Flux Collection and Self-Clean Technique in Reflow Applications

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Abstract

The flux management system for a reflow oven is highly critical to the quality, cost, and yield of a reflow process. Flux accumulation and dripping inside the oven not only requires frequent maintenance, it can also result in poor quality, low throughput, and safety issues. Understanding that high volume electronics manufacturers do not like downtime for maintenance, this is the driver for continued development of advanced flux management systems that incorporate self-clean features and do not require interruption of production for maintenance activities.

This paper will review some basic past and present flux chemistries that affect flux collection methodology. It will also review some of the most common flux collection methods, self-cleaning techniques, and maintenance goals. And, finally, data will be presented from high volume production testing of an advanced flux management system.

Introduction

The strong desire to reduce production downtime for maintenance is driving reflow oven manufacturers to continue the search for the most effective flux management solution. The changes in flux chemistries over the years have added to this challenge. In addition, success is no longer measured by collection efficiency alone, rather, a combination of efficiency, production downtime, ease of maintenance, and cost of ownership.

Flux Chemistries

Advancements in flux formulations of solder paste have been a welcome sight to most electronics manufacturers. While many of these improvements have been necessitated by lead-free and other initiatives, others have been developed specifically to benefit other aspects such as paste life, printing quality, and post-reflow residues. However, many of these solder paste enhancements have increased the amount of volatiles emitted during the reflow process. This has challenged reflow oven manufacturers to continue development of flux management systems in order to contain this increased emission.

Old generation rosin based fluxes for eutectic solder used to contain approximately 30% solids. This high solids content resulted in a large amount of post-reflow residue left on the PCB. Of course, this was not appealing to the end product, but it meant that there was a limited amount of evaporation inside the reflow oven to contain.

New generation no-clean flux formulations contain less than 5% solids. The potential for evaporation during reflow is significantly greater for these pastes than of years past, as shown in figure 1. In many cases, this has yielded the much sought after goal of reducing post-reflow residues to almost undetectable or insignificant levels. However, this also means that these volatiles are now released during reflow and must be contained inside the oven.

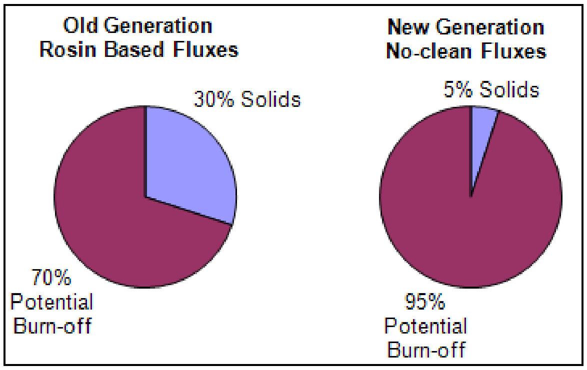

Figure 1-Flux Formulation Comparison

Of course not all of the liquid flux content evaporates during reflow. The actual burn-off amount for no-clean fluxes is generally about 50% of the initial flux weight. So, to put all of this into perspective, consider a typical high production environment that processes 10kg of solder paste per day through the oven. Consider a typical solder paste with 88% metal content and the remaining 12% is a combination of flux, solvents, and activators, as shown in figure 2. This calculates to an astounding 600g of volatiles per day evaporated inside the oven that must be effectively contained to eliminate accumulation inside the oven.

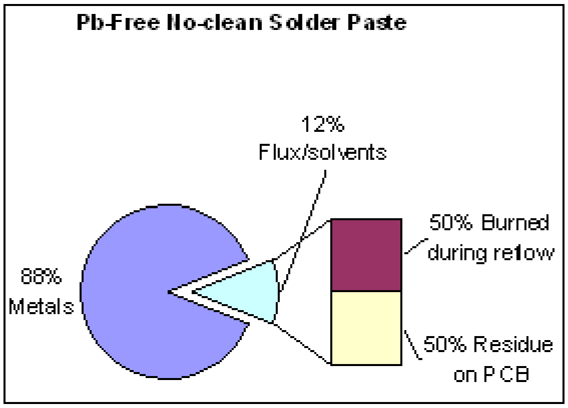

Figure 2-Solder Paste Composition

Location, Location, Location

One of the most important, and often overlooked, components of effective flux containment is the location of the extraction ports. Typical evaporation of volatiles begins around 90°C and continues through the reflow stage, as shown in figure 3. Systems that focus extraction in only one or two locations often result in flux accumulation inside the oven. When volatiles are required to travel long distances to reach an extraction port, many of them come into contact with condensing surfaces inside the oven before they reach their intended destination. This results in flux accumulation inside the oven and the potential for product contamination via dripping.

