Practical Pollution Prevention Guide

Chromium Emission Reduction for Electroplaters and Anodizers

Program for Toxic Air Pollutant Studies
University of Northern Iowa

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Introduction

This manual is for owners, supervisors, and environmental managers at facilities engaged in chromium electroplating and/or chromic acid anodizing. It provides a straightforward view of chromium emissions and how to reduce or control those emissions.

The manual is divided into five sections:

- ⇨ Incentives to reduce air emissions
- ⇨ Chromium emissions
- ⇨ Conventional control technologies
- ⇨ Alternative control technologies
- ⇨ Choosing a Chromium Emission Reduction Strategy

The first section on incentives provides the latest information regarding federal regulations and applicable federal operating requirements. Other incentives for reducing chromium emissions are also addressed.

"Chromium Emissions," explains how emissions are generated during chromium plating and chromic acid anodizing. This section includes a brief glossary of terms commonly used in the metal finishing industry.

The section titled "Conventional Technologies" describes current methods used to control emissions from plating and anodizing processes. It also includes basic sketches showing the difference between various pieces of emission control equipment. Cost estimates for acquisition, installation, and operation of each type of equipment are provided.

"Alternative Technologies" compiles the results of applied research and field testing of pioneer strategies for reducing chromium emissions. These strategies have been tested in the laboratory, at an applied research setting using an intermediate sized tank, and in the field at industrial sites. Cost estimates for acquisition, installation, and operation of each strategy are addressed.

The final section, "Choosing a Chromium Emission Reduction Strategy," provides emission reduction results and sample data generated from various technologies, both conventional and alternative. This allows for a review of pertinent information regarding end results which can be reasonably attained from each type of control technology.

This manual will help chrome platers/anodizers understand how regulatory requirements can be met using the emission reduction or control method that is most suitable to their needs.

Testing of alternative techniques is now underway. Revisions to this guide will be provided when results are available that will aid in selecting the best, most effective approach to chromium emission reduction.

Chapter 1

Incentives to Reduce Air Emissions

Chromium Emission Reduction
for
Electroplaters and Anodizers

Incentives to Reduce Air Emissions

Air Emission Regulations

The Clean Air Act Amendments (CAAA) of 1990 require the U. S. Environmental Protection Agency (EPA) to develop emission standards for 189 hazardous air pollutants, including chromium and chromium compounds. EPA has proposed limiting chromium emissions by requiring chromium electroplating and anodizing facilities to meet an emission concentration limit or install a specified control technology. The concentration limit will be the maximum chromium concentration allowable in air emissions, regardless of local air quality.

When determining the concentration limits and specified control technology, EPA classifies chromium electroplaters and anodizers into five categories:

- Large hard chrome electroplaters
- Small hard chrome electroplaters
- Decorative chrome electroplaters using chromic acid process
- Decorative chrome electroplaters using trivalent chrome process
- Chromium anodizers

Large hard chrome electroplaters are those facilities whose maximum cumulative potential rectifier capacity is greater than 60 million ampere-hours per year.

Small facilities are those that have a maximum cumulative potential rectifier capacity less than 60 million ampere-hours per year.

The "maximum cumulative potential rectifier capacity" is the sum of the total installed rectifier capacity at the facility, multiplied by 8,400 operating hours per year and 0.7, which assumes that the electrodes are energized 70 percent of the total operating time.

The proposed standards for each of these categories are summarized in Table 1.

Table 1
Proposed Standards for Chromium Emissions

Facility/process	Emission Limit	Alternate Method
Hard chrome, large facilities	0.013 mg/dscm+	
Hard chrome, small facilities	0.030 mg/dscm	
Decorative chrome, chromic acid process	0.003 mg/dscm	40 dynes/cm*
Decorative chrome, trivalent chrome	0.048 mg/dscm	55 dynes/cm*
Anodizing, chromic acid process	0.003 mg/dscm	40 dynes/cm*

+milligrams total chromium per dry standard cubic meter of ventilation air
*maximum bath surface tension during tank operation

EPA recommends use of a packed bed scrubber, mist eliminator or combination of these two control devices for removal of chromium from exhaust air. However, any type of control device may be used as long as the emission limit is met.

Existing hard chrome electroplating facilities (large and small) must achieve compliance with the new standards within one year of the effective date of the regulations (not yet established); new facilities must achieve compliance immediately upon startup.

Existing decorative chrome electroplating facilities and chromic acid anodizers must achieve compliance within three months of the effective date of the new standards. New sources must achieve compliance immediately upon startup.

Additional requirements proposed by the EPA standards include: (1) operation and maintenance plans for emission control devices such as scrubbers and mist eliminators, and (2) compliance monitoring and performance testing. In place of compliance monitoring and performance testing, a facility may install a packed bed scrubber or composite mesh-pad mist eliminator **and** ensure that the chromium concentration of the cleansing water is maintained below 45 mg/l.

Operation and maintenance plans must include:

- operation and maintenance criteria of the emission control device (including a standardized check list for documentation)
- procedures to be followed to ensure that equipment or process malfunctions due to poor maintenance or other preventable conditions do not occur
- systematic procedures for the identification of malfunctions
- procedures for the reporting of malfunctions immediately to supervisory personnel.

Wastewater Regulations

Many of the current technologies available to control air emissions rely on water washing of exhaust air. Due to the contaminants picked up by these wastewaters, they are potentially hazardous waste. Facilities have two options when managing wastewaters from air emission control equipment:

(1) Collect the wastewater and manage as a hazardous waste. This includes counting the amount generated toward the facility's monthly hazardous waste generation rate, proper labeling, storage time limits, and off-site disposal through an EPA permitted hazardous waste disposal facility.

(2) Treat the wastewater through a wastewater pretreatment system prior to sanitary sewer discharge. The added volume of wastewater may require a larger pretreatment system. Increased sludge amounts will also be generated as a result of the added wastewater. This sludge ultimately will require hazardous waste management, including the associated regulatory requirements and disposal costs.

Additional Incentives

In addition to the imminent regulatory standards, other incentives exist for reducing chromium emissions. These include:

- Improved air quality.
- Good public relations - efforts to reduce the amount of pollution generated are often well-received by the community and improve the public image.
- Reduced waste - some methods for reducing chromium emissions lend more efficiency to the chrome plating process, resulting in less waste.
- Increased worker safety - chromic acid emissions pose a severe health threat to those who work in electroplating facilities. Controlling the emissions can reduce employee exposure.

Chapter 2

Chromium Emissions

Chromium Emission Reduction
for
Electroplaters and Anodizers

Chromium Emissions

Process Description

Chromium plating is produced from chromic acid (CrO^3) solutions which contain one or more catalytic anions. The electrodeposited chromium metal is extremely hard and corrosion resistant. It has a low coefficient of friction and imparts exceptional wear characteristics to parts on which it is plated. This process is generally used to give a deposit thickness of greater than 0.1 mil and up to 20 mils or more.

The major uses are to provide coatings with superior wear, abrasion and/or corrosion resistance, and high reflectivity. Hard chromium deposits are thick and used to rebuild or salvage worn parts such as rolls and roll journals, molding dies and other tools, cylinder heads, crankshafts, and mismachined items. In decorative chromium plating, a thin coat of chromium is added to protect the already bright finish from tarnishing. For example, a car bumper has between 5 and 15 millionths of an inch of chrome over nickel finish. The nickel gives the bright finish and the chromium imparts a bluish hue to the metal and protects it from oxidation.

It is sometimes difficult to determine whether a finish is decorative or hard since both finishes share the advantages of a chrome surface. For example, the characteristics of hard chrome partially enhance a decorative finish and add to its quality and types of applications; while the bright finish of decorative chrome adds to the appearance (and hence acceptability) of hard chrome deposits.

