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Source Reduction and Metal Recovery Techniques for Metal Finishers

High waste management costs and disposal regulations have demanded the attention of many metal finishing operations, as well as a significant portion of their profits. To remain competitive and in compliance with environmental requirements, these companies must focus their efforts on pollution prevention to reduce waste generation and disposal costs, limit liability and restore maximum profits.

This fact sheet summarizes some of the opportunities for metal finishers to reduce waste while maintaining profitability and achieving compliance. By applying the pollution prevention (P2) concept, metal finishers can extract the most use from process chemistries while keeping process chemistries in their respective tanks.

P2 Techniques for Metal Finishing

Before turning to methods to recover metals from wastewater, metal finishers should examine processes and operations for opportunities to reduce the generation of wastewater and extend the life of metal finishing solutions.

P2 techniques for metal finishing include:

1. Slow down - Reduce the speed of parts removal and allow drain time above tanks to reduce dragout. Dragout occurs when the solution pulled from one tank in a plating operation is dragged into another. Excessive dragout can lead to increased plating chemical use, increased rinse water use or decreased rinse quality, increased dragin into next bath and increased wastewater generation. Use racks to hang parts to drain so workers can move to another task. Automation also can help.

2. Counter-current rinsing - Fresh water is fed into the rinse tank farthest from the plating tank and overflows backward through the flowing rinse tanks until it reaches the rinse tank immediately after the plating tank. Installing multiple rinse tanks after process baths will improve rinse efficiency and reduce water consumption.

3. Reactive rinsing - Reuse the acid rinse effluent as influent for the alkaline rinse tank, thus allowing the fresh water feed to the alkaline rinse tank to be turned off. This can also be applied to process tank rinses.

4. Static rinse - The first rinse after a process bath should be a static rinse that builds up a concentration of “dragin” and is used instead of fresh water to replenish the process bath. Use purified water to make the static rinse.

5. Rack to reduce dragout - Position the part so that fluid will flow together and off the part by the quickest route. Do not position parts directly over one another. Tilt parts to avoid fluid pockets.

6. Bath chemistry - Regularly monitor bath chemistry with pH and conductivity controls. Testing methods are available from your supplier. Sometimes supplier specifications for concentration levels are set high. By experimenting and lowering levels to just above the point when defects start to occur, you can reduce chemical costs and the costs associated with disposal or treatment.

7. Restrict water flow - Simple in-line flow restrictors can limit the water flow rate. Turn off flowing rinses when not in use.

8. Drain boards - Place a drain board over the lips of two adjacent tanks to catch dragout. Slope the board back to the first tank (this also keeps the solutions off the floor).

9. Agitate baths - Agitation can be done by manually moving the part (better if part is completely removed and then re-immersed), with a mechanical agitator or with forced air or solution in an immersion tank. You may need to filter baths to remove sediment prior to agitation.

10. Fogging/Spray/Air Knives - After a part is removed from a bath, these devices, located above process tanks, can force excess solution off of workpiece and into process bath.

Dragout reduction and recovery is an important P2 technique for metal finishing. It is a simple technology used by metal finishers to return plating chemicals to their original bath before they become integrated into a waste stream. It involves using drain boards, drip tanks, fog-spray tanks or rinse tanks separately, or in combination, to capture chemicals dragged out of plating tanks. Drain boards are widely used throughout the metal finishing industry to capture plating solutions. These boards are suspended between process tanks and are constructed of plastic or plain or teflon-coated steel. Solutions drip on the boards and drain back into their respective processing tanks.

In contrast, a drip tank recovers process chemicals by collecting dragout into an empty tank from which it can be returned to the process as needed.

Another dragout recovery option is a fog-spray tank, where plating chemicals are recovered by washing them from parts with a fine water-mist. The solution that collects in the fog-spray tank is returned to the process tank as needed. The added water helps to offset evaporative losses from the process tanks.

Another option is a dragout tank. Dragout tanks are essentially rinse tanks. Dragout chemicals are captured in a water solution, which is returned to the process tank as needed.

There are advantages and disadvantages to dragout recovery. The presence of airborne particles and other contaminants in recovered plating chemicals may necessitate treatment of collected solution to remove the contaminants prior to reuse. Depending upon the solution, up to 60 percent of the materials carried out of a plating tank can be recovered for reuse, thus lowering material and waste management costs. However, reusing dragout can affect metal deposition and surface finish quality. Impurities can concentrate in the solutions causing deterioration to the plating process when returned to the plating bath.

