# In Situ Recycling of Cleaning and Rinsing Fluids to Meet Lean & Green Cleaning Process Targets

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**INTRODUCTION**

Recycling cleaning and rinsing fluids in the manufacturing process is becoming very popular for many reasons. Competitiveness is the key issue as the electronics industry ages. In our golden years, paying attention to the expenses is very important in managing the bottom line. Up to 50% of the monthly utility bills to run the manufacturing line can be related to cleaning the product[1]. Implementing fluid recycling can feed the savings and align management with a positive environmental impact and improved employee health and safety. Accelerating this change is management's awareness of new and proposed government regulations to protect the work force and the environment. The purpose of this paper is to provide an understanding of how to achieve these targets at the lowest possible cost.

Choosing the best recycling system requires knowledge of the cleaning process and current available recycling technologies. Recycling systems can be specific to a cleaning fluid type. In some instances, the cleaning fluid can be changed to a more recycling friendly fluid. Fluid properties such as alkalinity or flammability can complicate the selection process. Understanding the cleaning process, the fluids used, and appropriate recycling technologies available is very important in selecting a lean and green cleaning process that meets the planned corporate targets.

In situ machine recycling has become the new standard for new cleaning systems. These systems recycle the cleaning fluids in the machine versus sending the fluids to a remote location in the plant or to a third party recycler. These systems can be built into new or existing cleaners. Recycling the cleaning fluids within the cleaner, almost always gives the lowest cost due to reduction of logistics, storage, transport, and third party charges. A cost model should be used to evaluate the choices and select the best options for your cleaning process. To better illustrate the decision process, A cost model is evaluated to compare an open loop aqueous inline cleaner, a remotely located closed loop inline and a in situ closed loop inline. The cost model with field data is used to estimate the cost savings of recycling for each system.

**Setting Cleaning Recycling Targets**

The business of recycling remains mostly voluntary, with few government imposed rules or quotas. Most laws focus on restricting regulated pollutants from entering air, soil and water. Huge fines and penalties have been levied against corporate offenders for polluting. This punitive approach keeps honest corporate officials wary of drawing public attention to poor environmental practices. A corporate recycling strategy helps avoid these areas of concern even though recycling is not mandated with government action. A corporate recycling strategy should therefore focus on areas of concern specific to their business that uses the most material and utility resources. In most cases, the cleaning processes are top candidates.

Today, everyone wants to jump on the recycling bandwagon and spread the "feel good" to employees and customers alike. This makes good marketing and public relations fodder, but in the end it is only a fading fad if it does not provide real and sustainable advantages to the company and consumer. Consumers ultimately want a lower price with their "feel good" and corporate managers want more profit with their "feel good". Oddly enough, both are achievable if common sense prevails. Example; hybrid cars are becoming ubiquitous and are purchased for two reasons; some individuals purchase them because they want to be "green" and help the environment, others acquire a hybrid vehicle because they provide a payback with fuel savings. Side note; few people buy because of government directives. Those who buy to help the environment receive a monetary reward, and those who seek a monetary reward receive a bonus of helping the environment. Therefore, corporate recycling targets should be set for conserving our resources as well as for monetary payback.

**Resource Savings Pay for Recycling**

The number one driver behind the market shift to solvent recycling is saving money. This allows companies to provide a lower price or the possibility of a higher margin. Imagine this; there are two projects in the capital meeting; one reduces cost and one may avoid government fines. The savings of the first are real and predictable and in the second the possibility of fines and penalties hinges on government legislation and enforcement. Most companies will go for the real saving because we know that natural resources like water and oil are not likely to be going down in price wereas the government direction can change with an election or the stroke of a pen. The best solvent recycling target to shoot for is to achieve the maximum saving. Follow the money and start by determining how much your company is spending on cleaning resources such as power and cleaning chemicals. Look at the whole picture including chemical costs, power, DI columns, waste treatment or waste management logistics.

On today's production line, the rapid shift to cleaning fluid recycling is being justified by economic savings alone. Cleaning is the most resource-intensive process on the assembly line. The cleaning operations alone can consume over 50% of the total chemicals, water and power resources needed to manufacture an electronic device. Setting specific reduction targets for chemicals, water and power depends largely on the type of cleaning system currently being utilized.

To get started, conduct a resource consumption survey of the cleaning processes to establish what materials and utilities are needed and the rate they are being consumed. Consider strategies to save and reuse chemicals, water and power and to prepare a cost model to estimate the cost of implementation and the expected payback. Go for the low hanging fruit. Close looping a water-based system can save 99% of the water consumed and 25% of the operating power. Close looping a solvent system can extend solvent life 5-10X, reducing material, maintenance and disposal costs. Organizing these thoughts and developing a fact-based cost model helps set realistic targets to save money, save the environment and feel good about both.

