

Recycling Batch Screen and Stencil Cleaner Wastewater

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Closed-loop recycling offers an efficient, cost-effective alternative to evaporation.

Users of batch aqueous cleaning systems, such as screen and stencil cleaners, are constantly faced with disposing of contaminated wastewater, which is hazardous waste primarily due to its lead content. Several disposal options are currently available, including hauling, evaporation and recycling.

Hauling the wastewater away is expensive, so equipment suppliers have built evaporation systems that connect to the various cleaning machines. These systems boil away the water, leaving a concentrated sludge that still must be hauled, but in much less volume and, therefore, at less cost.

However, this approach is not as simple as it may first appear. Evaporation is only practical for small volumes of wastewater, and many additional costs and problems are associated with it. A better solution is closed-loop recycling, a process that offers cost and material savings and simplifies the waste disposal issue without expensive hauling or excessive production line downtime.

The Waste Stream

Batch printed circuit board (PCB) and screen and stencil cleaners create a waste stream that requires treatment and disposal. Aqueous cleaning processes typically used for cleaning PCB assemblies (PCBAs) generally use a rinse cycle to remove any traces of contamination and cleaning chemistry from the object being cleaned. Rinsing is especially important on PCBAs, where any contamination left on a circuit can lead to failure of the product over time.

As the rinse water is used, residual contaminants in it increase to levels at which the water must be properly disposed of or treated to remove those contaminants. This rinse water contains lead from solder and other waste materials not suitable for discharge to the drain. The procedures for handling this waste stream must comply with local and federal hazardous waste

regulations. Each manufacturer's chosen procedures must consider existing in-house capabilities as well as the needs of the manufacturing facility.

The least attractive method of handling the wastewater involves continuous discharge to bulk containers and hauling. This choice is only viable for companies that clean very few stencils where the waste volume would be limited to one or two 55-gallon drums per month to be hauled away. Beyond this volume, the cost of handling and hauling would be prohibitive.

Evaporation: Not A Simple Option

Currently, evaporation is the most widely used and accepted option for wastewater disposal. This method safely concentrates the waste to sludge or even a solid waste that can be cost-effectively disposed of in an appropriate landfill by a waste hauler.

The process of evaporation can be divided into two parts: adding enough energy to heat the wastewater to the boiling point (212°F); and then adding enough additional energy to change the water from a 212°F liquid to a 212°F vapor. The following equation illustrates the first step in the process, using 60°F wastewater:

$$(1 \text{ lb water}) \times (1 \text{ Btu/lb/}^\circ\text{F}) \times (212^\circ\text{F} - 60^\circ\text{F}) = 152 \text{ Btu}$$

The second step is to add enough energy to change the water's phase from liquid to vapor. Tests have determined that 970 Btu/lb is needed for this phase change. Thus, the total energy required to evaporate one pound of 60°F water is: $152 + 970 = 1,122$ Btu. Approximately 13.5 percent of the total energy ($152/1,122$) is used to heat up the water, and 86.5 percent of the energy ($970/1,122$) is used for evaporation.

Evaporation greatly decreases the needed frequency for the handling and hauling of wastes and reduces cost. However, this method's limita-

tion becomes apparent when a manufacturer must increase the number of cleaning cycles per day. Many evaporators have very limited capacity for evaporating the waste stream; some are as low as five gallons per hour. They become even less efficient as the sludge buildup increases in the holding tank.

When multiple production lines are being serviced, this limitation can quickly create a bottleneck that affects production and extends cleaning cycles by allowing solder paste and epoxies to be exposed to the air and dry out. The evaporator itself can also be negatively affected by running at maximum capacity, increasing the need for maintenance.

Another drawback of evaporation is its high-energy use. Electrical immersion or panel-mounted heaters are typically used for evaporative processing, and these heaters consume considerable electrical power for extended periods of time.

Evaporating wastewater also requires downtime. As a facility becomes busier, it will outgrow the evaporator's capability to keep up with the increased volume, energy costs will increase and more downtime will be needed to service the equipment.

Additionally, the water vapor produced by evaporation cannot be vented to the work area, so ducting must be installed to vent the vapor to the outdoors. This ducting can be expensive in terms of installation, materials, permits and compliance with local and state codes.

