Water Management Alternatives for Aqueous Cleaning

Although no-clean process technology has advanced and gained widespread acceptance, the decline in aqueous cleaning seen in the mid-1990's has, to some degree, reversed its trend. Aqueous cleaning is common in contract assembly operations, the highest growth segment of the business, and has gained acceptance in high reliability electronics. Augmenting the popularity of aqueous cleaning are the advancements made in water management options available to the end-user.

For the past several years, the viability of aqueous cleaning has not been a question. Leading equipment manufacturers have made sufficient technological advancements in pump/nozzle design and drying methods to achieve the most stringent cleanliness standards. In addition, aqueous cleaning requires fewer machine complexities than some of the alternative processes, such as semi-aqueous. The most significant issue with aqueous cleaning stems from water management. Where do I get all that water, how is it purified, and where does it go after the cleaning process? And, how is all of this accomplished within the framework of environmental responsibility?

Fortunately, the biggest problem with water management is not the lack of technology or equipment, it's the lack of process knowledge. This paper will provide a basic overview of aqueous cleaning and associated water management techniques. Although emphasis is placed on in-line cleaning of circuit boards and stencils, much of the information transfers to batch cleaning and other processes.

Process Overview

Before considering water management options, it is best to divide aqueous cleaning into two categories:

- Straight aqueous – water only, no chemical additives
- Saponified aqueous – wash water includes saponifier, detergent, or some other additive

The straight aqueous process is ideal for removing organic acid, water-soluble fluxes. Water, especially deionized water, is a powerful polar solvent, and it will remove polar contamination like the acid residue left behind after soldering. Water alone, however, will not remove non-polar contamination such as the sticky rosin in rosin-based flux (R, RA, or RMA). Without adding a non-polar component to water, potentially harmful acids and particulates will be trapped by the rosin and could eventually degrade the electrical characteristics of the circuit board. (Note that even no-clean flux is cleaned in some processes). The most common additive used is a saponifier, which is an alkaline detergent with surfactants that will solubolize rosin into a water-soluble soap that can then be rinsed off with water. This process is significantly more complex than straight aqueous, and these complexities translate to water management techniques as well.

Water Management of the Straight Aqueous Process

An in-line cleaner used in this process typically features a prewash, recirculating wash (with tank), recirculating rinse(with tank), final rinse and dry. The purest water used in the process (from whatever source) enters the system in the final rinse and cascades to each previous section, finally exiting to drain at the prewash. Thus, the product to be cleaned enters the prewash, where gross contamination is removed to drain. A high-pressure wash follows, and the board moves through progressively "cleaner" water until it reaches the dry section. Ideally, water in the final rinse is pure enough (ie. it has low conductivity/high resistivity) that any residue evaporated onto the board during drying will have insignificant ionic characteristics relative to board cleanliness specifications. Cleaners typically require 3-5 gallons per minute of incoming water at approximately 140^{o}F. Incoming water should be preheated to enable the cleaner to maintain stable process temperatures and facilitate the drying process.

Often, incoming water is treated with carbon ion-exchange to provide a level of deionization commensurate meeting desired board cleanliness levels. Water that goes into a cleaner, must come out of it so, in an "open loop" system, 3-5 gpm of heated water goes down the drain. Naturally, a number of variables are involved in determining cost of this type of operation, such as:

- Quality of incoming tap water
- Municipal water and sewer charges
- Cost to heat water (electricity or gas)
- Frequency and cost of regenerating DI tanks

Various cost models exist, but based on 2,000 hours of operation per year, an open loop DI system (granular activated carbon (GAC), anion, cation, mixed bed) can cost in the range of $35-40,000. Water management techniques to make the process more efficient, effective and environmentally responsible include:

- Heat recovery through use of a heat exchange system
- Complete recycle without pretreatment of incoming water
- Complete recycle with pretreatment of incoming water

