Component Pressure Exposure Validation in An Inline Wash System and Why Low-Pressure Exposure is Critical

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ABSTRACT
Inline cleaners are a fast and reliable method of cleaning printed wiring assemblies. These machines are designed to give maximum exposure to assemblies with cleaning solution and DI-Water. The challenge with these machines is that because of the way the machines are designed, it has always been a challenge to understand what the assemblies and the parts on those assemblies are seeing from a pressure exposure.

Why does pressure matter? Pressure matters because as technology becomes more complex certain parts are designed in such a way that large pressure exposure from the inline cleaner could in fact induce extreme damage. These parts may cost thousands of dollars and replacing them is not an option that manufacturers what to deal with or can afford.

The purpose of this research is to measure what circuit cards and parts on those assemblies are exposed to during the wash and rinse process of inline cleaning. This study will utilize numerous pressure sensor systems, strain gages and other tools to measure force and pressure on the parts of the circuit cards.

As part of this research two different simulations will be developed and used to compare against what the pressure sensing systems will measure as they are ran through the inline cleaning system. If differences are present, we will use a off the shelf pressure sensor system that will measure pressures as the pressure system travels through the inline cleaner. The second method of testing the pressure question will be using off the self-gorilla glass parts that are designed to simulate what real components would see during the standard inline cleaning process.

INTRODUCTION
No-Clean Fluxes are the primary flux technology used in the electronic assembly build process. With No-Clean Fluxes High Reliability assembly companies discovered that to guarantee cleanliness and ability to apply conformal coat, they must in fact clean the no-clean fluxes. This development encouraged the inline cleaning manufacturers to develop and implement systems that utilized numerous spray bar and nozzle configurations.

As the electronic industry progressed from large high stand-off parts to small compact parts with very low stand-offs. The need to understand what pressures were being seeing became ever more important.

Why would the pressure matter to the electronic assembly? High reliability companies tend to clean assembly’s numerous times before they are complete. Some high reliability companies may clean up to ten times before they are finished. With assemblies seeing pressures from spray bars and nozzles up to ten times it has become critical to understand what parts on circuit boards are seeing from a pressure point of view to make sure parts are not damaged in a way which could cause failure to high reliability assemblies.

POTENTIAL HARM
Assemblies used in the high reliability world tend to have parts on them that are made with ceramics, coils, high standard off LED’s, plastic body parts, epoxies to hold parts, flex cables, and wires to interconnect circuit boards. All the parts mentioned have potential to be damaged by water at great pressures if the machines are set up incorrectly or if they are spraying incorrectly which then could cause additional pressure issues of the high-pressure side.

The exact opposite issue could happen if the machine is set up in such a way that there is barely any spray bar pressure or nozzle spray patterns. The boards could not be clean and cause greater issues with needing rework and handling of assemblies.

So, in-line cleaning manufacturers must walk a fine line of not enough pressure and to much pressure. This line is a line that inline machine vendors try and meet but has never been judged to be super critical to the industry as a whole do to the fact that the high reliability sector of electronic manufacturing focuses on cleanliness not pressure hitting the parts on circuit cards.

This research is being used to develop a starting point to understand what pressures are being seen and how they can be determined in a economical manner so that all high reliability companies can determine what pressure are correct for them to clean no-clean fluxes but damage assemblies.

Step 1: Nozzle Configuration

- In-Line wash set up to simulate high reliability configuration which includes pre-wash, wash, chemical isolation, wash, chemical isolation rinse, final rinse, and dry sections.
- Nozzle Configuration: 16 Spray bar JIC/V-Jet Intermix for Wash Section 1, 16 Spray Bar JIC/V-Jet Intermix for wash Section 2, 16 Spray Bar JIC/V-Jet Intermix for Rinse. See Figure 1. and Figure 2.

Figure 1. V-Jet Spray Bar

Figure 2. Intermix High Volume

Step 2: Component Design and Considerations

To understand how pressure from spray bars and nozzles could damage parts on a circuit card. A test was developed in which ten assemblies with parts on both sides were assembled using gorilla glass and soldered to circuit cards. On each side four parts were made using the gorilla glass and soldered to the circuit cards.

