Good morning, welcome to the Metal Finishing Sector Pollution Prevention Workshop
Value of this training. This training should make you more comfortable in identifying potential pollution prevention opportunities at metal finishers and coaters that you inspect. We hope to give a broad but accurate overview of plating processes and situations that you may encounter. Each section will have some basic keys to look for when visiting a plating facility. We want you to be confident in suggesting options for facilities to pursue and know where to find resources and assistance should a facility be open to considering P2 opportunities.

What’s in it for Me?

- Understanding of Metal Finishing Unit Processes
- Skills for Identifying Process Optimization (P2!) Opportunities
- Knowledge of Tools and Resources for Providing Technical Assistance
This is a very basic input output diagram to begin to consider opportunities for reductions in raw materials and subsequent waste streams.
Basic metal finishing process usually incorporate these 3 major steps

1) Some type of cleaning and preparation step, in order to allow the work piece to accept a coating.
2) The coating or Plating process where metal ions are attached to the surface by a bond
3) Some sort of protective coating to seal the finish

Surface preparation will usually start with removal of fluids from machining and or shipping protective coatings. This step should be the beginning of the P2 focus at a facility. Carry over from the cleaning or preparation phase will impact the plating solution and possibly subsequent rinses.

Alkaline cleaning: oil, dirt, coating removal
Electropolishing: reverse plating process, remove thin coating of metal from part, shiny surface (from which the name is taken)
Oxide removal: acid stripping of rust also done for surface preparation, longer is pickling.
Electroplating is the electronic deposition of a metal ion on the surface of a negatively charged work piece.
Electroless plating is the same deposition process except current is not used, a solution of metal ions still deposits on the work piece.
Anodizing: this process is basically the same as electropolishing except the purpose is to form a thin oxide on the surface of the part.
Chromate Conversion Coating: this process uses chromic acid to form a thin gel like film of chromic oxide and aluminum oxide on the part surface. This is frequently used so that paint or adhesives will adhere to aluminum parts.
Phosphating: a thin layer of phosphate crystals on the metal surface, for coating adhesion.
Plating Line/Department  Except for vapor degreasing, which normally is performed off-line, plating operations are normally incorporated into a sequence of tanks, called a "line."

A plating line may be designed to produce a single coating or a number of coatings. While not always the case, the process line contains tanks lined up in sequential order. Automated lines may or may not contain tanks in sequential order.

A zinc plating line may therefore consist of 13 tanks, each containing a chemical processing solution or rinse water, soak clean, electroclean, rinse, acid, rinse, zinc plate, rinse, bright dip, rinse, chromate, rinse, hot water rinse, and dry. If the line is for barrel plating, each tank may have one or more "stations," that is, places to put a barrel. A six-station zinc plating tank can plate six barrel-loads of parts at one time. To economize, some shops may have one cleaning line that services several plating lines. There also are tanks for rack stripping, stripping rejects, purifying contaminated solutions or holding solutions that are only sporadically used. The entire lineup of tanks and lines creates a "layout" of the shop, with parts entering the plating department from one direction, traveling through the process lines, and leaving the plating department.
Rinse water effluent receives metals loading, cleaners, etchants and often requires pH adjustment. Volume of the waste water is a key, along with any alternative chemistries for cleaning, coating, etc. Always ask if a process step is required by the customer, or if alternatives would be acceptable.
Least toxic chemicals, starting with coolants fluids or lubes if parts are machined, then cleaners, etchants, and plating solutions themselves. A key is to ask how solutions are prepared and maintained. (If they describe their process as a number of glugs, jugs, scoops, handfuls etc.) Take note, process chemistries should be carefully maintained. If they are proactive they will talk about extending the life of their baths and rinses. Be alert to fixed dump or batch replacement schedules. (like we dump that bath every Thursday) solution life is variable based on use, soil loading.
Rack Plating

- Workpieces hung or mounted to frames (racks)
- Most common and versatile processing method
- Dragout rates and rinse water use easier to control

Dragout most easily managed due to ability to drain or rinse properly, covered in more detail in the dragout control areas
Barrel Plating

- Parts processed in containment “barrel”
- Typically small parts with low level of plating or processing tolerance requirements
- Dragout rates and water use relatively high