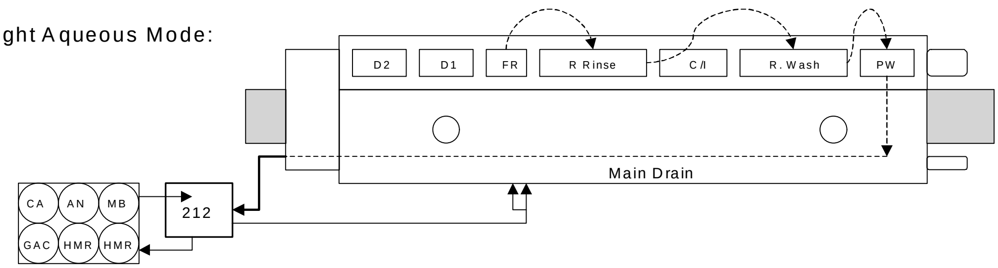
The decision of whether or not to recover thermal energy from drain-bound water is almost trivial in nature. Sending heated water to drain is equivalent to sending money down the drain. A heat recovery system takes hot water exiting the cleaner and runs it through a heat exchanger to recover much of the thermal energy. In an open loop system, this energy can be used to heat fresh incoming water, or, in a recycle system, can heat water returning to the prewash. Capital investment for a heat recovery system is such that favorable economic payback can usually be realized in a relatively short period of time.

Complete recycling in a straight aqueous system reduces water usage by approximately a factor of 10 and eliminates the ongoing waste stream (3-5 gpm). Water usage is limited to make-up water for evaporative and exhaust losses, and dragout. Several configurations are available, but most involve a recycle system (tank, recirculation pump, control system), a media tank set and a booster heater. Effluent from the cleaner's main drain feeds the recycle system, either by gravity or from a transfer station. The central unit provides pressure to push the effluent through the media tanks, the booster heater, and back to the final rinse. State-of-the-art media sets include the ability to isolate heavy metals (the HMR process) such as lead and copper, and retain them for disposal by a licensed waste hauler. Deionization occurs as the water flows through granulated activated carbon (GAC), cation and anion tanks. This basic system will typically achieve resistivity in the range of 1-3 meg-ohms. Additional deionization can be obtained by adding a mixed bed tank (anion and cation in one tank), which will result in water approaching the highest level of DI at 18.2 meg-ohms. Most circuit board cleaning applications can be accomplished with a basic media set. In summary, complete recycling of the straight aqueous process results in dramatic reduction in water usage, savings in energy costs, and eliminates process water from going to drain.

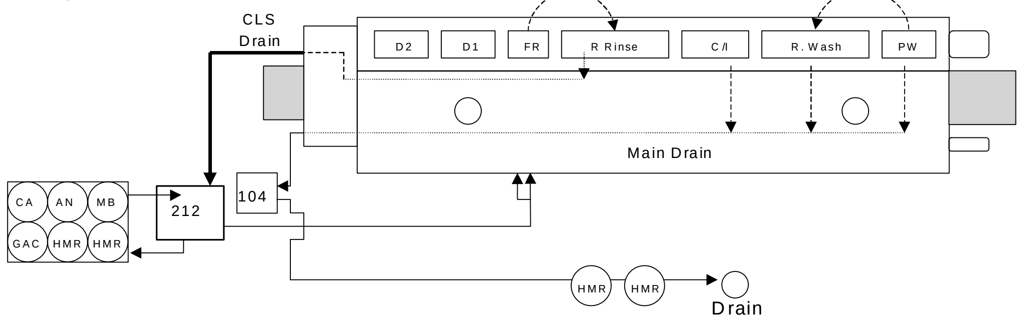
Media tanks need to be regenerated when their ability to deionize water drops below a predetermined level. This will be affected by the amount of flux and contaminants inherent in the process, and the quality of incoming make-up water. In many cases, incoming tap water has a high level of total dissolved solids (TDS), which will increase the burden on media tanks and increase regeneration frequency and costs. To address this problem, incoming make-up water can be filtered and purified by a separate reverse osmosis (RO) system. This process takes the water stream and forces it through membranes. As the stream splits, a portion goes through the membrane and some is used to keep the membrane clean. Product water typically has a resistivity of 25,000 to 500,000 ohm-cm, which is significantly better than 2,000 to 3,000 ohm-cm of tap water. The waste stream can be directed to drain, since no contaminants were added to it. Again, several cost-payback models exist, but, in general, the addition of RO to the recycle process makes sense when tap water quality is poor.

The following schematics depict common process alternatives for a single cleaner. Diagrams A and B show the straight aqueous process, and diagrams C and D the saponified process which will be reviewed next.

