Process improvement with selective solder

BAE Systems has improved flow time, increased processing flexibility, reduced costs and maintained a low defect rate through implementation of a new soldering technology. This paper addresses their elimination of a vapor phase soldering system and the associated processing steps necessary to solder two-sided connector boards using selective soldering. It also discusses how processing flexibility has improved by transferring complicated mixed technology boards from wave solder to selective solder by incorporating a dual reflow process. The ultimate goals of implementing dual reflow and selective solder were to positively affect the bottom line and to increase customer satisfaction.

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Keywords: selective soldering, vapor phase solder, mixed technology boards, dual reflow process

Implement selective solder to replace vapor-phase soldering

For more than ten years, BAE Systems' Irving, Texas, facility utilized a combination of vapor phase and wave solder to solder two sided connector boards. Previously, one side of a two-sided connector board was wave soldered and the other side was vapor-phase soldered. Vapor-phase soldering involved melting solder preforms that were installed on connector pins. The vapor phase machine used heat transfer from the condensing vapors of a boiling fluorinated liquid to melt the solder preforms. This common electronic fluid poses no ozone depletion potential, since it contains no chlorine atoms. However, it does have a high global warming potential due to its long atmospheric lifetime and must be carefully handled to minimize atmospheric emissions.

Figure 1. Vapor phase soldering system.

Advantages of vapor phase soldering include the ability to reach high temperatures required for thick connector boards and the ability to apply exact amounts of solder where required. Solder preforms are available in a variety of sizes, so excess and insufficient solder defects are usually rare. The BAE Systems vapor phase process had a relatively low defect rate and was considered stable.

The disadvantages of vapor phase processing include high cost of ownership and processing limitations. The boiling liquid was costly (in excess of $50K per year) and has environmental risks due to its long atmospheric lifetime. Vapor phase processing required tedious tweezer application or expensive fixturing to aid in the installation of solder performs.

Additionally, due to the age of the vapor phase machine, both routine and emergent maintenance requirements had significantly increased.

BAE's Irving factory is a high-mix, low-volume production facility manufacturing avionics and support gear for commercial aircraft. Ninety percent of the printed circuit boards (PCBs) produced were wave-soldered and only ten percent were vapor phase soldered. Therefore, equipment sat idle for long periods. Additionally, vapor phase was limited to soldering two-sided connector boards. Through-hole component leads that were clinched would not accept solder preforms, so mixed-technology boards having clinched leads were not processed through the vapor phase system.

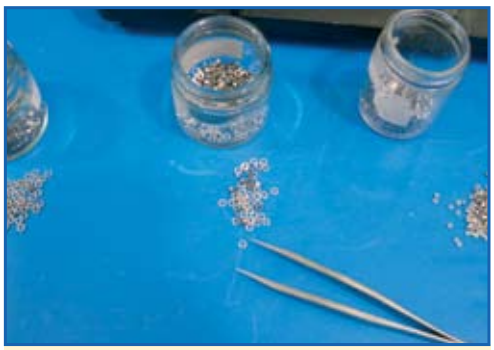

Figure 2. Solder preforms.

Figure 3. Typical solder preforms placement tooling.

Figure 4 is an example of a two-sided connector board. The processing steps to solder this board were:

1. Install three blue rectangular connectors.
2. Apply masking material to the six round connector locations (56 places) to prevent wave solder from filling the PTHs. (Masking material could be either water soluble tape or liquid maskant).
3. Prebake the board.
4. Wave solder the three blue connectors.
5. Semi-aqueous clean to remove maskant.
6. Install six round connectors.

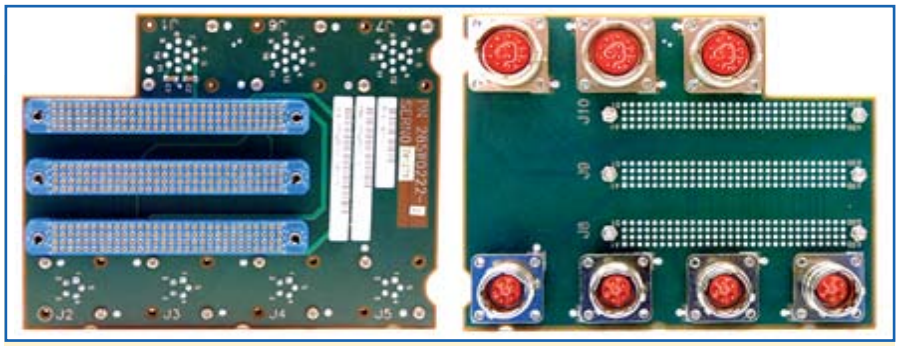

Figure 4. Two-sided connector board without clinched leads.