**What Can Be Recycled in a Circuit Cleaning Process?**

Just about all cleaning agents can be recycled to save the company money and resources. This includes water, aqueous mixtures and most organic solvents and solvent blends. Water is the least expensive and the most often used cleaning fluid. An aqueous-based cleaner without a recycling system uses 1 to 5 gallons of water to clean a circuit assembly each time it is cleaned, and it may be cleaned multiple times. Organic solvents can be recycled as well. They are typically used in lower volume, but cost more per gallon. Energy required to heat or boil the fluids can also be recycled. In short, most cleaning fluids can be recycled using one method or another. The key to unlocking the recycling savings is to identify and understand the solvents being used and the soils being cleaned and choosing the recycling system best suited for the application.

**GETTING STARTED**

Setting up a solvent recycling program is much like recycling at home in that the materials must be sorted into recycling streams and dealt with appropriately. Cleaning fluids can be divided into 6 categories based on primary or base composition and hazards of use, such as flammability or toxicity. The basic categories of cleaning fluids are 1) water only, 2) aqueous-based mixtures and 3) organic solvents. The aqueous mixture category can be further sub-classified into aqueous mixture with neutral pH, and aqueous mixtures with an alkaline pH. The solvents are further sub-categorized based on fire safety, with classifications of non-flammable, combustible, and flammable. Once the cleaning and rinsing fluids are known, an appropriate recycling configuration can be designed. These choices are shown in table 1.

**Table 1: Choice of recycling system based on fluid type**

| Cleaning/Rinsing Agent | Absorption | Distillation | Filtration | Replenish Ingredient |
|---|---|---|---|---|
| **Water Only**<br>Tap<br>DI | Recommend | Not Used | Used | Not Used |
| **Water Mixture, Neutral pH**<br>Ionic<br>Non-ionic | Not Used | Not Used | Used | Recommend |
| **Water Mixture, Alkaline**<br>Single phase<br>Split phase | Not Used | Not Used | Used | Recommend |
| **Organic, Non-flammable**<br>Halogenated | Used | Recommend | Used | Not Used |
| **Organic, Combustible**<br>Glycol Ethers<br>Esters | Recommend | Used | Used | Not Used |
| **Organic, Flammable**<br>Alcohols<br>Light Hydrocarbons | Recommend | Used | Used | Not Used |

The four recycling technologies shown in Table 1 are the most common recycling strategies used to extend life of cleaning fluids today. Absorptive filters such as DI, activated carbon and xeolites can remove the soils and other contaminates from both pure water and organic solvent systems. Absorptive filter beds are popular for de-ionizing water and other polar organic solvents of ionic soils. Distillation remains the standard with non-flammable, azeotropic degreasing solvent blends of halogenated solvents. New absorptive materials are now available for recycling halogenated solvents alternative to distillation. Filtration is commonly used in combination with most other recycling technologies to remove solids. There are certain aqueous mixtures which allow the flux soils to form precipitates when cooled, thus allowing the soils to be effectively removed by filtration. The final category, replenishment, is a bath life-extension strategy that replaces certain agents that become depleted by chemical reactions or evaporative loss in the cleansing process. This strategy is often used with aqueous mixtures and can significantly extend bath life at fraction of the cost of a new bath.

Some cleaners with different washing and rinsing fluids may require two or more recycling approaches. A semi-aqueous cleaner, using an aqueous mixture for washing and DI water for rinsing, will require separate approaches to provide a completely closed loop system to save both cleaning agents and water. The wash could be reused for extended periods by metering replacement cleaning agent to keep a working concentration. The DI water rinse would be closed with absorptive carbon and DI filters.

Most cleaning and rinsing fluids are candidates for recycling in systems that pay for themselves with resource savings. The cleaning fluid's chemical and physical properties largely determine the best and safest approach to recycle cleaning fluids. The key to optimize recycling savings for any solvent is to understand the cleaning and rinsing fluids in combination with the soils before selecting a recycling approach.

## CHOOSING THE RECYCLING TECHNOLOGY

Solvent recycling systems allow the re-use of cleaning and rinsing fluids for many more cycles than would otherwise be possible due to solvent loading or ingredient depletion. The term "closed loop cleaning" is often misunderstood and misused. Is does not mean that waste is not generated. It does mean that the wash and or the rinse fluids are recycled and reused. Figure 1 shows a simple mass balance diagram of a cleaner with a recycling system. In this system the parts are cleaned and the soils end up in the recycling system as waste that must be dealt with.

