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A Comparison of the Environmental and Operating Costs of Spray in Air Batch Cleaners and Small Inline Aqueous Cleaners

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Abstract

This paper will discuss the environmental and financial cost of operating both batch cleaners and small inline aqueous cleaners. It is not the goal of this paper to endorse one type of cleaner over the other type, but rather to provide end users with a balanced look at the pros and cons of both batch cleaners and small inline cleaners.

Both types of cleaners have been widely available for use in production facilities since the 1980's. Choosing between a small inline and a batch cleaner can sometimes be an easy decision, but is most often a difficult dilemma without an obvious best choice. An objective look at the environmental and financial impact of both types of cleaners can help end users make a better decision for their specific applications.

This paper will compare the amounts of water, chemistry, and electricity used by both batch and inline cleaners. The environmental and financial impact of these measures will be discussed. Other factors such as floor space requirements, initial costs of the cleaners, and throughput capacity will also be examined.

Introduction

The challenges in cleaning printed circuit boards have become more complex. The miniaturization of PCB designs, the implementation of lead free soldering, and stricter environmental controls have all made cleaning more difficult.

The miniaturization of PCBs has several consequences for cleaning. Space under components has decreased while at the same time, interconnect densities on the boards have increased. This reduction in "empty" or "free" space on the board is problematic for cleaning for two reasons. First, the fluxes used in soldering can completely fill in these spaces. Once these empty spaces are filled, the physical resistance to cleaning increases. Second, the reduced empty space on the board impedes cleaning fluids from reaching under components or between interconnects. And when the cleaning fluid does penetrate into those empty spaces, it can be more difficult to remove and eventually dry the boards.

In February 2003, the European Union adopted the Restriction on Hazardous Substance Directive (RoHS) with an implementation date of July 2006. This was the beginning of a worldwide shift (either voluntarily or legislatively) to the use of lead free solders. These lead free solders generally require higher wave and/or reflow temperatures which had an impact on the fluxes and often made cleaning more challenging. Not only did the temperatures that fluxes were exposed to change, so did many of the flux compositions themselves. Even the so called "no clean" fluxes needed to be cleaned. This has many PCB manufacturers moving away from batch cleaning because their cleaning volumes and cleaning challenges have increased.

Not only has the cleaning of PCB become more challenging, the chemistries used to clean those boards have been restricted by the Environmental Protection Agency (EPA) and the Air Quality Management District (AQMD). According to a proposed EPA schedule, new designations for ozone standards will become effective in August of 2011. Businesses operating in California have already had to conform to requirements established by the AQMD. While these regulations have a positive effect on our environmental health, they do limit the chemical solutions that can be used to clean fluxes and residues from PCB.

As a result of the cleaning challenges manufacturers face, the choice of cleaning equipment has become even more important. In response to these challenges, manufacturers of spray in air batch cleaners and inline aqueous cleaners have made improvements to both types of machines. However, there are still some significant differences between the capabilities and costs of batch and inline cleaners. These differences should help PCB manufacturers decide which type of machine best suits their needs.

Background
For this paper, a batch cleaner and a small inline cleaner were tested and compared on several parameters. Before the procedures and results are discussed, it is important to understand the equipment being used and how each one approaches the challenges of cleaning.

Spray In Air Batch Cleaners
Batch cleaners are so named because they take a batch of PCBs and clean them all at once. The PCBs are loaded by an operator into one or two stainless steel racks and then processed within a stainless steel chamber. A batch cycle includes wash, rinse, and drying . One persistent myth is that a batch cleaner is nothing more than a glorified dishwasher. And while some batch cleaners may look from the outside like the dishwashers found under countertops, the internal function of a batch cleaner is specifically designed and manufactured for removing flux and residues from PCBs.

Batch cleaners spray liquid into the process chamber. Manufacturers of batch cleaners differ in their preferred approach on how to get the cleaning liquid to the PCB. The two most common methods are listed below.

Method 1: Some manufacturers use stationary medium energy fan sprays to hit the PCBs with the cleaning fluid. To try to compensate for the shadowing effect of the stationary spray, the rack moves back and forth during the cycle. This type of batch cleaner usually has 1 rack as standard equipment.

Method 2 (the method used for this study): Other manufacturers use high energy coherent jets to hit the PCBs with cleaning fluid. The shadowing effect is reduced by the randomized spray of the coherent jets. In this method, the boards are stationary during the cleaning process and the upper and lower racks (both standard equipment) are independent of each other. (See figure 1)

Figure 1 – Batch Configuration Used
Independent Top and Bottom PCB racks shown with standard stainless steel inserts.
Note the Spray Bars with coherent jets -- one on top, one under the top rack, and one
Under the bottom rack (not visible.)