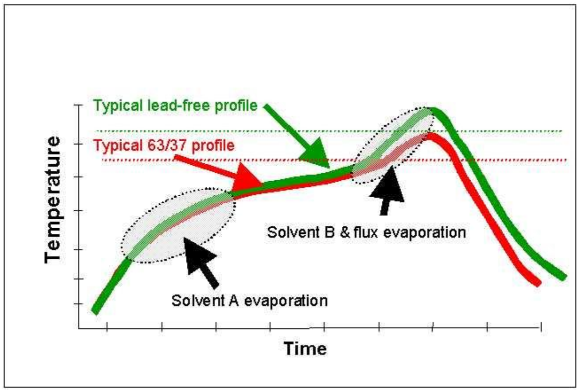

Figure 3-Volatile Burn-off Profiles

The most effective systems will extract fumes close to the point of release, reducing the possibility for accumulation inside the oven. This means extracting fumes throughout the preheat, soak, and reflow sections of the oven, as shown in figure 4. In addition to limiting the travel distance of the volatiles, multiple point extraction also results in a large amount of air recycling without causing a significant airflow bias within the oven.

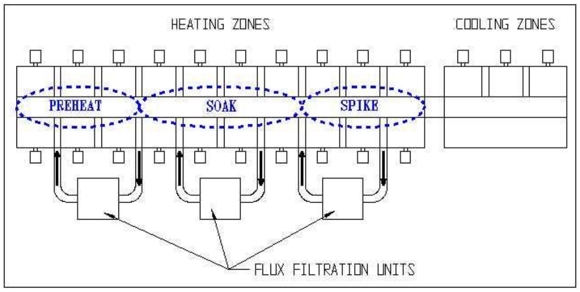

Figure 4-Multiple Point Extraction

Another critical point to mention on the subject of location is the distance from the extraction port to the flux collection device. Vaporized flux contaminants will begin to condense immediately upon experiencing a temperature drop, which usually occurs in the ducting from the oven to the collection device. Any significant length of ducting will likely cause condensation to occur inside the duct, which will eventually accumulate enough flux to clog the system and render the flux management system completely ineffective. Multiple collection devices positioned in very close proximity to each of the extraction ports can minimize, if not eliminate, this problem.

Flux Collection Methods

The most widely used method for flux collection is condensation via chilled water passing through a radiator type heat exchanger. While this is quite efficient for collection of heavy flux particles, many of the lighter solvent particles pass through the heat exchanger and are returned to the oven. In addition, finned radiators are very prone to clogging and are generally difficult to clean. They also usually require the additional purchase of a water chiller, which significantly adds to the overall cost of the unit.

A simpler and less expensive version of the above is an air-to-air condensation system. The cooling medium is generally compressed air and the heat exchanger is usually a simple cooling coil. This type of system is typically less efficient than chilled water systems, but it is also less prone to clogging and considerably easier to clean.

Another method is a filter or series of filters not requiring any external air or water facilities for cooling. While these systems can be quite efficient for collection of all types of particles, they are very prone to clogging and generally require frequent maintenance. This additional cost in maintenance usually negates the lower initial cost of the system.

The final method of discussion is an advanced collection system that combines some of the best attributes of the previously mentioned methods to obtain high efficiency, low cost of ownership, and minimal maintenance. This system separates collection into two stages: 1) condensation via air-to-air heat exchanger with compressed air as the cooling medium and 2) filtration via a packed bed filter cartridge, as shown in figure 5. The heat exchanger condenses the heavy flux particles and the packed bed filter traps the lighter solvent particles. This type of "staged" approach has the ability to significantly extend maintenance intervals if designed to minimize clogging potential.