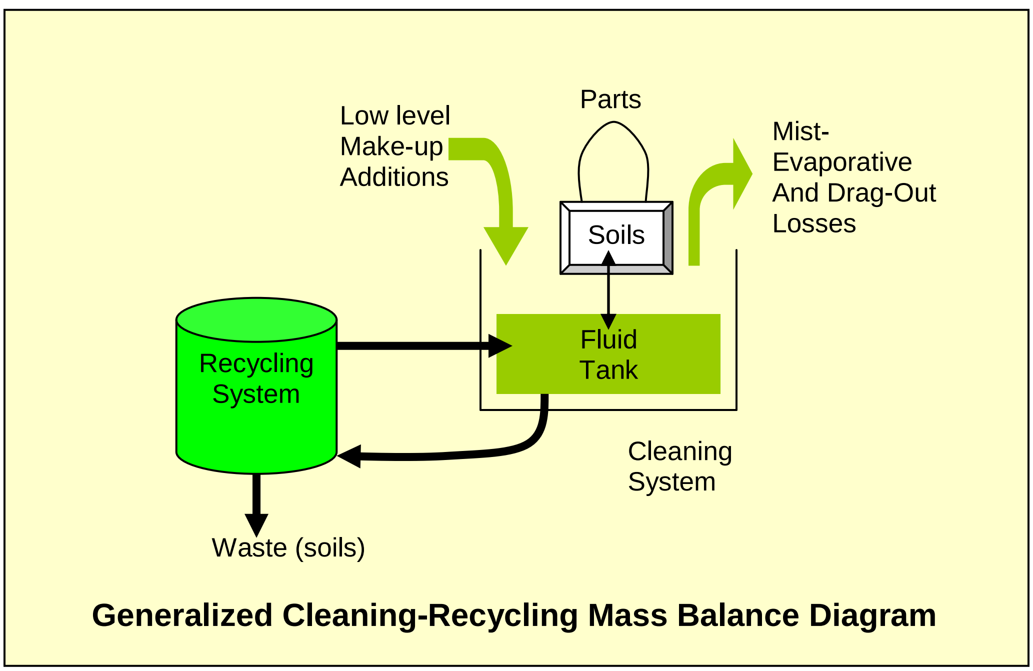


***Figure 1; Mass balance diagram of a generalized cleaning process equipped with a solvent recycling system***

The recycling system should remove the soil at a rate sufficient to remove the peak soil loading rate expected in sustained production. Evaluate the impact of all potential soils other than flux residues such as temporary solder masks, uncured adhesives or raw solder paste. Remember what goes in must go somewhere. Consider the costs and the logistics required to properly handle waste streams created in any given recycling system.

Figure 1 also identifies the low level make-up additions needed to offset the fluid losses due to evaporation, misting and drag-out of fluids by the parts, baskets, and conveyors.

**Key Ingredient Replacement**

Key component replenishment strategies have been used for many years in the electronics industry to extend the aqueous wash baths in cleaners using a saponifier or other semi-aqueous washing fluids. Replenishment systems require some form of testing to determine the key ingredient concentration. Automatic monitoring and metering systems are available from most equipment suppliers and from some chemical suppliers. Using a key ingredient replacement strategy can extend the wash bath replacement frequency significantly and in theory could run in a steady state continuously if mass balance losses in the vent and drag-out to rinse are sufficient to strike a working equilibrium. Key component replenishment has also been used to maintain non-azeotropic components of degreasing fluids.

**Subtractive Recycling Technologies**

Recycling systems that remove soils from the cleaning fluids can be referred to as subtractive recycling as opposed to replenishment recycling mentioned above. This is the most popular choice for rinsing fluids and non-ionic washing solvents. There are many types of subtractive technologies including: distillation, filtration, precipitation, absorption, ion exchange, and reverse osmosis. The subtractive recycling technologies fall into one of three basic categories based on the mechanism of removal as shown in Table 2.