Anodizing is an electrochemical treatment whereby stable oxide films or coatings are formed on a metallic surface. Both chromic acid and sulfuric acid processes are used to form the oxide film. Chromic acid processes generate film thicknesses between 0.02 and 0.04 mil. The advantages of using chromic acid over sulfuric acid include increased corrosion protection, excellent base for paint or other organic coatings, and little or no effect on fatigue strength. For these reasons, chromic acid anodizing is used for threaded parts and aircraft parts.

Generation of Emissions

Plating and anodizing involve use of electricity and hot, corrosive solutions. Important factors that are controlled in plating and anodizing include:

- bath temperature
- anode surface area
- cathode surface area
- amperage
- voltage
- current density

To a large extent, these factors are not variable, but must be set within a narrow range to achieve good results. Other factors that remain constant and are not adjustable are:

- bath surface area
- part geometry
- anode/cathode geometry

While each of these factors plays a key role in producing the desired finish, each also contributes to the amount of mist generated during bath operation. The mist is produced from oxygen and hydrogen gases formed at the anode and cathode, respectively.

Approximately 80-90 percent of the electrical charge applied to a chrome plating solution goes into the formation of hydrogen and oxygen gases.

The generation of these gases results in the formation of tiny gas bubbles, which eventually rise to the surface of the solution. These bubbles burst and generate fine aerosol droplets. The aerosols that arise vary in size and are comprised of the plating bath solution components. The droplets are then carried away from the chrome plating tank by the exhaust ventilation system.

Pollution Prevention and Control

Pollution prevention and control measures focus on preventing the formation of chromic acid mist or capturing the mist after it has been generated and leaves the plating solution.

Preventing the formation of chromic acid mist generally involves either containing the gas bubbles by placing a barrier on the surface of the plating bath or by reducing the energy with which the bubbles burst by lowering the surface tension. This guide addresses the following technologies:

Conventional

- Floating plastic balls
- Mist suppressants
- Wetting agents

Alternative

- Tank covers

Capturing the chromic acid mist as it leaves the work area involves use of a ventilation system and a pollution control device. There are a number of commercially available pollution control devices that will perform this function. Technologies specifically addressed in the guide include:

Conventional

- Mesh-pad mist eliminators
- Blade-type mist eliminators
- Packed bed scrubbers
- Venturi scrubbers
- Cyclone scrubbers
- Fan-separator packed bed scrubbers
- Spray towers
- Dry scrubbers

Alternative

- Baffle systems
- Condensing coil systems
- Combined systems
  - Baffles and floating plastic balls
  - Condensing coil system and floating plastic balls
  - Baffle and condensing coil systems

For each technology, considerations for effective use and associated costs are outlined.

Chapter 3

Conventional Technologies

Chromium Emission Reduction
for
Electroplaters and Anodizers

Conventional Technologies

Emissions Reduction and Control

Hydrogen and oxygen gas formation are responsible for generating chromium mist. Other factors, such as high viscosity of the chrome plating solution and surface tension, also affect chromium mist generation. Additions or alterations to the chrome plating or anodizing process can affect these factors and reduce the amount of chromium mist generated. Another approach is to install mechanical pollution control devices to control chrome emissions after the mist is generated.

Existing chromium emission control technologies are based on one of the following approaches:

- Preventing the chromium-laden mist from escaping the solution
  - Floating plastic balls
  - Mist suppressants
  - Wetting agents

- Capturing the chromium-laden mist after it leaves the tank
  - Mist eliminators (blade-type, mesh pad)
  - Wet scrubbers (packed bed)

Prevention of Chromium Mist in Exhaust Air

The goal of pollution prevention is to minimize or prevent the creation of pollution that will then require control or treatment. In the case of chrome plating or anodizing, pollution prevention can be implemented to inhibit the release of chromium mist into the air. This can be accomplished by forming a physical barrier atop the plating bath, such as plastic balls or mist suppressants, or by altering the chemistry of the bath with the addition of wetting agents.

Floating Plastic Balls

Solid polypropylene balls, 3/4" to 1 1/2" in diameter, placed on top of the plating bath will retard mist formation and evaporation (see Figure 1). They may prevent up to 70 percent of the mist from escaping the plating solution. These balls can be effectively used in both decorative and hard chrome plating processes.

Considerations

Polypropylene is reasonably resistant to chromic acid solutions at temperatures up to 140°F. Higher temperatures may cause swelling and breakage of the balls. Solid balls are used rather than hollow balls because hollow balls may develop seam leaks and allow the solution to be trapped within the ball.

When using balls in a plating solution, pre-cleaning of parts is essential. Small amounts of oil and grease from dirty parts may float on the bath surface and adhere to the balls. As parts are raised and lowered in the bath, the oil-covered balls may drag across the part surface and prevent effective plating and rinsing, resulting in a flawed chrome surface. This is not usually a problem in captive shops where incoming parts are fairly clean.

However, in some job shops, parts are received completely covered with oils and/or greases. Improved cleaning to prevent carry over of unwanted oils and greases into the plating solution is critical for effective emission reduction when using the plastic balls.

The most common problem with using plastic balls is that they become trapped in recessed areas of parts and prevent plating or cause burning or dulling of the part plated. The size of the balls is an important factor in whether or not the balls will become entrapped. If possible, balls that are larger than the recessed area of the parts should be chosen. To help prevent entrapment of balls, plastic mesh bags can be used. The bag will keep the balls together on the surface, and reduce the likelihood of balls being carried over into subsequent tanks.

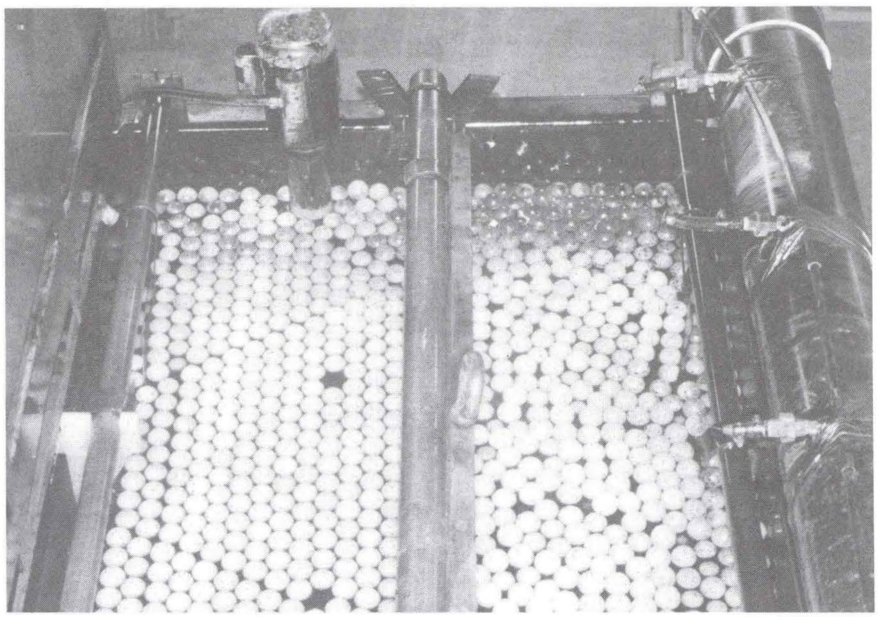

Figure 1 - Polypropylene balls being used in a plating bath

Costs

The cost of polypropylene balls ranges from approximately \$45 to \$200 per 1,000 balls, depending on the ball size and total quantity purchased. An average tank requires about 2,500 balls at a cost of \$400.

Since the balls operate on a "stand alone" basis, there are no additional operating costs for utilities or process related waste treatment. There may be an occasional need to replace some of the balls on an annual basis depending on the operating conditions of the tank and carry out losses.

Mist Suppressants

A mist (or fume) suppressant is a chemical which forms a barrier on the surface of the bath solution to prevent the mist from escaping. During operation of the plating or anodizing process, the mist suppressant generates a foam blanket and traps the process gases either between the bath surface and the blanket or within the foam blanket itself. Mist suppressants can be over 99 percent efficient in reducing emissions from decorative chrome plating and anodizing.

