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Soldering Process Improvement of Critical SMT Connectors and for the Retention of Press-fit SFP Cages

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Abstract

As Original Design Manufacturers (ODM) adopt the use of finer pitch connectors, with increased pin count on PCB assemblies. It becomes challenging for Electronic Contract Manufacturing Services (EMS) to build with very low or zero defects in the Printed Circuit Board Assembly (PCBA) operations.

In this paper we will share our experiments for improving the SMT process with these connector types: 1. Samtec's SEARAY™ (AEAM/AEAF Series) connectors with 500 leads which have a unique solder charge design. The leads themselves are on a 50 x 50 mils pitch from row to row. 2. Two Press-fit SFP Cages with different lead lengths, 1 with protrusion and 1 with no lead protrusion on an 18 layer fab (2.5mm thickness).

Case1. Samtec's SEARAY™ (AEAM/AEAF Series) connector
The connector leads have a solder charge (pre-tin), and the minimum stencil thickness requirement is 6 mils. However the assembly supports a mixture of component technology for this product, where many components need the use of a 4 mils stencil thickness. The fab thickness is 40 mils. There are two main SMT process improvements which we did to eliminate defects: 1. Use 6 mils stencil thickness with a Step-Down to support the 4 mils thickness requirement of other components on the assembly, and replaced the use of a Mini-stencil for the connectors to solve operator handling issue that have been causing damage to the solder charge and others; 2. Based on experimental data, we also adjust the profile for optimization of the solder joints of the connector. With new stencil and oven profile, the defects reduced from 15% to < 0.5% for the connector.

Case2. Two Press-fit SFP cages with different lead lengths
Because there were issues with these Press-fit SFP cages failing mechanical drop test. The customer requested us to add solder to the peripheral row of pins of the SFP cages, for a stronger retention to the fab. We couldn't make all pins have a good solder joint with a Non-modified wave fixture, and wave as a normal process. Therefore, we have new process designs (a. Modified wave fixture, add flux on the top side of PCB, and wave as a normal process for the 2 different vendor's components; b. A non-modified wave fixture and add flux on the top side of PCB and wave as a normal process; c. Modified wave fixture and wave as normal process). All these Selective Wave process methods are working: these cages now have good retention with the fab, passing mechanical drop test, and no defective pins for current boards were building. We use 2DX with tilting angle detector to check the solder joints of the cages.

We used 2DX machine to identify boards with critical connectors by optimized method.

Introduction
Connectors are commonly used in system interconnect more widely today. It is challenging to the PCBA process to have reasonable yields, and zero defects. In this paper, we would like to report our experience to improve SMT process with two types' of connectors: Samtec's SEARAY™ (AEAM/AEAF Series) connectors with 500 leads, and Molex and Tyco Press-fit SFP cages.

With SMT and wave process improvements for these two connectors, we have reduced the number of defects significantly: less than 0.5% for Samtec's SEARAY™ connectors, and zero defects for Molex and Tyco Press-fit SFP cages. We use 2DX with tilting angle detector to evaluate solder joints of the connectors.

Components

1. **Samtec's SEARAY™ (AEAM/AEAF Series) connector**

The connector leads have solder charges which are offset making the leads appear to be in pairs. The leads themselves are on a 50 x 50 mils pitch, but solder charges are poisoned back to back because the lead orientation alternates from row to row[1]. Figure 1 shows solder charge location on adjacent rows from an end view, and Figure 2 shows its orientation alternates from row to row. The minimum stencil thickness requirement for the connector is 6 mils.

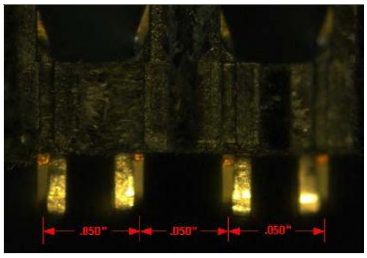

Figure**1. Solder charge location on adjacent rows – end view**

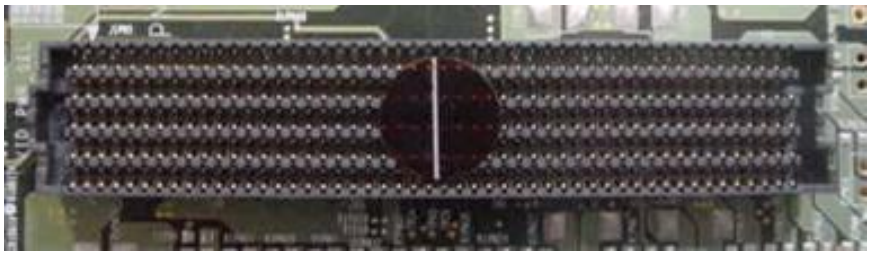

Figure2. 50 mils x 50 mils pitch: its orientation alternates from row to row

2. Molex and Tyco Press-fit SFP cages

The only variation is component pin length: they are 2.05 mm and 3.05 mm for Tyco and Molex respectively. These three new process designs of experiment (DOE) are described in Figure 3.