Table 2: Comparison of fluid recycling methods

| **Recycle Method** | **Type** | **Used with** | **Waste stream** | **Waste disposal handler** | **System Complexity level** | **Safety concern** |
|---|---|---|---|---|---|---|
| Chemical addition | Additive Key Ingredient | 1) Reactive Aqueous Mixtures (saponifiers) | Soil loaded tank dump | Company | Technician | Medium |
| Ion Exchange | Subtractive Absorption | Rinse water Alcohols Glycols Esters | Depleted DI resins | Third party | Operator | Low |
| Carbon Absorption | Subtractive Absorption | Rinse water | Carbon media with organics | Third party | Operator | Low |
| Zeolite Absorption | Subtractive Absorption | NPB CFCs HCFCs | Zeolite with adsorbed contaminate | Third party | Operator | Low |
| Chelation | Subtractive Absorption | Water with heavy metals | Chelation media with heavy metals | Third party | Operator | Low |
| Distillation | Subtractive Distillation | NPB CFCs HCFCs | Non volatile residues | Company | Technician | High |
| Filtration | Subtractive Filtration | All fluids | Filters with contaminate | Company | Technician | Medium |
| Reverse Osmosis | Subtractive Filtration | Rinse water | Reject fluid stream | Company | Technician | Medium |

**Absorptive Recycling**

Absorptive methods involve pumping a fluid through media, typically in a tank or bed, to adsorb the soils and cleanse the cleaning fluids. The ionic purity of the fluid is usually monitored and controlled using electrical conductance or resistance. Organic loading can be monitored with COD test kits or with more practical standards such as color or process indicators such as foaming. Three type of media set are available for absorptive removal; ion exchange resins (DI resins), granular activated carbon (GAC) and Zeolite. The major advantage to absorptive systems is that they are simple to use and the waste streams are typically handled by third party professionals. DI resins are used extensively throughout industry to generate DI water. Closed looped cleaning systems using DI beds for water purification should have dual GAC and DI beds if organics are present. Many polar organic solvents such as alcohols, esters and glycol ethers, can be purified with DI resins. Non-polar organic solvents such as n-propyl bromide (NPB) and chloroflorocarbons (CFCs) can be cleansed with zeolite adsorbers.

**Distillation**

Distillation is the process in which the solvent is evaporated and the vapor is condensed leaving most of the contaminates behind in the boiling sump. Distillation is rarely used to recycle cleaning fluids because of safety concerns and compositional control of solvent blends. The one notable exception is the distillation of non-flammable, azeotropic cleaning fluids in all vapor degreasers. Vapor degreasing use has declined significantly since the early 1990's when most halogenated solvents used for vapor degreasing were restricted or banned from use as cleaning agents because of ozone depletion concerns. The distillation process is not 100% effective in removing soils as they may be volatile or carried over in liquid mist created in the boiling process. The waste residues generated in the distillation process are often messy and difficult to deal with in house.

**Filtration**

Filtration can be used as the sole method of contamination removal if all soils are insoluble in the cleaning fluids. Most often filtration is used in conjunction with other replacement or absorptive recycling strategies used to extend cleaning and rinsing bath life. The filtering system should have the right pore size to remove the insoluble soils and be sized properly for maintenance and flow. Filters should be easy to change and be equipped with pressure relief and flow isolation for maintenance purposes. The filter housing, gaskets and the filter should be compatible with the cleaning fluid used.

**Reverse Osmosis**

Reverse osmosis involves using a molecular filter in which the smaller solvent molecules are passed, but the larger soil molecules are rejected to a waste stream. This process is most often used to generate feed water to make up evaporative or drag-out losses from a closed loop cleaning system.

Selecting the right recycling method primarily depends on the type of cleaning fluids and the soils removed in the cleaning system. Both additive and subtractive, closed loop recycling methods can be used, even in the same system. Waste is generated in all closed loop cleaning systems. Waste handling, storage, and disposal responsibility are very important considerations in selecting the best recycling approach. Size recycling systems to meet the peak production demand. System safety features and ease of maintenance will help assure a rapid payback in material saving over the long term.

**THE IMPACT OF RECYCYLICING LOCATION**

The location of the recycling system is a key variable in determining both the initial cost of the cleaning system and the operational and maintenance cost when the system is installed in production. There are three options when it comes to choosing any cleaning solvent recycling location; an offsite location, somewhere else in the factory, or at the machine.

**Off-site Recycling**

Recycling cleaning fluids offsite is rarely used in the electronics industry, but is common in other industries such as the automotive repair industry where there is a significant 3rd party infrastructure to pick-up, recycle, and re-supply customers. Logistically it is difficult for the electronics industry to use 3rd party recyclers because the waste is more hazardous, lower volume, and variable. It is very common to use a 3rd party to reactivate spent DI and carbon beds from closed loop systems.