No matter which method is used for getting the cleaning liquid to the PCB, the rinse phase of the batch cycle continues until a predetermined water cleanliness level for the rinse water is reached. This is usually measured by the electrical resistance of the rinse water. It is important to note that this measure of cleanliness is not a direct measure of board cleanliness. Once the desired cleanliness level of the rinse water is reached, the drying phase begins. The chamber is heated and air is added into the chamber to dry the PCBs. When the entire cycle is completed, the chamber is opened and the boards are unloaded by an operator.

Small Inline Aqueous Cleaner
An inline cleaner uses a conveyorized system to move the PCBs through the cleaner. Product is either loaded onto the inline cleaner conveyor manually or via an automatic feed conveyor. As the board travels through the cleaner, it goes through a wash stage, a rinse stage, and a drying stage. There is sufficient space between the wash and rinse stages to prevent chemistry cross over as well as anti-drag out air knives at the end of the wash and beginning of the rinse sections (see figure 2). The drying stage consists of adjustable air knives powered by blowers (see figure 3). The conveyor speed is adjustable,

which allows the operator to control the amount of dwell time. Boards that are harder to clean generally need a longer dwell time. This gives the cleaning liquid longer to react with the fluxes and residues.

The cleaning liquid is sprayed onto the PCB through multiple nozzles on stationary spray bars (see figure 4). Nozzles for the spray bars come in many interchangeable sizes and patterns. Liquid can also be delivered to the PCB through a cascading curtain or sheet of liquid dispensed through a specially designed spray bar with one gap that the runs the entire length of the bar. This is sometimes referred to as a water knife. For this study, the inline cleaner was configured as follows: 4 upper / 2 lower spray bars and 1 upper / 1 lower anti-drag out air knive as the wash section; 1 upper / 1 lower spray bar and 1 upper / 1 lower anti-drag out air knives in isolation, 3 upper / 3 lower spray bars in the rinse section, and finally 4 upper / 2 lower adjustable air knives in the drying section.

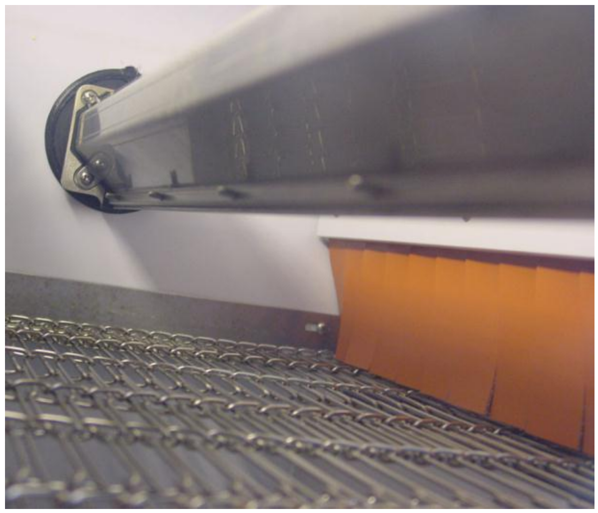

Figure 2 – Anti -Drag out Air Knife at end of Wash Section

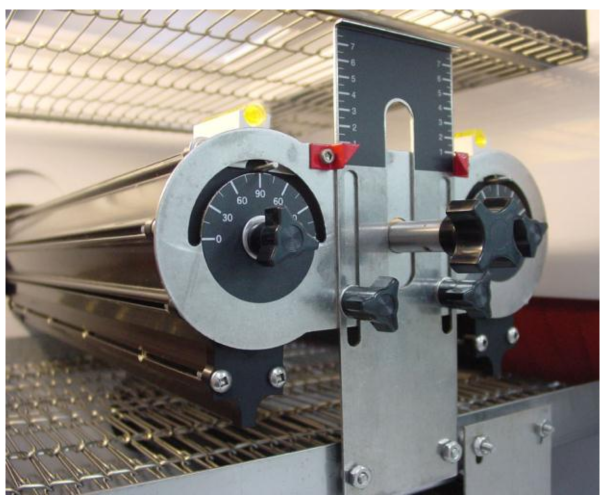

Figure 3 – Adjustable Air Knife Blower in Drying Section

Figure 4 – Spray Bars in Inline Cleaner
Upper spray bars with green nozzles
Lower spray bars with blue nozzles

Purpose

When a company is looking for an aqueous cleaner to process their boards, sometimes the decision is easy. The cleaning capabilities and process flexibility of an inline cleaner are far better than those offered in a batch system. If a company processes a large variety of boards or particularly difficult to clean boards they would also be best served by an inline cleaner. Also if the company is running high volumes of boards, an inline cleaner is the likely choice due to the higher throughput of an inline cleaner. Sometimes the size of the product (either very large or very small) necessitates an inline cleaner.