Consequently, poor drainage and difficulty in rinsing make barrel plating a challenge.
Basically un-automated rack plating. Keys are agitation, withdrawal rate, hang time and tilting. Manual process changes must be addressed as a training/management issue. (Worker controlled) Can be potentially very effective if implemented properly.
Automated or Semi-automated plating could be either racks or barrels. Main features of automated plating both good or bad is consistent withdrawal rates, rinsing, agitation etc. Semi-automated with hoists has the same procedural constraints as manual plating (worker controlled) training issue.
Keys to Identifying P2 Opportunities at Metal Finishing Facilities

• Basics of Metal Finishing
  – does the facility monitor and measure their plating or coating solutions, how are additions made
  – does the facility have specifications for each part they finish, mil thickness, quality standards?
  – does the facility have procedures and training in place for coating time, withdrawal rate, drain time, rinsing, part orientation?
  – does the facility know addition and flow rates for water in their cleaning and plating solutions and rinses?
Now that you have seen an introduction to dragout, we can discuss how to measure and understand it better. If you can measure dragout, you can identify material losses and wastes, and establish a baseline data point so you can measure improvement.
Now lets look at the metal finishing diagram shown earlier during the Metal Finishing the Basics portion of our training.

Dragout from the process or plating bath has multiple impacts.

As shown in the video, dragout causes material losses. The material in this case is the process/plating chemicals. Plating chemical additions are more frequent because of these losses.

The dragout decreases rinse water quality which leads to an increase rinse water flow and use.

The excess chemicals from dragout and increase rinse water flow send more rinse water to wastewater treatment.
Increase wastewater generation has a direct correlation to wastewater treatment chemical use. This use increases because more gallons must be treated and there is a higher metal ion concentration from the dragout plating bath.

More chemicals and plating solution in the effluent produces more wastewater sludge and more disposal responsibilities including cost, paperwork, and liability.
Once a metal finishers is aware of dragout, they should measure it to establish baseline data and can measure improvements and reductions.

There are 3 methods of measurement;
Direct volume measurement (dragout volume from parts)
Metal concentration/conductivity in rinse tanks
Wastewater contaminant concentration

Conductivity measurement is the easiest and most effective. Direct volume is time consuming and difficult to measure total volume and Wastewater concentration can be expensive because of lab testing. Also, with WW concentration, targeting a particular plating line or solution is difficult.
Calculating dragout volume in L/rack is possible. The estimated slope of the stagnant rinse tank is 1.5 mg/L/rack. That is delta C. We can assume that the rinse tank volume in 1000 L and the process bath metal concentration is around 70,000 mg/L. Dragout volume is about 21 mL/rack.
Measuring dragout with conductivity works because conductivity versus concentration is linear. This make measurement easy yet effective.
By measuring with conductivity, dragout costs can be estimated for particular parts. This can help when analyzing what changes are most cost effective and/or save the most money.

It may help a company make cost/benefit decisions; Which will have the largest and most effective impact?

Lower Dragout or slower withdrawal rates
Lower dragout or longer hang time
Worker training
Incentive programs
WWTS
Recovery technologies to reclaim plating bath

Benchmarking is an important part of dragout measurement. A standard of measurement must be set to establish a reference point for future reductions and improvements.
Identifying and measuring dragout is the first step. From here, dragout reduction techniques can be applied.
You have a copy of this diagram in your manual.

It is important to look at the “4 m’s” that cause raw material loss through dragout

Methods, Man, Materials, and Machine
How parts are placed and positioned on a rack effects dragout rates. Racks are made of metal and be receive the plating solution themselves as shown in the video. This leads to odd shape clusters that increase surface area for dragout to collect. Maintaining the racks are significant.

The parts geometry themselves can attribute to dragout. Certain shaped parts like the ones on this slide and collect excess plating solution. They must be racked accordingly, for instance, with a different angle. Also, part overlap is critical so that the plating solution doesn’t drip directly onto the next part below.

Finally, barrel rotation and hang time are important factors also. As seen in the video, a few extra seconds on hang time can reduce dragout significantly.
Barrel rotation also has impacts on dragout. 8 ppm/rack difference or nearly 20% reductions will be significant over a months and years production time.
Drain time should be increased but only with reasonable time standards. As mentioned earlier, conductivity can be used to decide between dragout reduction methods and how they are implemented. Based on this graph, drain time’s greatest impact on dragout is the 5 to 10 seconds.
Many metal finishing shops have manual operations or semi-manual operations. Worker practices are therefore important when completing a dragout reduction initiative.