**Remote Recycling in the Plant**

This approach places the recycling system in a logistically convenient location remote to the cleaner or cleaners. A central or plant wide system is often used when multiple cleaners are present in one factory. Central DI supply systems can be modified to become closed loop by adding a return loop for cleaning systems currently discharging dirty rinse water.

The penalty of this approach is energy consumption. Transferring fluids requires energy and treated fluids loose heat when piped long distances. Cool DI water arriving at the remote DI system would need to be reheated and maintained for delivery, or if redistributed at ambient temperatures would add significant load to reheat at the cleaner.

## In Situ Recycling

"In Situ" means being in the original position; not having been moved or transferred to another location[2]. In respect to the cleaner, this means designing the recycling system into the cleaner. This approach usually cost less because it saves transfer energy and utilizes components like tanks and pumps that already exist in the cleaner.

Vapor degreasers are the most common cleaner used for cleaning electronics designed with an in situ recycling design. Solvent recycling is inherently simple when the fluid is boiled and condensed. If you selected a non-flammable, azeotropic solvent as your cleaning fluid, then a vapor degreaser may work for your application.

## AQUEOUS CLOSED LOOP DESIGN

Aqueous based cleaning mixtures require additive and absorptive technologies to close loop the cleaner. A combination of both DI and carbon is required to remove both polar and non-polar soils. In most closed loop aqueous based cleaners, an additive system is employed to make-up key ingredient losses in the wash fluid. This is not necessarily a direct replacement percent as the water evaporates at a higher rate than the chemistry.

The rinsing system is regenerated with a combination of carbon, DI and particulate filters. These DI systems can typically output a water purity of 10 to 18 megohm water.