Gorilla glass version 3 was selected because it does have a 50Kg or 100 pounds, cracking and breaking and can handle drop testing up to 4 feet off the ground. Another reason this glass was selected was the fact that if the pressure from the spray bars and nozzles were in fact too great the parts would shatter on the assemblies. This shattering would then be immediately visually reviewed and determined to be a failure of the machine spray bars and nozzles.

See Figure 3, Figure 4, Figure 5, and Figure 6 for examples of the glass part soldered to the circuit board.

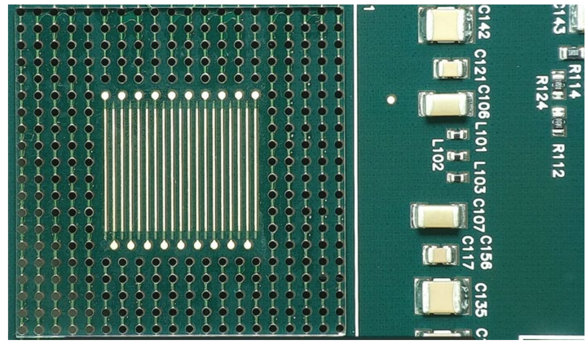

Figure 3. BGA Glass

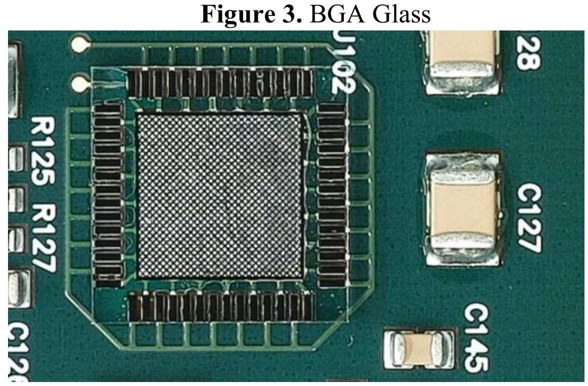

Figure 4. QFN Glass

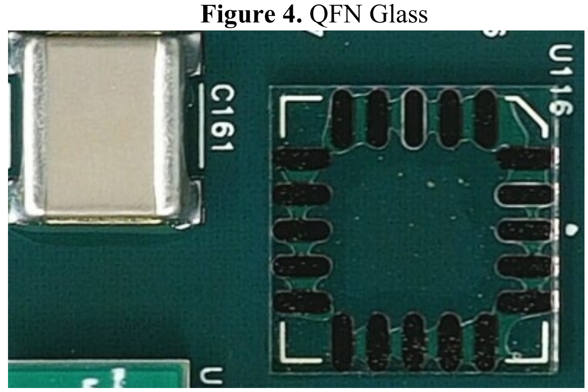

Figure 5. QFP Glass

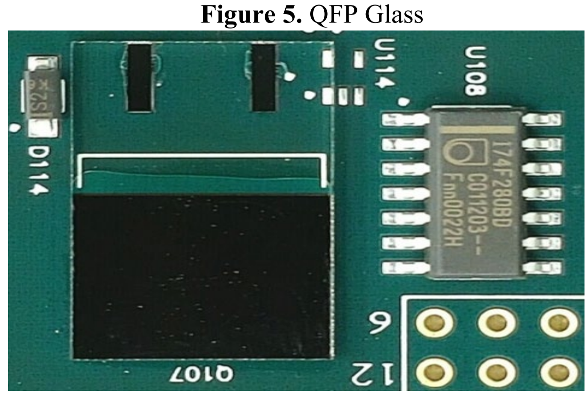

Figure 6. D-Pak Glass

Step 3: Visual Inspection Using 1 and 5 scale

- Assemblies were built using standard Surface Mount Assembly processes and no-clean fluxes.
- Assemblies were then cleaned based on the height off the meshing and the spray bar pressure set on the machine Pressures were 60 PSI and 70 PSI at 1.5 feet per minute conveyor speed. See Table 1 and Table 2 for parameters. The boards were placed at meshing level, 1 inch above meshing level, 2 inches above meshing and 3 inches above meshing. Each assembly was run through 60 PSI and 70 PSI which tends to be in general what industry is using for inline cleaners.