Considerations

Mist suppressants are chemical additives which may affect the chemical balance of the plating or anodizing solution. Because of this, a generic suppressant is not available for wide spread use. Within a shop, depending on various types of baths available (i.e., hard, decorative, proprietary) a different mist suppressant may be required for each bath; or a different concentration of mist suppressant may be required to achieve the desired result.

A second factor when using mist suppressants is the amount of foam generated during bath use. Too much mist suppressant will cause a large foam blanket that may result in excessive carry-over into subsequent rinse tanks. This will lead to increased need to replenish the suppressant in the operating tank. The foam blanket may also be drawn into the exhaust system, allowing a more concentrated chromium exhaust required to achieve the desired result.

A second factor when using mist suppressants is the amount of foam generated during bath use. Too much mist suppressant will cause a large foam blanket that may result in excessive carry-over into subsequent rinse tanks. This will lead to increased need to replenish the suppressant in the operating tank. The foam blanket may also be drawn into the exhaust system, allowing a more concentrated chromium exhaust to be released from the stack. Finally, too much mist suppressant can lead to spill over onto the facility floor or into other tanks, thereby generating large amounts of waste requiring clean-up, treatment and disposal. In any case, the thickness of the layer of foam has to be monitored for optimum efficiency.

Because hydrogen is the primary gas formed during the plating or anodizing process, dissipation of the gas is important. Build up of hydrogen within the foam, or under the foam, will pose a serious explosion risk. This is especially true when parts are removed "hot" (electric current still on). When "hot" parts are removed the hydrogen gas is spontaneously ignited and may result in equipment damage and serious personal injury, as well as causing an increased fire risk.

When using mist suppressants, it is best to start with half of the manufacturer's recommended amount, and go from there to determine the actual amount required to achieve the desired results. Remember that more suppressant chemical may be required on days when less plating is being performed, but that on busy days this extra suppressant may generate a huge, unmanageable foam.

Some mist suppressants have to be replaced due to the degradation of the active ingredient. These are known as "temporary." Other mist suppressants only have to be replaced when they are diminished through carry-over.

Costs

Mist suppressants come in liquid and free or compressed powder form, and may range in cost from approximately $10.00 to $60.00 per pound. The amount of mist suppressant chemical necessary to form a sufficient foam barrier will vary depending on the type of chemical mist suppressant used, tank size and frequency of plating. Trial and error additions will determine the amount of mist suppressant necessary to form an adequate but not excessive foam for an individual plating bath.

According to manufacturers' instructions for different mist suppressants, the recommended amount of chemical to add ranges from 0.01 to 0.1 percent of the total volume of the plating bath to approximately one ounce per 500 gallons initially with frequent additions thereafter. When used in the appropriate amount there is minimal carry over, thus replenishment is not required very often and maintenance costs are minimal.

Since mist suppressants are also "stand alone" emission controls, utility requirements are nonexistent, except perhaps for make-up water in the case of powders. Improper use of mist suppressants can generate serious waste management problems due to spills into other tanks or on the floor; or ruin the plating or anodizing solution itself.

Wetting Agents

Reduction of the surface tension of the chrome plating or anodizing bath will reduce the rate of mist generation by causing the gas bubbles to burst with less intensity. Surface tension reduction can be achieved by the addition of stable wetting agents. For chrome finishing, decreasing the surface tension to 40 dynes/cm will achieve excellent chromium emission reduction. In addition to reducing the amount of chrome emitted, this will cause less bath solution to adhere to the part being electroplated or anodized, producing less chromium-laden wastewater from rinsing.

Considerations

Because wetting agents are chemicals added to the bath, they may affect the quality of the deposit. Too much may cause burning, pitting, cloudiness, or poor adhesion resulting in a high reject rate. Insufficient amounts may result in little or no effect on reducing chromium emissions. Surface tension can be measured by using a "tensiometer", an instrument that measures the force necessary to lift a metal wire ring off of the surface of a liquid. Tensiometers cost around $2,000. A second method for measuring surface tension is the use of a "stalagmometer". While stalagmometers are much less expensive, they can be difficult to use. One major problem is that the plating solution tends to dissolve the ink marks used to make the calculations for surface tension.

A direct benefit of using wetting agents would be reduced plating or anodizing solution carry over into subsequent tanks. This would result in a savings of chemical resources within the process and reduced chromium loading in process wastewaters.

Many commercially available wetting agents also form foams. These double-action wetting agents/mist suppressants are slightly more efficient in reducing emissions, and not as much product is required.

Costs

The cost of wetting agents averages $25-$30 per gallon, but can be as low as $10 per gallon. Wetting agents may be carried out of the bath on parts or degraded over time, thus requiring periodic replacement. Typically, wetting agents are used up more frequently than mist suppressants. Utility costs are negligible or non-existent, since wetting agents would also be considered a "stand alone" control technology.

Improper use of wetting agents can result in defective plating or anodizing and may even ruin the solution. Replacement of the solution can be expensive in terms of new bath purchase, old bath disposal and down time while the situation is corrected.

Capture of Chromium Mist in Exhaust Air

When pollution prevention cannot be implemented, or is insufficiently effective in reducing emissions, the pollutants in the mist must be trapped after they have left the plating bath. Pollution control technologies available to capture chromic acid mist include mist eliminators and wet scrubbers. Many pollution control devices on the market combine different technologies.

Mist Eliminators

A mist eliminator is a device placed in the air stream of mist leaving the plating bath. The mist eliminator creates an obstacle, causing the pollutant-laden exiting air to change direction and lose velocity. As the air flow velocity decreases, the vapor condenses back into a liquid on the surface of the mist eliminator. The condensed liquid can then be routed back into the plating solution or treated as wastewater. There are two primary types of mist eliminators:

Mesh Pad Mist Eliminator

A mesh-pad mist eliminator consists of a mesh pad mounted on a frame and placed in the air stream to trap the liquid droplets entrained in the air flow (see Figures 2 and 3). The droplets coalesce until they are large enough to flow off of the mesh pad. The mesh pad is composed of one or more layers of intertwined fibers.

Considerations

Mesh pad mist eliminators can be up to 99 percent efficient and can be used alone. Additional mesh pad layers increase collection efficiency. For better collection efficiency, the mesh pad should be rinsed down at least once a day to remove chromic acid build-up and prevent the mesh pad from clogging. Collection efficiency depends in part on the velocity of the air stream and droplet size. Depth and configuration of the mesh pad is also a factor in determining collection efficiency.

Costs

For smaller platers and anodizers, the initial costs of installing a mesh pad eliminator system may range from $30,000 to $70,000. Annual operating costs of these systems varies from $13,000 to $20,000. Operating costs include employee time spent cleaning and maintaining the equipment, electricity, and possibly wastewater treatment and disposal.

