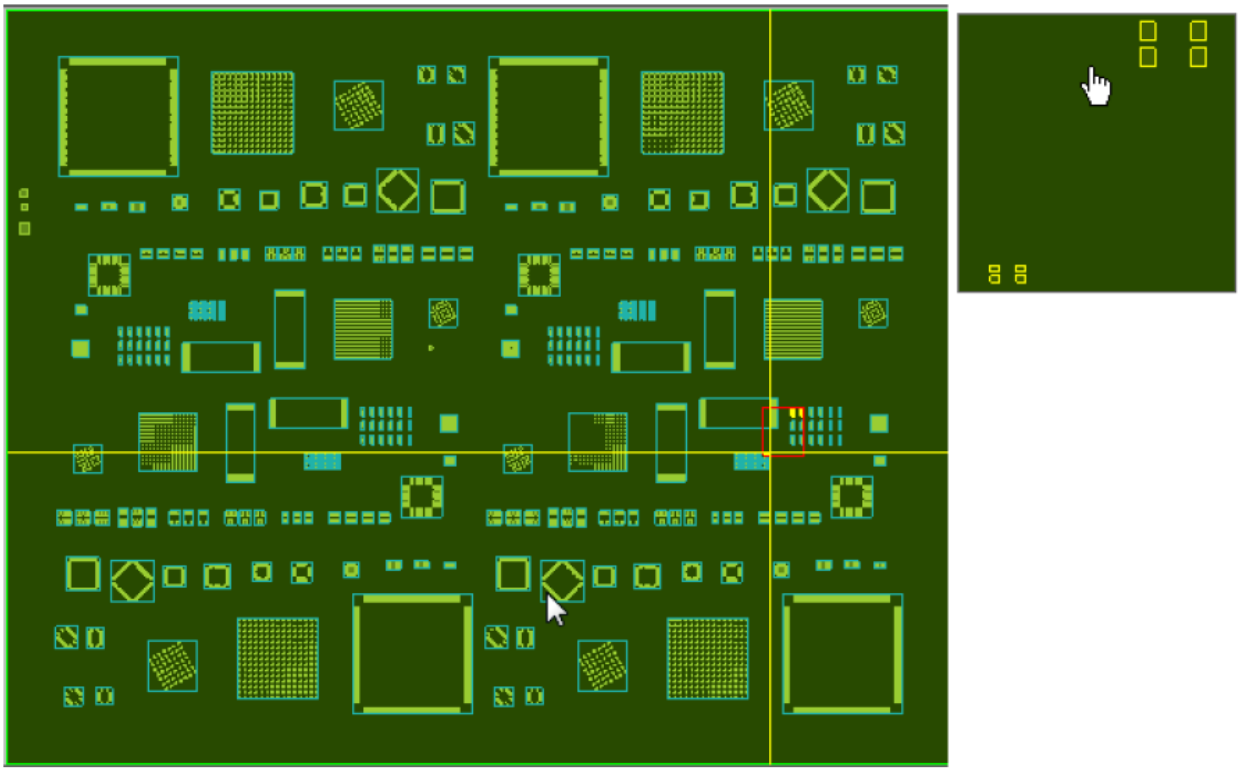

Figure 2. 10in X 8in FR4 Test Vehicle board and illustration of 0402 pads.

The solder paste chosen for testing was down selected by the solder paste inspection (SPI) maker after testing various paste samples, ranging from standard SMT pastes to high flux containing dispense pastes. The solder paste that was chosen to move forward in this testing was a SAC305 (96.5%Sn-3.0%Ag-0.5%Cu), Halogen Free, No-Clean dispense paste with 80% metal load.

SPI JET DISPENSE TOOL SETTINGS

A solder paste inspection (SPI) machine with the capability of measuring insufficient solder paste deposits and jetting paste in those insufficient deposit locations was chosen for this test. The smallest industry needle gauge of 34 (80um) was evaluated, along with a targeted paste deposition height of 100um.

The settings used on the SPI machine can be seen below in figures 3 and 4.

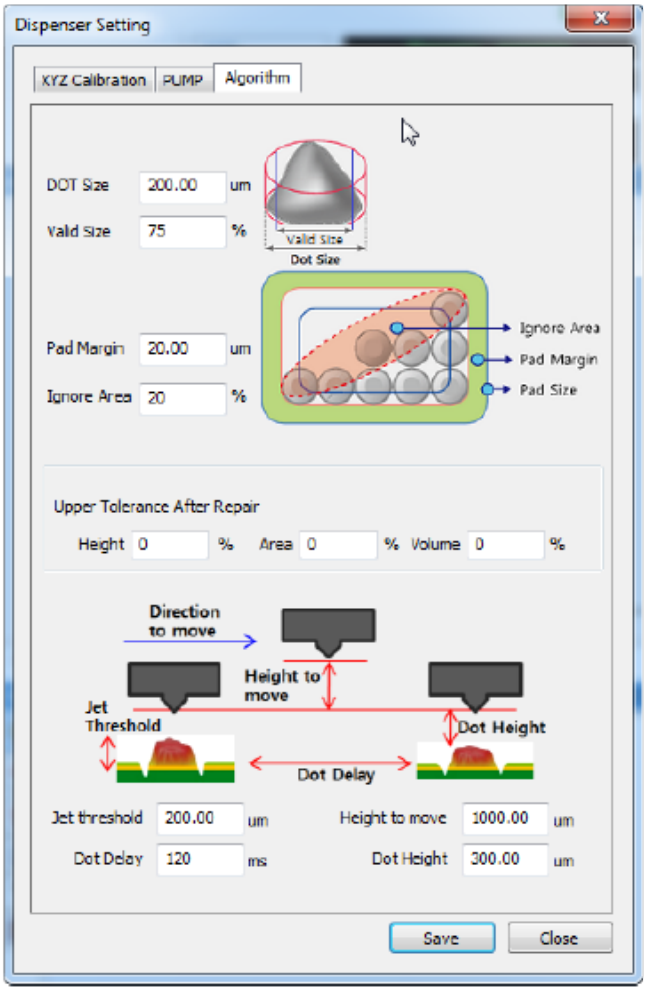

Figure 3. Illustration of dispenser algorithm settings.

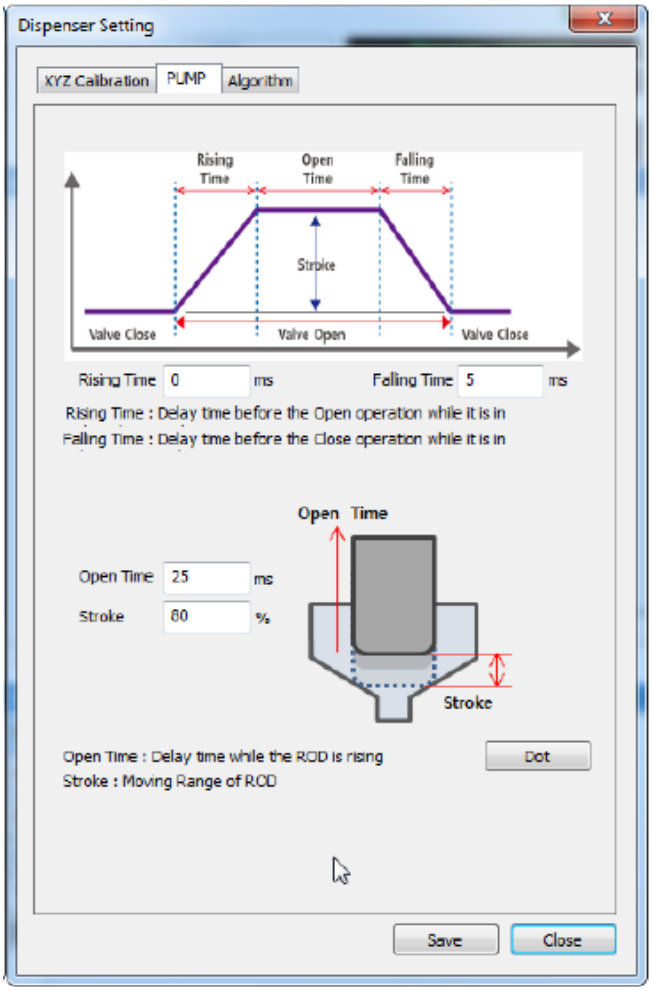

Figure 4. Illustration of dispenser pump settings.

75% of a 200um dot size with a margin of 20um was used for the SPI algorithm, which ignores 20% of the tested 250um pad area (to insure accurate SPI measurement and paste jet dispense).

The chamber pump settings chosen were a rising time of 0, falling time of 5, with an open time of 25ms and stroke of 80%.

TEST PROCEDURES

Purge Test

Prior to beginning operation of the jetting tool, the solder paste must be purged throughout the system to fill the tool completely. During a purge sequence, the nozzle moves to a capture cup as the machine uses air to pressurize, push and prime all the jetting tool chambers prior to dispense.