Table 1. Parameters 1

Board	Height off Mesh	Pressure of Spray Bar
BD1	0 Inch	60 PSI
BD2	1 Inch	60 PSI
BD3	2 Inch	60 PSI
BD4	3 Inch	60 PSI
BD5	0 Inch	60 PSI
BD6	1 Inch	60 PSI
BD7	2 Inch	60 PSI
BD8	3 Inch	60 PSI
BD9	0 Inch	60 PSI
BD10	1 Inch	60 PSI

Table 2. Parameters 2

Board	Height off Mesh	Pressure of Spray Bar
BD1	0 Inch	70 PSI
BD2	1 Inch	70 PSI
BD3	2 Inch	70 PSI
BD4	3 Inch	70 PSI
BD5	0 Inch	70 PSI
BD6	1 Inch	70 PSI
BD7	2 Inch	70 PSI
BD8	3 Inch	70 PSI
BD9	0 Inch	70 PSI
BD10	1 Inch	70 PSI

- Assemblies were run through inline cleaner 10 times to simulate worst case scenario for high reliability assemblies being processed. See Table 3 and Table 4.

Table 3. Assemblies Results 1

Board	Height off Mesh	Pressure of Spray Bar	Number of Passes	Rating for Glass: 1 = Zero Failure 5 = Failure
BD1	0 Inch	60 PSI	10	1
BD2	1 Inch	60 PSI	10	1
BD3	2 Inch	60 PSI	10	1
BD4	3 Inch	60 PSI	10	1
BD5	0 Inch	60 PSI	10	1
BD6	1 Inch	60 PSI	10	1
BD7	2 Inch	60 PSI	10	1
BD8	3 Inch	60 PSI	10	1
BD9	0 Inch	60 PSI	10	1
BD10	1 Inch	60 PSI	10	1

Table 4. Assemblies Results 2

Board	Height off Mesh	Pressure of Spray Bar	Number of Passes	Rating for Glass: 1 = Zero Failure 5 = Failure
BD1	0 Inch	70 PSI	10	1
BD2	1 Inch	70 PSI	10	1
BD3	2 Inch	70 PSI	10	1
BD4	3 Inch	70 PSI	10	1
BD5	0 Inch	70 PSI	10	1
BD6	1 Inch	70 PSI	10	1
BD7	2 Inch	70 PSI	10	1
BD8	3 Inch	70 PSI	10	1
BD9	0 Inch	70 PSI	10	1
BD10	1 Inch	70 PSI	10	1

The data indicates that the gorilla glass never saw a large amount of pressure during the 10 wash cycles since a 100 pounds is needed to break the glass.

Spray Pressure Sensor.

The Spray sensor utilized in this experiment is a 5491 Spray Pressure Sensor purchased from PPS Sensor systems.

Pressure sensor utilizies capacitive tactile sensors which captures data by utilizing capacitance, the ability to store an electrical charge.

Specifications for the pressure sensor system are: Pressure Range up to 20 PSI per element, total of 1920 elements located on a test panel which is 10.2 inches by 10.6 inches. See figure 7.

Figure 7. Test Panel

Spray Pressure System
Data was recorded using the sensor and the water-resistant cord which measures 30 feet in length. The in-line wash measures 34 feet. The water-resistant cord was removed from the computer system once it reached 25 feet. See Figure 8 for sensor and computer image.

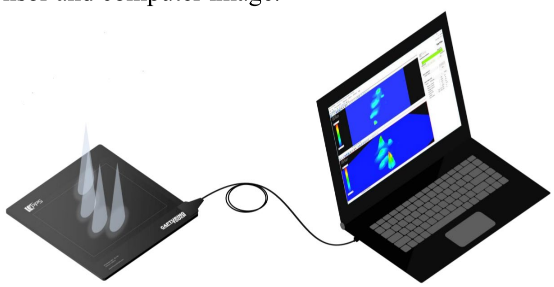
Figure 8. Sensor/Cord/PC

Spray Pressure Sensor Visual data.
The spray pressure system generates data that is visual and excel based so individual sensor data can be reviewed and processed. Visual Inspection image can be viewed in Figure 9. And Figure 10.

