Automating the Control of Moisture-Sensitive Components Benefits and ROI Analysis

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Introduction

The control of moisture-sensitive devices (MSDs) prior to SMT reflow is a critical assembly issue that has a direct impact on final product reliability and customer satisfaction as well as manufacturing costs.

The guidelines for storage and handling of MSDs are clearly defined in the IPC/JEDEC standard J-STD-033. However, the proper identification, tracking and calculations have always been very challenging to implement with manual procedures and they are prone to a high level of human errors. In most cases, implementation of an internal manual control procedure requires simplifications to the industry standard. This can have two possible effects:

1. When simplifying on the safe side, the user will end up baking parts that don't really need it. This has serious implications in terms of lead solderability and solder joint reliability due to intermetallic growth. It also impacts material availability, which can affect production schedule, on-time delivery and inventory levels.
2. With other simplifications to the standard, a significant number of components that should have been baked will be assembled and reflowed. Although this may only happen to a small percentage of all the lots, it will typically involve a partial tray or reel containing many parts. Since MSDs are typically the most expensive components and there can be many such components on each PCB, even a small level of escape (less than 0.1% by component) can result in very high material costs and unacceptable levels of early life failures.

It is now possible to use an automated control system that is both simple-to-use and can insure a very high level of control. The foremost objective of the system is to avoid assembling components that have exceeded their allowable limit. This is achieved by automatically tracking each reel or stack of trays from the time they are removed from their original dry bag until all parts are placed prior to reflow. The second objective is to minimize the number and duration of bake cycles by taking into account all applicable rules from the industry standard and ambient conditions, while providing real-time status and advance warnings.

Part I – Overview of Evaluation

This paper describes the actual benefits of an automated control system in a real CEM production environment. The study was performed on one SMT line over a two months period, from Feb. 22 to Apr. 25, 2001. All of the cost figures are based on actual statistics that were compiled by the automated control system during the evaluation period. The ROI was based on comparing an optimal manual procedure to the automated control system.

Production Statistics

Single sided SMT line, multiple products, high mix (one changeover per shift on average)

62 different PNs that are Moisture Sensitive, with the following mix:
Level 1: 3 (5%)
Level 2: 2 (3%)
Level 2a: 1 (2%)
Level 3: 36 (58%)
Level 4: 12 (19%)
Level 5: 8 (8%)
Level 5a, 6: 0

Number of different lots (bags) of MS components used during the evaluation: 188

Average quantity per lot: 80

Total number of components: 15,040

Average cost of MSDs: $110 (USD)

Number of times that a lot of MS components were loaded on a placement machine: 334
(this means that on average each lot was loaded twice)

Number of bake cycles: 13
(2 additional lots were baked upon reception due to improper packaging)

Important Notes Relative to Dry Storage
In a high mix production environment, a majority of the lots of components will be returned from the production line in the form of partial trays and reels. These parts are normally stored in dry bags or dry cabinets until they are needed again.

The above number of bake cycles is based on complete adherence to the IPC/JEDEC standard relative to dry storage. This means that the clock of exposure time is NOT stopped when previously exposed components are returned into dry storage.

Many assemblers deviate from the industry standard by assuming that it is acceptable to stop the clock of exposure time when previously exposed components are returned to dry storage. An analysis of the production statistics has shown that during this evaluation, 10 lots out of 13 that were baked would not have exceeded their floor life if the clock had been stopped during subsequent dry storage. Thus, this type of simplification would have represented a very significant exposure for the reliability of the finished product.

In order to take into account the drying effect of the desiccant inside re-sealed dry bags, the automated control system was configured to automatically apply the short duration rule when the proper conditions were met (re-set the clock of exposure time when 8 hours or less of exposure time, followed by 5X the duration in dry storage). During the evaluation period this rule was applied 73 times and avoided an additional 54 bake cycles.

Additional opportunity
The IPC/JEDEC standard provides a de-rating table to take into account the actual factory conditions. The automated control system can be configured to automatically apply this de-rating. Since in many cases the actual conditions are well below the default 30C/60% RH, this can significantly increase the floor life process window and reduce the number of unnecessary bake cycles.

