“Greening” the Chrome Plating Industry: Case Study

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May 6th, 2010
Outline

• The Basics of Chrome Plating
• Why?
  – Hazards of Chrome Plating
• Outline of Case Study
  – Ottawa Gage
• Current State of Operations
• Development of Action Plan
• Results of Study
• Conclusions
• Future Plans
• Questions
Basics of Chrome Plating

- Electroplating or Electrodeposition uses electrical current to reduce metal cations within an aqueous solution (chromic acid) onto a conductive part or workpiece in the form of a thin layer on the part surface.
  - The properties of the chrome layer include wear resistance, hardness, low coefficient of friction and visual appeal.
Hexavalent chromium ($\text{Cr}^{+6}$) is plated onto a workpiece surface with a reduction.

A catalyst initiates this process. At the end of the reduction, only pure chromium ($\text{Cr}^{+0}$) is plated onto the workpiece.

Solution is a mixture of (99%>) hexavalent and (1% or less) trivalent chromium. The workpiece is the only point where chromium is fully reduced.

Process gives off oxygen and hydrogen at the surface.

Image Source: Swicofil AG Textile Services
Site: [http://www.swicofil.com/textile_metallization.html](http://www.swicofil.com/textile_metallization.html)
Retrieved (2/26/10).
Why the concerns?

• Environmental and Health Concerns
  – Hexavalent Chromium
    • Highly Toxic, Carcinogenic
  – Exposure limits set by OSHA. 2/06
    • Can not release dust, fumes or mists from the operation.
    • Permissible Exposure Limit (PEL) of 5.0 µg/m³
      – Maximum allowable 8 hour concentration exposure.
      – Air samples must be taken during working hours.

• MDEQ has set air emission restrictions.
  – Compliance guidelines control a set permissible level for small platers of 0.03 mg/dscm (milligrams per dry standard cubic meter of exhaust air).
  – Hexavalent chromium is extremely mobile and travels into the water tables very easily.
Case Study: Ottawa Gage

• Designer and manufacturer of precision crafted gages and measuring instruments.
  – Serving the automotive, aircraft and construction equipment industry.
  – Located in Holland, MI.
  – ISO/IEC 17025 Accredited
Chrome Plating Operation

• Ottawa Gage approached GMI regarding the press release back in October.
  – Discussed interests of the group and expressed concerns with a hexavalent chrome plating process at their facility.

• A university/industry collaborative was formed to work on reducing the environmental impact of their small-scale chrome plating process.
Current Process Concerns

• Energy Conservation
  – More efficient electronics and controls.

• Hazardous Waste Mitigation
  – Managing and preventing waste.

• Alternative Processes
  – Investigating alternatives to hexavalent chrome plating.
Current Environmental Standpoints

• The three tanks source an air purification system.
  – Hexmaster Air Scrubber unit.
    • Removes chromic acid from the air that is generated by bursting air bubbles at the surface of the tanks.
    • Captured by duct system and hoods on each tank.
    • Runs dry with a periodic wash down cycle.
      – Wastewater is used to replenish evaporation from tanks.

Image Source: Met-Pro Corporation (2010)
Current Statistics

• Energy Consumption
  – Plating Rectifiers
    • Negligible.
  – Tank Heaters
    • Operate approx. 5 hrs/day, yearly
    • $1,941.54/yr in heating costs for all three tanks

• Hazardous Waste
  – 660-825 gallons/yr of chromic acid and contaminated work area supplies (towels, wood framing, etc.)
    • $3,600-4,500/yr- Cost of disposal to treatment facility.
Implementation Plan

• Critical Objectives of Our Work
  – 1. Improve the safety of the work environment.
  – 2. Reduce or eliminate the amount of hazardous waste from the process.
  – 3. Improve energy efficiency of the plating tanks.

• Provide cost analysis for all implementation plans.
Hazardous Waste Remediation

• Investigated switching to alternative process.
  – No process will fit the requirements of the products plated in an economical manner at this time.