With evaporation, almost all water is ultimately converted to water vapor, so this method does not conserve water, which may be an issue in geographical areas where water is costly or in limited supply.

During the process, in the most common evaporator system, the wastewater is fed into the main evaporator tank in either a batch or continuous mode (automatic fill). The water is then heated to boiling by a heat exchanger, which may use either electric heaters or gas-fired systems.

A blower draws ambient air into the tank and across the surface of the heated water, sweeping away water vapor as it breaks the surface. This moisture-saturated air then passes through a coalescent-style mist eliminator that removes oil mist and

droplets; only steam is allowed to pass through. This steam is then released up a stack for ventilation outdoors.

Free oils and oils whose emulsions have been thermally broken are removed separately to an external waste receptacle. Precipitated solids settle to a sloping trough and are removed via a clean-out port.

For small batch processing, evaporation may be acceptable in the short term, but its chief disadvantages remain zero water conservation and high-energy requirements. Gas-fired evaporative systems, while still energy hungry, reduce the electricity usage demand, but are subject to the availability of gas utilities.

The disadvantages of evaporation are really only of concern with higher volumes of wastewater generation. In such cases, closed-loop recirculation and filtration should be considered.

Closed-Loop Recirculation

Closed-loop recirculation can handle higher volumes of wastewater and also accommodate production growth. This method saves water and energy, is self-contained and cost-effectively removes wastewater contaminants for disposal in an appropriate landfill. Closed-loop recirculation also offers minimum downtime. Often, the filtration media can be exchanged without interrupting production, and the only real cost is that of the media.

In a closed-loop system, rinse tank water is constantly recirculated through various filtration media. These media operate in succession, first trapping particulates down to a certain size, then using activated charcoal and possibly ion exchange media to remove dissolved contaminants and heavy metals such as lead. These media return high-purity water to the rinse chamber on a constant basis. Sometimes, heaters are used to maintain the water at a desired temperature so that when it is returned to the rinse tank, it is at the same temperature as the water already in the tank.

Sensors and instrumentation such as a refractometer can be used to monitor contamination levels in the rinse water and alert the operator when the levels rise beyond preset levels, indicating that a filtration media change is necessary. Sensors can be added to monitor water levels and automatically add makeup water as needed or alert operators of a low water level.

One closed-loop system uses a three-stage filtration system to clean the wastewater and then store the filtered water for reuse. This approach eliminates the need for wastewater to be sent to an evaporator or to a collection point every day. With regular replacement of filter cartridges, the water stored in the reservoir can be used indefinitely. Some users of this system have operated over six months without changing the rinse water and reported no problems in production or with the quality of their rinse water.

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Advantages to closed-loop recirculation and filtration are zero discharge of emissions; no stack emissions as with an evaporator and no continuous stream of wastewater. Users of such systems can meet the strict guidelines of ISO 14000 Environmental Management Systems.

Closed-loop recycling, including both recirculation and filtration, is cost effective in production volumes. With closed-loop recycling, the bath life of both the wash and rinse tank flu-

ids can be extended up to six months or more, depending on the application. A properly filtered wash tank using the correct chemistry can maintain its effective cleaning properties under heavy use of 20 to 30 stencil cleaning cycles daily with only monthly changing of filter elements and replenishing fluids lost to evaporation as needed.

Closed-Loop Operation/Costs

In the closed-loop system, two separate filtration and recirculation processes occur. The first process is for the wash tank, which contains a proprietary cleaning chemistry. This water-based chemistry is recirculated, with particulate filtration and particle traps to remove any solid particles such as solder and dried flux.

Eventually this solution becomes contaminated, and it must be drained and disposed of as liquid hazardous waste. Current users find it necessary to exchange this chemistry once every six months, or twice a year. The disposal cost is approximately \$350 for each change out. In contrast, stencil cleaners without on-board filtration and recirculation typically need their wash tank fluids changed every two to three weeks.

The second process is for the rinse water tank, which has a separate recirculation system with three-stage filtration. In the first two stages, spun-bond polypropylene filtration media remove solder particles and some organics. In the third stage, carbon powder filtration media remove the remaining organics.