Recovery Techniques

After utilizing the P2 techniques previously mentioned, recovery techniques can be used to recover metal for reuse. Recovery should begin with segregation of waste streams.

Waste Stream Segregation

Segregation of waste streams is essential for most recycling and resource recovery technologies. To reuse a waste material for another process, recover valuable chemicals from a waste stream or recycle rinse water, the waste stream must be kept separate from other wastes that will disturb the reuse or recycling process. Once the waste solutions have been isolated as much as possible, there are a variety of methods that can be used to remove the metals or process chemicals.

Evaporation

Heat or natural evaporation is used to evaporate water from the rinse water containing dilute plating chemicals. Once sufficient concentration of the plating chemicals is achieved, the solution can be reused in the plating bath.

There are essentially two types of evaporators: those that operate at atmospheric pressure and those that operate under vacuum.

Atmospheric evaporators, the most commonly used units, are less expensive to purchase than vacuum evaporators. They are open systems that use process heat and warm air to evaporate water. The source of air is important because the bath may absorb impurities from air. A packed bed evaporator is an example of an atmospheric evaporator.

Vacuum evaporators are also used to recover plating chemicals. They are closed systems that use steam heat to evaporate water under a vacuum. The water vapor is condensed for reuse as rinse water. These evaporators operate by removing rinse water from the first rinse tank and boiling it at a reduced pressure. A climbing file evaporator is an example of a vacuum evaporator.

A typical evaporative recovery system consists of an evaporator, a feed pump and a heat exchanger. Plating solution or rinse water containing diluted plating chemicals is circulated through the evaporator. The water evaporates and concentrates the plating chemicals for reuse. In open evaporator systems, the water evaporates and mixes with air and is released to the atmosphere. (Note: It may be necessary to vent the contaminated air stream to a ventilation/scrubber treatment system prior to release.) In enclosed evaporators, the water is condensed from the air and can be reused in rinses, which further increases savings. Water reuse is preferred whenever possible.

As with all process equipment, the design and size of an evaporator system depends on volumetric flow, specifically the rinse water flow rate required and the volume of process solution dragout. In order to reduce sludge waste, the volume of water used to rinse the parts must be reduced. Therefore, rinsing efficiency becomes an important factor.

Manufacturers can improve rinsing efficiency in several ways. First, turbulence can be utilized to reduce the amount of water needed to rinse the part. Turbulence includes spray rinsing and water agitation. Furthermore, the contact time between the part and the rinse bath can be increased. This usually is achieved by multi-stage rinse baths and counter-current rinse systems.

Advantages:
- recovered chemicals can be reused;
- reduced volume to waste treatment facility;
- self-operating;
- low maintenance;
- widely applicable;
- atmospheric evaporators are inexpensive; and
- vacuum evaporators recycle rinse water.

Disadvantages:
- evaporators increase impurities;
- impurities require further treatment;
- energy intensive;
- vacuum evaporators are capital intensive;
- needs accompanying system for recycling;
- plating chemicals corrosive to evaporator;
- may require pH control; and
- evaporation can degrade or volatilize bath additives.

Ion Exchange

Ion exchange is a molecular exchange process where metal ions in solution are removed by a chemical substitution reaction with an ion-exchange resin. The metal salt produced can sometimes be returned to the plating bath for reuse. Ion exchange can be used with most plating baths. The ion exchange unit's size (volume of resin) is determined by the amount of metal to be removed from the recovered solutions.

Advantages:
- recycles process water;
- recovers process chemicals;
- efficient in removing ions from dilute solutions, handles dilute feed;
- resins can be selected to remove certain ions; and
- low energy demands.

Disadvantages:
- produces a concentrated solution which needs to be further treated;
- usually run as a batch process;
- difficult to find a suitable resin for treatment of a waste solution containing mixed metal ions;
- needs accompanying systems for metal recycling;
- sensitive to temperature, solids and organics;
- requires tight operation maintenance, equipment complex;
- limited concentration ability;
- excess regenerate required;
- feed concentration must be closely monitored; and
- ion exchange column takes time to regenerate.