Withdrawal rates, drainage time, tilting and hang bars can influence losses of plating solutions.
The video demonstrated how the speed of withdrawal rates impact dragout rates. A faster withdrawal rate leaves a thicker film on part than a slow rate.
Process layout and maintenance can also influence dragout reduction. The video discussed proper tank spacing and drain boards.

The right tank sequence is important also, like including dragout tanks and spray rinsing.
Installing dragout tank that collect excess plating bath and returns to original bath reduces metal discharge by 30% per day. At the same time, rinse water flow rate was reduced by 30% also which yields water savings.
Spray rinsing, which we will go into more detail this afternoon can reduce metal discharge by more than 50% and reduce rinse water flow without installing a dragout tank. Sometimes both dragout tanks and spray rinse can be used if plating operations has space.
Cost savings of a typical spray rinse system is 60%.
This section focuses on how to utilize the relationship between conductivity and dragout to optimize rinse water usage. From discussion earlier conductivity and dragout are directly related and can be used to effectively measure dragout (increasing concentration of ions) in the subsequent rinse baths.
Keys to Identifying P2 Opportunities at Metal Finishing Facilities

• **Conductivity Control**
  – does the facility use conductivity measurement to manage their rinse system(s)?
  – if they have a system, what type is it, how do they operate it, what are their results?
  – if they do not have system do they know the relative costs and benefits of installing one?
These components are an example of a fully automated conductivity control system. There could be wide range of layouts and degree of automation utilized in implementing this approach. Including manually adjusting flows utilizing a continuous readout conductivity meter or even a hand held unit and control charting.
Problems with this system are caused because the cathode in the solution is going to “plate” with the metal ions in the solution. This requires constant cleaning & recalibration of the sensor.
Measures an induced current in the solution. This method avoids the fouling problems with conventional sensors.
Keys to good control are representative measurement of the conductivity in the tank. Another item not on the list would be to have the sensor stationary and not in various positions over time. Good circulation of rinse water also is very helpful and can be achieved through mechanical mixing or double dipping of parts in the rinse tank.
Establishing the initial set point is very important for assuring that changing the rinse flows will not effect product quality. Product quality and conductivity need to be measured carefully and measured together. The concept is the same as many other P2 opportunities, utilize the least amount of a raw material while maintaining product quality. The net result will be an increase in efficiency and a consistency in the product quality due to process control.
This is the effect seen by establishing a set point and operational range for tank refill, and operating the rinse tanks with the controls in place. As you can see the effect is very dramatic and is typical for instituting controls.
As mentioned in the Drag-out portion of this morning’s session, spring rinsing can reduce dragout significantly.

But spray rinsing has other benefits;

Less raw material wasted because of reduced dragout
Less contamination of process baths by dragin (I’ll show an example of this process later)
Lower rinse water flow rates required in running rinses
More efficient, higher quality rinsing
Benefits of Reducing Rinse Water

- Lower water bills and sewer fees
- Wastewater treatment impacts
  - Lower treatment chemical costs
  - Higher retention time
  - Less O&M requirements
- Decreased sludge generation

Similar to dragout reduction, reducing rinse water can have the same WWTP benefits.

A efficient rinse water system can lower water bills and sewer fees.

Less water means lower treatment chemical costs and a higher retention time due to a lower flow rate.

In turn, Operational and maintenance costs and requirements are reduced
Some basic techniques to improve rinse efficiency

Agitation

- Rack motion
- Forced air and/or forced water
- Sprays
- Double dipping

Flow Controls and Water Quality

- Flow restrictors
- Conductivity control systems
- Tap water vs. deionized water

Flow controls & water quality

- Flow restrictors - must be used properly to determine most efficient flow
- Conductivity control systems - Ron covered this
- Tap water vs. deionized water - depends on product/customer specs and production process
Techniques that Improve Rinse Efficiency

- Tank Design
  - Size (not bigger than necessary)
  - Eliminate short-circuiting
- Tank Layout
  - Multiple tanks
  - Countercurrent rinses are extremely efficient
    - 90% reduction compared to a single rinse
    - Most old shops can not accommodate the larger “footprint”

Techniques continued

Tank Design
- Size is important (a large tank does not mean better rinse efficiency)
- Eliminating short-circuiting-improper mixing of rinse tank/stratification

Tank Layout
- Multiple tanks-dragout tanks and rinse tanks
- Countercurrent or counterflow rinsing can often yield 90% reduction in rinse water compared to single rinse
- However, many old shops cannot accommodate major layout changes or the large tank “footprint”
As I mentioned, counter current or counter flow is another rinse water reduction technique.