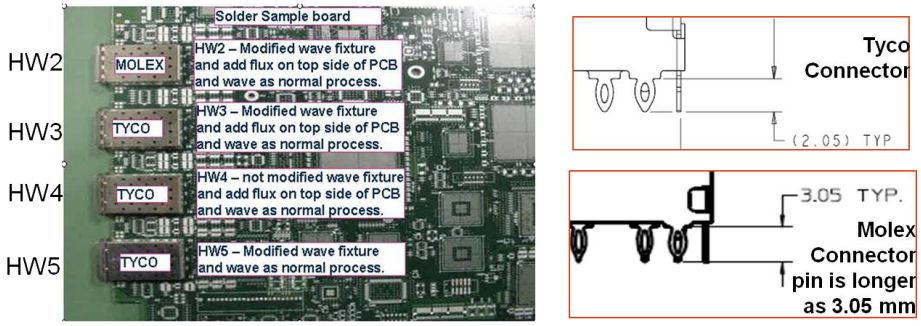

Figure3. Connector Type & Process Type

Improvement Procedure and Analysis

1. Samtec's SEARAY™ (AEAM/AEAF Series) connector

Our previous process to meet the connector minimum stencil thickness requirement 6 mils is:

- Paste 4 mils solder to the board

Note: from the time of paste printing, the assembly must be processed through the reflow oven within 30 min.

- Load board into SMT carrier

- Hand print additional paste to the device using mini stencil
- Hand load connector to board
- Process thru reflow with adjusted and approved profile
- Screen for defect visually and with 5DX/Dage
- Report out on any additional observations

The solder is Lead Free: Senju M705 GRN360-K1-MK-VS Sn3Ag0.5Cu. The profile Peak Temperature is 231 to 233 ^{o}C; Reflowing time above melting point, 220 ℃, is between 46 – 57 seconds. And soak time is about 99 seconds; Ramp rate is 1.75 ℃ per second. However we had open defects for boards, and Table 1 listed 10 boards information. Most of defects are open which is verified with Dage 2DX machine.

Table 1 – 40% boards failed at SMT and 5DX

Board #	SMT	5DX
1	Pass	Pass
2	Fail	Fail
3	Fail	Fail
4	Pass	Pass
5	Pass	Pass
6	Pass	Pass
7	Pass	Pass
8	Pass	Pass
9	Fail	Fail
10	Fail	Fail

The main stencil improvement is using a 6 mil thickness with a 4 mil Step-Down thickness for other components. Stencil type is stainless steel and laser cut. The stencil aperture is 35 mils, and its pad diameter is 35 mils. The stencil Area ratio is 1.46, and Aspect ratio is 5.83.

Lead free solder is same as previous. However we modified Peak temperature to 241-243 ^{o}C. Reflowing time above melting point, 217 ^{o}C, is about 65 seconds. The soak time is about 100 seconds with a ramp rate of 2.12 ^{o}C per second. Table 2 listed parameters of oven profiles for the original and modified process (current).

Figure 4 is 2DX images for the connector pins which shows good solder joints. The key operation is to find the right tilting angle to check solder joints with the Dage 2DX machine[2]. With new stencil (step-down 6 to 4 mils), the defects reduction went to < 0.5% from 15%. This is a big savings! The SMT process time reduction ($70/hour X 0.05 hour/board): represents a cost savings of about $6500 alone for six months. Table 3 lists time savings from the previous to the current process; Table 4 lists improvement of the current process.