The purpose of this test is to evaluate the time required to prime the entire pump, from solder paste syringe installation, into a cleaned, dry, empty pump, until the paste correctly jets material.

The parameters of the purge test can be seen below in Figure 5. The machine pressure used was 40psi, and the time it took to purge the system was 30 seconds.

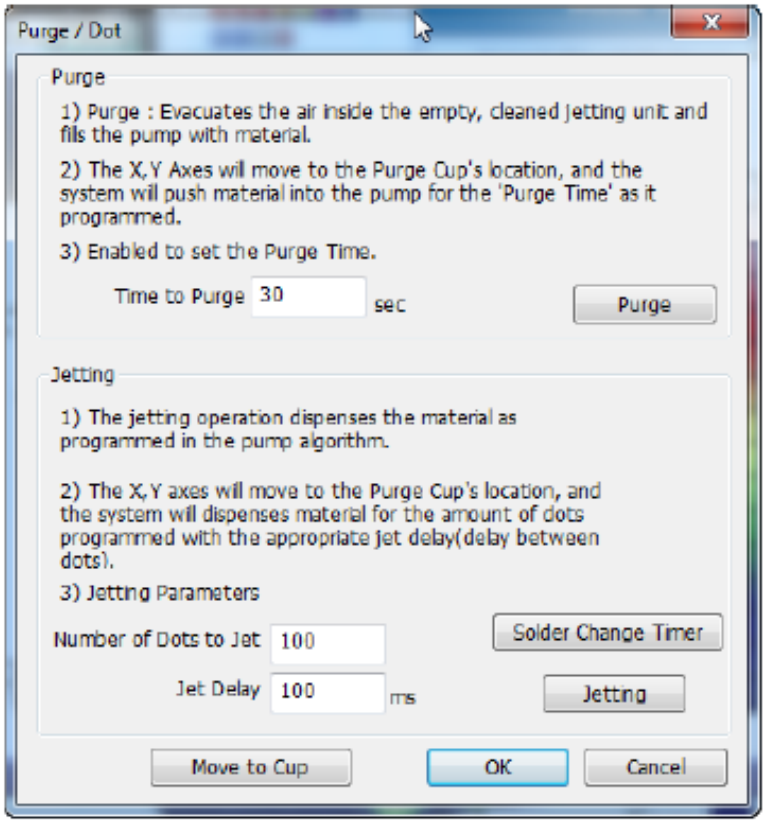

Figure 5. Illustration of purge/dot result and jetting settings

Purge Test Result

On the first try, after purging for 30seconds, 100 dots with 100ms delays were jetted onto a piece of white paper in order to verify the material dispensed correctly and wouldn't stick to the nozzle or clog. The material dispensed well, without any particle or flux distribution issues, and no paste remaining on the nozzle tip was seen. The same result was achieved after leaving the paste on the production floor for 1 week.

250um Pad Test

This test evaluates the smallest possible dot size that can be created using the 80um nozzle in combination with the SPI tools 'small-single dot' setting onto a pad, after 3 passes. A 10X10 array with 250um diameter pads was used for this testing. 10 boards of SPI data total were captured.

Bare boards were placed into the SPI machine and programmed to inspect the 10X10 array and repair (i.e. jet paste). According to the SPI tool maker, the machine will often take up to 3 passes in order to jet a sufficient amount of paste on a bare pad, so 3 passes max were chosen for the test. The number of passes, average height, area and volume of each pass was recorded, along with the final number of insufficient pads after 3 passes (based on 50% of the maximum theoretical volume).

250um Pad Test Result

The average result on 100 pads for the 10X10mm array with 250um diameter pads is shown below in table 1.

Table 1. 250um pad test results

Target Height = 100um	Height	Area	Volume
Pass 1	45%	20%	<10%
Pass 2	69%	46%	28%
Pass 2	92%	64%	51%

On the first pass it was possible to obtain a solder paste deposit with 10% theoretical volume of the pad that contained 20% of the theoretical area, and 45% of the theoretical max height (100um). On the second pass, the volume more than doubled, and the area was almost 50% of the pad. The third and final pass was able to obtain 51% of the theoretical volume, 92% of the theoretical height, and 64% of the pad area.

Figure 6 is an example of one of the deposits on a 250um pad after the third pass.

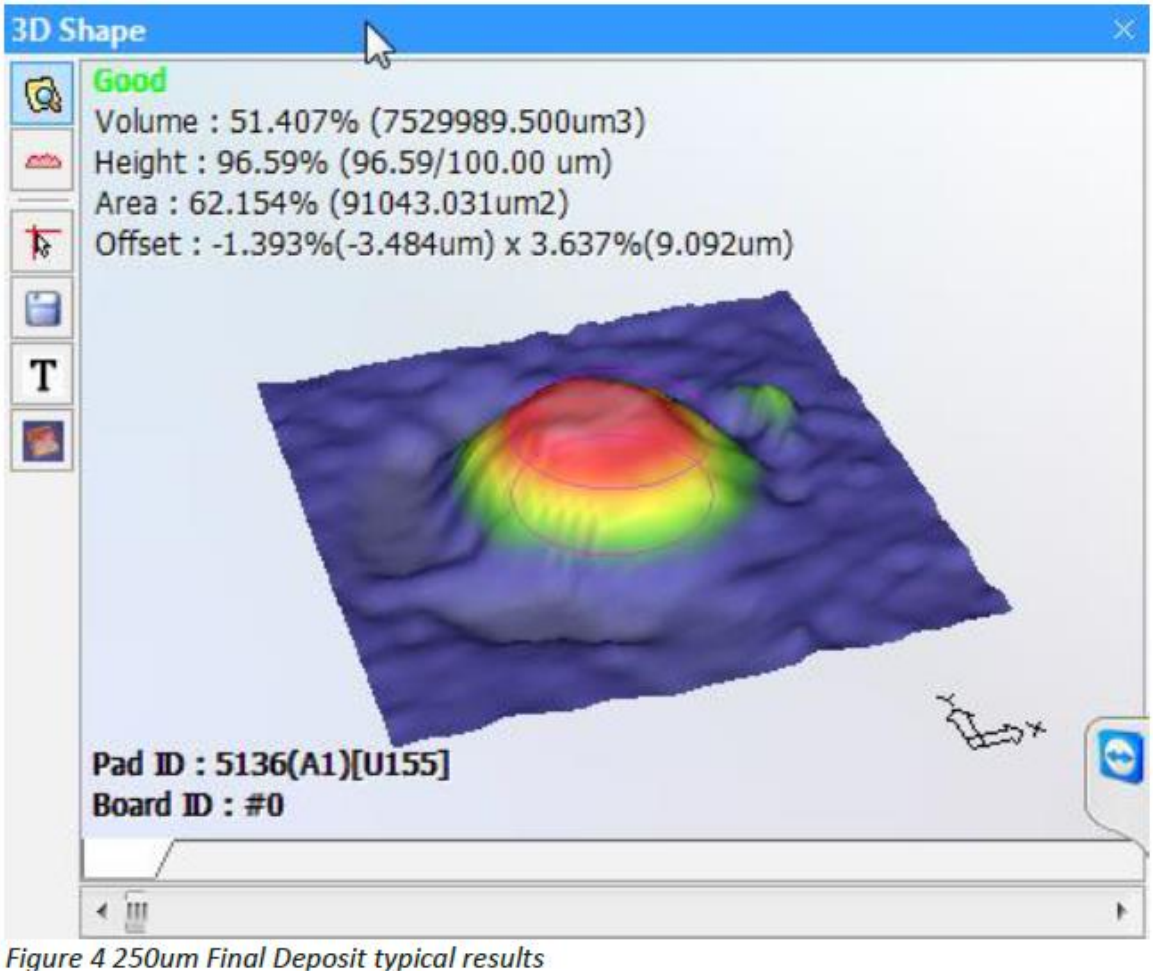

Figure 4 250um Final Deposit typical results

Figure 6. Illustration of jetted paste deposit after three passes on a 250um pad.

0402 & 0201 Pad Test

This test evaluates the time and amount of passes it takes to obtain a paste deposit with over 50% theoretical volume, on 0402 and 0201 pads using the SPI tool's 'multi-dot' setting, which is typically used for larger pads.

For the 0402, four pads on ten PCB's were chosen for testing. For the 0201, eight pads on ten PCB's were chosen for testing. An example of the deposits on the first board and the tenth board can be seen below in figure 7 and figure 8.