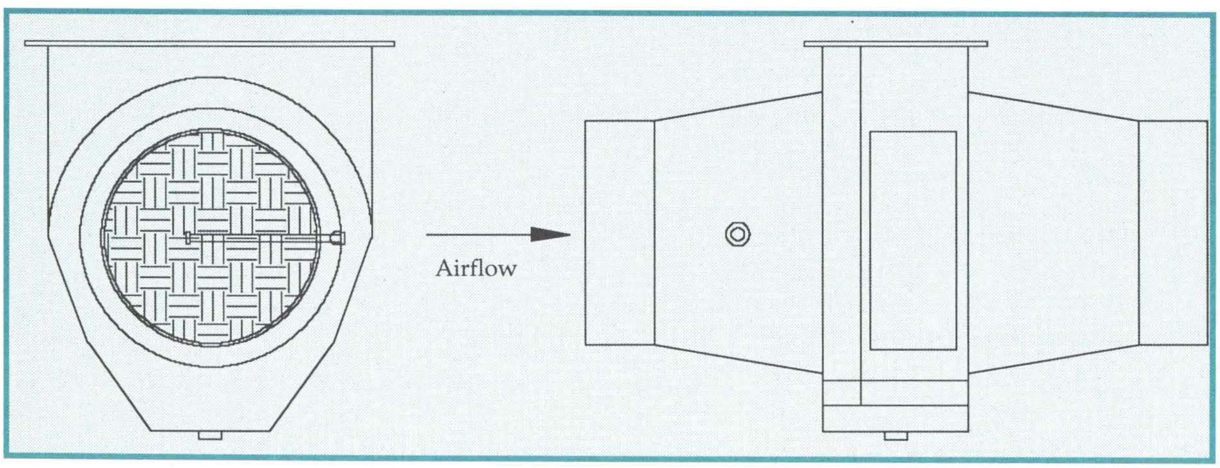

Figure 2 - Mist Eliminator - Location of the Mesh Pad

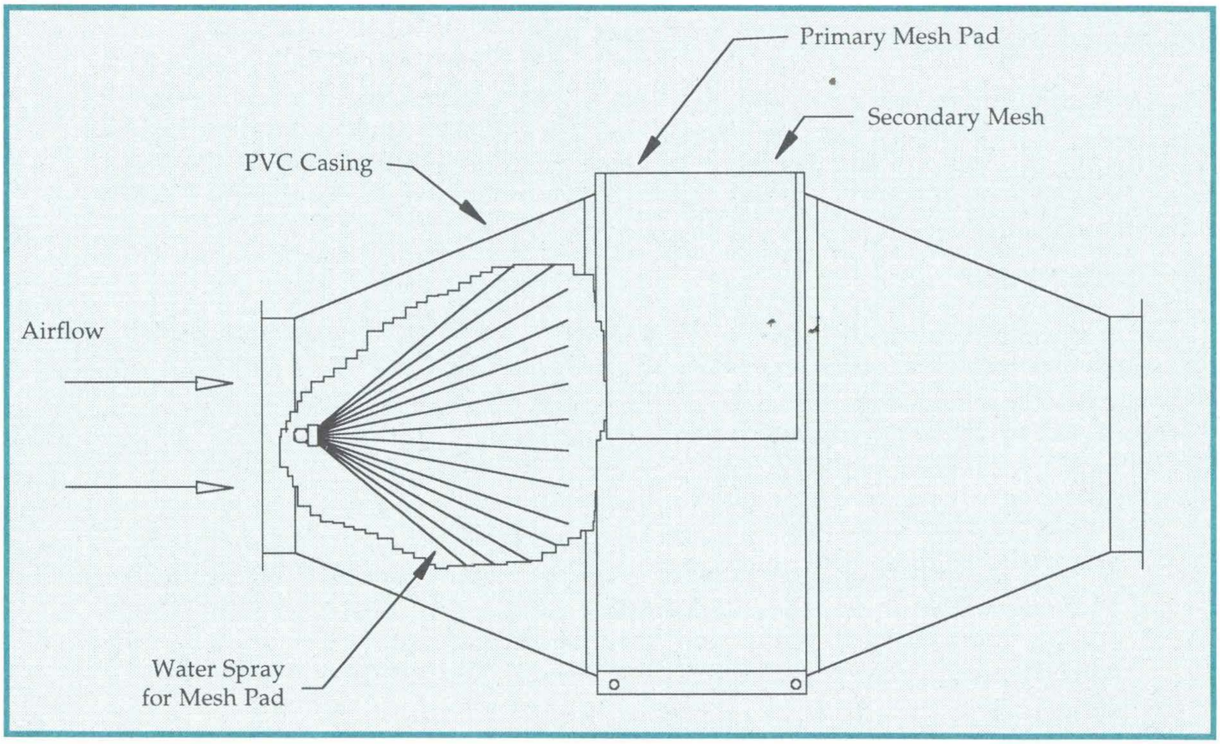

Figure 3 - Basic Design of a Mesh Pad Mist Eliminator

Blade-Type Mist Eliminator

This type of mist eliminator consists of vertically-mounted blades which provide directional changes for the incoming pollutant-laden air (see Figures 4 and 5). As the incoming air from the plating or anodizing bath flows around the blades, the mist portion adheres to the surface of the blades and either flows off due to gravity or is rinsed off when the blades are cleaned. The blades may be chevron shaped.

Considerations

Chevron blade mist eliminators can be up to 95-98 percent efficient. The efficiency of blade-type mist eliminators decreases as the particle size of the pollutants decreases. Since chromium particles in the chromic acid mist are so small, blade-type mist eliminators are not usually used alone for chrome plating and anodizing purposes, but in conjunction with other pollution control technologies.

The amount of space between the blades as well as the quality of the seal of the blades to the wall of the eliminator body affect collection efficiency. Too little space between the blades can result in clogging while too much space between blades might not provide sufficient directional change, thus allowing mist droplets to pass through the blades. The blades should be rinsed at least once a day to prevent clogging. The ventilation fan should be off during rinsing or the sudden water overload may cause water contaminants to pass through the blade area into the atmosphere

Costs

Initial installation costs for blade-type mist eliminators can range from $20,000 to $60,000 with the annual operating costs ranging from $13,000 to $20,000.