Here is a general diagram describing the process. The cleanest rinse and rinse water inlet is always in the last rinse tank. It then flows over or is pumped back to the first rinse tank.
Example of counterflow rinsing reducing dragin

A zincate rinse before an electroless nickel bath. Before counterflow rinse,
Rinse water flow rate was 2 gpm
Original zinc conc. in rinse was 415ppm

After two-stage counterflow zincate rinse,
Final rinse stage zinc conc. is 222ppm
Electroless bath dragin was 6.1 ppm of Zinc per day and now is 0.02 ppm

That's is a 305% reduction!!!
Reactive Rinsing

Parts

Alkaline Cleaning

Rinse Tank

Parts and Dragout Process Steps

Acid Etch

Parts to Additional Process Steps

Rinse Tank

Rinse Water Effluent

Clean Water
Reactive Rinsing Example

- 172 Acid Bath Dumps/Year
  - 200 gallon bath
  - $23k/year for bath makeup

- In-Shop Measurements:
  - Alkaline Rinse pH: 12.15
  - Acid Rinse pH: 1.32
  - Combination: 1.77

- Estimated 50% Reduction in Acid Use/Dumps
  - Capital: $1,250
  - Payback: <1 month
Spray rinsing might work well and save money and plating bath, but it must be set-up and properly designed to accomplish any of these reductions.
Keys to Identifying P2 Opportunities at Metal Finishing Facilities

• Rinse Tank Optimization & Spray Rinsing
  – are any measures in place to extend the life of the rinse baths, skimmers, agitation, sludge removal, water treatment?
  – are spray rinses utilized, if so, where are they located, how are they operated and why?
  – are rinse tanks utilizing counter current flow, are there flow restrictors or controls?
  – is the quality of the rinse water monitored or measured?
  – has the facility experimented with different rinse configurations, flows, or sprays?
Spray rinsing on Nickel line reduced dragout by 58%

50.0 gallons per month to 20.8 gallons
As mentioned in the beginning of this session, the correct spray rinse system and equipment is important. Using a garden hose spray gun compared to air-atomized spray gun can use over 36,000 gallon/yr more.
## Air-Atomized Spray Guns

<table>
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<tr>
<th>AIR-ATOMIZING SPRAY RINSING</th>
<th>RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Reduction</td>
<td>Annual Savings</td>
</tr>
<tr>
<td>Spray Rinse Water Use</td>
<td>36,960 gal.</td>
</tr>
<tr>
<td>Wastewater Generation</td>
<td>36,960 gal.</td>
</tr>
</tbody>
</table>

Total Savings = $1,179/\text{year} \\
Total Cost = $636 \\
**Payback Period < 7 months**

*Annual savings for wastewater generation is based on estimated treatment chemical use reduction.

These savings are significant with a short payback period.
You can see a 61% reduction in the conductivity slope and how bath life can be extended.
Great payback of less than 2 months

<table>
<thead>
<tr>
<th></th>
<th>Annual Reduction</th>
<th>Annual Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Dye Use</td>
<td>43.2 lb</td>
<td>$2,419</td>
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<tr>
<td>Wastewater Generation</td>
<td>14,856 gal.</td>
<td>$1,247*</td>
</tr>
</tbody>
</table>

Total Savings = $3,666  
Total Cost = $355  
**Payback Period < 2 months**  

*Annual savings for wastewater generation includes $186 in process water purchases and $1,061 in wastewater treatment O&M.
Tools and Resources for Assistance
Available Tools

- Metal Finishing P2 Videos
  1. DHWM Preserving the Legacy Series: “The Metal Plating and Finishing Industries”
  2. USEPA “Pollution Prevention for Metal Platers: Drag-out Reduction”

- Advanced P2 Technical Assistance
  - TECHSOLVE P2IRIS “Metal Finishing”
    http://www.techsolve.org/iamsorg/p2iris/metalfinish/default.html

U.S. EPA/NAMF/AESF

- Strategic Goals Program
  http://www.strategiegoals.org/