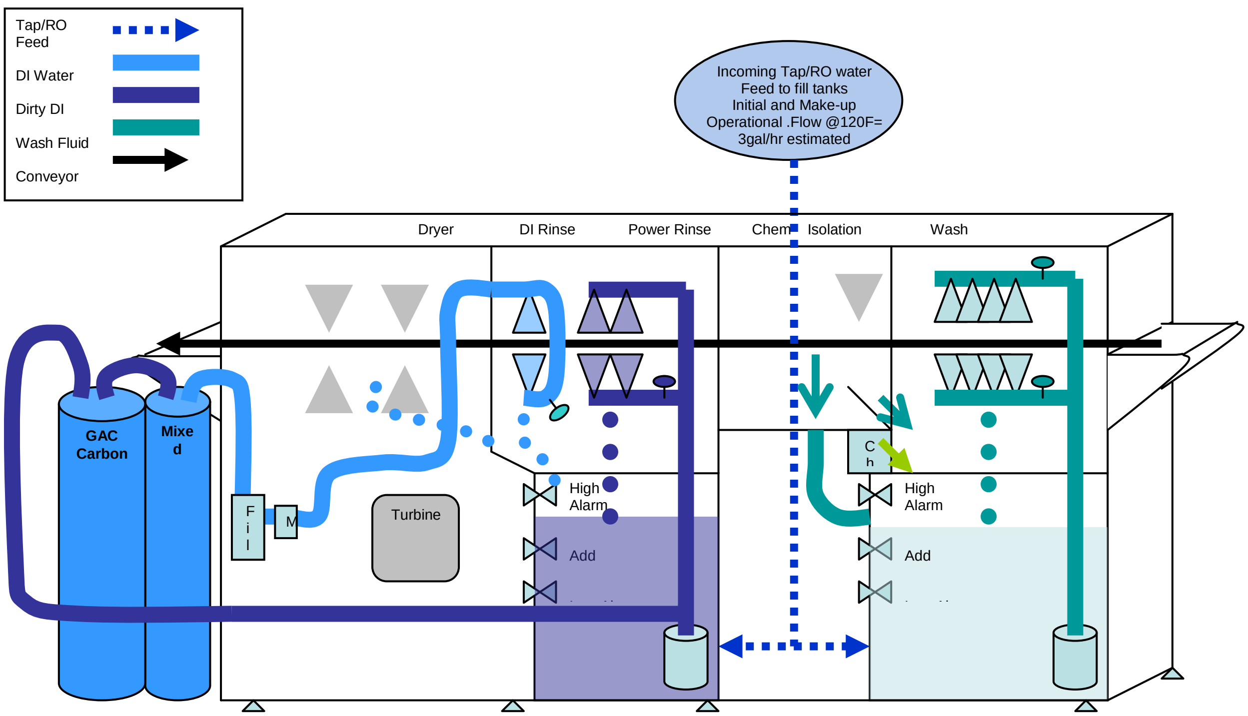


***Figure 2; Back view diagram of a situ closed loop inline aqueous cleaner.***

## GAC Media

Granular activated carbon (GAC) is recommended to remove the non-ionic compounds such as surfactants, oils and other non-ionizable materials from the soiled rinse water. It comes in several forms that depend on the source of carbon. GAC is heated and acid washed to remove acid soluble ions in the activation process. The absorptive capacity of GAC varies considerably based upon the material being absorbed and the pH of the solution from which it is taken. Data collected by Glusti, Conway, and Lawson[3], suggest that GAC can effectively remove non ionic surfactants an undissociated carboxylic acids common to fluxes as well as amines, alcohols, esters, ethers, and glycols common to cleaning agents. Table 3 List the percent reduction several of the compounds.

**Table 3 Carbon Adsorption of compounds in solution ( 1g/L)**

| **Compound** | **Mole Weight** | **Water Solubility %** | **Adsorption g soil/ g GAC (@[1g/L])** | **Adsorption % reduction** |
|---|---|---|---|---|
| 2-ethyl butanol | 102.2 | 0.43 | .170 | 85.5% |
| Mono-ethanol amine | 61.1 | ∞ | .015 | 7.2% |
| Di-ethanol amine | 105.1 | 95.4 | .057 | 27.5% |
| Nitro-benzene | 123.1 | 0.19 | .196 | 95.6% |
| Butyric acid | 88.1 | ∞ | .119 | 59.5% |
| Ethylene glycol mono butyl ether | 118.2 | ∞ | 0.112 | 55.9% |

**DI Media**

Deionizing media is made by depositing resin containing either an acid or a base on the surface of a solid pellet referred to as the matrix. DI resins can be made from weak or strong acids and based and the matrix as well as the size and number of active sites can vary. There are literally hundreds of different DI resins to choose from. When screening DI resins it is important that both the matrix and the resin are insoluble in the cleaning fluid to be deionized[4].

In the deionizing process, the contaminated cleaning or rinsing fluids passes through a column filled with a stoichiometric mixture of the anionic and cationic ion exchange media. In a stoichiometric mixture there are an equal number of H+ and OH- sites in the mixture. This is often refer to as a mixed DI bed. The H+ from the acid sites is bumped off by any cationic contaminants in the water. In a similar way, anions picked-up in the cleaning process take the place of the OH- from the base sites. The resulting H+ and the OH- ion generated then combine to form a water molecule eliminating the ions from the cleaning fluid.

GAC tanks should always precede the DI tank to remove organic materials that could coat active sites on the DI resins rendering them unusable.

**Filter Media**

Filters come in many sizes, shapes, materials and designs. The filter must be compatible with the cleaning fluids. Mono filament polypropylene spun wound are the standard when filtering both aqueous wash and rinse water. They come in pore sizes down to 1 micron. A 5 or 10 micron pore size is commonly used. Sub-micron filters may be needed if molecular sieves are used as an absorbent. Filtration is recommended in most closed loop systems to as minimum remove particles that could clog valves or nozzles. The particle filter should follow the absorptive and DI beds to protect the cleaner plumbing against media breach.

**Media Tank Selection and Sizing**

Aqueous based cleaning mixtures are heated to improve the rate of cleaning.. Absorptive tanks used to close loop aqueous cleaner should be rated at the temperature and pressure expected in the cleaning/rinsing fluids. Fiberglass tanks are usually rated to 140F at 80 psig. Stainless steel tanks are good to 210F. If non-water based solvents are to be used then stainless tanks are recommended.

Tanks can be purchased outright or, in some areas, can be rented from your media supplier. In either case, it is recommended to have a spare set of tanks available to swap out when one set expires. Plumbing them in parallel allows a quick and easy change over. Many cleaners can give warning before the tank completely expires if equipped with the proper sensors and software.


Photo 1 Fiberglass absorptive media tanks
($2.5ft^3$, $1.5ft^3$, $1/4ft^3$ shown)

Photo 2 Stainless absorptive media tank
(½ $ft^3$ shown)

**ESTIMATING BED LIFE**

The life of a closed loop system varies greatly based on factors such system factors such as soil load and type, feed water purity, and media tanks sizes. It is a self evident fact that the cleaner the feed water, the longer the DI beds will last. Some local water supplies have dissolved ionized minerals in excess of 1 gram per gallon as compared to ~0.02 grams per gallon in previously deionized dirty inline rinse water.