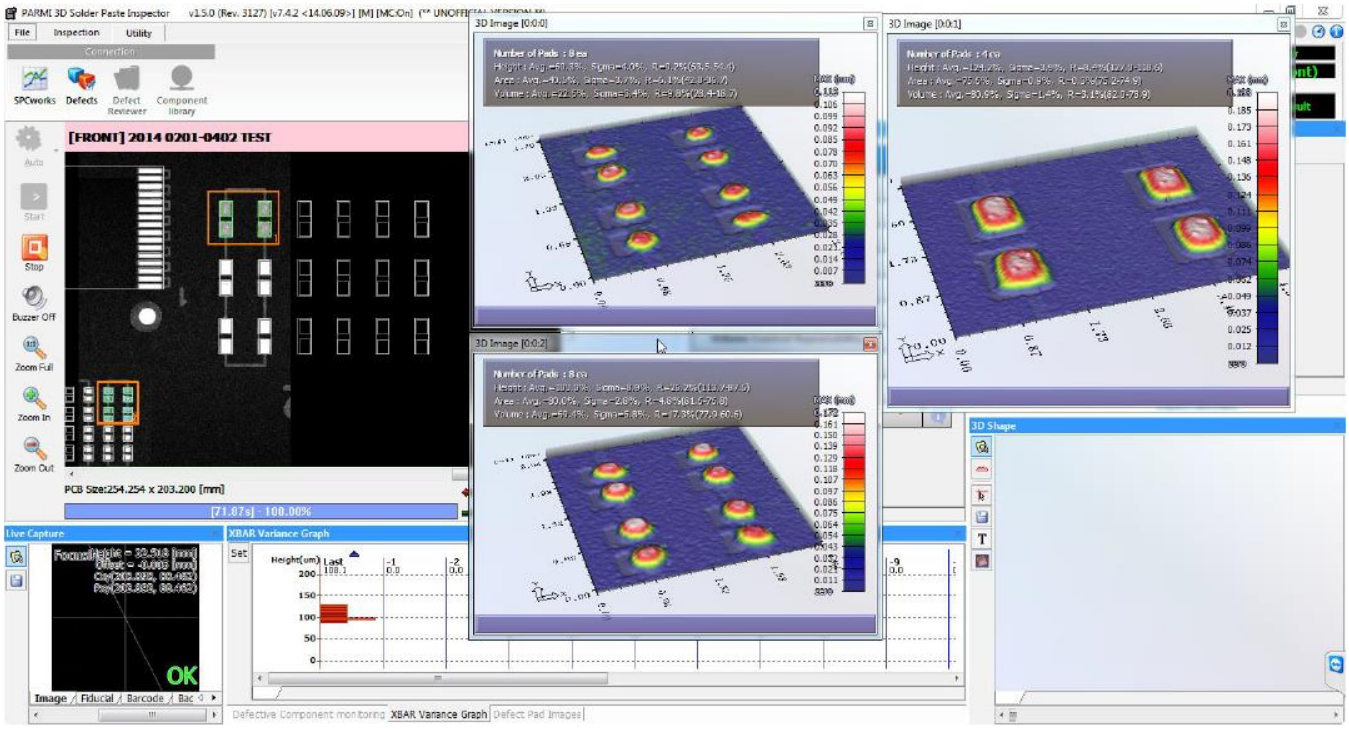

Figure 7. Board 1 after paste jetting.

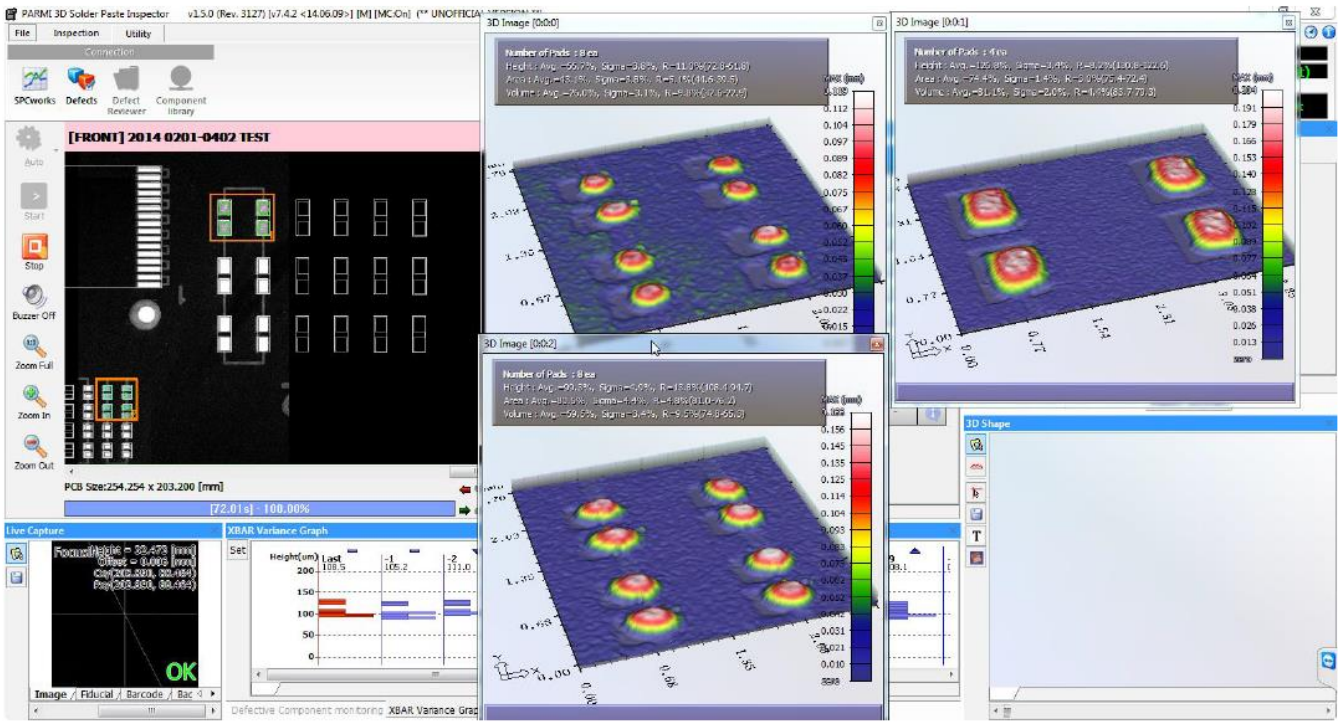

Figure 8. Board 10 after paste jetting.

0402 & 0201 Pad Test Result

For the 0402, on the first pass, 81% of the theoretical volume was achieved…

For the 0201, on the second pass, 70% of the theoretical volume was achieved… The complete table of results can be seen below within table 2…

Table 2. 250um pad test results

Target Height = 100um	Height	Area	Volume
0201 Pass 1	67%	43%	26%
0201 Pass 2	99%	81%	70%
0402 Pass 1	127%	74%	81%

JET SPI DISPENSE TOOL CONCLUSIONS

Based on these results, an SPI machine with jetting capabilities can be a viable solution for preventing issues related to insufficient solder paste deposits, which is a significant help towards mitigating or eliminating Head-in-Pillow as well as Tombstone defects, or improving solder joint fillet formation and in turn solder joint reliability.

The 0402 results also indicate an SPI machine with jetting capabilities can be a viable solution to increasing solder paste volume to improve solder fillet formation, and in turn solder joint reliability.

In conclusion, the process may be used as a stand-alone paste deposit method or may be used in conjunction with the existing standard SMT paste print process. This allows the operator to further consider small and precise modifications to the pre-attached deposit.

REFERENCES

1. IPC – 7525 Stencil Design Guidelines
2. Ashmore C., The Development of a 0.3mm pitch CSP assembly process using standard materials, SMTA-International 2011.
3. Berry M., Optimization of the 01005 discrete assembly process, SMTA-International 2011.

ACKNOWLEDGEMENTS

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PASTE JETTING WITHIN A SOLDER PASTE INSPECTION PROCESS

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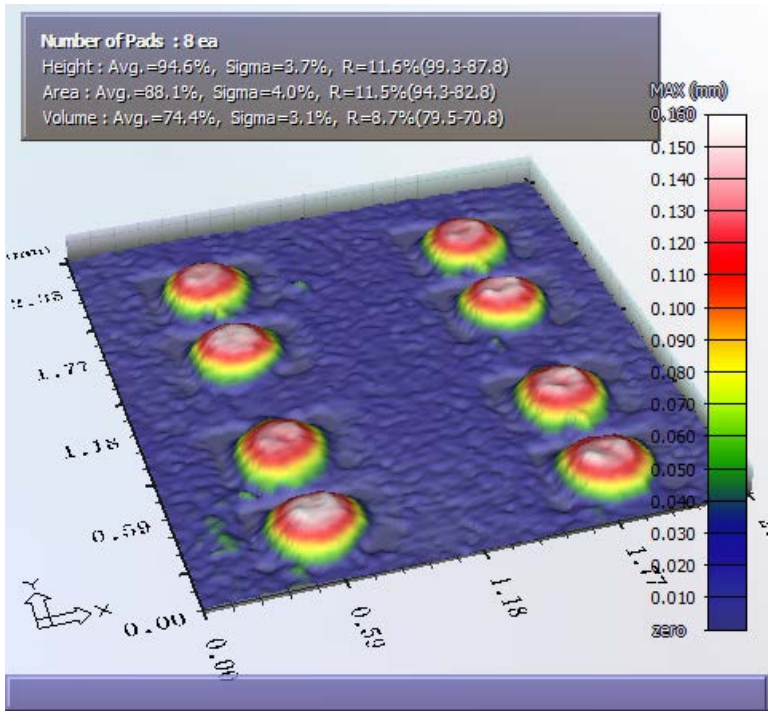