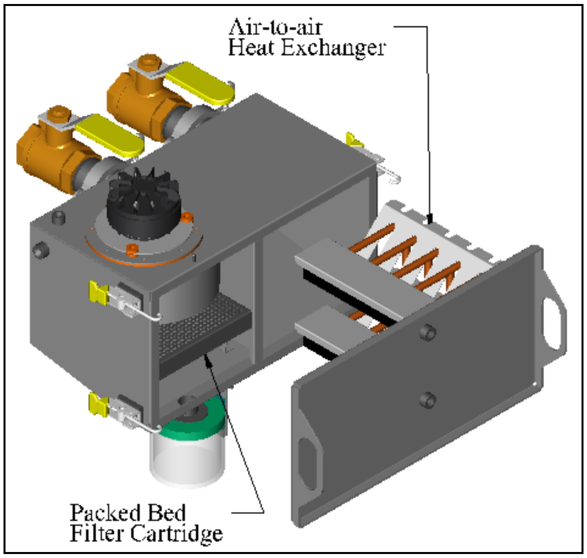

Figure 5-Multiple Stage Condensation/Filtration

Self-clean Technique

Many of the flux management systems in use today provide a disposable jar fed via a gravity drain for collection of condensed particulate. The theory is that the collected flux will drip from the collection device and flow to the jar for easy disposal. But, unfortunately, the collected flux generally becomes very viscous, almost a paste-like consistency that loses its ability to flow.

However, if collected fluxes are heated, they generally will reduce in viscosity to a point where they can flow. So, if a heater is installed on or near the point of collection, the flux can be heated to a temperature that will cause it to drip and drain via gravity. A system such as this can be further enhanced by software control of the cleaning cycle, whereas the user selects cleaning intervals and the software controls the heaters to energize for a pre-determined time at these intervals. If designed properly, this self-cleaning can be performed without interruption to production and virtually invisible to the user. In addition, if the cleaning is effective the maintenance required by the user can be greatly reduced.

Maintenance

One of the biggest contributors to the total cost of ownership of a reflow oven is the cost of maintenance for the flux management system. This not only includes the labor associated with the maintenance activities, but also the lost production if the oven must be shut down for this maintenance.

Flux management systems that are designed to minimize clogging potential and incorporate effective self-cleaning can greatly increase the intervals between maintenance, thus reducing the associated labor costs. This can be even more enhanced if the condition of the flux management system can be monitored via temperature, flow, pressure, etc. and warn the user of conditions that require maintenance.

Ease of maintenance is another consideration to reduce the cost of ownership. Accessibility of the flux collection device and ease of access to the internal portions of the device for cleaning is paramount. Also to be examined with close scrutiny is the ease of removal, cleaning, and replacing of the collection media. These considerations not only directly affect the time spent on maintenance activities, but also the safety of users performing the maintenance.

The final consideration, and likely the most costly, is the lost production due to oven downtime for maintenance. In a high production environment, downtime of as little as an hour can cost a company thousands of dollars in lost revenue. Therefore, a flux collection system that is designed such that it can be isolated from the oven for maintenance without affecting oven performance or production is an extremely valuable asset.

Experimental Work

The experimental part of this work consisted of two stages: 1) reflow simulation and 2) actual reflow environment.

Reflow Simulation:

A series of experiments was conducted to determine the effectiveness of each of the previously mentioned flux collection methods using a closed environment, laboratory set-up. The experimental set-up consisted of a flux burning unit connected to a flux collection unit with airflow as diagrammed in figure 6. A standard, commercial grade, Pb-free flux was used throughout the experiments. A pre-determined quantity of flux was burned using a time and temperature set-up that was representative of a real reflow process. The fumes from the burned flux were then extracted and passed through the collection device. The uncollected fumes from the collection unit were exhausted outside the system so only a single pass was filtered.