7. Install solder preforms to the round connector pins (56 places).
8. Prebake the board.
9. Apply flux.
10. Vapor-phase solder the round connectors.
11. Semi-aqueous clean.

As a result of this and other complex flows, BAE Systems researched alternatives. Laser soldering and selective soldering were both considered as possible technologies to replace the expensive vapor-phase soldering process. After an extensive technology evaluation, selective soldering was determined to be the preferred soldering method to replace vapor phase for these assemblies since it is as thermally capable and utilized technology that is considered mature. Selective solder is a method of applying tightly controlled amounts of molten solder to preprogrammed locations on a printed circuit board. Each solder joint can be differently controlled with respect to dwell, height, approach and withdrawal, unlike wave solder where the entire circuit board is maneuvered over the wave in a fixed direction.

A selective solder machine manufactured by Pillarhouse was selected as the best choice to meet BAE's requirements. In early 2006, after completion of process development, the transfer of product from vapor phase to selective solder began. The Pillarhouse Ruby selective soldering system is shown in *Figure 5*.

Figure 5. Pillarhouse Ruby selective soldering system.

The same two-sided connector board previously discussed is now processed using the method below.

1. Install three blue rectangular connectors.
2. Selective-solder one side.
3. Install six round connectors.
4. Selective-solder the opposite side.
5. Semi-aqueous clean.

'Sleeping time' - the time product waits on a shelf before value-added work can be performed - has been greatly reduced. In addition, a study proved that baking of PCBs prior to selective soldering was not required. This further reduced flow time.

Use selective solder to reduce masking requirements

An additional benefit from the implementation of selective solder was the ability to transition product from wave solder and eliminate the expense of masking. *Figure 6* shows an example of a PCB that was wave-soldered.

Figure 6. Typical masked board.

The large ground plane required extensive masking to protect it from the solder wave. As a result of the complexity of the solder-free requirements for this assembly, masking was done using both water-soluble tape and liquid maskant. The water soluble tape is a clear tape and is present on the ground plane in this photograph. The liquid maskant is shown here in red and has been applied to some hardware and plated through holes that were to remain free of solder. The total time for the masking, curing and baking was 2 hours and 45 minutes. Fixturing could have been used to restrict the flow of solder as the assembly went over the wave; however fixture design, fabrication and testing are expensive, and fixturing is not always successful. Any gaps between the fixture and the ground plane allow solder to leak in where it is not wanted.

With solder applied selectively to the through-hole leads, masking of the ground plane is not necessary. Elimination of maskant also reduces wear and tear on the semi-aqueous cleaner. Elimination of masking defects has eliminated a significant source of solder touchup. Additionally, operator hand and wrist pain due to tape application is also minimized.

Dual reflow and selective solder reduces defects

Dual reflow utilizes paste and reflow to solder surface mount devices (SMDs) to both sides of the PCB instead of running paste & reflow on the near side and then gluing far side SMDs for wave soldering. When SMDs are glued on, there is a chance that they will be accidentally knocked off through handling or wave solder. Dual reflow eliminates these concerns because there are no glued parts. After dual reflow, the through-hole components that require soldering are done in the selective solder process.

Figure 7 shows the performance on one PCB part number that had experienced a high missing component defect rate. Through dual reflow and selective solder, the defects have been nearly eliminated.

Some PCB designs that are a challenge for wave solder are easily soldered using the dual reflow/selective solder process. The same PCB part with missing component problems was also the top solder defect generator in the BAE Systems-Irving facility. Through implementation of dual reflow/selective solder, the defects per assembly rate (DPA) has been reduced dramatically, as shown in *Figure 8*.

Additional Discussion

BAE Systems-Irving has recently purchased a Pillarhouse Jade selective soldering system to compliment the Ruby machine already in production. As previously discussed, a dual reflow / selective solder process has been shown to drastically reduce touch-up and rework. An additional benefit is that it also eliminates many hand soldering operations that have historically been required.