During the evaluation the system was set at the default value of 30C/60% RH. However, the actual ambient conditions during this period never exceeded 25C/40%RH. An analysis of each lot that was baked has shown that more than half of the bake cycles (7/13) would have been avoided by taking this factor into account. This de-rating is most significant for common Level 3 "thin" components, i.e. less than 2.1mm body thickness, (TSOP, SOIC, TQFP, TBGA) that have an unlimited floor life under conditions below 40% RH. A review of the MSD component database shows that 29 different part numbers were classified as "thin" Level 3 parts (i.e. 80% of all level 3 or 47% of all components).

Part II - ROI Analysis (all figures are in US funds)
This financial analysis takes into account some of the major elements of savings associated with a higher level of process control during the evaluation period. When needed, very conservative assumptions and estimates have been made and are clearly documented. All these savings are applicable to one SMT line over a two months period:

1. Improvement in final product reliability (early life, MTBF).
2. Improvement in test yields (ICT, FCT) (See Table 1.)
3. Reduction in the cost of the bake process and scrapped components (prior to assembly).

These two elements are nearly impossible to measure directly. This is due to the relatively low level of defects and also to the technical difficulty in performing the appropriate component removal and subsequent failure analysis. This challenge is very similar to what was experienced many years ago when manufacturing engineers were trying to calculate the ROI for ESD controls. However, unlike the situation with ESD, in this case many elements of a control system (exposure time, # bake cycles, etc.) can be measured and can be used to quantify the expected level of defects.

Number of components that exceeded their floor life limit during the evaluation: 480 (6 lots out of 80)

The numbers of defects at electrical test and in the field are conservatively estimated to be only 10% of the expired components that escaped through the control procedure or system.

Table 1 – Improved Test Yields

	Manual procedure	Auto System	Savings
System Efficiency:	75%	99%	
Number expired components escaping	120 (0.8%)	4.8 (0.03%)	
Defects at electrical test	12 (0.08%)	0.48 (0.00%)	
Cost	$1,560.00	$62.40	$1,497.60
Defects in the field	12 (0.08%)	0.48 (0.00%)	
Cost	$3,720.00	$148.80	$3,571.20

Because of the cumulative component degradation associated with bake cycles, the IPC/JEDEC standard states that only one bake cycle is allowed for each component. The automated control system keeps track of the first bake cycle by logging this information on the RF tag. A message is displayed when a second bake cycle is attempted on the same lot of components. The usual procedure is to scrap these components to avoid potential issues.

If we assume that an optimal manual procedure could take into account the short duration rule but not the ambient de-rating factor, the number of bake cycles would have been 13 for a manual procedure Vs 6 for the automated control system. In addition, we assume that a manual procedure uses the standard default bake duration of 48 hours for simplicity reasons. The automated control system provides optimal bake duration based on the MS level and body thickness for each level, making it possible to track multiple bake cycles with different start and finish times. (Table 2 and Table 3.)

Table 2 - Cost of Bake Cycles (rate of $3.25 Per Hour for Energy and Handling)

	Manual procedure	Auto System	Savings
Number bake cycles	13	6	
Average duration of bake cycles	48 hours	19 hours	
Cost	$2,028	$370.50	$1,657.50

Table 3 - Cost of Scrapped Components

	Manual procedure	Auto System	Savings
Number components with one bake cycle	1040 (6.9%)	480 (3.2%)	
Number components with 2nd bake cycle	36 (0.48%)	8 (0.10%)	
Cost	$3,955.32	$842.55	$3,112.77

4. Increased productivity

The automated control system requires a simple scan operation to read and update the RF tags every time that a lot of MSDs is loaded or unloaded from a placement machine. In comparison, a manual tracking procedure will require cumbersome date/time calculations and verification of different rules. This is time consuming and it will have a measurable impact during product changeover when many different parts have to be unloaded and reloaded from the placement machine. (See Table 4.)