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2. Why SPI jetting?
3. How to evaluate dispensing paste for SPI jetting.
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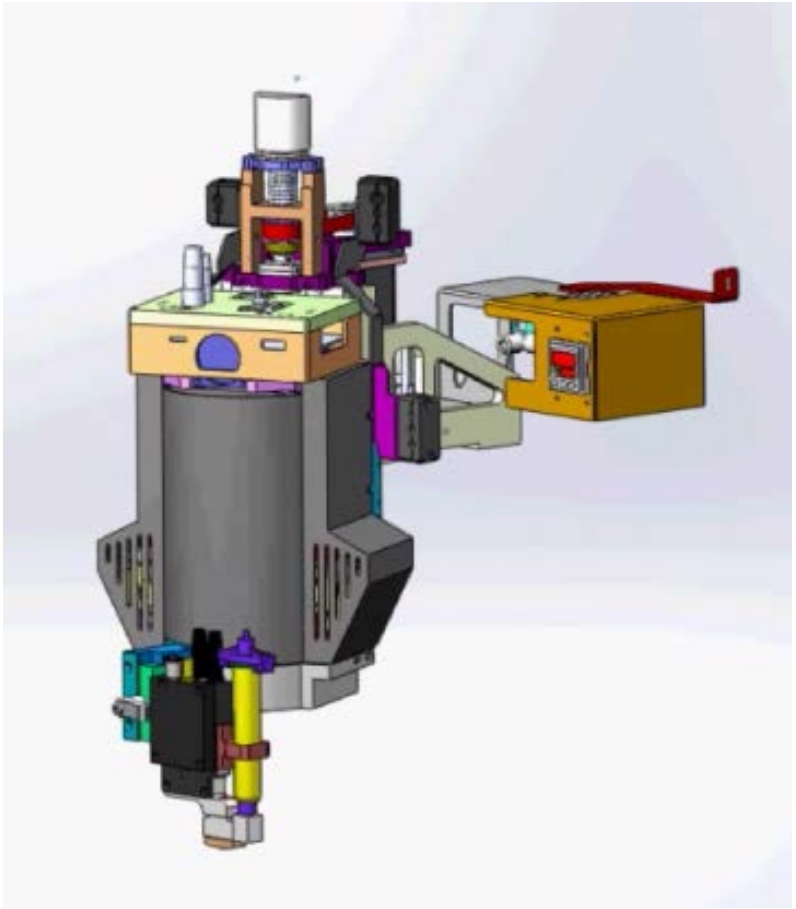
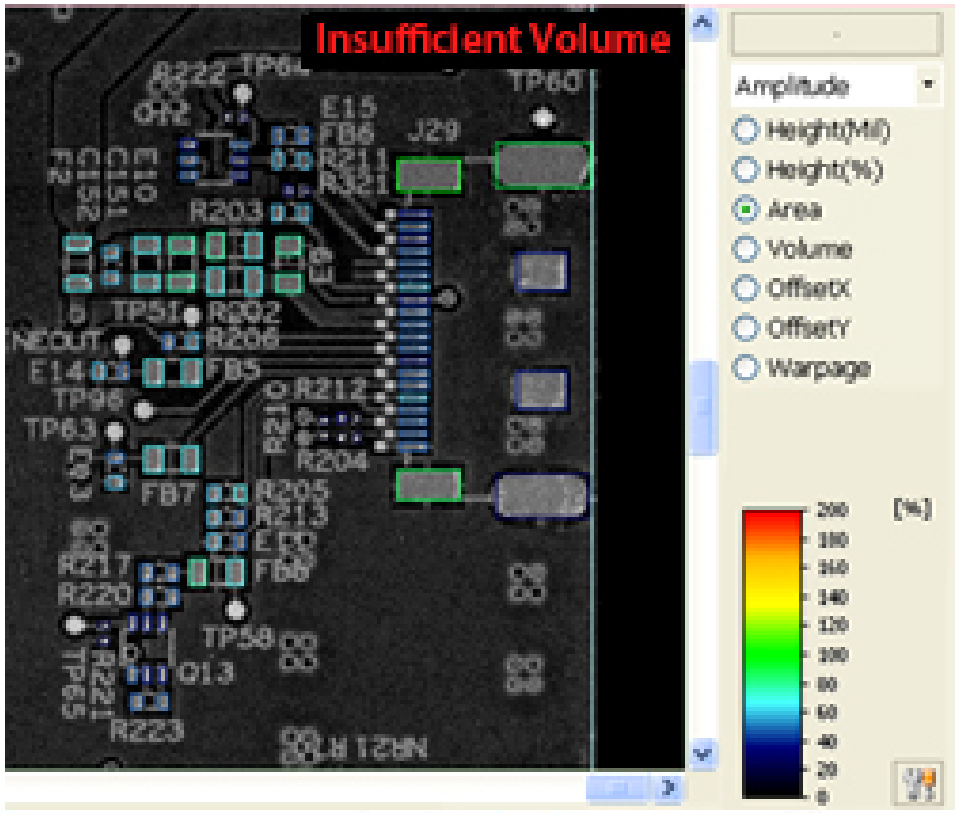
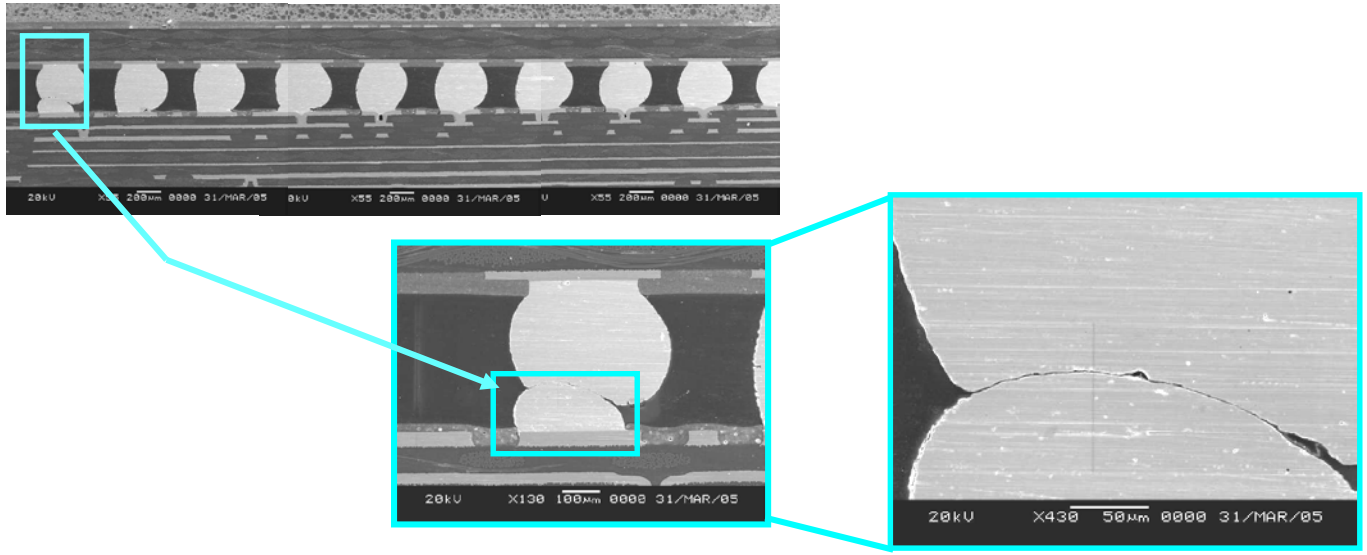
    b. Dot Test
    c. Discrete Component Test
    d. Purge Test (aged paste)
    e. Additional Tests
4. Conclusion

WHAT IS SPI JETTING



WHY SPI JETTING





HOW TO TEST DISPENSE PASTE FOR SPI JETTING

Purge Test: ***Using a dry, clean, empty pump measure the time it takes to prime the entire pump system, until the paste correctly jets material (without clogging, sticking or erratic dispensing).***

Dot Test: ***Tests the smallest dot size possible for the nozzle used.***

Discrete Components Test: ***Tests the multi-dot capability of the system for use on discrete components.***

Paste Recovery Test: ***Check the paste capability over 1 week aging in room temperature to simulate a real-life production environment***