Table 2 – Parameters for Original and Modified Oven Profiles

Item	Original Profile	Modify Profile
Temperature Peak @ 220 ^{o}C	**231.1**	**243.17**
Time (Second) above @ 220 ^{o}C	**46**	**65**
Soak Time (Second) @ 150 - 220 ^{o}C	**99**	**100.3**

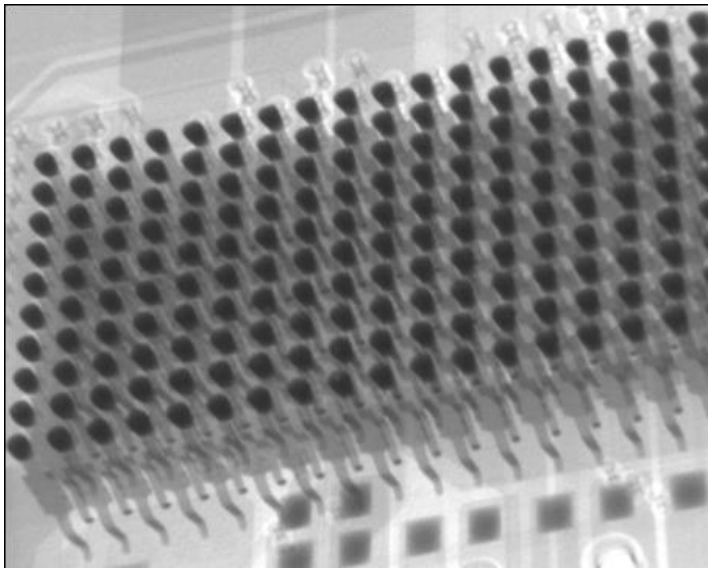

Figure4. 2DX Images shown connector's pin have good solder joints

Table 3 – Time Costs for Previous Process

Step	Process	Time needed (s)
1	remove connector from tape reel	10
2	inspect solder charge	10
3	place connector on fixture holder	15
4	align mini stencil of connector	20
5	print solder stencil	60
6	remove mini stencil	15
7	remove connector with solder pase	10
8	inspect solder paste and solder charge	30
9	install connector on board	10
	Total time needed	180

Table 4 – Comparison of Previous and Current Process

Stencil Type	Previous: 4 mils + mini stencil 4 mils	New: Step - down 6 to 4 mils
Total Connectors loaded	5648	1870
Defects %	15	0.50%
Total defective connectors	848	10
Total process time (second)	1,016,640	336,600
Total time added (hour)	282.4	93.5

2. Molex and Tyco Press-fit SFP cages

Because there were issues with these Press-fit SFP cages failing mechanical drop test. The customer requested us to add solder to the peripheral row of pins of the SFP cages, for a stronger retention to the fab. These two different manufacturer SFP cages have different lead lengths. The assembly uses a .093 thick fab, the Molex part has a .021 lead protrusion, and the Tyco part has no lead protrusion with this fab thickness, which is fine for the press-fit process, but our concern was getting enough barrel fill during the wave process to ensure part retention. We couldn't make all pins have a good solder joint with a Non-modified wave fixture, and wave as a normal process. Therefore, we have three new process designs (a. Modified wave fixture, add flux on the top side of PCB, and wave as a normal process for the 2 different vendor's components; b. A non-modified wave fixture and add flux on the top side of PCB and wave as a normal process; c. Modified wave fixture and wave as normal process). Therefore we use three different process methods for the experiments (Figure 3). As listed in the figure 3, the Molex SFP cage on HW2, and Tyco SFP cages are on HW3, HW4, and HW5. The wave fixtures were modified as Figure 5 shows; and Table 5 lists the Original and Modified Wave Fixture Dimension.

The wave process different for HW2, HW3, HW4, and HW5 are listed here:
HW2: Modified wave fixture and add flux on the top side of PCB and wave as normal process (Molex SFP cage)
HW3: Modified wave fixture and add flux on the top side of PCB and wave as normal process (Tyco SFP cage)
HW4: Not modified wave fixture and add flux on the top side of PCB and wave as normal process (Tyco SFP cage)
HW5: Modified wave fixture and wave as normal process (Tyco SFP cage)

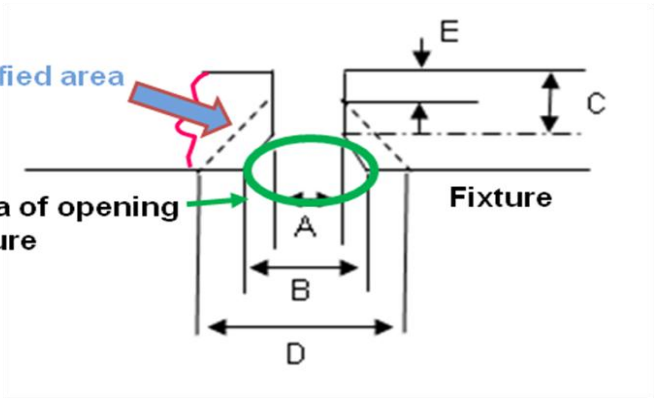

Figure5. Modified Wave Fixture

Table5. Original and Modified Wave Fixture Dimension

Original Fixture Dimension (mil)			Modified Fixture Dimension (mil)	
A	B	C	D	E
172.5	412.5	155	696.5	90