Table 4 –Increased Productivity

	Manual procedure	Auto System	Savings
Set-up and verification of MSDs	60 min/day	10 min/day	
Machine-cost	$1,920.00	$320.00	$1,600.00
Operator-cost	$320.00	$53.33	$266.67

5. Training and Support Costs

The typical MSD control procedure is considered by many to be the most complicated manual procedure that exists on the manufacturing floor. It must be regularly updated based on changing conditions, such as new process, equipment, material logistics, revisions to the standard, etc. To generate and maintain a good manual procedure requires significant time from a qualified engineering resource. This is especially true if no data is available to make informed decisions. (In this analysis the engineering time is divided by the total number of SMT lines, in order to be consistent with the overall savings per line.)

It takes a significant amount of time and effort to train each employee who is involved in handling MSDs. The training material must be updated by engineering whenever a change is required due to the reasons listed above. Due to this issue's complexity, operator training must be refreshed on a regular basis. In comparison, the automated control system only requires operators to scan the RF tags and follow instructions provided by the system's interface whenever the parts are moved from one location to another. (Table 5 and Table 6.)

Table 5 - Training and Support Costs

	Manual procedure	Auto System	Savings
Update Procedure	16 hrs	2 hrs	
Engineering time	$256.00	$32.00	$224.00
Ongoing training and support	20 hrs	4 hrs	
Engineering time (1/3)	$106.67	$21.34	$85.33
Operator time (2 per line)	$320.00	$64.00	$256.00

Table 6 – Summary of Cost Savings

	Manual Procedure	Automated System	2 Months Savings	Yearly Savings
Defects at electrical test	$1,560.00	$62.40	$1,497.60	$8,985.60
Defects in the field	$3,720.00	$148.80	$3,571.20	$21,427.20
Bake cycles	$2,028.00	$370.50	$1,657.50	$9,945.00
Scrapped components	$3,955.32	$842.55	$3,112.77	$18,676.60
Productivity Machine	$1,920.00	$320.00	$1,600.00	$9,600.00
Productivity Operator	$320.00	$53.33	$266.67	$1,600.00
Update Engineering time	$256.00	$32.00	$224.00	$1,344.00
Training Engineering	$106.67	$21.34	$85.33	$512.00
Training Operator	$320.00	$64.00	$256.00	$1,536.00
Total				$73,626.40

Since the cost of the system was below $22,000 the payback was less then 4 months.

This return will be even more attractive for additional lines since part of the cost is associated with a central workstation in the stockroom, which will be shared by multiple lines.

Part III - Other Benefits

There are a number of other benefits that could not be directly quantified during this evaluation but should be considered in the justification of the system.

Perhaps the most significant direct benefit is related to customer satisfaction due to significant improvements in quality. It was reported during the evaluation that customers who visited or audited the manufacturing area have been positively impressed by the automated control system. The robustness of the system, combined with the complete historical database provided a very high level of confidence that this element of the process was under complete control. Over time it is also expected that the system will improve on-time delivery due to being more pro-active in reducing the number and frequency of bake cycles.

This type of automated material and process control system can become a differentiating factor when OEMs evaluate and compare different manufacturing partners with otherwise similar offerings.

Future Opportunities

The ongoing historical database that is available with the automated control system will provide very detailed and up-to-date information that can be used to measure the key metrics of MSD process control, such as number of bake cycles, average exposure time, etc. This quality data is essential to continuous process improvement and it allows engineering to predict the impact of any future change in manufacturing operations.

The automated control system currently offers a very high level of control for all MSDs prior to reflow. For new products that include MSDs on both sides of the board, the system can be expanded to track boards and associated components between the first and second pass through reflow.

The automated control system and the associated database may be integrated with other manufacturing systems to further improve material planning and inventory control for limited shelf-life materials in general. The use of the system may also be expanded in the future to track and control other expensive components that may not have floor life limitations but would benefit from a higher level of traceability and control, or simply to verify the loading of SMT equipments.

Conclusion

The evaluation of the automated control system of moisture-sensitive components and subsequent analysis have clearly demonstrated that process control is a very complex logistical issue that has far-reaching implications in many critical aspects of the material flow and assembly process.

Even the best manual procedures will have many significant shortcomings. Automating the control of moisture sensitive devices will yield significant savings in terms of quality, productivity and material costs, which lead to a very straightforward financial justification. Increased customer satisfaction and confidence are additional benefits that are just as important although more difficult to quantify.