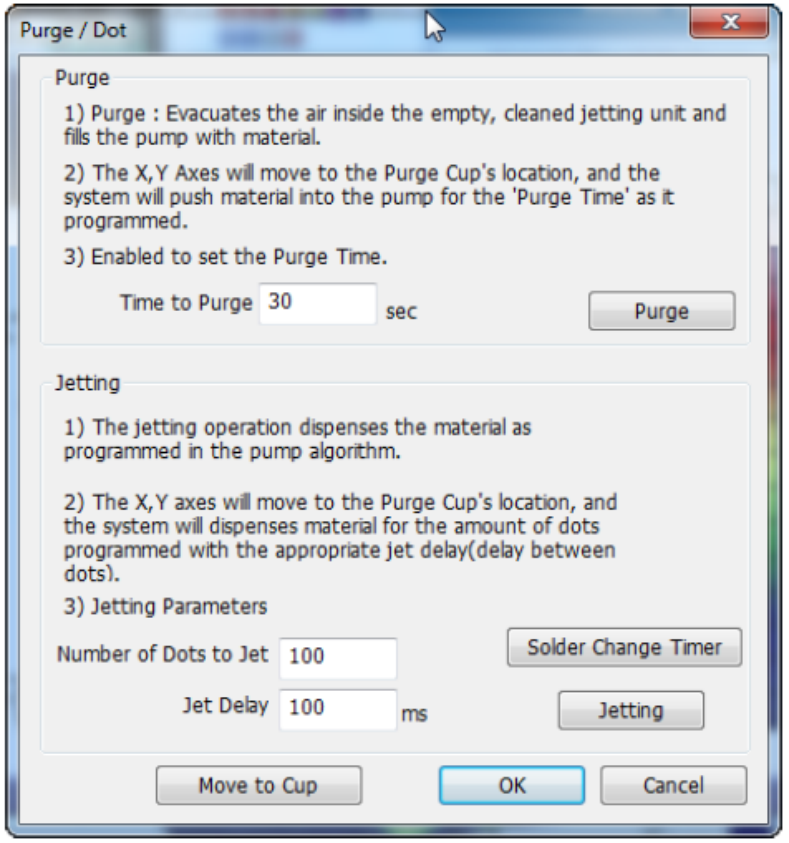
PURGE TEST PROCEDURES

Solder Paste Tested: SAC305, Type 6 mesh, Halogen Free, No-Clean, Dispense Paste with 20% flux.

Nozzle Size: 80um (34 Needle Gauge)

Target Height: 100um

Purge Test: ***Using a dry, clean, empty pump measure the time it takes to prime the entire pump system, until the paste correctly jets material (without clogging, sticking or erratic dispensing).***



Purge Test Procedure:

*Set Cartridge Pressure to ~40psi

*Add a full, 5cc paste syringe

*Run purge sequence until verified paste dispense.

1.Prime for 30 seconds

2. Jet 100 dots with 100ms jet delay.

3. Verify jetted material on paper only.

PURGE TEST RESULTS

Solder Paste Tested: SAC305, Type 6 mesh, Halogen Free, No-Clean, Dispense Paste with 20% flux.

Nozzle Size: 80um (34 Needle Gauge)

Target Height: 100um

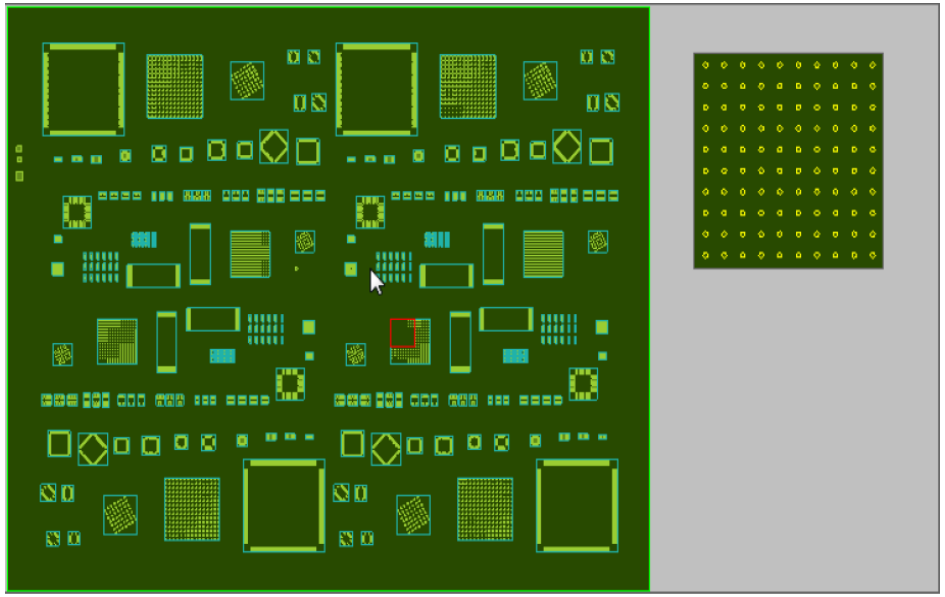
Purge Test Result:

*Fully primed system using vacuum pump on ***1st try.***

*Purge time = ***30 seconds***

*Purge Dots = ***100 dots (no clogging, no sticking to nozzle tip, no erratic dispensing).***

DOT TEST PROCEDURES



Solder Paste Tested: SAC305, Type 6 mesh, Halogen Free, No-Clean, Dispense Paste with 20% flux.

Nozzle Size: 80um (34 Needle Gauge)

Target Height: 100um

Test Board: A demo board, with a 10X10 array and 3X3 array selected for testing.

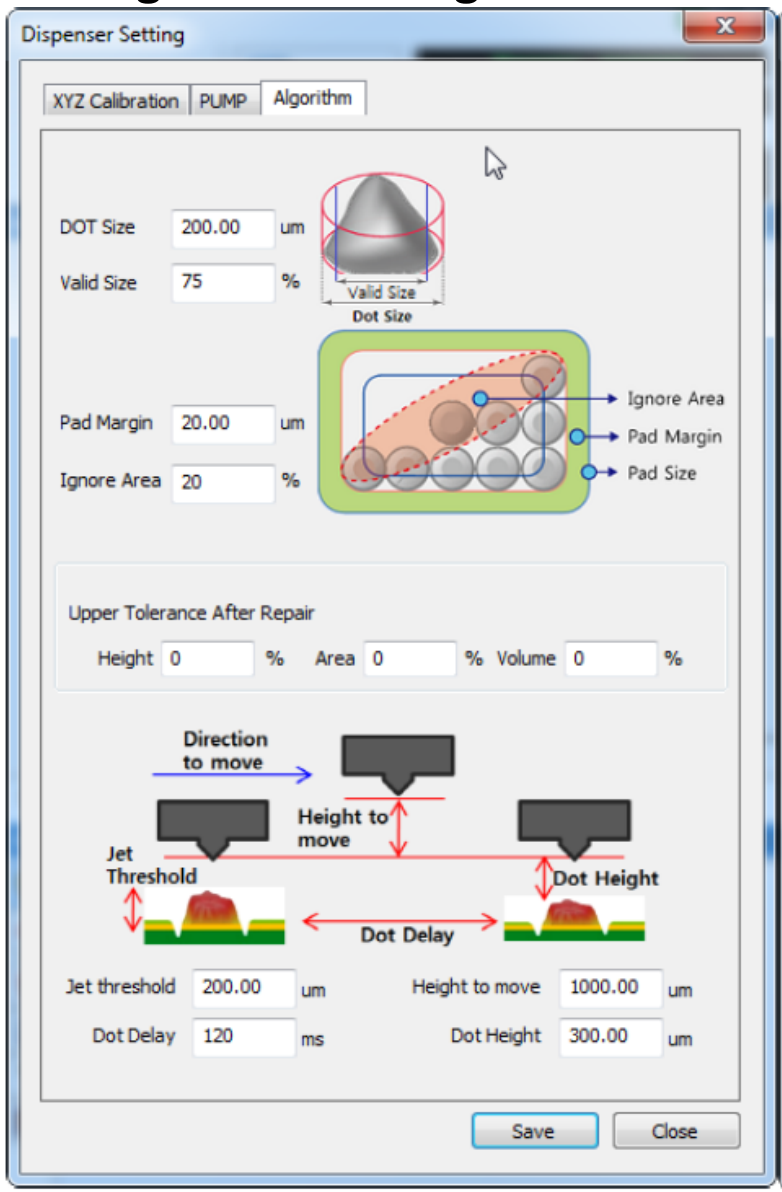
Dot Test: ***Measures the smallest possible dot size for the nozzle used.***

Dot Test Procedure: Use the demo board and SPI with jet SPI defect repair to program the SPI machine to inspect and repair the given 10X10 and 3X3 array, then run a bare board into the system. The system will automatically inspect, repair and jet paste to insufficient pads (anything below 50%). Record number of passes, along with volume, area and height of each Pass. Record final number of insufficient pads. Capture 10 boards worth of data.