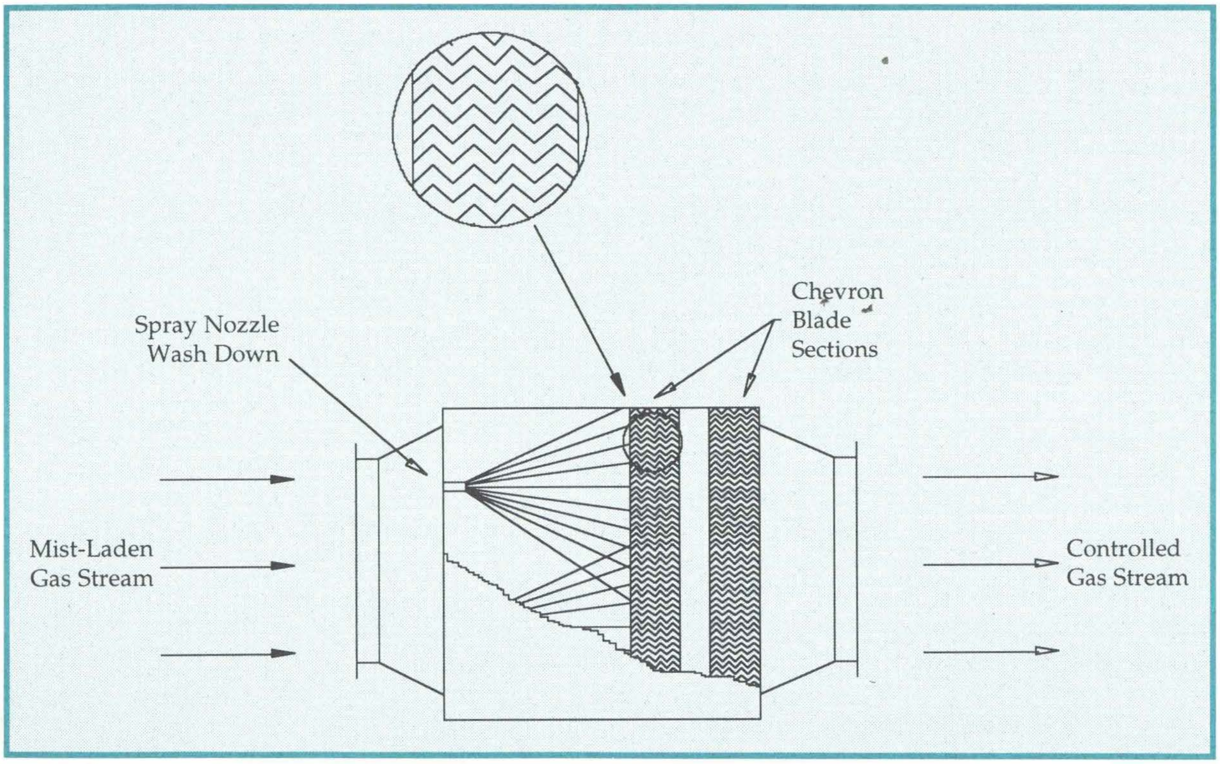

Figure 4 - Chevron Blade Mist Eliminator - Top View

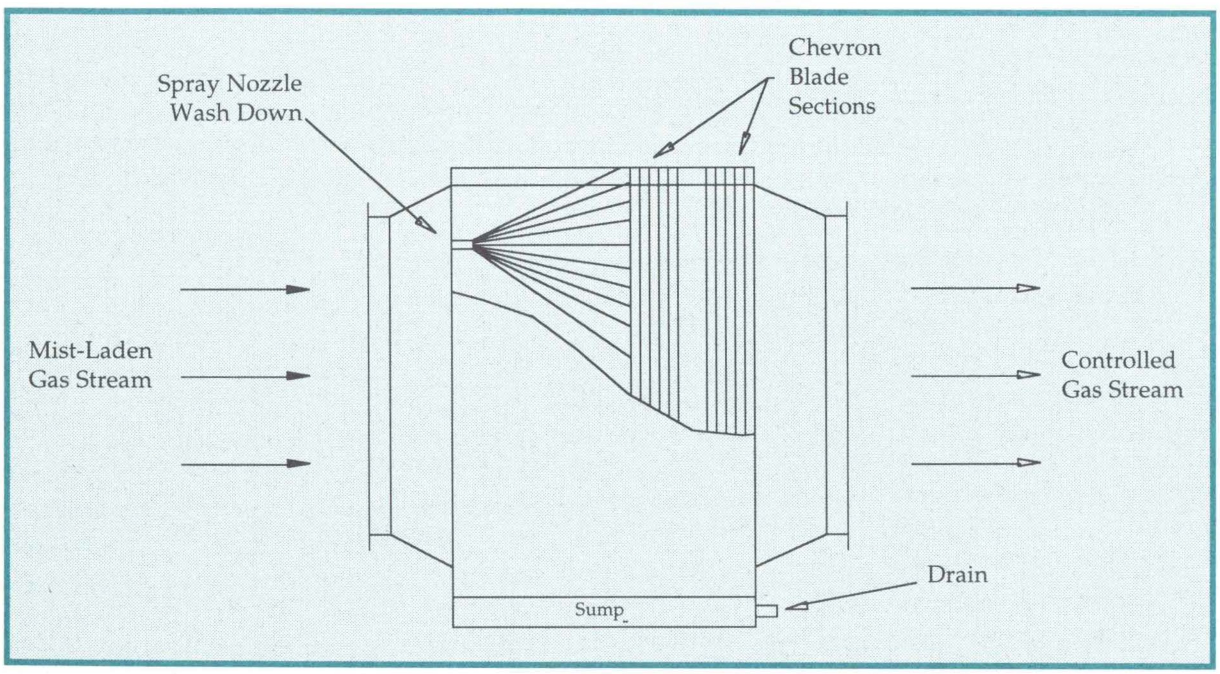

Figure 5 - Chevron Blade Mist Eliminator - Side View

Wet Scrubbers

Wet scrubbers have the ability to collect high temperature, wet dusts or gases. Some types of scrubbers are effective in controlling chromic acid mist from electroplating and anodizing, while others are not appropriate.

Scrubbers operate on the theory that high energy impaction causes the gas or mist to combine with the liquid, thereby making the pollutants easier to remove from the air stream.

Water is introduced near the inlet to the scrubber where it collides with the incoming dirty air. The pressure drop causes the water to collect particles from the fumes, or absorb the gas. The droplets containing the particles or gas combine until they are large enough to be collected.

Some scrubbers have an additional air purifying device to remove the finer particulates and further purify the outgoing air stream. One example is a wet cyclone separator using centrifugal force to remove particles from the air stream. The dirty air stream enters, is doused with a liquid and subjected to cyclonic air flow which causes the heavier particles to fall out of the air stream.

The type of scrubber most commonly used to control chromic acid emissions is the packed bed scrubber.

Packed Bed Scrubber

Because of their efficiency and level of technology, packed bed scrubbers are the most appropriate type of scrubber for chrome plating and anodizing emissions. Some scrubbers are not effective in controlling chromium mist, while others, like the venturi scrubber, are effective, but provide more technology (and more cost) than is necessary.

In a packed bed scrubber, the fumes enter and immediately travel through a spraying area and layer of packing material saturated with the scrubbing liquid, usually water. Much of the mist or gas is captured and removed. Figure 6 shows a variety of packing materials commonly used in scrubbers; Figure 7 depicts the basic design for a packed bed scrubber.