By contrast, if a company is running a very low volume of boards like a research lab or rework facility than a batch cleaner may be the best solution for their cleaning needs. Even if a company is processing a nominal volume of PCBs and their boards are easily cleaned in a batch process, they may consider using more than one batch cleaner to meet their needs.

Many companies fall in between the extremes of the examples above. For these companies the choice between a batch cleaning system and a small inline cleaning system is not so cut and dry.

Procedure

A spray in air batch cleaner and a small inline aqueous cleaner were both subjected to testing in a controlled, laboratory environment. The batch cleaner was allowed to run a full cycle and timed. The amount of time the batch cleaner took to finish its cycle was then used as the amount of time the inline batch cleaner was set to run. Then both sets of data were converted to per hour numbers for comparison. For both cleaners the following measurements were taken: amount of wash fluid (chemistry) used during the cycle, the amount of rinse water used during the cycle, and the amount of electricity used during the cycle.

In this particular batch cleaner, the wash fluid is recaptured and reused within the batch cleaner itself for a true closed loop system for the wash fluid. (There are batch cleaners that use the wash fluid once and send it directly to drain.) In the inline cleaner the wash fluid usage was measured by the drop in volume of the wash tank after 1 hours of continuous operation. Neither the batch cleaner not the inline cleaner was set up in a closed loop system for the rinse. This gave us a comparable water usage measurement to the inline cleaner.

If a company sets up a closed loop system for the rinse section in either a batch cleaner or their inline system, this will reduce the amount of new water needed during the rinse cycle. However, the costs to clean would have to be augmented by the cost of additional equipment (i.e. DI unit, sump tank, or evaporator) and the recurring costs of consumables (i.e. DI Beds or filters). While not a part of this discussion, it should be a consideration in any company's complete cost analysis.

Results

Table 1- Average Results for 1 Hour of Runtime per Cleaner Type

	Wash Liquid Loss Liters (Gallons)	Rinse Water Loss Liters (Gallons)	Power Consumption (KW)
Batch	.52 (.14)*	52.99 (14)	21.2
Inline	23.85 (6.3)	681.04 (180)	51.93

* There is no measurable loss after 1 cycle in this closed loop system. The initial wash tank fill is 7 gallons and can last through 50 or more cycles. For the purpose of this comparison we will use a 50 cycle mark for replacing the wash tank fluid.

Once both machines were run for an equal amount of time, the number of boards per hour processed by each type of cleaner was calculated. For the batch cleaner, the actual number of boards used in the fully loaded cycle (top and bottom racks) were counted and measured. (The numbers for a single rack batch cleaner are also presented since some batch manufacturers offer only a single rack as standard.) For the inline cleaner, the number of boards per hour was based on a nominal conveyor speed of 2 feet per minute using the same size boards as used in the batch cleaner. The boards were run with a space of 2 inches between the boards.

Table 2 – Boards Sizes and Quantities Processed within 1 Hour

	Board 1 4” x 9”	Board 2 4’ x 7”	Board 3 5” x 7”	Total Boards Cleaned per Hour
Batch –Single Rack	6	6	6	**18**
Batch – Top & Bottom Racks	12	12	12	**36**
Inline – 18” Conveyor Width	99	99	99	**297**

These results were then extrapolated into the resulting wash fluid loss, rinse water loss, and electrical usage per board.

Table 3 – Average Losses / Usage per Board

	Wash Liquid Loss Per Board Liters (Gallons)	Rinse Water Loss Per Board Liters (Gallons)	Power Consumption Per Board (KW)
Batch – Single Rack	.028 (.008)	2.94 (.76)	1.211
Batch – Top & Bottom Racks	.014 (.004)	1.47 (.38)	.589
Inline – 18” Conveyor Width	.080 (.021)	2.27 (.60)	.173

The results indicate the batch cleaner has much lower wash fluid (chemistry) loss per board than the inline cleaner. The batch cleaner with 2 racks has less rinse water loss per board than the inline cleaner. (If the batch cleaner were run with just 1 rack, the decline in board throughput gives the rinse water loss advantage to the inline cleaner.) The inline cleaner uses less power than the batch cleaner does per board.

From the data above the per board wash liquid loss of the inline compared to the batch is about 5.5 : 1. The per board rinse water loss of the inline compared to the batch is about 1.5 : 1. The power consumption per board of the inline compared to the batch is 1 : 3. (See figure 5)