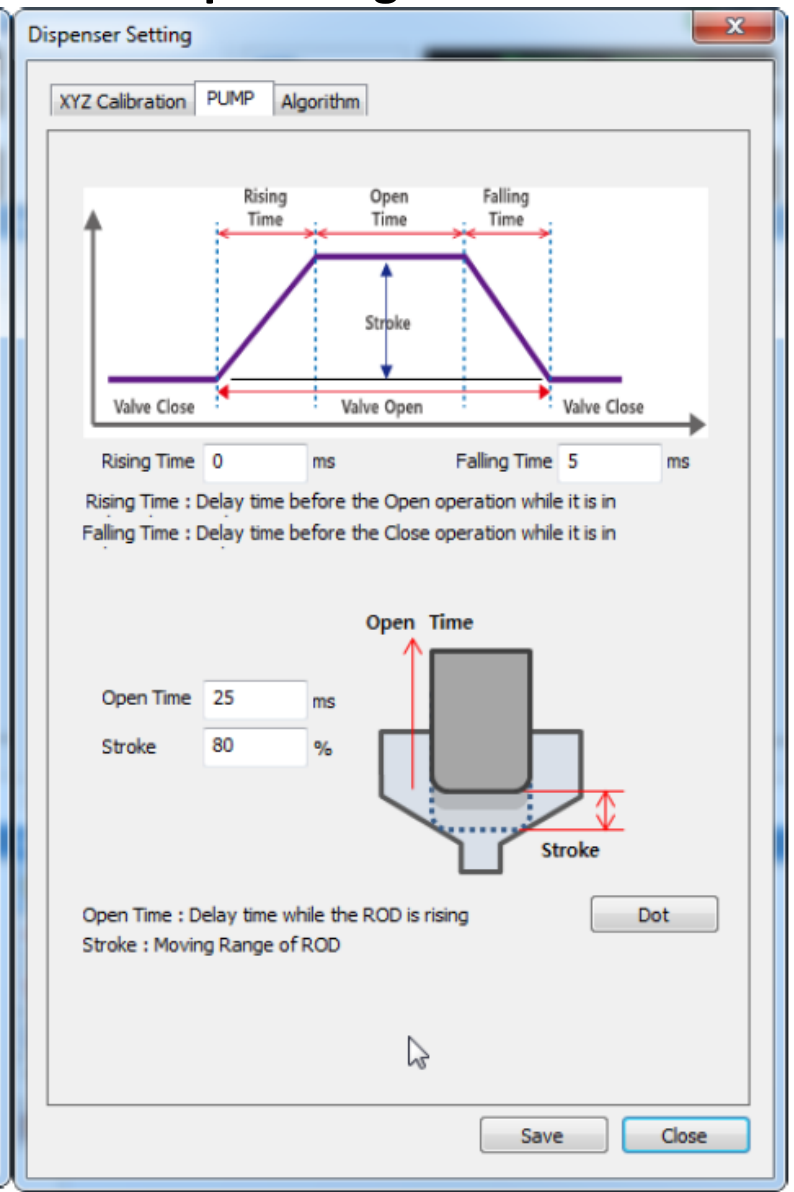
DOT TEST - JET SETTINGS

Algorithm Settings

Dot Size: 200um
Valid Size: 75%
Pad Margin: 20um
Ignore Area: 20%
Jet threshold: 200um
Dot Delay: 120ms
Height to Move: 1000um
Dot Height: 300um