Most appealing is the fact that many

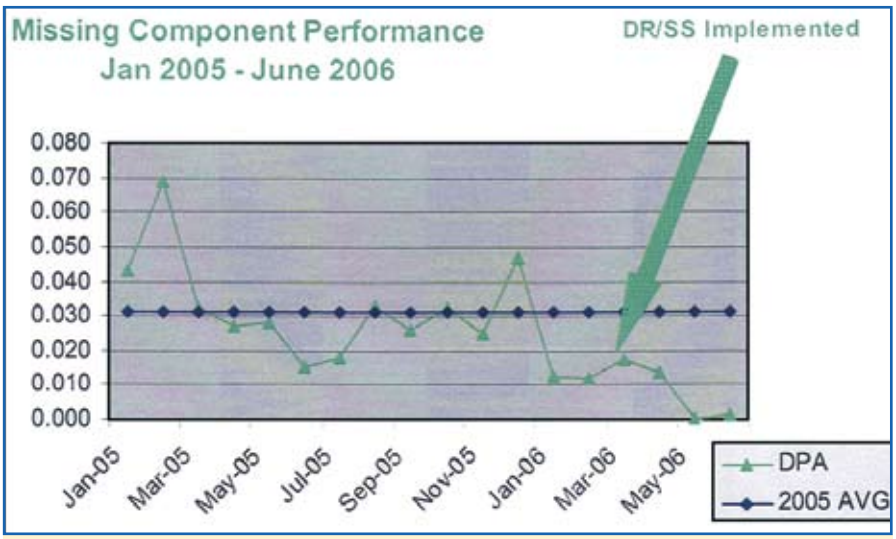

Figure 7. This PCB part number shows a high missing component defect rate with the vapor phase/wave solder system.

of these hand solder operations were the ones offering the most challenge to operators due to mass and/or component configuration issues.

The Jade also has included with it a lead-free pot that can be changed out in a matter of minutes, further increasing the flexibility of the soldering operations and supporting engineering development activities.

Dual reflow and selective solder summary

- Expensive chemicals required of the vapor phase process have been eliminated.
- Maskant materials required for vapor phase/wave soldering have been eliminated.
- Product movement has been significantly reduced.
- A baking step has been eliminated.
- A cleaning step has been eliminated.
- Product flow time has improved.
- Operator wrist pain concerns have been reduced.
- On some part numbers, defects rates have been driven to an all time low
- Processing flexibility has increased.
- Requirements for hand soldering have been reduced.
- Employee morale has improved due to elimination of manual operations.
- Customer satisfaction has increased due to increased throughput and lower defect rates.
- Facilitates improved Pb-free development activities.

Conclusion

BAE Systems-Irving has met its goal of identifying a soldering technology that would significantly reduce manufacturing costs by eliminating the need for the constraining vapor-phase process. Selective solder provides flexibility by being able to solder multiple

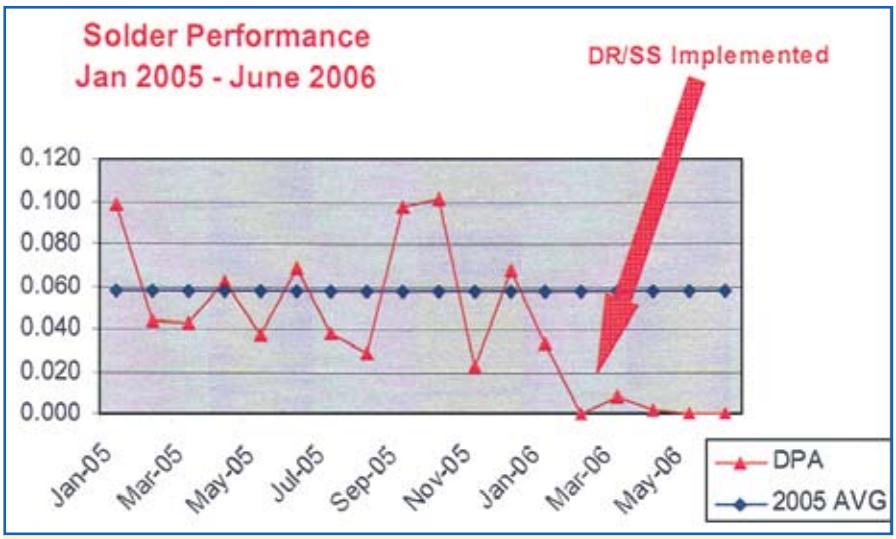

Figure 8. Implementation of dual reflow/selective solder has dramatically reduced DPA.

Figure 9. Pillerhouse Jade selective soldering system.

configurations and solves many hand, wave, and masking assembly problems.

Combining dual reflow with selective solder has resulted in soldering processes that are more lean, more flexible, and more responsive to customer demands.

Acknowledgements

The authors would like to thank Larry Stone for contributions towards the creation of this article and Allen Curtis for photographic services.

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