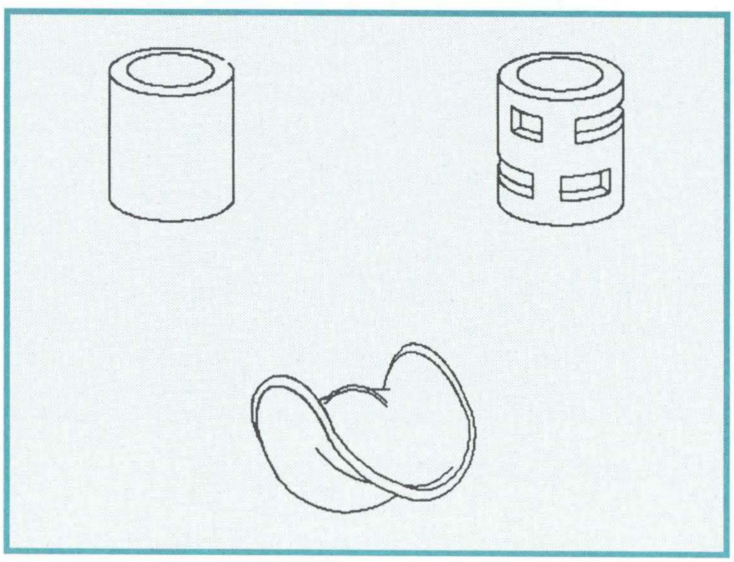

Figure 6 - Packing Media

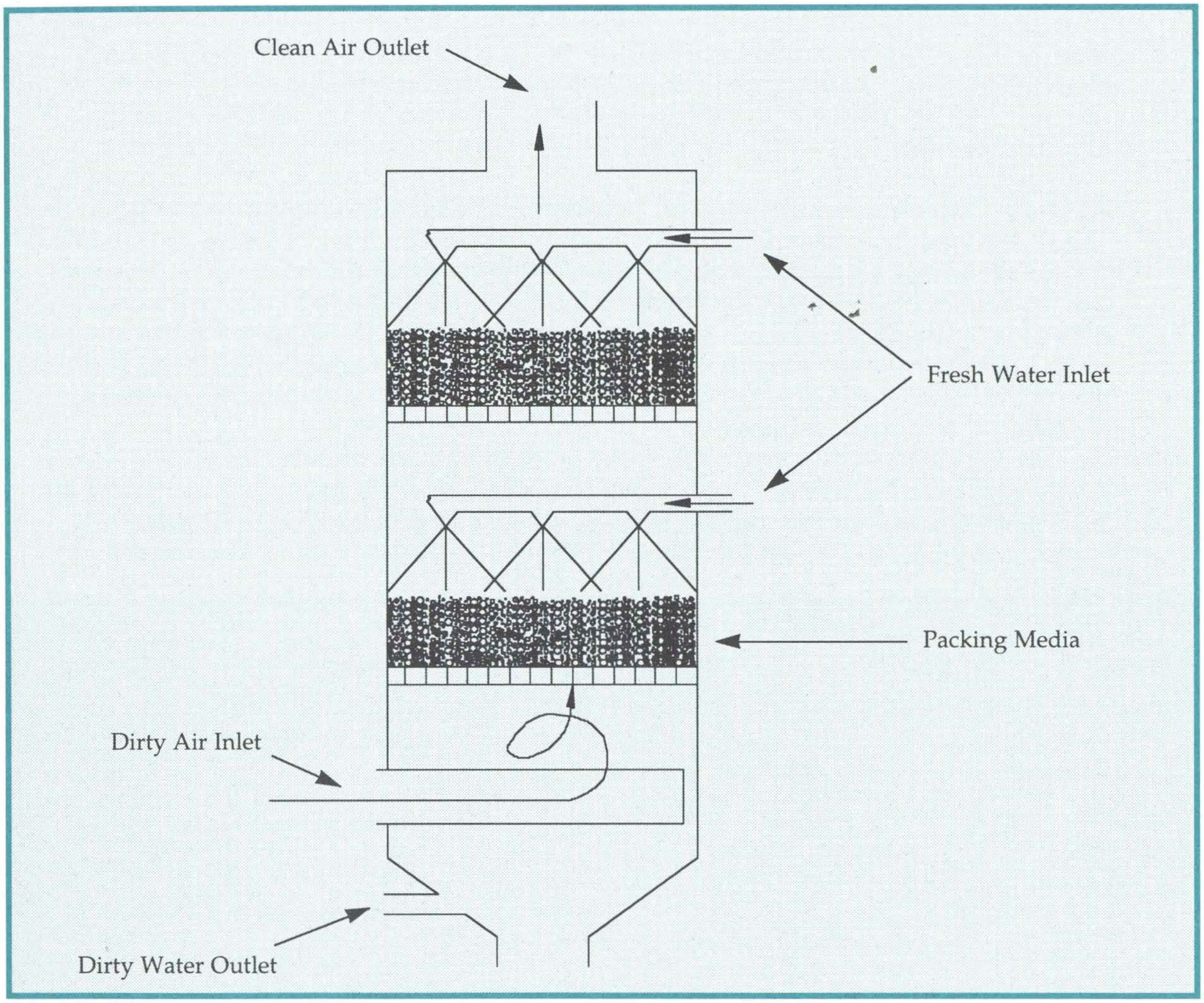

Figure 7 - Basic Design of a Packed Bed Scrubber

Considerations

Packed bed scrubbers are considered by the EPA to be the "Maximum Achievable Control Technology" for reducing hard chromium emissions. The efficiency of a packed bed scrubber is affected by the velocity of the incoming gas and the proportion of incoming gas to scrubbing liquid. If the velocity of the gas passing through the packing media is too high or too low, efficiency will decrease. Similarly, too much scrubbing liquid or too little would result in lowered efficiency. Additional layers of saturated or non-saturated packing media or liquid spray areas may increase the removal efficiency.

Costs

The average initial cost for a packed bed scrubber is $45,000; average annual operating costs total $15,000. Operating costs include electrical demand, fresh water supply, wastewater treatment and disposal, and maintenance requirements. It is important to remember that the size of scrubber and amount of energy necessary to operate a scrubber are proportional to the amount of air emissions being processed.

A reduction in the amount of chromium mist entering the scrubber would mean a smaller size scrubber and lower initial costs. In addition, the electricity and fresh water demand would be lower, resulting in lower operating costs.

Venturi Scrubber

A Venturi scrubber is a wet scrubber which has a "figure 8" structure (see Figure 8). The fumes and mist enter at the top. Water is introduced just above the narrowest part of the throat; the fumes and water interact just below this point. The pressure change causes the gas and/or particles to be absorbed by the water. The heavier, pollutant-laden droplets fall to the bottom of the throat. The lighter droplets continue on to a separator that removes the remainder of the now-contaminated water from the air stream. The water generated from this process may be recirculated within the scrubber or treated as wastewater.

Although Venturi scrubbers can remove chromium mist from an air stream, they are not recommended for this purpose because packed bed scrubbers provide an equivalent level of efficiency at a lower cost.

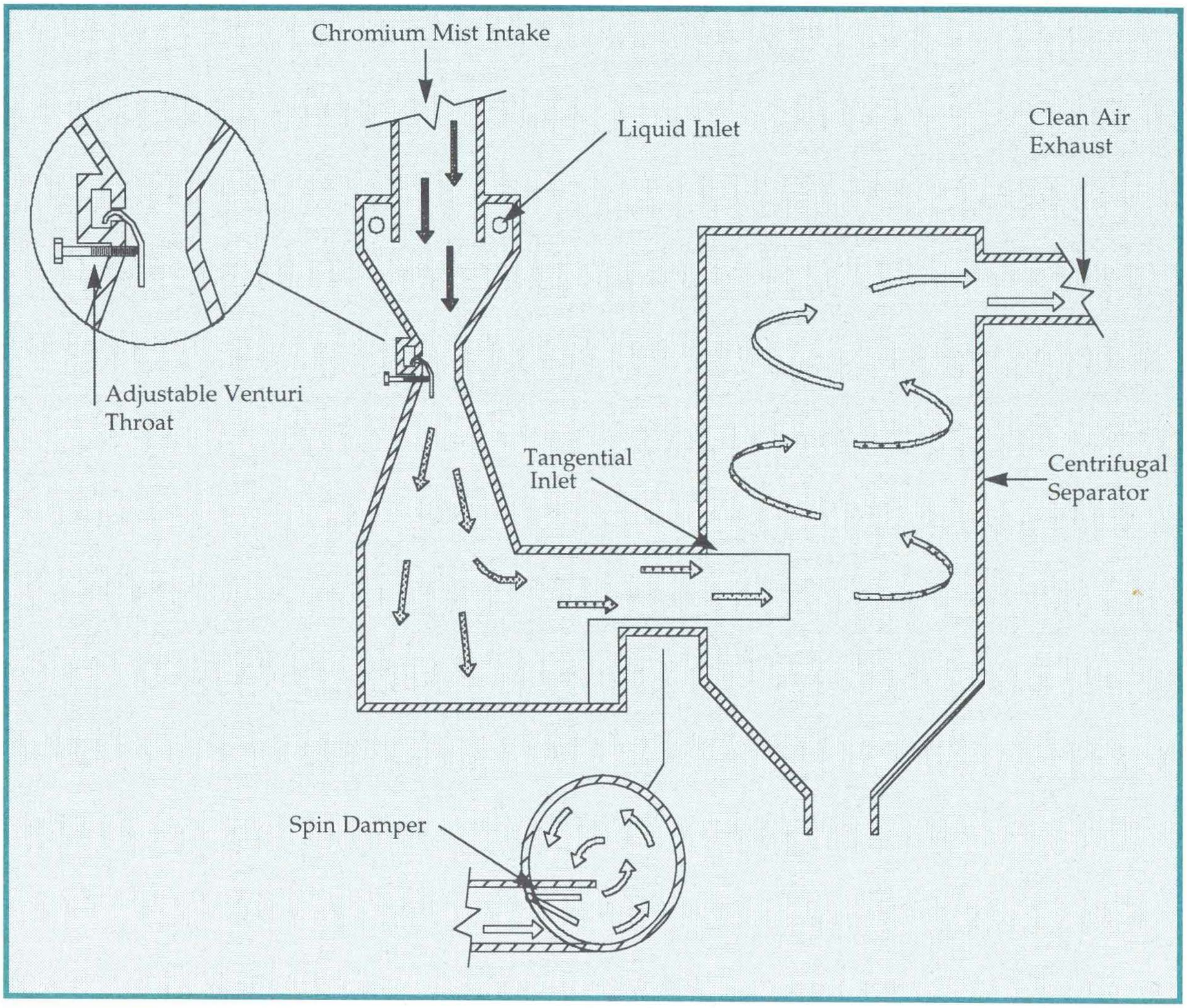

Figure 8 - Basic Design of a Venturi Scrubber

Cyclone Scrubber

This type of scrubber removes incoming pollutants by using cyclone-like (centrifugal) air flow generated by a blower, and a water rinse stream. This type of scrubber is not widely used for chromic acid emissions.

Fan-Separator Packed Bed Scrubber

In this type of scrubber the pollutants are removed first using wet centrifugal air flow generated by a fan and then by a layer of packing. This type of scrubber is not widely used for chromic acid emissions.