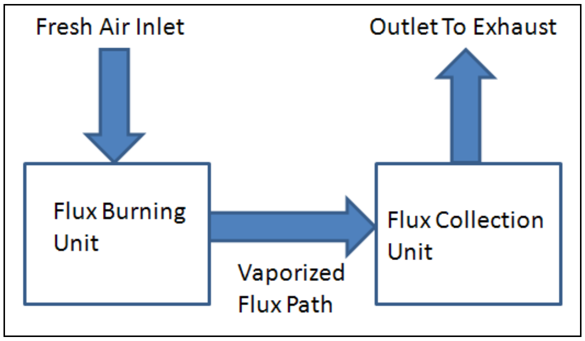

Figure 6-Simulation Test Airflow Diagram

Since the most widely used collection method in the industry is chilled water-to-air condensation, this was used as the benchmark against which all other systems would be compared.

Simulation Results:

Figure 7 shows typical flux collection results for the above experiment. It is evident from these results that the multiple stages of condensation and filtration is the most efficient system. This advanced system, which utilizes air-to-air condensation combined with packed bed filtration, approximately doubled the collection of flux contaminants when compared to the benchmark condensation system.

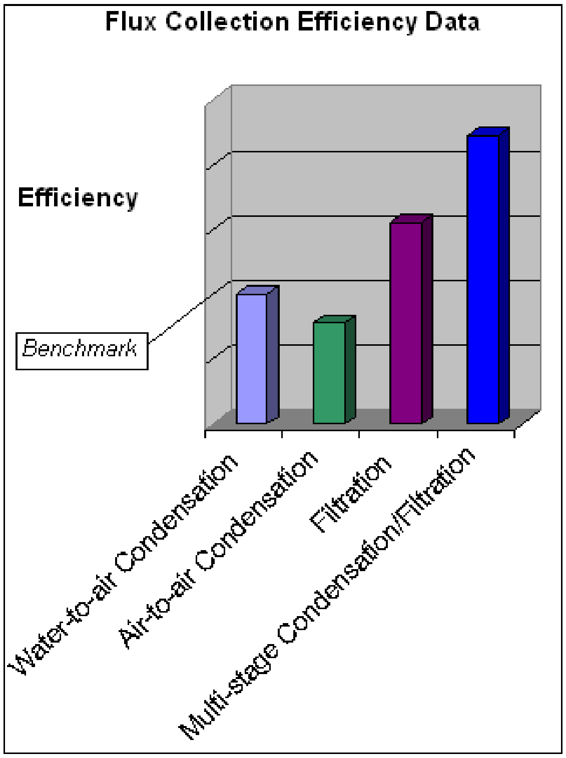

Figure 7-Flux Collection Efficiency

Actual Reflow Environment Testing:
Based on the reflow simulation results, the multi-stage condensation/filtration system was chosen to be field tested. A multiple stage condensation and filtration system was built and assembled on a reflow oven in a high-production manufacturing environment. This particular oven was running a continuous 24/7 operation and processing 15kg of solder paste per day. The system was allowed to run for 6 weeks while flux extraction data was collected and the condition of the flux extraction system was monitored on a weekly basis.

Actual Reflow Testing Results and Discussion:
The flux collection effectiveness was observed to be similar to the results obtained from the laboratory simulation testing. What was eye-opening from this test was the dramatic improvement in the maintenance of the flux extraction system. The advanced multiple stage system operated for a period of over 6 weeks before any maintenance was performed. Meanwhile, past performance of this identical process using some of the other collection methods discussed earlier resulted in maintenance intervals ranging from 2 days to less than 2 weeks.

In addition to extending the maintenance cycle, this advanced multiple stage system is designed such that the components can be easily cleaned. Figure 8 shows the progression of flux collection on the air-to-air heat exchanger over this testing period. It is clear from the picture that the components can be restored to “like new” condition with minimum effort, as this particular system was cleaned using an automated parts cleaner.

This greatly extended period between maintenance cycles results in quite significant savings in terms of production that is not lost to downtime. Consider an average throughput of 150 boards/hour, an estimated return of $10/board, and a maintenance downtime of 2 hours. With this production, a flux system with a 2 week maintenance interval costs a manufacturer over $70,000 per year in lost production, as shown graphically in figure 9. However, if this interval is extended to 6 weeks, the revenue recuperated from the additional production uptime exceeds $50,000 per year.