• Developed the root causes for hazardous waste disposal.
  – 1st Source: Plating bath is contaminated and no longer plates out onto parts.
    • Three sources of contamination.
      – Hexavalent chromium is reduced to trivalent chromium.
      – Mineral contamination from the water source.
      – Dirt and Iron from the pre-plated workpieces.
  – 2nd Source: Degraded rubber tank liners, wood framing from tanks and clean up supplies are contributors to solid waste that is contaminated by chromic acid.
    • All waste needs to be sent to the same hazardous waste facility.
Methods of Solution Filtration

• Types of Filters to remove metallic contaminants from a solution.
  – Ion-exchange
  – Electrodialysis membranes
  – Semi-permeable polymer membranes.
  – Electrolytic separation
    • Unfortunately, many of these methods will not withstand the strong corrosive chromic acid (Guddati, 1999).
Reoxidation of Trivalent Chromium

• Electrolytic separation is the best option for small plating systems.
  – Typically these units are called porous ceramic diaphragms.
  – Applying a current from a rectifier allows metallic contaminates to accumulate within the ceramic pot.
    • This waste can be collected in sludge form or plated to the cathode.
    • Simultaneously, the trivalent is reoxidized at the anode of the device.
      – Further ensuring solution life.

Site: www.hard-chromesystems.com (Retrieved 4/22/10)
Contamination at the Water Source

• Currently the three tanks source a municipal water source with no internal filtration.
  – Typically, with electroplating systems a high water purity is desirable for the solution bath and top-off water.

• RO/DI units serve as a good method for filtering water economically for small plating systems.
Basics of RO/DI

• How does it work?
  – The RO/DI system utilizes pressurized water to permeate a membrane and a series of filters to remove particulate matter and ions from the water.
  – The water is processed into two streams.
    • Purified water will go to the plating process.
    • Rejected water will go to alternative processes within the plant facility.

Image Source: SpectraPure (2010)
Design new system to source a RO/DI Unit

• The unit is a SpectraPure 100 GPD RO/DI unit with microprocessor control for automatic filter cleaning and storage top-off.
  – All new solution will be made with filtered water. Also the evaporation top-off and air scrubber filter water will source the unit.
  – A layout was designed to make the system closed loop. All rinse tanks and air scrubber water sources back to the original plating tanks.
Rejected water used in other plant operations

Municipal Water Supply

Air Scrubber Filtration Unit

RO/DI Unit

RO/DI Storage Tank (Purified Water)

Air Scrubber Waste Water

Recycle rinse water back to tanks

Clean Air To Atmosphere

Mist Hood

Mist Hood

Tank #1

Tank #2

Rinse Tank

Closed-Loop System

Western Michigan University
College of Engineering and Applied Sciences
Manufacturing Research Center
Workpiece Contamination

• Proper washing of parts removes grease and grime from previous processes.
• Small portions of iron added to the bath from the plated parts is removed by the ceramic diaphragms.
• No additional countermeasures are needed to eliminate this source of contamination.
Solid Wastes

• Rubber tank liners are constructed of PVC.
  – Oxidation at ‘liquid-line’ causes PVC to breakdown.
    • Current life of the tank liners is 1.5-2 years before replacement.
    • Disposed as hazardous waste.
• Framework of tank and air scrubber hood is made of wood currently.
  – The chromic acid often causes the wood to breakdown and results in replacement on a biyearly basis.
    • Wood sent to hazardous waste.
• Towels, paper, rags, etc. to clean up work area and dripping due to pulling parts from the solution.
  – All these supplies sent to treatment facility as well.
PVC Liners w/ Teflon Skirt

- Increases the life of a liner from 1.5-2 yrs to 6-7 yrs.
  - PTFE or Teflon barrier prevents oxidation of liner at the surface.