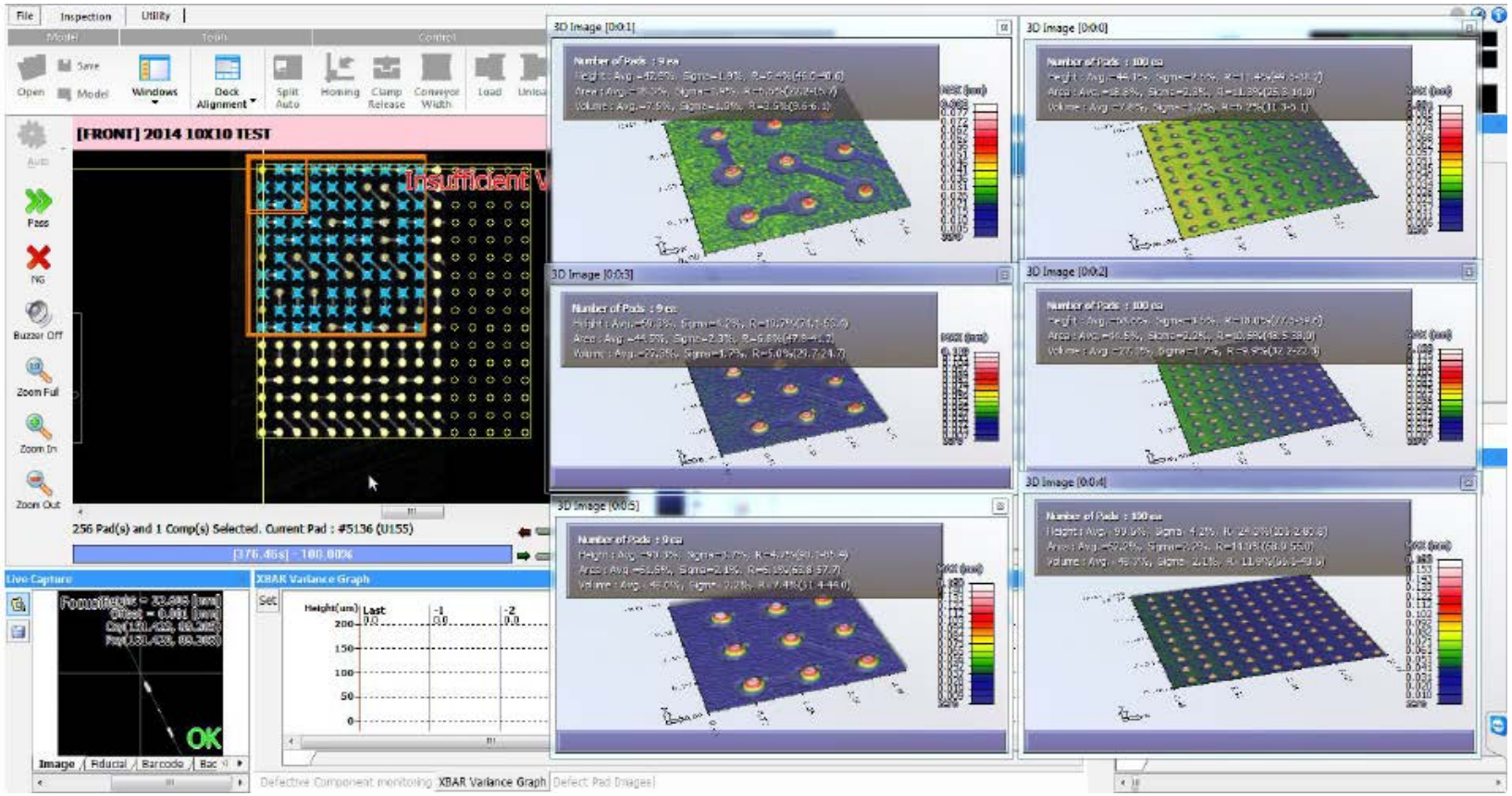


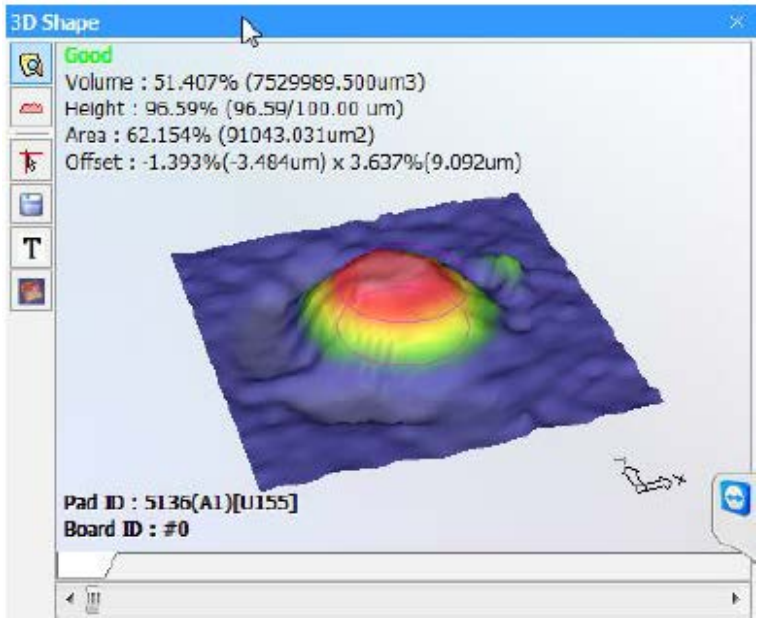
Pump Settings



Rising Time: 0ms
Falling Time: 5ms
Open Time: 25ms
Stroke: 80%

DOT TEST RESULTS

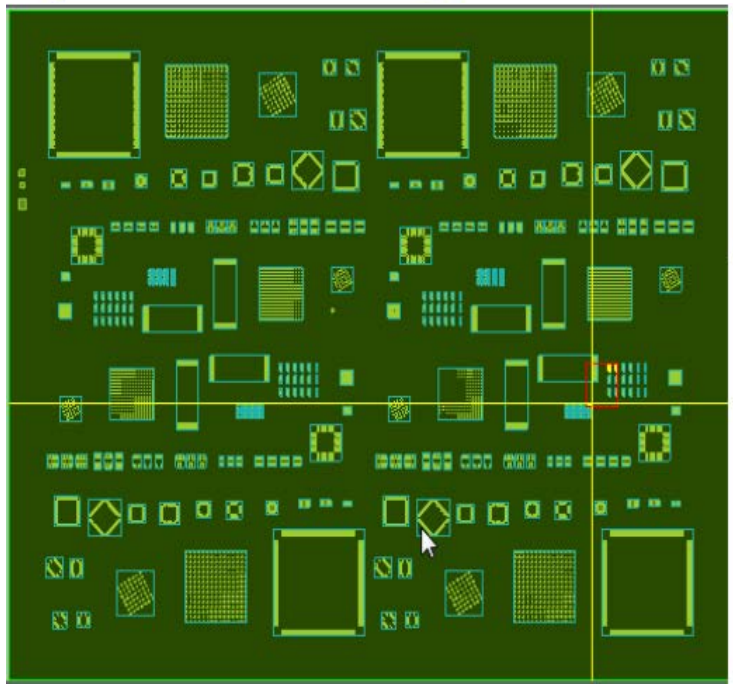


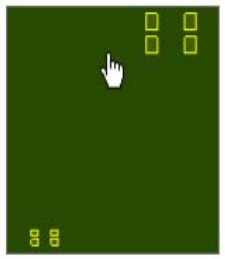


Target Height = 100um	Height	Area	Volume
Pass 1	45%	20%	<10%
Pass 2	69%	46%	28%
Pass 3	92%	64%	51%

Obtained around 10% volume in one pass, 25% on two passes and over 50% on three passes…

DISCRETE TEST PROCEDURES





Solder Paste Tested: SAC305, Type 6 mesh, Halogen Free, No-Clean, Dispense Paste with 20% flux.

Nozzle Size: 80um (34 Needle Gauge)

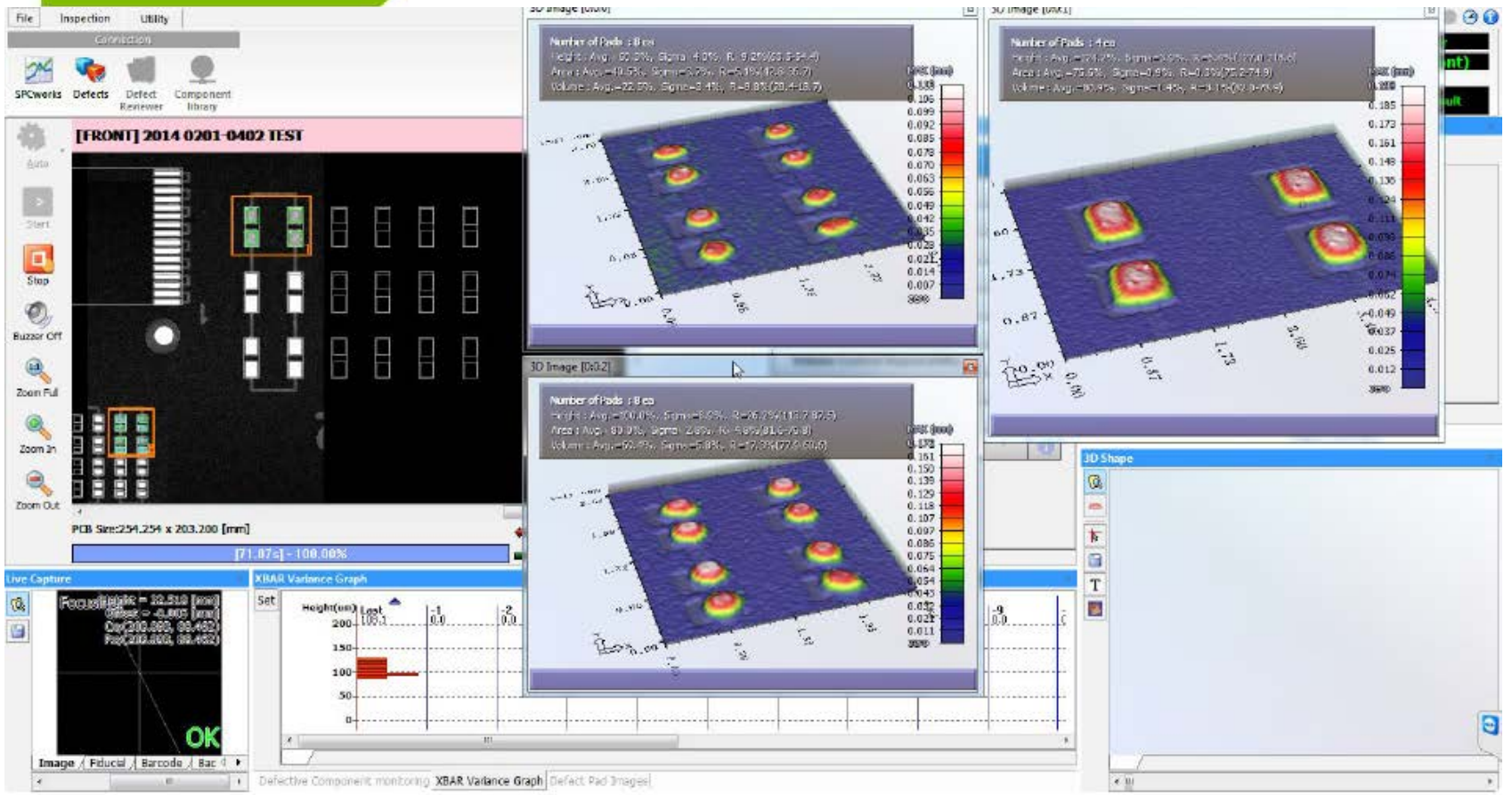
Target Height: 100um

Test Board: A demo board, with 0402 (2 components) and 0201 (4 components) pads selected for testing.

Dot Test: ***Tests the multi-dot capability of the system for use on discrete components.***

Dot Test Procedure: Program the SPI to use 15-20 dots per pad for 0402 (based on the smallest capable dot size and overlap of pad) and 2 dots per pad for 0201 component pads. Use a bare demo board and inspect and repair the section with 0402 and 0201 pads. The system will automatically inspect, repair and jet paste to insufficient pad areas (anything below 50%). Record number of passes, along with volume, area and height of each pass. Record final number of insufficient pads. Capture 10 boards worth of data.

DISCRETE TEST RESULTS



Obtained over 25% on first pass for 0201 and over 80% on first pass for 0402 components.

Target Height = 100um	Height	Area	Volume
0201 Pass 1	67%	43%	26%
0201 Pass 2	99%	81%	70%
0402 Pass 1	127%	74%	81%

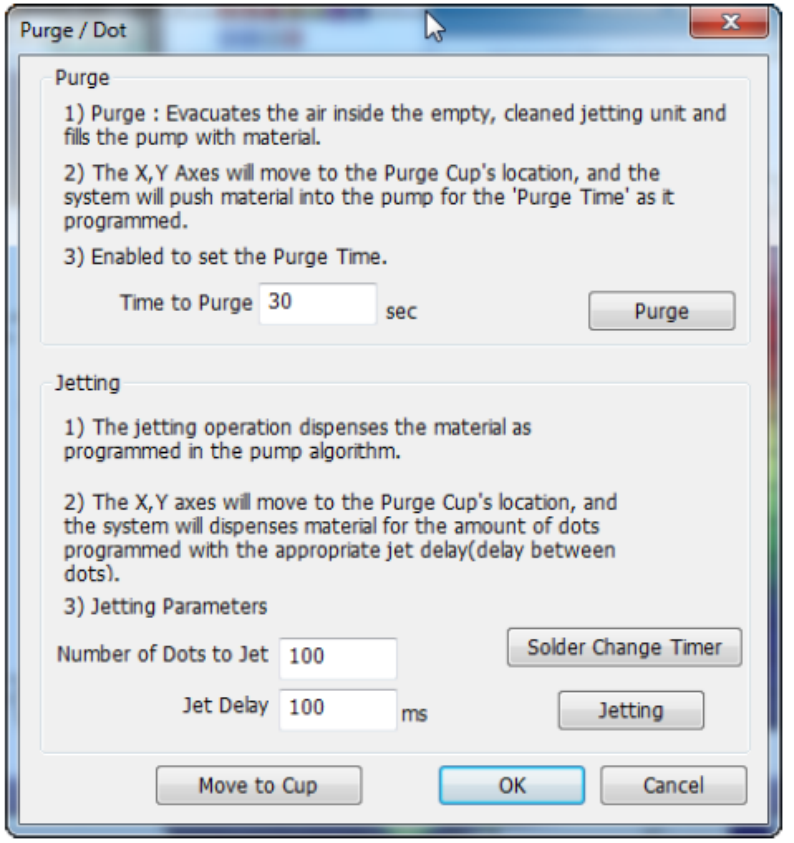
PURGE TEST PROCEDURE (Aged)

Solder Paste Tested: SAC305, Type 6 mesh, Halogen Free, No-Clean, Dispense Paste with 20% flux.