A. Straight Aqueous Mode:



B. Saponified Aqueous Mode:



Water Management of the Saponified Aqueous Process

In saponified aqueous cleaning, both machine and water management techniques increase in complexity. Because saponifier, or any other chemical additive, is costly, it is desirable to recirculate the chemistry by closing the prewash drain and directing the flow back to the wash tank. Thus, the prewash and wash combine to make one larger wash section. In addition to the cost factor, saponifier is highly ionic in composition, so it cannot be left on the circuit boards, and it will have an immediate detrimental effect on the life of media tanks.

A well constructed cleaner will be designed to minimize dragout of saponifier into subsequent sections of the cleaner. Different equipment manufacturers have different techniques, but one of the most effective is to utilize an interstage rinse between the wash and recirculating rinse (sometimes called chemical isolation) that floods saponifier off the board, and uses an airknife to squeegee it off. The cleaner will have not one effluent stream, as in the straight aqueous process, but three:

- Wash tank - when the tank is drained
- Interstage rinse - ongoing, approx. 1 gpm
- Rinse – ongoing process stream of 3-5 gpm

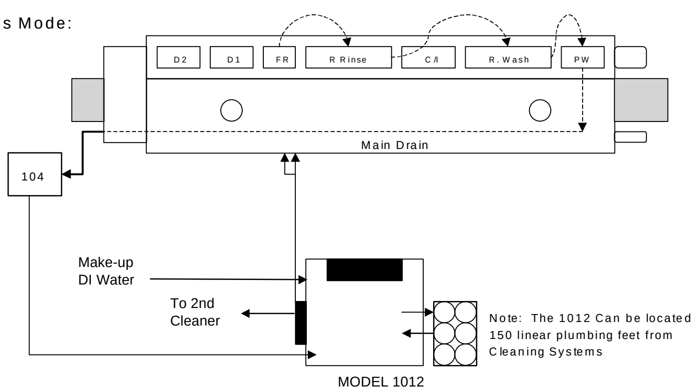
The rinse stream, in effect, becomes a straight aqueous process loop and can be recycled by conventional means. The interstage rinse stream will have residual saponifier and, possibly some lead content. In some municipalities, the level of contamination is low enough that this stream can be sent to drain. Where regulations are more stringent, this stream (and the wash stream) must be treated by drain media to remove heavy metals. (Note that some local regulations will require additional pH treatment, or possibly evaporation to achieve compliance. Local regulations must always be understood when specifying a water management system).

The same argument for RO pretreatment of incoming water applies to saponified aqueous cleaning (see diagram D).   Potential benefits of RO are augmented since purified water is supplied not only to the ongoing rinse process stream, but also to the interstage rinse.

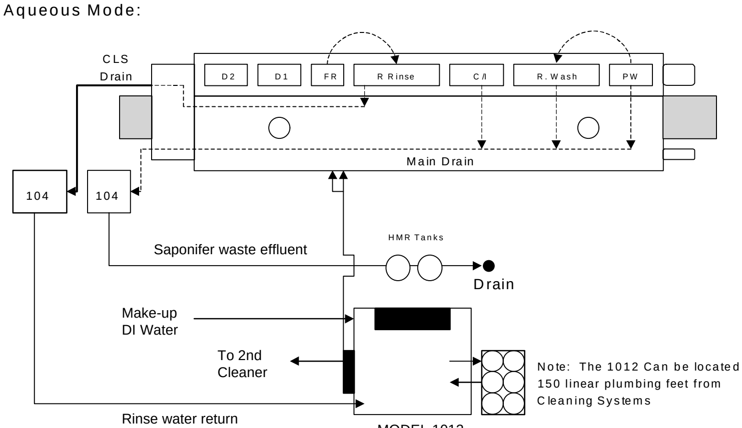
Water Management with Multiple Cleaners

In production situations where dual or multiple cleaners are utilized, the potential cost benefits of heat recovery, recycling and recycling with RO are increased. High capacity systems are now available to support up to four cleaners from one central unit. On the following pages are schematics showing a system that supports one or two cleaners, and a super-high capacity system that can support up to four cleaners. In all cases, the water management techniques are similar to those previously reviewed.