When these figures are multiplied by the number of production lines in a facility, the potential revenue should be enough to gain the attention of any manufacturer. Unfortunately, however, this aspect is often overlooked at the time of oven purchase, as it is generally overshadowed by initial equipment cost. More often than not, this neglect leads to an unpleasant surprise in total cost of ownership when the machine hits the production floor.

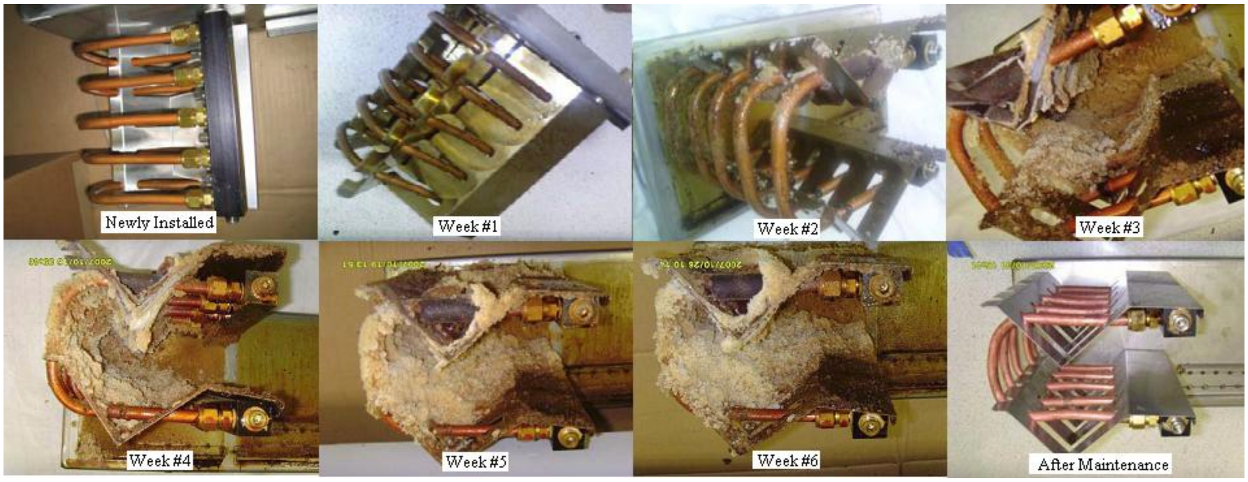

Figure 8-Production Testing Flux Accumulation

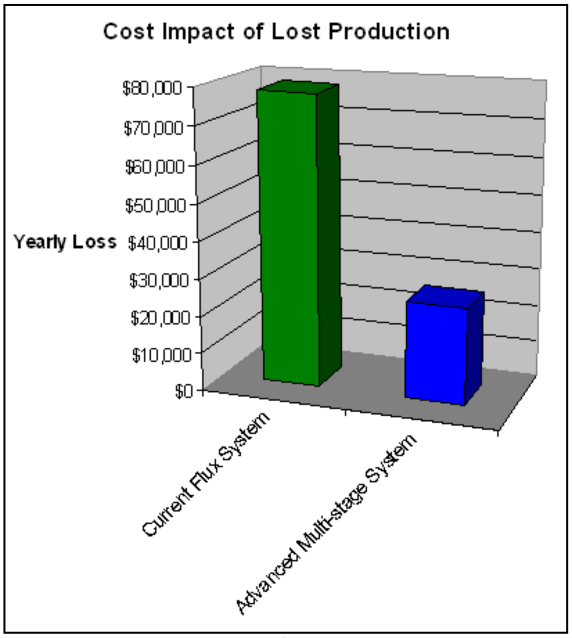

Figure 9-Cost of Lost Production

Conclusion

There are many different flux collection devices in the reflow market, and just as many ways to measure the effectiveness of each system. However, the real measurement in today's demanding production environment is determined by which system is designed for the least possible production downtime. This means the system must not only be efficient at collecting flux, but also located properly to entrap particles, designed to minimize clogging potential, employ some type of self-cleaning, and provide the opportunity to do maintenance without stopping production. When added to a system that has good accessibility and is easy to clean, the result is the lowest cost of ownership flux management solution.