The cleaning chemistry passes through the filtration media and is not removed by it. After months of operation, enough chemistry gets into the rinse water to raise its concentration level such that the water is no longer rinsing effectively. At this point, the rinse tank is drained and refilled with fresh water. The old rinse water is mixed with fresh chemistry in the proper dilution and used to refill the cleaning tank at its change out. In this manner, only the cleaning tank chemistry is disposed; the old rinse water is reused for another six months as cleaning tank chemistry. Current users change their rinse and wash tanks simultaneously every six months, reducing downtime and waste haulage costs.

No ion exchange filtration media is used because deionized water is not

needed for stencil cleaning. Any small amount of lead contaminants in the mix is properly disposed of when the wash tank contents are hauled. These contents typically constitute a single 55-gallon drum of waste or less. Currently, liquid hazardous waste haulage ranges from about \$200 to \$350 per 55-gallon drum, depending on the area and the disposal company being used.

The cost of the filter change out every six months is as follows:

- wound fiber filters: \$5 to \$10 each
- thermally or spun bound filters: \$7 to \$15 each
- carbon filters: \$20 to \$25 each.

As a comparison, one evaporator model evaporates wastewater at 15 gallons per hour (gph), using LP gas at 2.13 gph. The LP gas costs approximately \$1.25 per gallon, so $(2.13 \times 1.25) \div 15 = \0.1775 per gallon of wastewater evaporated.

Electric evaporation uses approximately 62.5 kW per hour at \$0.12 per kWh, so $(62.5 \times 0.12) \div 15 = \0.50 per gallon of wastewater evaporated. Clearly, the electric cost is almost eight times that of the natural gas, which itself is still more costly than simple closed-loop operation with an inexpensive filter change out every one to two months and liquid change out every six to nine months.

Closed-Loop Recycling Example

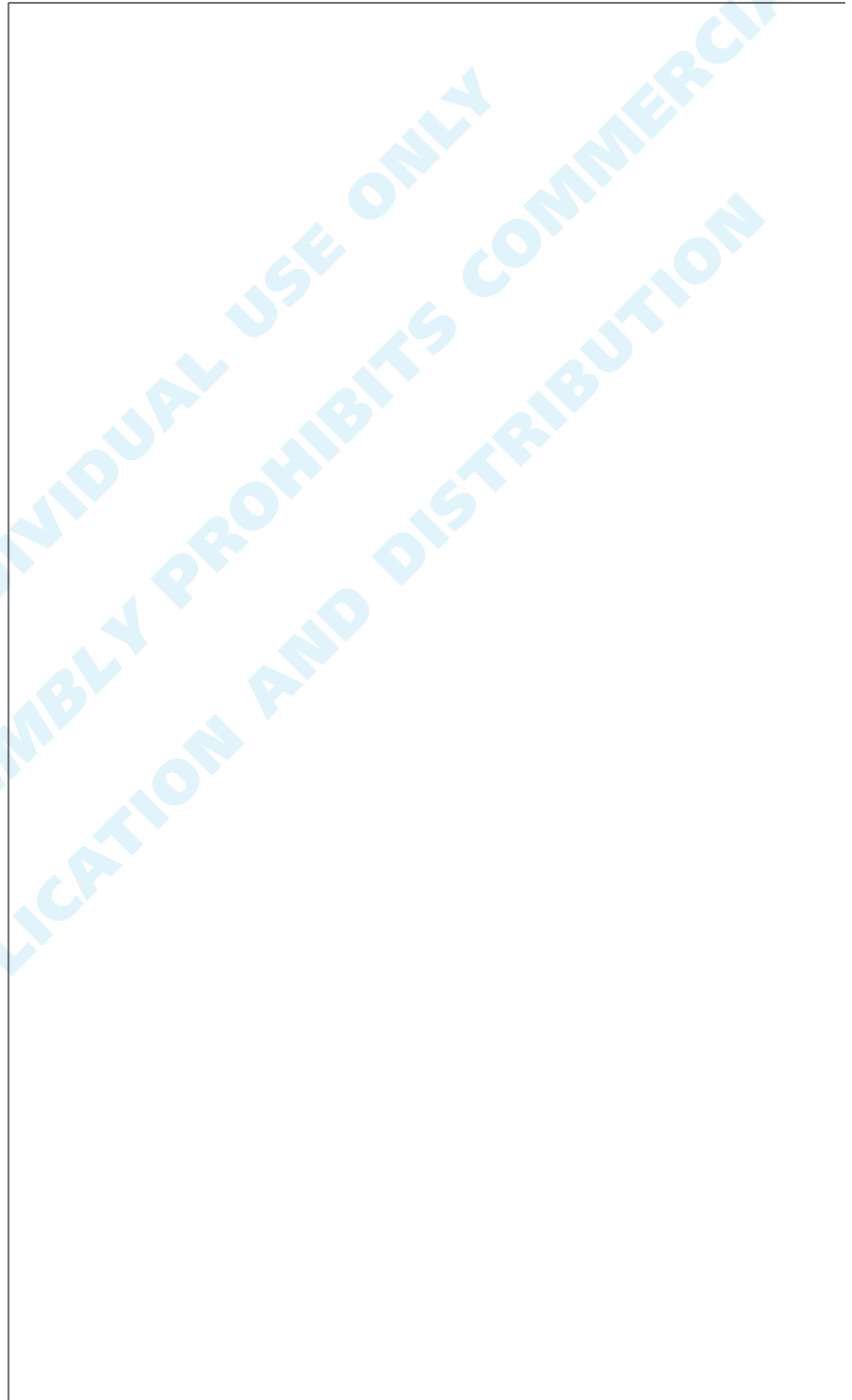
As an example, an ultrasonic stencil cleaner has a closed loop recirculation and filtration (RFS) system for the wash tank fluids that is internal to the cleaner (Figure 1). This RFS system filters and recirculates the wash tank fluids using aqueous cleaning chemistry. It includes a solder trap with a stainless steel mesh filter that separates out the larger solid particulates and a 5-micron polypropylene fiber-wound filter that filters smaller solid particulates and water soluble particles.

