New Water Management Techniques for the Aqueous Cleaning Process

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Generally, there are two motivations for changing a production process, quality improvement or cost reduction. In some fortunate circumstances, a change may achieve both. With aqueous cleaning, however, there are often other requirements, such as regulatory compliance or environmental responsibility that dictate change. Unfortunately, these opportunities are often viewed as complex problems due to lack of understanding of the latest water management techniques.

Following is a basic overview of the latest aqueous cleaning and associated water management techniques. Although emphasis is placed on in-line cleaning of circuit boards, much of the information transfers to batch cleaning and other processes.

Water management techniques involve several considerations, the most obvious of which are:

1. How much incoming water is needed?
2. What is the temperature requirement?
3. What level of purity is required (deionization, dissolved solids, softness, etc)?
4. Does the wash process use chemical additives (e.g. wash chemistry)?
5. And finally, where does the effluent go?

With the above in mind, it is best two divide the aqueous cleaning process into two categories when considering water management techniques:

- Straight aqueous – water only, no chemical additives
- Modified aqueous – wash chemistry (detergent, biomass-derivative, etc.)

The straight aqueous process is ideal for removing organic acid, water-soluble fluxes and “non-sticky” particulate matter. 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. 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 some processes include cleaning of no-clean fluxes as well. Generally, these require a wash additive for removal). Wash chemistries include alkaline detergents with surfactants that will solubilize rosin so it can be rinsed off with water, biomass alcohol derivatives, and other “proprietary” chemicals. Although this process is significantly more complex than straight aqueous, water management techniques are now available to treat all phases of the process.

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 enters the system (from whatever source) in the final rinse and cascades to each previous section, finally exiting to drain at the prewash. The circuit board moves through progressively “cleaner” water until it reaches the dry section. Ideally, water in the final rinse is pure enough (i.e. 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°F. Incoming water should be preheated to enable the cleaner to maintain stable process temperatures and facilitate the drying process. The diagram below illustrates a typical, straight aqueous recycle system.

**SIMPLE FLOW DIAGRAM**
**STRAIGHT AQUEOUS PROCESS**

Often, incoming water is treated with carbon/ion-exchange to provide a level of deionization commensurate with 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. Failure to recapture heat 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 effluent through the media tanks, booster heater, and back to the final rinse. State-of-the-art media sets include the ability to isolate heavy metals such as lead and copper, and capture 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, although most processes don’t require these levels.

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 or make-up water requirements are high.

**Water Management of the Modified Aqueous Process**

As previously stated, both cleaning system and water management techniques increase in complexity. Because chemical additives are 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 are combined to make one larger wash section. In addition to the cost factor, wash chemistry may be highly ionic in composition, so it cannot be left on the circuit boards. It will also have an immediate detrimental effect on the life of media tanks.

Different equipment manufacturers have different techniques to minimize chemical dragout, but one of the most effective is to utilize an interstage rinse between the wash and recirculating rinse (sometimes called chemical isolation) that floods cleaning chemistry 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 – 1.5 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 cleaning chemistry and, possibly, some lead content. In some municipalities, the level of contamination is low enough that this stream can be sent to drain. Where treatment is required, or desired, a new recycling technique is available using a proprietary process. Alternatively, interstage effluent may be treated for pH and heavy metals, then directed to drain. Note that local regulations must always be understood when specifying a water management system. The diagram below illustrates a typical chemistry cleaning/recycle process.

The same justification for RO pretreatment of incoming water applies to modified aqueous cleaning. 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. State-of-the-art cleaner manufacturers power cascade the chemical isolation water from the recirculating rinse tank. This approach improves the integrity of the chemical isolation supply (quality and temperature), but places a higher demand on the rinse water recycling system. RO pretreatment is ideally suited for this water management technique.

Multiple Cleaner Applications

In production situations where 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.

Successful Water Management Techniques

As with any production situation, process monitoring, equipment maintenance and common sense are keys to success with water management. 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. 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 after implementing
water management to determine a baseline of operation.

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.

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”
- Enhanced product quality

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