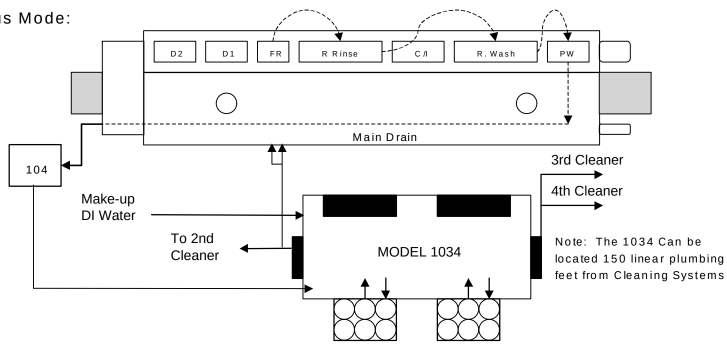
A. Straight Aqueous Mode:



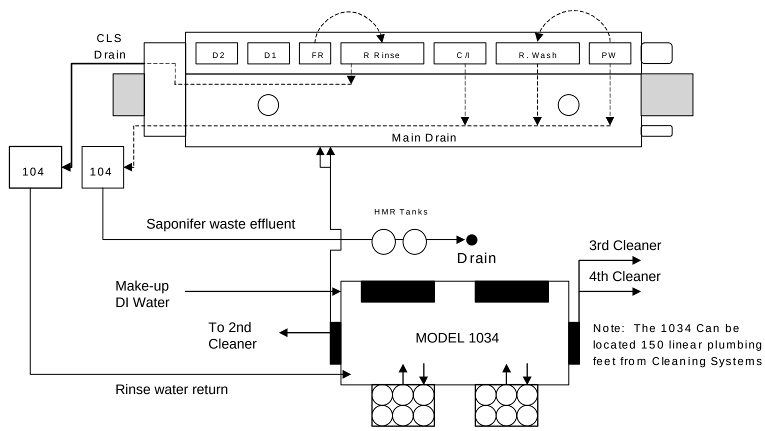
B. Saponified Aqueous Mode:



A. Straight Aqueous Mode:



B. Saponified Aqueous Mode:



Note: The 1034 system is also available with high capacity RO capability in lieu of supplying DI make up water.

Keys to Success with Recycle Systems

As with any production situation, process monitoring, equipment maintenance and common sense are keys to success with recycle systems. The most frequent complaint with recycle systems is the length of time between regeneration of resins. This period of time depends on a number of variables including, volume of water processed (directly related to run time), quality of incoming water (which can be greatly improved by using RO pretreatment), and amount and type of contaminants introduced to the process water. Anything ionic in nature is going to burden the resin beds. Likewise, organic matter can plug up GAC tanks. Therefore, when possible, contaminants added to the process should be avoided. A common problem area is the use of water soluble tapes and masks. The manufacturer of these materials should be consulted for information regarding impact on the carbon ion exchange process.

Many times a perceived reduction in media tank life is due to an increase in production hours or board volume. The more water and contaminants processed, the faster tanks will need regeneration. A log of cleaner run time and board volume should be kept for the first few months after implementing water management to determine a baseline of operation. Thereafter, audits can be performed to see if any changes have occurred.

Another key to success is following the equipment manufacturer's instructions for safe, compliant operation. This is especially important in regard to HMR (heavy metal removal) tanks. These tanks must be taken off line at the recommended intervals and disposed of by a licensed waste hauler. Failure to do so can cause lead break-through into subsequent media tanks.

Effluent Treatment for Stencil Cleaning

Another opportunity for water management has arisen in recent years with the increased popularity of surface mount technology. Most surface mount operations involve applying solder paste to boards using stencils. In recent years, several aqueous-based machines have come to market that offer a safe, effective means of cleaning stencils. The problem with these systems is the effluent from them is contaminated with lead and is typically high in pH. Both of these characteristics preclude compliant release to drain.

An effluent treatment system is available specifically to aid in regulatory compliance in the stencil cleaning process. This unique system receives effluent from the stencil cleaner(s) and provides for pH adjustment and removal of heavy metals. The Heavy Metal Removal process removes particulate and solubilized lead and other heavy metals that might be found in the effluent. As with water management in in-line cleaner applications, the HMR tanks must be disposed of properly by a licensed waste hauler.

Benefits of Recycling and Water Management

Utilizing any or all of the techniques discussed will yield tangible benefits, such as:

- Cost reduction due to:
    - Reduced water usage
    - Reduced energy consumption
    - Reduced (or eliminated) sewer assessments
    - Improved consistency of the cleaning process
- Aid with environmental compliance
- Improved company reputation for being "environmentally friendly"
- Improved operator safety (no exposure to lead in stencil cleaning)

Realizing these benefits depends upon a good understanding of water management techniques, strong engineering of equipment, and partnership with a vendor who provides the service and expertise to ensure success.