Spray Tower

Spray towers are the simplest type of scrubber. They consist of a series of nozzles to spray water droplets that trap particulate matter, and a water removal system. Spray towers are used primarily to control large particulate matter, and are thus not useful in controlling chrome plating or anodizing emissions.

Dry Scrubbers

Dry scrubbers are mainly used for acid gas control. They are not designed to handle high temperature mists and are not recommended for chrome plating or anodizing emissions.

Chapter 4

Alternative Technologies

Chromium Emission Reduction
for
Electroplaters and Anodizers

Alternative Technologies

Alternative Technology Development

Since the Clean Air Act Amendments (CAAA) were passed on November 15, 1990, the industrial community has become aware of the need to control toxic air emissions. This is especially true for larger corporations where funds are available for in-house environmental staffs and high technology pollution control equipment. Smaller businesses, on the other hand, usually do not have the technology or resources to reduce their own toxic emissions.

The Program for Toxic Air Pollutant Studies (PTAPS) at the University of Northern Iowa, is investigating existing situations at small businesses to develop low-cost, low-technology strategies for reducing toxic air emissions. The goal of PTAPS' chrome plating project is to identify low-cost but effective alternatives to the conventional, costly methods of reducing emissions of chromic acid to the environment. PTAPS is funded by a grant from the U.S. Small Business Administration.

This section will discuss alternative technologies which have been field or laboratory tested:

- Tank covers
- Baffle systems
- Condensing coil systems
- Combined technology systems

These technologies are practical, cost-effective means of reducing chromium emissions. Both baffle systems and condensing coil systems can be used alone or in conjunction with another emission control technology. The primary advantages to using these alternative technologies are their low capital cost, minimal maintenance requirements, and easy integration into existing exhaust systems.

Results from further testing of these technologies will be incorporated into the next edition of this guide.

Tank Covers

Thin plastic sheets can be placed over the plating bath to reduce emissions by trapping and condensing vapors at the tank. During testing, the cover was placed almost directly on the chromic acid solution, resulting in very little free space between the cover and the solution.

Construction

The tank cover can be constructed of plexiglass, or other suitable plastic, and cut to fit the size of the tank. When fabricating the cover, a facility needs to determine how the cover will be removed to allow transfer of parts and equipment during plating or anodizing operations. For rigid plastic covers, it is easiest to use anchors and hinges for allowing tank access. The cover operates similarly to a door or window. Flexible plastic sheeting may be anchored on one side and rolled back and forth across the tank by inserting a rigid pole in the end of the sheeting on the other side. This type of cover would operate similar to a window shade.

Considerations

Tank covers may not be practical when parts need to be frequently lowered into and removed from the plating bath since this would require that the cover be continually removed and replaced. Also, the chromium environment can dry out or corrode plastics, requiring them to be replaced. Replacement will depend on the care provided to the cover and the amount of chromium mist generated and trapped by the cover.

Baffle Systems

The principle behind baffling is to create an obstruction or an interruption in the air flow from the chrome plating bath. This interruption causes the air carrying the chromium mist to change its directional flow. In this manner, some of the chromium condenses on the baffle surface. When the air leaves the tank, after passing through the baffle, less chromium remains entrained.

Construction

The baffle used in the bench top setting was made of three plastic sheets with two pieces of tubing as spacers. This unit was not bonded together, but bolted together to enable the addition of more sheets. At the pilot scale facility, where a 500-gallon operating tank has been installed, the three sheets were separated approximately three to four inches using six pieces of PVC pipe. A section of pipe was placed at each corner and in the center of the two longer sides of the exhaust vent. Angle bar was attached to the long sides of the exhaust vent and each sheet was then bolted to the angle bar (see Figure 9).

The sheets had 1/2-inch holes that were approximately one inch apart. The top and bottom sheets had identical hole patterns, while the middle sheet had a pattern of holes off-set from the other two sheets. The off-set pattern of the holes forces the air flow to undergo directional changes. When drilling the holes, regardless of size, material, and material thickness, it is recommended to use a Bullet® Drillbit[1]. This type of drillbit will assist in directing plastic turnings away from the sheet. High speed drillbits are not recommended because they tend to melt the plastic during machining. As the plastic cools, it binds the drillbit; no successful tap oil was found to be useful in correcting binding.

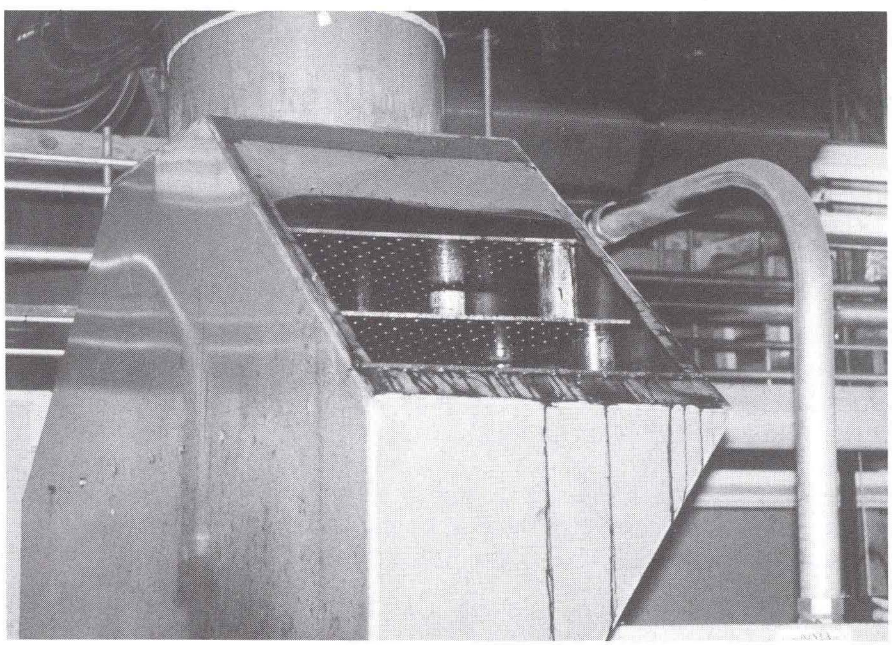

Figure 9 - The baffles are placed inside the exhaust system.

[1] Bullet is a registered trademark of The Black & Decker Corporation

Considerations

Baffle systems have not yet been tested on a full scale. The 76% emissions reduction figure is based on bench scale laboratory testing. Current pilot scale testing is underway which should provide additional data.

Baffles must be constructed of a material that can withstand the corrosive property of the chrome bath. The best suited materials for construction appear to be Schedule 80 PVC and polypropylene. Lexan baffles were used in the laboratory with no problem but did not work at the pilot scale test facility. The Lexan became brittle during prolonged exposure to the chromic acid fumes. Following embrittlement, the baffles fractured into several pieces from stress caused by the force of the exhaust air moving through the system.

Use of angle bar should be eliminated where baffles will be installed for extended periods of time. The angle bar can be replace by welding plastic PVC sheet to the inside of the duct work to form the necessary brackets. It is also recommended not to use metal bolts in the baffle system. Any metal will eventually be corroded by the acid fumes in the exhaust, thus requiring replacement. If nylon screws or bolts are to be used, the diameter of the main shaft should be more than 1/8" in order to withstand the stress of the system when the exhaust fan is drawing air.

Sufficient ventilation to exhaust the work area must be maintained.

Currently there are no manufacturers of pre-fabricated baffles. Consequently these systems will need to be individually fabricated. Individual fabrication will allow the chrome plater to specify the exact size and number of baffles needed for each tank (see Figure 10). Installation of the baffle system will cause little disturbance to the plating process, since the baffle is installed within the existing exhaust duct work (see Figure 11).