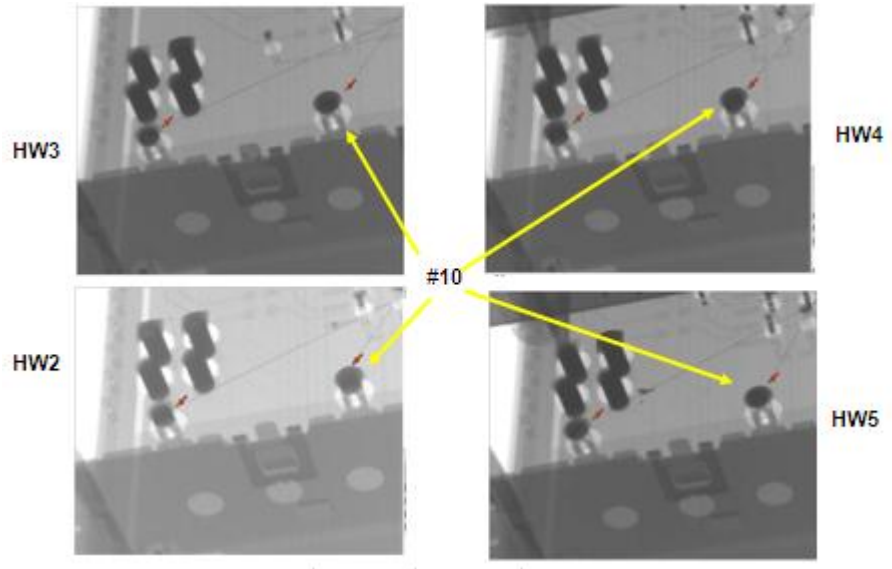

Figure6. 2DX images of connector pins (#10 & #11) for HW2, HW3, HW4 and HW5

It is working with the new wave process methods, these connectors have good retention to the fab, and no defective pins for current boards we are building. We use 2DX with tilting angle detector to check the solder joints of the SFP cages. Figure 6 is 2DX images of connector pins #10 and #11 for HW2, HW3, HW4 and HW5. There is no significant different between solder joints for HW2, HW3, HW4 and HW5. The 2DX Rotation angle is 105 degree; and its Oblique angle is 52 degrees for these images taken.

We also used a Pull test to examine the amount of force before solder joint failure, utilizing the Chatillon Digital Force Gauge - Model DFIS 200. The speed is 500 mil /second. Table 7 is our documented Pull test results. The Pull test data also

show these three methods work well. HW2 and HW3 is the same method with different connector pin length from different vendor. It is no surprise that HW2 has almost 3 times full force as HW3 because HW2 has longer pin as shown in Figure 3. As a result of this process modification we have had zero defects on several hundred boards that have been built with the HW2, HW3, HW4 and HW5 process.

Table7. Pull Test Results

Connector Name	Process ID	Pull Force (lb)
Molex	HW2	45.6
Tyco	HW3	15.8
Tyco	HW4	19
Tyco	HW5	16.8

Conclusions

1. Samtec's SEARAYTM (AEAM/AEAF Series) connector

There is signification yield improvement for Samtec's SEARAYTM connector with new stencil design, oven profile.

- New stencil (step-down 6 to 4 mils) reduced defects to 0.5% from 15%.
- Modified Peak Temperature is about 243 ^{o}C. Reflowing time above melting point, 220 ^{o}C, is about 65 seconds. And soak time is about 100 seconds. Ramp rate is 2.12 ^{o}C per second.
- SMT process time saving 3 minutes for each board (3.5 per board); and the defective pins reduced to 0.5% from 15%.

2. Molex and Tyco Press-fit SFP cages

Part retention improvement was successful, and passed structural test, with the use of the wave solder process implement for all three methods: modified wave fixture and add flux on the top side of PCB and wave as normal process; or not modified wave fixture and add flux on the top side of PCB and wave as normal process; or modified wave fixture and wave as normal process.

Acknowledgement

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Reference

1. Samtec Connector, "Processing Recommendations for Samtec's SEAEAY (SEM/SEAF Series) Connectors", Samtec, March, 2009.

2. Zhen (Jane) Feng, Juan Carlos Gonzalez, Evstatin Krastev, Sea Tang, and Murad Kurwa, "Non-Destructive Techniques for Identifying Crack Defect in BGA Joints: TDR, 2DX, and Cross-section/SEM Comparison", SMTA Proceeding, August, 2008.