All absorbents have an absorptive capacity (**$Ab_{cap}$**) for a given compound, which is how much the absorbent will absorb per unit volume or mass. The amount of total absorption (**$Ab_{total}$**) possible in a given bed or tank volume (**$V_{ab}$**) of absorbent is determined by multiplying the absorptive capacity times the total volume of absorbent as shown in equation #1 below.

$$\mathbf{Ab_{total} = Ab_{cap} \text{ X } V_{ab}}$$

Equation 1; Absorptive Capacity of a given bed or tank

Given we now know what the total absorptive capacity of the tank as calculated above, we can then determine the theoretical life of the tank (**$Bed_{life}$** )by dividing the total absorptive capacity by the mass flow rate of contaminate as expressed in grams of contaminate per volume of feed liquid. The life of a given bed can be estimated by equation #2 below.

$$\mathbf{Bed_{life} = Ab_{total} / MF_{Con}}$$

Equation 2; Absorptive Capacity of a given bed or tank

Equation 2 mathematically illustrates the concept that the purer the feed stream the longer the bed will last.

Deionizing bed life can be calculated in a similar manner. The major difference is that DI absorptive capacity is calculated in equivalence per volume which is slightly different than mass per volume as described above for traditional absorbants.

When calculating the absorptive capacity for ionic soils, the ion charge must be taken into account. An ion with a single charge bonds to one site, but an ion with a double charge will take two sites on the DI media and deplete the column twice as fast everything considered equal. This relationship is expressed in equation 2 below.

$$\mathbf{DIAb_{total} = (DIAb_{cap}\ X\ \ VDI_{ab})\ /\ Ion\ Charge}$$

Equation 3; Absorptive Capacity of a given DI bed or tank

For example $CaCO_3$, this produces a +2 charged calcium ion and a -2 charged carbonate ion. So according to the relationship in equation 3, the DI resin will absorb ½ the number Di-valent CaCO3 molecules as compared to the mono-valent NaCl ions. This makes sense in that there are only so many active sites to capture a charged particle. If a particle has a charge of one it is one charged particle parked on one active resin site. Once the total DI absorbance is known for a given ion pair, the DI bed life can be calculated per equation 2.

**Extending the Life of Closed Loop Beds**

To extend bed life one should minimize the flux loading on the board and avoid excessive use of other loading soils such as water soluble masking agents. As previously mentioned, the use of a carbon tank is important to remove non-ionic flux constituents such as detergents or surfactants and prevent foaming. As a general rule, GAC tanks should contain 1.5 to 2X more volume than the mixed DI tank volume to allow sufficient absorptive capacity and contact time to remove foaming organics. This is particularly important when cleaning water soluble fluxes.

When cleaning non-clean and rosin based fluxes, a cleaning agent containing ionic materials such as organic amines, or other organic and inorganic salts must be used to effectively remove the non-water soluble flux residues. Aqueous cleaning chemistries used in the wash will carry through to the rinse stages becoming a closed loop load that must be removed in the closed loop system. In batch cleaners a longer drip time between the wash and rinse cycles will help minimize the carry over to the closed loop rinse. Inline cleaners are designed will that minimize the drag out with a chemical isolation section designed between the wash and the first rinse. This can be as simple as a drip section or can incorporate active blowers and, or wet spray to facilitate effective removal from the product and surrounding surfaces.

**THE COST MODEL**

A cost model was developed for aqueous inline cleaners based upon the theoretical calculations above for bed life and feed water purity. In this model an open loop cleaner is compared to both an inline cleaner with a remote closed loop system and a inline cleaner with an in situ closed loop system.

There are both capital and operational costs in the model. The capital assumptions include both cleaner and closed loop system costs and transport costs. Installation cost is included in the equipment costs. The amortization schedule is a variable but is set to 7 years in the example shown in table 4 below. The process and facility variables include water make-up rate, the cost of tap water and power, cost to regenerate beds, feed water purity, final rinse rate, operating power, hours of operation, and number of shifts per day.

The DI water feed purity is defined in both in concentration and ion type. For the open loop system, the source is presumed to tap water with calcium carbonate ions at 500mg/gal. The tank capacity for a standard 1,5 cubic foot DI tank was calculated using equation #3 for two closed loop models the ions are assumed to be a reacted carboxylic acid activator, tin succinate and a much lower concentration of 20mg/gal. The bed life was then calculated using equation #2 above.

