Integrating Pollution Prevention (P2) into the Inspection Process

Metal Finishing Operations (Plating Processses)

Background

The metal finishing industry uses a wide variety of materials and processes to clean, etch, and plate metallic and nonmetallic surfaces to provide desired surface properties. The materials used include solvent and surfactants for cleaning, acids and bases for etching and metal surface pretreatment, and solutions of metal salts and other compounds to plate a finish onto a part. Physical, chemical, and electrochemical processes are all used to finish metal workpieces.

The process usually consists of a cleaning step, process bath, and then a rinse. This may be repeated depending on the type of finish being applied to the part. Some parts may need to be stripped before the desired coating is applied to them. Strip and "pickle" baths of nitric, hydrochloric, sulfuric, and hydrofluoric acids may be used for this purpose. Extensive progress has been made in recent years in improving metal finishing processes as regulations regarding discharges into the environment have become more stringent.

Alternative technologies are currently being explored to replace some of the more hazardous finishes such as cadmium and chromium plating using hexavalent chrome, cyanide-based plating processes–especially zinc, brass, bronze, and silver plating; and lead and tin plating.

Regulatory Issues

Air emissions: Metal finishing processes can create significant emissions that may need to be captured in control devices to reduce environmental contaminations, such as vapors and mists from hexavalent chrome baths. Degreasing and solvent cleaning processes also generate air emissions.

Hazardous wastes: Spent cleaning solvents, plating baths, spill cleanup materials, and wastewater treatment sludges can be generated from metal finishing processes. Spent chemical baths may be recycled or disposed.

Wastewaters: Rinse waters, chemical bathes, spills and leaks, and solutions from scrubbers and exhaust systems are generated in plating operations. Rinse water is by far the primary

Pollution prevention--*P2*--can help reduce the following:

- Volatile Organic Compounds (VOCs) and Hazardous Air Pollutants (HAPs)
- Hazardous waste disposal costs
- Raw material purchases
- Short-term liabilities associated with employee health issues
- Long-term liabilities from improper or catastrophic events associated with hazardous waste disposal

source of waste in the metal finishing industry and may require treatment (and permitting) before being discharged to the local POTW.

Where's the P2 Potential?

Change the Material

- Work with the parts supplier to use a corrosion inhibitor more easily removed or compatible with the cleaning system used on site.
- Arrange for just-in-time delivery to reduce or eliminate need for corrosion protection.
- Use a lower vapor pressure cleaner.
- Use an aqueous cleaner.
- Use less toxic plating solutions such as zinc instead of cadmium, trivalent chromium instead of hexavalent chromium, alkaline non-cyanide copper for cyanide copper, alkaline non-cyanide zinc for cyanide zinc, high pH nickel for copper strike, or nickel/tungsten/silicon carbide for hard chrome.
- Replace cyanide and barium salt baths with sulfate or chloride baths. Use alkaline cleaners instead of solvents.
- Use purer anodes, or regenerate plating solutions through filtration.
- Use deionized water for all chemical bath additions and initial mixes. Tap waters may have salts that shorten the life of bath chemicals, require more chemicals during wastewater treatment, and create more sludge.

Change the Process

Reduce Chemical Drag Out
Chemical drag out is the primary source of contaminated rinsewater, which requires treatment to remove harmful or regulated pollutants before the water is reused or discharged. If the drag out is reduced, the rinse waters will be less contaminated and will last longer. Reduction of drag out will also minimize the amount of process chemical additions to the bath and the mass of contaminants that need to be removed from the rinse water. The following process modifications reduce drag out:

- Lower the concentration of plating bath constituents; increase the plating solution temperature; both actions will reduce solution viscosity to enhance runoff.
- Rack workpieces being plated so that cavities open downward to promote draining.
- Use non-ionic wetting agents to reduce solution surface tension.
- Explore workpiece modification. Consultation with workpiece manufacturers to adjust design to provide better bath liquid release to reduce drag-out. Example: A plater asked his customer whether he could drill four holes in the workpiece to improve drainage. The customer agreed and this pollution prevention technique was successfully implemented.
- Extend drip time; install drip racks. A drain time of at least 10 seconds has been demonstrated to reduce drag-out by 40+%, compared to the three-second