In stencil cleaning, as opposed to PCB cleaning, ionic contamination is not as critical, because the stencil is only used as a mask to transfer the solder or other media to the PCB. The stencil is not, obviously, populated with sensitive components or running different voltages or other conductive signals on it like a PCB. Thus, the wash tank fluids are filtered so that they do not become loaded with contaminants. When the wash tank fluids are saturated with contaminants, they

lose their cleaning power and effectiveness, and they must be replaced.

Additionally, filtering minimizes or eliminates cross-contamination. Any contaminants that are not removed during the wash cycle can be removed during the rinse cycle, or they will evaporate off during the drying process.

Figure 1 depicts the plumbing and filter arrangement of the closed-loop system. It includes two machines that are connect-



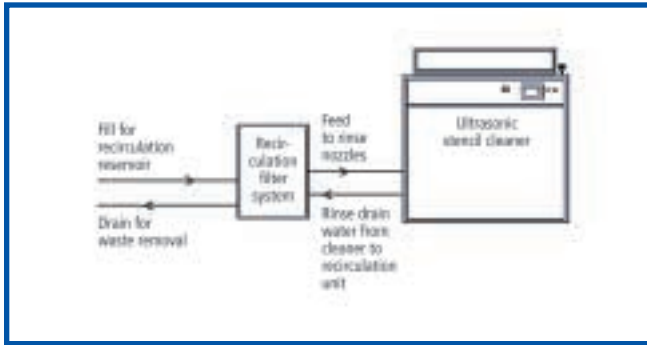


FIGURE 1: Closed loop recirculation and filtration (RFS) system of an ultrasonic stencil cleaner.