| | | | | |
|---|---|---|---|---|
| | **Open Loop Vs Closed Loop Estimated Operating Costs** | | | |
| | **Open loop vs remote CL vs In Situ Cl** | | | **Defluxing** |
| | Equipment/Process type >>>>>>> /Human Inputs Required /Calculated values | **Open Loop** | CL Remote | CL In sit |
| | **Process Data** | | | |
| | Equipment cost | $200,000 | $200,000 | $200,000 |
| | DI system system cost | $25,000 | $35,000 | $5,000 |
| | Shipping | $5,000 | $5,000 | $4,000 |
| | Water consumption rate gph (operating) | 300 | 10 | 10 |
| | Cost of water $'s/gal | $0.01 | $0.01 | $0.01 |
| | Cost to regenerate DI (1.5Ft3) | $300.00 | $500.00 | $500.00 |
| | Water purity (dissolved solids) mg/gal | 250 | 20 | 20 |
| | Final rinse rate GPM | 5 | 5 | 5 |
| | Power cost $s/Khr | $0.10 | $0.10 | $0.10 |
| | Operating KW (KV*A) | 100 | 110 | 75 |
| 7 | year equipment amortization | | | |
| 6 | Run time per Shift | | | |
| 300 | Shifts per year | | | |
| | **Process Costs ($'s/hr)** | | | |
| | Absorptive capacity (mg CaCO3 or Succinate) | 1,680,000 | 7,900,000 | 7,900,000 |
| | Bed Life (hrs of operation) | 3.7 | 219.4 | 219.4 |
| | Annual Cost of beds OL DI, CL DI+GAC | $144,642.86 | $4,101.27 | $4,101.27 |
| | Hourly Cost of beds | $80.36 | $2.28 | $2.28 |
| | Hourly cost of tap water | $3.00 | $0.10 | $0.10 |
| | Power costs/hr | $15.00 | $16.50 | $11.25 |
| | **Total Power and water cost $/hr** | **$98.36** | **$18.88** | **$13.63** |
| | Equipment Amortization cost per hr | $16.43 | $17.14 | $14.93 |
| | **Total Equipment + Water + Power ($/hr)** | **$114.79** | **$36.02** | **$28.56** |

The model above showed that the open loop system costs significantly more than either closed looped inline cleaners. The primary differences were in the cost of DI beds and arose because of poor quality of the tap water feed. This cost can be mitigated by using RO water to feed the system or by using significantly larger DI tanks which cost less per $ft^3$ to regenerate. The power costs are calculated based upon a set point temperature of 140F and the calculation presumes both the open loop and the remote supplied DI feed are unheated. The in situ closed loop cleaner is predicted to have the lowest cost because of both water and power savings and lower capital cost.

**SUMMARY**

Recycling systems allowing reuse of cleaning and rinsing solutions is becoming more popular because of social and economic pressures to recycle and save earth's resources. Achieving these goals can enhance the Companies image and bottom line. This pace is now accelerating to lower capital and resource consumption in cleaning systems.

There are recycling strategies available for every cleaning and rinsing fluid. In the future cleaning fluid suppliers will certainly improve the compatibility with close looping new fluids. The evolution of the new formulas will move away from compounds that are deleterious to closed looped systems.

In situ machine recycling will likely become the new standard for new cleaning system design because of lower capital and operational costs. A cost model should be used to evaluate the choices and select the best options for your cleaning process. In situ closed loop cleaning systems offer the lowest capital and operational costs for modern high volume cleaners.

Recycling cleaning and rinsing fluids has the potential to save companies hundreds of thousands of dollars per year over the cost of operating open loop systems. The down side of recycling is that companies will need knowledgeable people and capable cleaning systems to achieve the savings. At some point in the near future it will no longer be acceptable to send water, heat, and chemicals down the drain. Companies that do achieve the savings will have a competitive advantage.

**Author. Information**

Mr. Steve Stach is the President and CEO of Austin American Technology Corporation. He has been responsible for development of new cleaning new cleaning systems for the last 27 years. Steve also has 10 years of experience as a Process Engineering Manager for both Defense and Medical Electronics firms specializing in cleaning processes. He has authored or co-authored more than 50 research papers on cleaning as early as 1979. Steve has a BS in chemistry and graduate work in chemical engineering. He holds several patents in cleaning technology.

**Footnotes**

1. S. Stach, Reducing the Enviromental Iimpact of Cleaning Electronic Assemblies, SMTAI Technical Conference, 2012 Ft. Worth Texas
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3. Richard Conway, Richard Ross, Handbook of Waste Disposal, Van Nostrand Rienhold publisher, p 175 – 181.
4. Phone conversation, Mr Steve Gallagher, Ultrapure Industry Services, Austin Texas

**Speaker for This Session has not supplied Materials for the 2013 Technical Conference**