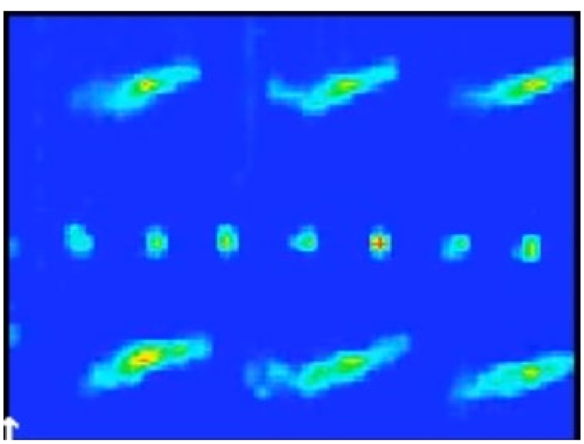
Figure 9. Intermix and V-Jet Spray patterns

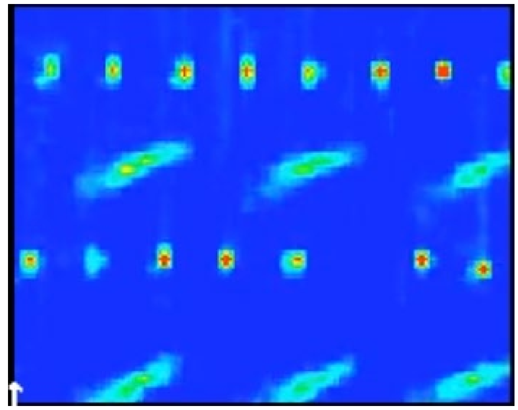
Figure 10. Intermix and V-Jet Spray patterns

When looking at figure 10 the first set of intermix spray bar you can notice that there is a sensor that is not recording data. It was discovered during the testing that the spray bar had plugged opening and was not allowed to have water flow through the opening.

Testing Data from Spray Pressure System
The sensor testing was set up just as the gorilla glass testing test.

- Pressure Sensor System was run through the in-line cleaner 10 times. The sensor was mesh level Table 5, 1 inch above mesh Table 6, 2 inches above mesh Table 7, and 3 inches above mesh Table 8.
- The Machine was run at 60 PSI and 70 PSI at 1.5 feet per min conveyor speed.

60 PSI Run Data.
The following charts list the highest-pressure value for each InterMix and V-Jet spray bar set-up. The values may be in wash area 1, wash 2, or rinse area.

Table 5. Sensor at Mesh Level

Test Run	Sensor Maxium Pressure for InterMix Spray Bar (PSI)	Sensor Maxium Pressure for V-Jet Spray Bar (PSI)	Spray Bar (PSI)
1	5.414	12.943	60
2	4.876	11.958	60
3	5.012	13.045	60
4	4.997	12.445	60
5	5.015	13.552	60
6	4.775	13.025	60
7	4.998	12.858	60
8	5.224	13.255	60
9	4.785	13.082	60
10	5.033	12.777	60

Table 6. Sensor at 1 inch Mesh

Test Run	Sensor Maxium Pressure for InterMix Spray Bar (PSI)	Sensor Maxium Pressure for V-Jet Spray Bar (PSI)	Spray Bar (PSI)
1	5.459	18.245	60
2	5.205	19.543	60
3	5.578	18.757	60
4	5.658	19.025	60
5	5.925	19.044	60
6	5.852	18.454	60
7	5.458	19.025	60
8	5.665	18.565	60
9	5.872	19.225	60
10	5.656	18.775	60

Table 7. Sensor at 2 inches Mesh

Test Run	Sensor Maxium Pressure for InterMix Spray Bar (PSI)	Sensor Maxium Pressure for V-Jet Spray Bar (PSI)	Spray Bar (PSI)
1	7.054	26.583	60
2	7.553	27.454	60
3	7.605	25.556	60
4	7.455	27.453	60
5	7.252	25.558	60
6	7.102	26.452	60
7	7.088	24.889	60
8	7.032	24.665	60
9	7.441	25.444	60
10	7.526	26.454	60

Table 8. Sensor at 3 inches Mesh

Test Run	Sensor Maxium Pressure for InterMix Spray Bar (PSI)	Sensor Maxium Pressure for V-Jet Spray Bar (PSI)	Spray Bar (PSI)
1	9.502	34.525	60
2	9.656	35.454	60
3	9.898	36.225	60
4	9.454	34.505	60
5	9.558	35.452	60
6	9.565	35.992	60
7	9.777	35.447	60
8	10.021	35.547	60
9	9.566	36.025	60
10	9.822	37.003	60

At 60 PSI entering the spray bar and at Mesh level which is 4 ½ inches from the bottom of the spray nozzles. The InterMix and V-Jet nozzles had pressures that are not very strong. This strength level could be enhanced with cleaning agent which then helps remove flux residues from under parts and rinses.