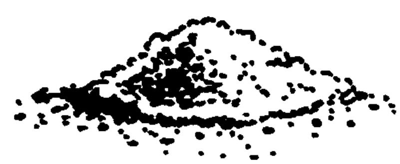
industry average. Longer drain time over the process solution allows more drag-out to be returned to the bath. Drain times can be controlled by posting them at tanks as a reminder to employees or by building in delays on automatic process lines.
- Install drainage boards between tanks to route drag-out into the correct process tank. Drain boards are used to collect drag-out/drippage from workpieces on racks and direct the solution back into its previous bath. Drainboards save solutions and keep them off the floor. These boards may be constructed of any compatible material. It is important that they be oriented so as to direct drips to the correct tank. Use of drain boards is a cost-effective technique which will reduce chemical consumption as well as the amount of rinse water needed.
- Install air knives or water misters to remove drag out. When mounted on the edge of a process tank, a pipe directing air or water at the work-pieces through appropriate nozzles can reduce the amount of solution carried over to subsequent process tanks. Either fixed or movable nozzles can be used. This procedure keeps a solution in its tank of origin, rather than passing into another tank as a contaminant. Spray rinses can be used above any heated process tank to recover drag-out; in many cases, spray nozzles can be sized and water flow rates adjusted such that the spray rinse water balances the evaporative losses.
- Reduce workpiece withdrawal rate. The speed with which workpieces are removed from a process solution can have the greatest impact of any single factor on drag-out volume. Workpiece withdrawal rate will influence the amount of solution remaining on the part. The more slowly a workpiece is withdrawn from a process bath, the thinner the chemical film on it and the less chemical contaminants in rinse waters.
- Implement the use of angled barrels.

For large, horizontal, double-hung type barrels, the following modifications of existing barrels may prove useful in minimizing drag out:
- Lengthen or shorten one arm, so as to create an off-horizontal position, which allows for quicker runoff. This may require alteration of tank depth to accommodate angled barrels.
- Attach a drip bar at the bottom of barrel edges to facilitate droplet collection and runoff.
- Install an internal mister in barrel.

Reduce Rinse Water Use
- Reducing chemical drag in by methods listed above.
- Install automatic flow controls. Flow restrictors are placed directly in the rinse water inlet of a rinse tank in order to restrict the flow of water to a predetermined acceptable level. However, because restrictors are non-adjustable in use, they may be less suitable in job shops where the variety of materials being plated typically requires variable flow rates. Flow controllers utilizing conductivity cells can solve the problem of adjusting rinse water flow rates to variable production rates. These sensors give an indication of contamination in the rinse water (the higher the contaminant concentration, the higher the rinsewater conductivity). Sensors trigger the inflow of clean water when the tank

water becomes contaminated, the excess contaminated water overflowing to the drain.