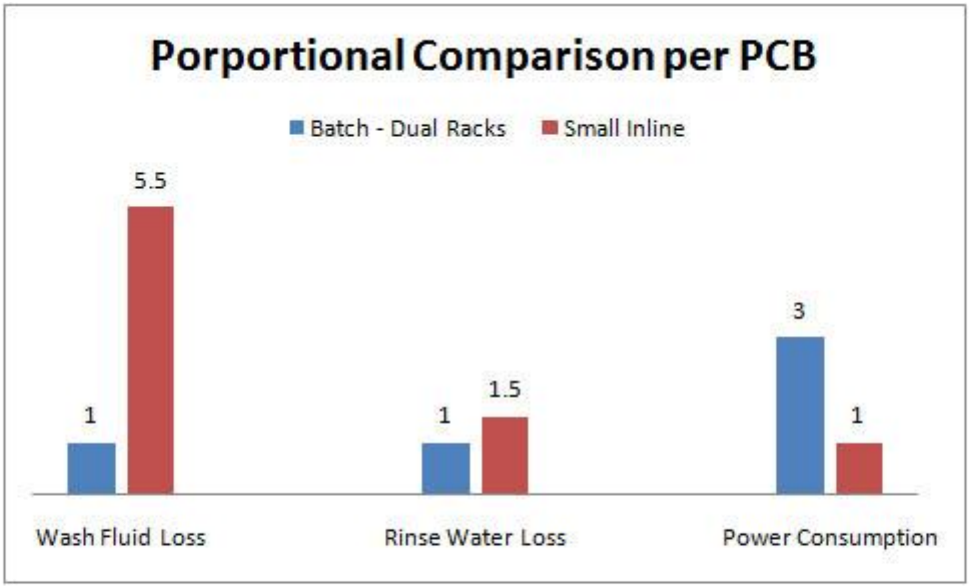

Figure 5 – Proportional Comparison of Losses / Consumption

The argument can be made that if the most important environmental concern is reducing your total chemistry usage and you cannot use a water only process to clean your boards, than a batch cleaner with a closed loop wash system is better choice. If lowering power consumption per board is a higher priority, than a small inline cleaner may be the better choice to achieve the lower per board electrical cost. The better type of machine for water conservation is a closer call. The batch with the dual racks uses less rinse water per board than the small inline cleaner. However, if you are using a single rack batch cleaner, the advantage shifts to the inline cleaner.

Of course it is not just a matter of conserving water, electricity, and chemicals. There is also a financial side to using fewer resources. Chemistry prices are fairly constant throughout the country. However, water and electricity costs vary not only from state to state, but also from water and power districts within a particular state. In some regions water and electricity are much less expensive than in other parts of the country. This is the reason for the proportional comparisons above. The variation in the cost of these resources by districts does not make a direct comparison feasible.

Other Considerations

In addition to the factors discussed above, there are other variables to consider when making a choice between a batch and an inline cleaner. One of those factors is the physical space available for a cleaner. A typical batch cleaner footprint (see figure 6) is around 1.14m (45") L x 1.14m (45") W ; where as a small inline has a typical footprint of 4m (160") L x 1.5m (60") W.

Figure 6 – Cleaner Footprints

The initial expense of batch cleaners and inline cleaners also differ. A batch cleaner is generally 60% - 75% the cost of a small inline cleaner. However, the initial capital outlay is usually not the biggest expense of the cleaning process over the long term. There are several readily available detailed cost analysis spreadsheets that can be used to calculate the true cost of a new cleaner and include other factors not mentioned in this study (i.e. overhead costs, ventilation system costs, operator costs, etc.)

Conclusions

The results of our tests showed that with regards to environmental factors neither the batch nor the small inline cleaner was a unanimous winner. The batch cleaner uses significantly less wash fluid (chemistry) per board than a small inline cleaner does. The margin is not as great with the rinse water loss, but once again the batch had lower losses than the small inline cleaner. However, in the power consumption category, the small inline cleaner was the winner.

Based on the financial cost only, the decision to select a batch cleaner or an inline cleaner comes down to what will cost more – chemistry for the wash section, water in your region or electricity in your region. From an environmental stand point, the choice of which of these 3 factors is more important may likely be mandated by state or local regulations.

Of course this decision has to be made with more than just the environmental factors in mind. If the PCBs aren't getting clean in the machine you choose, all of the resources are wasted. A careful examination of the cleaning capabilities both types of machines should be done not just for a company's current requirements, but as much as possible with future requirements in mind. A small inline cleaner certainly offers more flexibility and capabilities than a batch cleaner. Those advantages also come with a higher initial capital investment, more floor space, and a greater use of chemistry. A batch cleaner is better at conserving chemistry in a closed loop wash system, but the throughput of boards is relatively small. The footprint diagram above (see figure 6), suggests that 3 batch cleaners would take up the same space as a small inline cleaner. Using 3 batch cleaners would triple the throughput, but would also triple the costs of the resources without adding any new cleaning capabilities.

There is no one size fits all solution for the problem of which type of cleaner to choose. Many factors must be considered in making the best choice possible for a company's particular cleaning requirements. Hopefully the consideration of these 3 factors will lead to a wiser choice when choosing a cleaner. Ideally it should not be only the cost but also the responsible use of resources – water, chemistry, and electricity that influence a decision to choose one type of cleaner over the other.