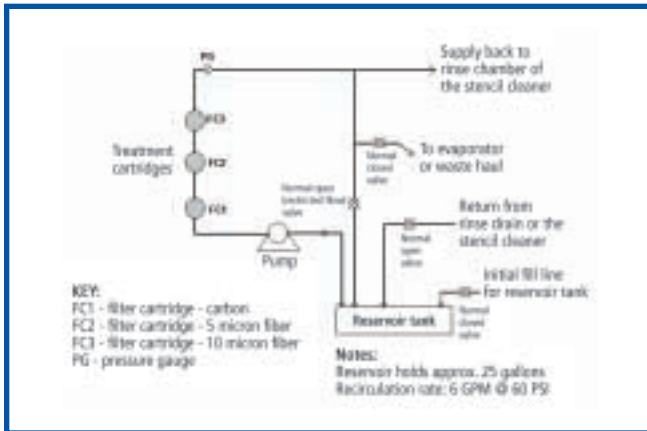


FIGURE 2: Detail of recirculation machine.

ed together to form the closed-loop process: the ultrasonic stencil cleaner and the recirculation filter system. A fill line for the recirculation system is used for the initial filling of that machine, replenishing fluids lost to evaporation, or replenishing fluids carried out with the stencil when it is removed from the cleaner. A drain line for the recirculation system empties the machine when the fluid needs to be changed, about once every six to nine months.

Figure 2 depicts the recirculation machine in detail. The three-stage filtration treatment cartridges include two thermally bonded micro filters and a powdered activated carbon (PAC) filter. This line permits use of an evaporator for those few times a year when the tank fluids must be dumped. The costs to evaporate are comparable to waste haul removal, but afford the user in-house control. Then, the user may only have a few pounds of sludge for disposal once or twice a year.

Also shown in Figure 2, the 25-gallon reservoir tank holds the rinse water and the pump supplies both the spray pressure and recirculation power. A solenoid valve (not shown), located within the stencil cleaner machine, controls the water from the recirculation machine to the rinse chamber. When the valve is open, it allows water to be drawn from it and sprayed into the rinse chamber. When the valve is closed and the RFS machine is running, the water in the reservoir tank will cycle through the three-stage filter system continuously for about six minutes, which is long enough to recirculate the entire tank contents

four times. Any water that accumulates in the rinse chamber of the stencil cleaner is allowed to free flow back into the RFS reservoir tank.

The closed-loop system (Figure 1) uses a spray rinse chamber that produces between two and 10 gallons per rinse cycle, depending on the cycle length and the spray pressure. Typical rinse cycle time for a stencil cleaner is about one minute, which produces four to five gallons of wastewater. A 30-second cycle generates about 2.5 gallons, whereas a two-minute cycle generates 10 gallons. An adjustable ball valve controls the output pressure to the spray and also affects the total volume of water that is generated over the length of the cycle.

Conclusion

Until now, the electronics industry has accepted evaporation as the preferred method of handling the aqueous waste stream, believing it to be the most environmentally friendly solution available. However, evaporation has several disadvantages.

While evaporation does remove most of the bulk contents of the waste stream, it still requires waste haul removal of the sludge that is left behind. Evaporation consumes a great deal of energy at a time when energy costs are rising and supplies in some areas are falling short of demand. With evaporative systems, vapors are emitted up a vent stack into the atmosphere, and the systems themselves become less efficient the more they are used. Additionally, evaporators are more expensive to buy than many closed-loop recycling systems and typically have more extensive installation requirements than closed-loop systems.

Most closed-loop recycling systems run on low power and typically only a few minutes every hour. In contrast, an evaporator consumes a lot of electricity and runs continuously, often 24 hours a day. The energy costs associated with closed-loop recycling are much lower, and the water savings can be considerable, depending on local costs.

The largest expense associated with closed-loop systems is the filtration media. However, filtration media can usually be sourced from several suppliers. Typically, the media are inexpensive and only need to be changed every one to two months.

When properly used and maintained, a closed-loop recycling system with a 25-gallon reservoir only needs to have the reservoir contents changed two to three times per year. These systems can handle the rinsing requirements of 20 to 25 stencil cleaning cycles per day, resulting in the annual disposal of little more than one 55-gallon drum of wastewater. This small amount of wastewater can be then sent to a local incinerator or to an evaporator.

When the total environmental impact of an evaporator is compared with that of a closed-loop recycling system, factoring in waste stream residuals, emissions and energy consumption, the closed-loop recycling system is a more environmentally friendly choice for handling an aqueous waste stream. ■

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