- Install multiple rinse tanks in a counter-current series system. This procedure substantially reduces the amount of water required for rinsing, thereby reducing the amount of wastewater to be treated. Implementation is most efficient when several rinse tanks are used in series. Fresh water is supplied to the rinse tank farthest from the process tank. The flow of rinsewater is from this farthest tank toward the process tank, countercurrent to the flow of plated workpieces. The counter-current rinse overflows to the preceding rinse tanks until it reaches the tank immediately following the process tank. Often the overflow from this first rinse tank discharges to the drain. However, if the process bath operates at a temperature high enough to cause sufficient evaporation, the overflow may enter the process tank, thereby reclaiming much of the drag out. Overflow to the process tank is only practical when deionized (DI) water is used for rinsing.
- Stop rinsewater flows when not using the lines, if possible. Using operator-actuated valves whenever they start a run, water will flow for a set amount of time for the run, automatically shutting the water off when not using that plating line.
- Agitate the rinsing bath to increase efficiency. Agitation of rinse water baths reduces required contact time and improves rinsing efficiency. Experience has shown that air sparging is often not an efficient agitation technique. Recirculation of a side stream from the rinse tank is reasonably effective, but use of a propeller-type agitator results in the highest efficiency.
- Install drag out collection tanks. If direct counter-current rinsewater overflow to the process tank is not possible, the first rinse tank after a process bath may be a static rinse that builds up a concentration of "drag in." Using the static rinse water to replenish the process bath reclaims much of the drag out. Good practice requires that the static rinse tank initially be filled with deionized water. Periodically the static rinse water should be concentrated for recycle/reclaim into the plating bath.
- Reduce sludge generation. The amount of sludge generated by treating plating wastewater is proportional to the concentration of platables and other ions that precipitate at alkaline pH. Any of the techniques for reducing drag out will also reduce sludge generation. As the hardness in the water supply will also form sludge, the use of deionized water for rinsing will reduce sludge generation. The use of magnesium hydroxide, instead of sodium hydroxide, to raise the pH and precipitate heavy metal hydroxides, will also reduce sludge generation because a lesser mass of precipitant is required and because the resultant sludge cake will de-water more easily.



Prolong Chemical Bath Life

- Filtration prolongs the life of baths; bath analysis should be checked after carbon filtration for replacement of organic brighteners or other organic constituents. Use a filter that can be unrolled, cleaned, and reused. Filter material may be hazardous waste due to heavy metal contamination and should be tested before disposal. If using a particle filter, make sure to draw water from the midsection of the tank to avoid drawing oils into a particle filter. Many shops run particle filters continuously and carbon (organics removal) filters only as needed.

- Remove fallen parts daily.
- Cover baths with lids when not in use to reduce evaporation and minimize particle contamination.
- Mechanically preclean parts as much as possible first.
- Run bath parameters at lowest acceptable concentrations and highest possible temperatures to reduce the surface tension of the fluid, which will reduce drag out, and keep plating activities high. High temperatures reduce bath volume more quickly to allow return of bath chemicals from the first rinse tank, reducing wastewater loading and raw chemical use.
- Establish and maintain bath operational parameters; test and monitor reqularly. Temperature, pH, chemical concentrations, additive concentrations, and surface tension should be monitored on a regular basis, or daily, if workpieces vary greatly from day to day.

Change the Technology

Bath maintenance practices can be used to extend plating/cleaning bath life. The following technologies are available to remove contaminants from plating baths:

- Electrowinning: If solution concentrations become high enough, platable metal ions may be removed and the solution partially purified by simply plating the metal ion onto a stub electrode.
- Porous pots: For hexavalent chromium plating baths, the technique of porous-pot plating has been used to extend bath life, thereby reducing the discharge of pollutants. During plating, the concentrations of iron and other cationic impurities build up in a hexavalent chromium bath to the extent that plating becomes unsatisfactory. If this bath is placed in a porous pot, in which a semipermeable membrane separates cathode from anode, and power is applied, the iron and other contaminant metal ions pass through the membrane and accumulate in the cathode chamber, from which they are periodically removed for disposal. Chromate ion remains in the anode compartment as part of an anolyte which, after purification, may be returned to the plating tank for further use. Less chromium is wasted by using this technique. The liquid in the cathode compartment must be handled as waste.
- Evaporation: Evaporation may be successfully used to recover various plating bath chemicals. This technology is based on physical separation of water from dissolved solids. Water is evaporated from the collected rinse water to allow the chemical concentrate to be returned and reused in the process bath.
- Carbonate freezing may also be used to remove metal contaminants from chemical baths/

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Metal Finishing Industry P2 Checklist

Parts Cleaning:

Mechanically preclean parts as much as possible first.
Determine level of cleaning needed.
Work with the parts supplier to use a corrosion inhibitor more easily removed or compatible with the cleaning system used on site.
Arrange for just in time delivery to reduce or eliminate need for corrosion protection.
Use a lower vapor pressure cleaner.
Use an aqueous cleaner.