The next three tables indicate that the closer to the bottom of the nozzle that the pressure sensor is, the greater the V-Jet data is. By raising the sensor to be within 1 ½ inches of the bottom of the nozzle there is potential challenges from the amount of pressure measured.

70 PSI Run Data.

The following charts list the highest-pressure value for each InterMix and V-Jet spray bar set-up. The values may be in wash area 1, wash 2, or rinse area.

- Pressure Sensor System was run through the in-line cleaner 10 times. The sensor was mesh level Table 9, 1 inch above mesh Table 10, 2 inches above mesh Table 11, and 3 inches above mesh Table 12.

Table 9. Sensor at Mesh Level

Test Run	Sensor Maxium Pressure for InterMix Spray Bar (PSI)	Sensor Maxium Pressure for V-Jet Spray Bar (PSI)	Spray Bar (PSI)
1	5.844	13.043	70
2	5.876	12.958	70
3	5.212	13.045	70
4	5.497	13.345	70
5	5.215	13.252	70
6	5.575	13.425	70
7	5.698	13.858	70
8	5.724	13.455	70
9	5.785	13.082	70
10	5.633	13.777	70

Table 10. Sensor at 1 inch Level

Test Run	Sensor Maxium Pressure for InterMix Spray Bar (PSI)	Sensor Maxium Pressure for V-Jet Spray Bar (PSI)	Spray Bar (PSI)
1	5.459	19.245	70
2	5.205	19.943	70
3	5.578	19.757	70
4	5.658	19.725	70
5	5.925	19.644	70
6	5.852	18.854	70
7	5.458	19.525	70
8	5.665	19.565	70
9	5.872	19.525	70
10	5.656	19.775	70

Table 11. Sensor at 2 inches Mesh

Test Run	Sensor Maxium Pressure for InterMix Spray Bar (PSI)	Sensor Maxium Pressure for V-Jet Spray Bar (PSI)	Spray Bar (PSI)
1	7.954	28.583	70
2	8.553	28.454	70
3	8.605	27.556	70
4	8.455	29.453	70
5	8.252	27.558	70
6	8.102	27.452	70
7	8.088	26.889	70
8	8.032	27.665	70
9	8.441	26.464	70
10	9.526	27.424	70

Table 12. Sensor at 3 inches Mesh

Test Run	Sensor Maxium Pressure for InterMix Spray Bar (PSI)	Sensor Maxium Pressure for V-Jet Spray Bar (PSI)	Spray Bar (PSI)
1	10.502	35.525	70
2	11.656	35.854	70
3	10.898	36.725	70
4	11.454	35.505	70
5	10.558	36.452	70
6	10.565	36.992	70
7	10.777	36.447	70
8	10.721	36.547	70
9	10.566	38.025	70
10	10.822	38.003	70

At 70 PSI entering the spray bar and at Mesh level which is 4 ½ inches from the bottom of the spray nozzles. The InterMix and V-Jet nozzles had pressures that are not very strong. This strength level could be enhanced with cleaning agent which then helps remove flux residues from under parts and rinses.

Like the 60 PSI data the closer you get to the bottom of the spray nozzle the greater the pressure is at the V-Jet spray bar.

CONCLUSION

The data from both the gorilla glass testing and the pressure sensor testing indicate that a larger amount of testing is needed. Even though the gorilla glass never broke, the pressure sensor does indicate that pressure does drastically increase the closer to the bottom of the V-Jet nozzles the sensor was. Is this pressure enough to damage components to early to determine? With assemblies becoming denser and component packages becoming ever more ceramic based additional testing will be needed. That testing will happen in the next year.

REFERENCES

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Water Proofed Spray Pressure Sensor System, Spray Pressure Sensor Spec Sheet, vendor PPS Tactile Systems