Nozzle Size: 80um (34 Needle Gauge)

Target Height: 100um

Recovery Purge Test: ***Using paste aged at room temperature for 7 days, use a dry, clean, empty pump and measure the time it takes to prime the entire pump system, until the paste correctly jets material (without clogging, sticking or erratic dispensing).***



Purge Test Procedure:

*Set Cartridge Pressure to ~40psi

*Add a full, 5cc paste syringe

*Run purge sequence until verified paste dispense.

1.Prime for 30 seconds

2. Jet 100 dots with 100ms jet delay.

3. Verify jetted material on paper only.

PURGE TEST RESULTS (Aged)

Solder Paste Tested: SAC305, Type 6 mesh, Halogen Free, No-Clean, Dispense Paste with 20% flux.

Nozzle Size: 80um (34 Needle Gauge)

Target Height: 100um

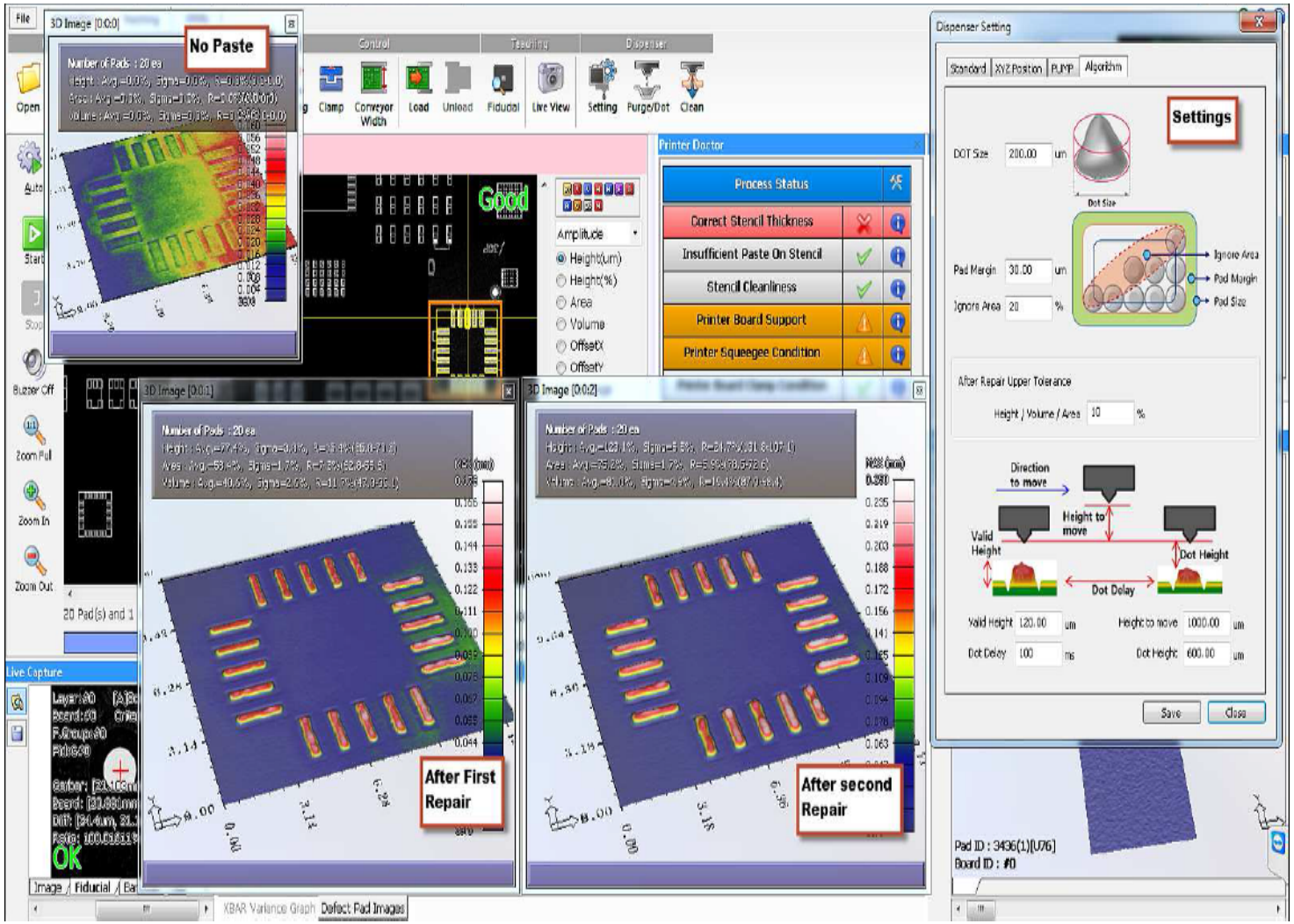
Purge Test Result:

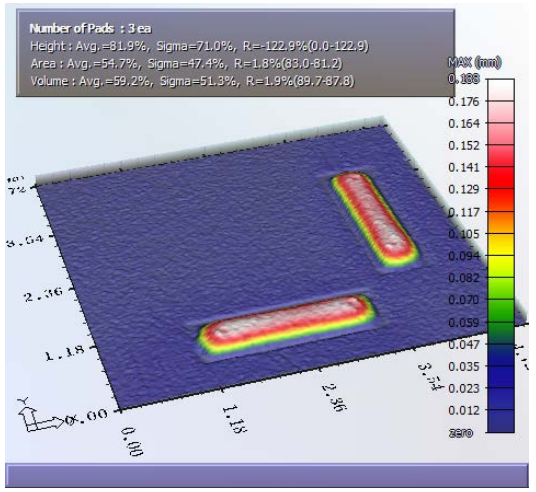
Fully primed system using vacuum pump on **1st try.*

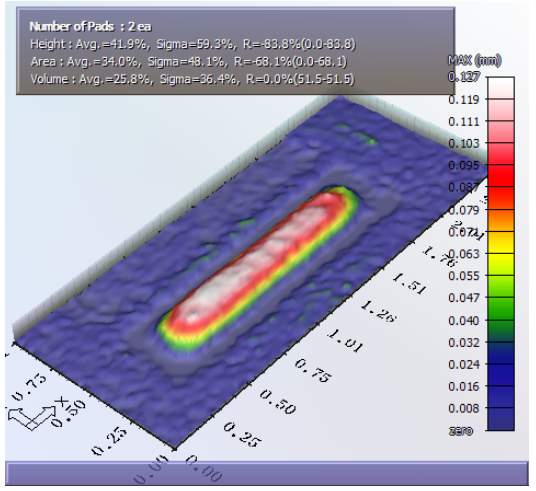
Purge time = **30 seconds*

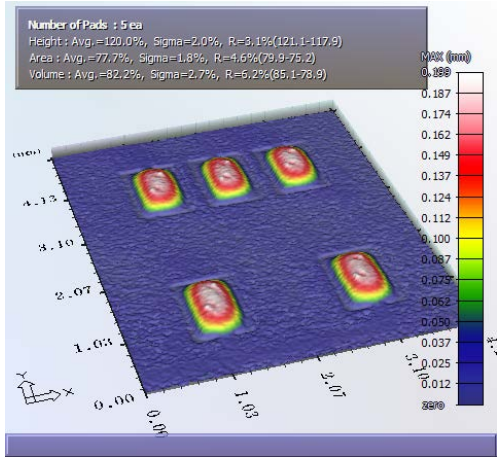
Purge Dots = **100 dots (no clogging, no sticking to nozzle tip, no erratic dispensing).*

ADDITIONAL TESTING









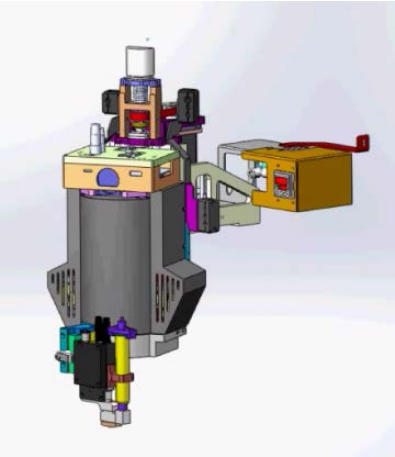
Additional testing to show the jetting capability.

CONCLUSION

Conclusion:

*Based on these results, an SPI machine with jetting capabilities can be a viable solution for preventing issues related to insufficient solder paste deposits, which is a significant help towards mitigating or eliminating Head-in-Pillow as well as Tombstone defects, or improving solder joint fillet formation and in turn solder joint reliability.

*The 0402 results also indicate an SPI machine with jetting capabilities can be a viable solution to increasing solder paste volume to improve solder fillet formation, and in turn solder joint reliability.



*This process may be used as a stand-alone paste deposit method or may be used in conjunction with the existing standard SMT paste print process. This allows the operator to further consider small and precise modifications to the pre-attached deposit.