Reduce Drag Out Losses:

Extend drip time; install drip racks.
Install drainage boards between tanks to route drag out into the correct process tank.
Reduce workpiece withdrawal rate from the chemical bath.
Install air knives or water misters to remove drag out.
Lower the concentration of plating bath constituents, increase the plating solution temperature. Both actions will reduce solution viscosity to enhance runoff.
Rack workpieces being plated so that cavities open downward to promote draining.
Use non-ionic wetting agents to reduce solution surface tension.
Implement the use of angled barrels.

Maintain Chemical Baths:

Reduce drag out losses and drag in contaminants.
Cover baths when not in use to minimize particle contamination.
Establish and maintain bath operational parameters; test and monitor reqularly.
Install drag out collection tanks or a static rinse to capture bath chemical for reuse.
Filter chemical baths. Use a filter that can be unrolled, cleaned, and reused.
Use a bath maintenance technology to “clean” chemical baths of unwanted metals.
Remove dropped parts daily.

Reduce Rinsewater Use:

Reduce chemical drag in by methods listed above.
Install multiple rinse tanks in a counter-current series system.
Install automatic flow controls, such as flow restrictors or conductivity sensors.
Stop rinse water flows when not using the lines, if possible.
Agitate the rinsing bath to increase efficiency.
Repair leaking tanks, pumps, and valves

Case Study

In 1989, the Ilco Unican facility in Rocky Mount plated 800,000 key blanks per day with nickel. During plating operations, rinse tanks were used to remove solution left on the product from the plating bath. The drag out from the plating bath inevitably built up in the rinse tank to a point where the tank was no longer pure enough to rinse the parts. Traditionally, the rinse water would be removed and treated to form a hazardous sludge. This treatment process was very costly, and it wasted nickel that could otherwise be used.

To eliminate this problem, Ilco Unican began using an inexpensive and low-maintenance atmospheric evaporation system by which dry air was passed over the plating solution, which increased the rate of evaporation of the water in the bath. Sufficient water was evaporated so that the rinse water could be recycled into the plating bath. This system not only reduced the need for rinse water treatment but also utilized nickel that would otherwise be lost. Evaporation rates can vary with air flow, bath temperature, air temperature, and humidity. To ensure optimum efficiency, the evaporator should be located next to a clean, dry, air source and the plating bath tank. If the air is not clean, contaminants can enter the plating bath and cause unacceptable finishes or increase the necessary plating time.

Ilco already used a carbon filtration system in the plating bath to remove contaminants that entered the bath from the materials being plated. With this system, Ilco has found that no plating or rinse baths need to be dumped and treated. The closed loop system eliminates the need to add any nickel sulfate or nickel chloride, whereas Ilco Unican had been using 6,400 pounds of nickel chloride and 22,000 pounds of nickel sulfate a year. The in-line recycling loop also allowed for an 80% (7,040 pounds) recovery of boric acid. Only the disposal or treatment of the plating bath sludge created by the filtration system was necessary. With installation, the two evaporator systems cost about $12,200. Maintenance and energy costs run approximately $24,741 per year. Reductions in nickel chloride, nickel sulfate, and boric acid saved the company $9,280, $19,360, and $3,328, respectively. The project also saw immense savings from the elimination of the rinse tank sludge. Disposal and handling of the waste were costing Ilco Unican $25,131 a year. The payback period for the project was 7.3 months, with subsequent annual savings of $36,223 a year.

Additional Resources

The Small Business Environmental Assistance Program, SBEAP, is a free, confidential, non-regulatory program funded by the state of Kansas to assist small businesses with environmental regulations and pollution prevention. For assistance or to order our manual on pollution prevention for the metal finishing industry, please contact the SBEAP at 800-578-8898 or http://www.sbeap.org
The electroplating (metal finishing) sector case studies contain listings of many metal finishing projects. Titles and web site links are provided at:
http://wrrc.p2pays.org/indsectinfo.asp?INDSECT=10#Case+Studies
Electroplating pollution prevention technologies are summarized in the fact sheet found at this web site:
http://www.nd.edu/Departments/EN/CEGEOS/faculty/ketchum/p2-plating.html