Reverse Osmosis

Reverse osmosis (RO) recovers plating chemicals from plating rinse water by removing water molecules with a semi-permeable membrane. The membrane allows water to pass through but blocks metals and other additives.

Diluted or concentrated rinse waters are circulated through the membrane at pressures greater than aqueous osmotic pressure. This action results in the separation of water from the plating chemicals. The recovered chemicals can be returned to the plating bath for reuse and the permeate, which is similar to the condensate from an evaporator, can be used as make-up water. RO units work best on dilute solutions.

The design and capacity of an RO unit depends on the type of chemicals in the plating solution and the dragout solution rate. Certain chemicals require specific membranes. For instance, polyamide membranes work best on zinc chloride and watts nickel baths, while polyether/amide membranes are suggested for chromic acid and acid copper solutions. The flow rate across the membrane is very important. It should be set at a rate to obtain maximum product recovery. RO systems have a 95 percent recovery rate with some materials and with optimum membrane selection.

Advantages:
- recovers process chemicals;
- recycles process water;
- high separation rate can be achieved;
- no chemicals used; and
- small floor space requirement.

Disadvantages:
- membrane durability problems;
- sensitive to hard water salts;
- fouling of membranes due to feeds high in suspended solids; feed filtration essential;
- returns ionic impurities to plating bath; and
- limited concentration range of operation.

Electrodialysis

In electrodialysis, electromotive forces selectively drive metal ions through an ion-selective membrane (in reverse osmosis, pressure is the driving force; in ion exchange, the driving force is chemical attraction). The membranes are thin sheets of plastic material with a series of alternatively placed cationic- and anionic-permeable membranes.

Advantages:
- energy efficient;
- only ionic materials are recovered, organics not concentrated, minimal return of unwanted inorganic material; and
- achieves higher concentration than reverse osmosis or ion exchange.

Disadvantages:
- membranes sensitive to clogging and ruptures, flow distribution, pH and suspended solids;
- efficiency drops as purity increases;
- feed must be filtered;
- equipment uses multi-cell stacks; and
- membrane life uncertain.

Electrolytic Recovery

In electrolytic recovery, metal ions are plated-out of solution electrochemically by reduction at the cathode. There are essentially two types of cathodes used for this purpose: a conventional metal cathode (electrowinning) and a high surface area cathode (HSAC). The HSAC cathode can effectively plate-out metals such as gold, zinc, cadmium, copper, nickel, etc. Therefore, electrolytic recovery can be used with most plating baths.

Advantages:
- metals are recycled;
- no chemicals used;
- recovers only metals;
- results in salable, nonhazardous product;
- energy efficient; and
- low maintenance.

Disadvantages:
- energy inefficient at very low concentrations.

Deionized Water

Using deionized water to prepare plating bath solutions is an effective way to prevent waste generation. Some ground water and surface water contains high concentrations of calcium, magnesium, chloride and other soluble contaminants that may build up in process baths, possibly shortening bath life. By using deionized water, build-up of contaminants can be more easily controlled. Technologies such as reverse osmosis and ion exchange also can be used to effectively remove soluble contaminants from incoming water.

References & Resources

Pollution Prevention for Metal Finishing (PowerPoint Presentation) from Ohio EPA Retrieved 12/02/04 from **www.epa.state.oh.us/opp/onlinetraining.html**

National Metal Finishing Strategic Goals Program Pollution Prevention Toolbox Retrieved 12/02/04 from **www.strategicgoals.org/tools/pollprev.htm**

P2 Checklist for Metal Finishing Facilities **www.epa.state.oh.us/opp/Kansas%20SBEAP%20Checklist.pdf**

Reverse Osmosis for Metal Finishing **www.epa.state.oh.us/opp/R.Osmosis%2002.01.02.pdf**

Extending Electro-less Nickel Bath Life Using Electrodialysis **www.epa.state.oh.us/opp/extende.pdf**

Reducing Rinse Water Use with Conductivity Control Systems **www.epa.state.oh.us/opp/condcs.pdf**

Reducing Dragout with Spray Rinses **www.epa.state.oh.us/opp/spray.pdf**

Modifying Tank Lay-outs to Improve Process Efficiency **www.epa.state.oh.us/opp/tanklay.pdf**

Leonhardt Plating Company P2 Case Study **www.epa.state.oh.us/opp/fact56.pdf**