New Work Station

• Incorporation of drip guards between tanks.
  – Removable and easy to clean.
  – Made from PVC or PTFE depending on service life desired.
  – All chromic acid falls back to plating tanks with design.
Work Surface

• New PVC work surface eliminates the need to throw away wood framing on biyearly basis.
  – PVC is resistant to corrosion from chromic acid and will last many years in operation.
• Custom cut to fit tanks.
Air Scrubber Hoods

• The new work surface also accommodates air scrubber hoods over the tanks.
  – Made from PVC for significant increase in useful life compared to steel or wood components currently used.
Economics and Waste Reduction

• Porous Ceramic Electrolytic Separation Unit
  – Initial Cost: $1,102.00
  – Yearly Operation Cost: $298.38/yr
    • Includes replacement/maintenance parts and electricity.
  – Reduction of Waste: ≈99% of previous volume.
    • 2 Gallons of hazardous waste/yr

• RO/DI Unit
  – Initial Cost: $1,093.94
  – Yearly Operation Cost: $252.47/yr
Economics Continued..

• PVC Liners w/ Teflon skirt
  – Based on difference in liner life there is an added cost to purchasing liners of approx. $10/yr.
    • This is recuperated with the reduced labor of installing liners.
      – Usually takes two people an 8 hr shift to switch out liner.

• PVC Work Surface, Hoods and Drip Guards
  – Approx. $3,000.00 to build unit including labor.
    • Payback is hard to quantify. Eliminates significant portion of waste thrown away.
    • Added worker safety with cleaner work environment.
Economics Continued...

• Waste expenditures go from $3,600-4,500 to an estimated $50/yr.
  – Payback period is less than 1.5 years.

• Hazardous waste will be reduced by approximately 97% overall.
Energy Conservation

- Conducted studies on the current system for energy consumption and utilization.
  - Investigated the amount of plating amperage and energy consumption of the rectifiers.
  - Checked the utilization of each tank system with respect to capacity.
  - Conducted a heating optimization study.
Utilization vs. Capacity

- Discovered the systems were running at low utilizations.
  - Combined tanks with similar products and plating amperages.
Heat Optimization Study

- Observed a significant amount of days with no production. Often batches would have substantial gaps between runs.
  - Turning off heaters was suggested as a possible option to reduce energy consumption.
Conducted Heat Transfer Studies of Current System

<table>
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<tr>
<th>From 2009 Data</th>
<th>Tank #1</th>
<th>Tank #2</th>
<th>Tank #3</th>
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<tbody>
<tr>
<td>Days of No Use</td>
<td>221 Days</td>
<td>243 Days</td>
<td>210 Days</td>
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<tr>
<td>Avg. Time between Batches</td>
<td>1.55 Days</td>
<td>2.17 Days</td>
<td>1.35 Days</td>
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<tr>
<td>kWh Saved on No Production Days</td>
<td>25.76 kWh</td>
<td>30.07 kWh</td>
<td>22.44 kWh</td>
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<tr>
<td>kWh to Reheat Tank</td>
<td>30.69 kWh</td>
<td>24.45 kWh</td>
<td>24.45 kWh</td>
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<tr>
<td>Days of No Operation- Breakeven</td>
<td>1.85 Days</td>
<td>1.47 Days</td>
<td>1.47 Days</td>
</tr>
</tbody>
</table>

Heater Energy Consumption Study
Conclusions

• Reduced the amount of hazardous waste by 97%.
  – Payback of under 1.5 years.
• Provided tank reconfiguration to reduce the size of the operation by 26%.
  – Optimizing the heating schedule reduced energy consumption by 53%.
  – Adjusted to downtime in the process.
Alternative Processes

• Currently we are investigating economical and environmentally sustainable alternatives to hexavalent chrome plating.
  – Trivalent chrome
  – HVOF thermal sprays
  – Electroless nickel
  – PVD and CVD coatings


Questions?

• Thank You