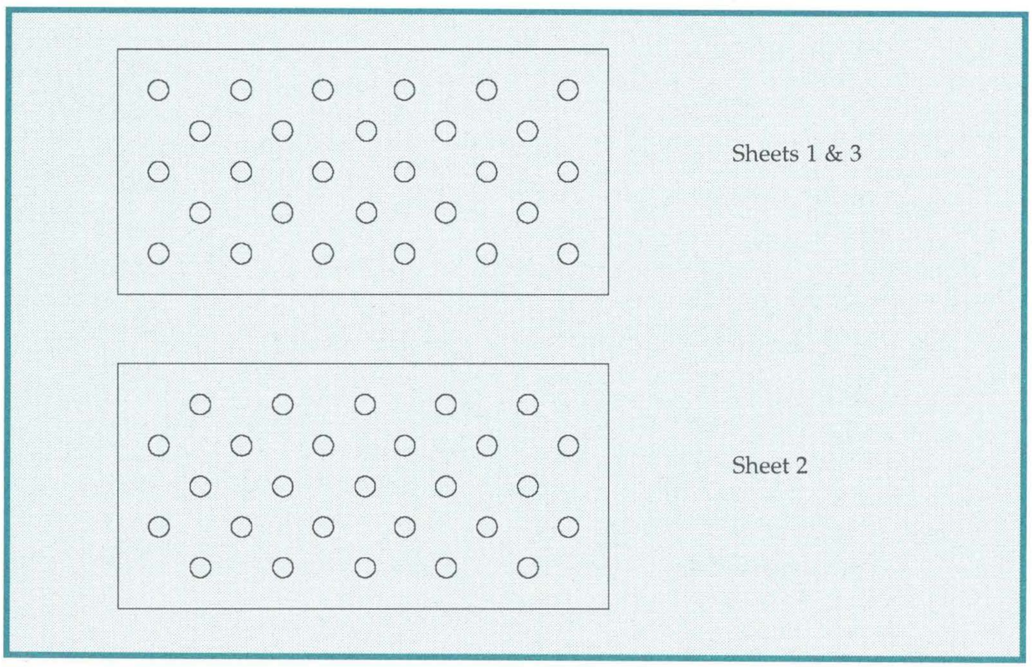

Figure 10 - Baffle System - Basic Hole Layout

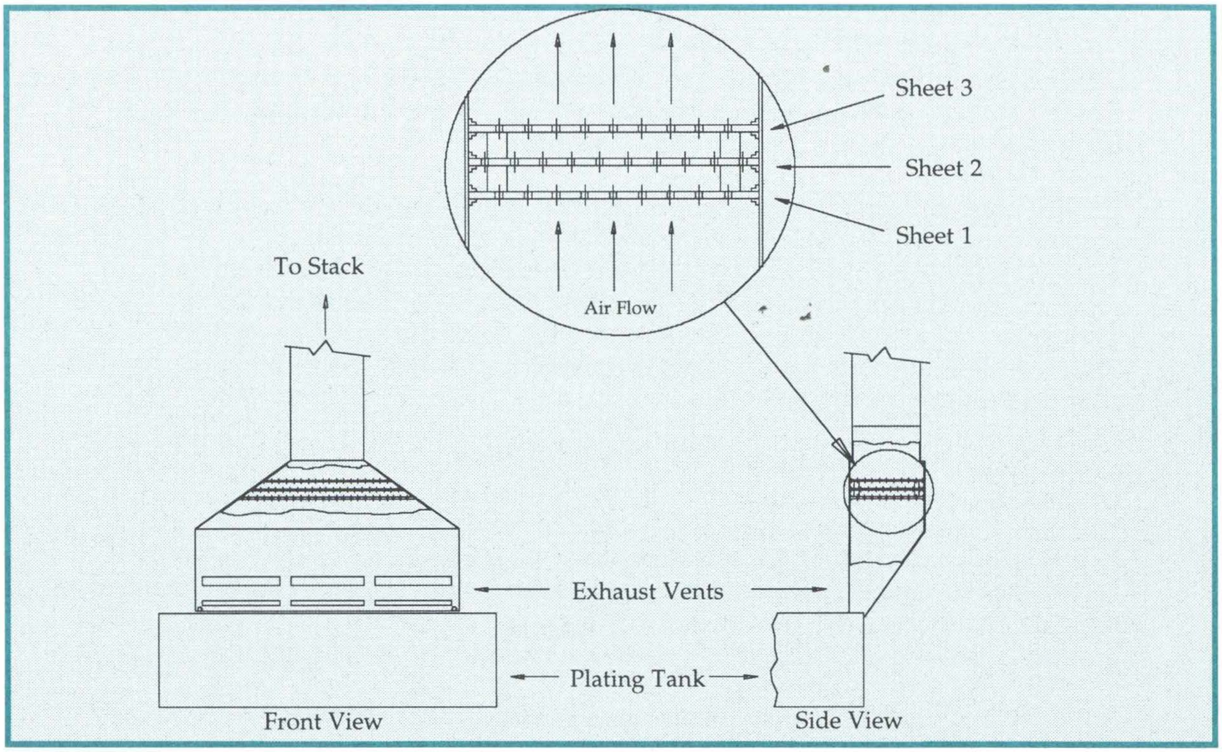

Figure 11 - Location of Baffle System in Exhaust Stack

Condensing Coil Systems

Condensing is the process of cooling hot vapor back into the liquid state, thereby reducing the effects of evaporation. To apply this concept to chromium electroplating, a condensing coil is placed in the entry area of an exhaust duct from the chrome plating bath. The hot chromium-bearing vapor rising from the plating tank will collect and return to the liquid phase on the condenser. At this point it can be routed back into the tank via a drain board, thus reducing the amount of chromium escaping into the atmosphere.

Construction

Condensers are relatively easy to construct. A simple condenser consists of a piece of sheet metal with an attached cooling coil. The cooling coil has both an intake and outlet through which cold water can pass.

Considerations

Installation of condensing units is simple and cost effective. Once measurements are taken of the existing ventilation unit, the fabrication of the necessary equipment can be done at nearly any sheet metal shop. Installation requirements are minimal, since the condenser can be placed within existing exhaust duct work (see Figures 12 and 13).

Pilot testing of this system has not yet been done, so emission control efficiency and reliability determinations are estimated.

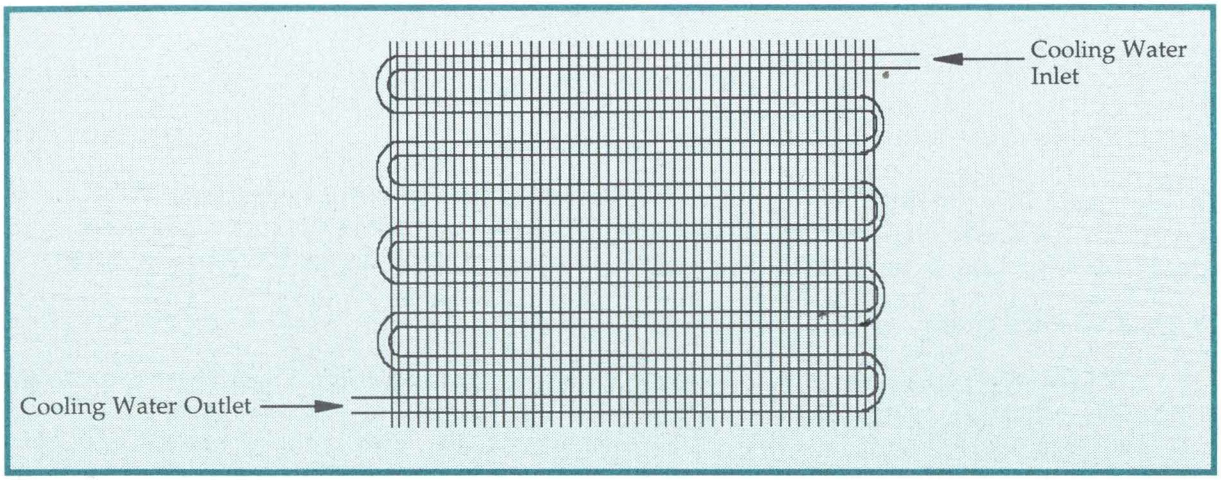

Figure 12 - Cold Condenser Design Layout

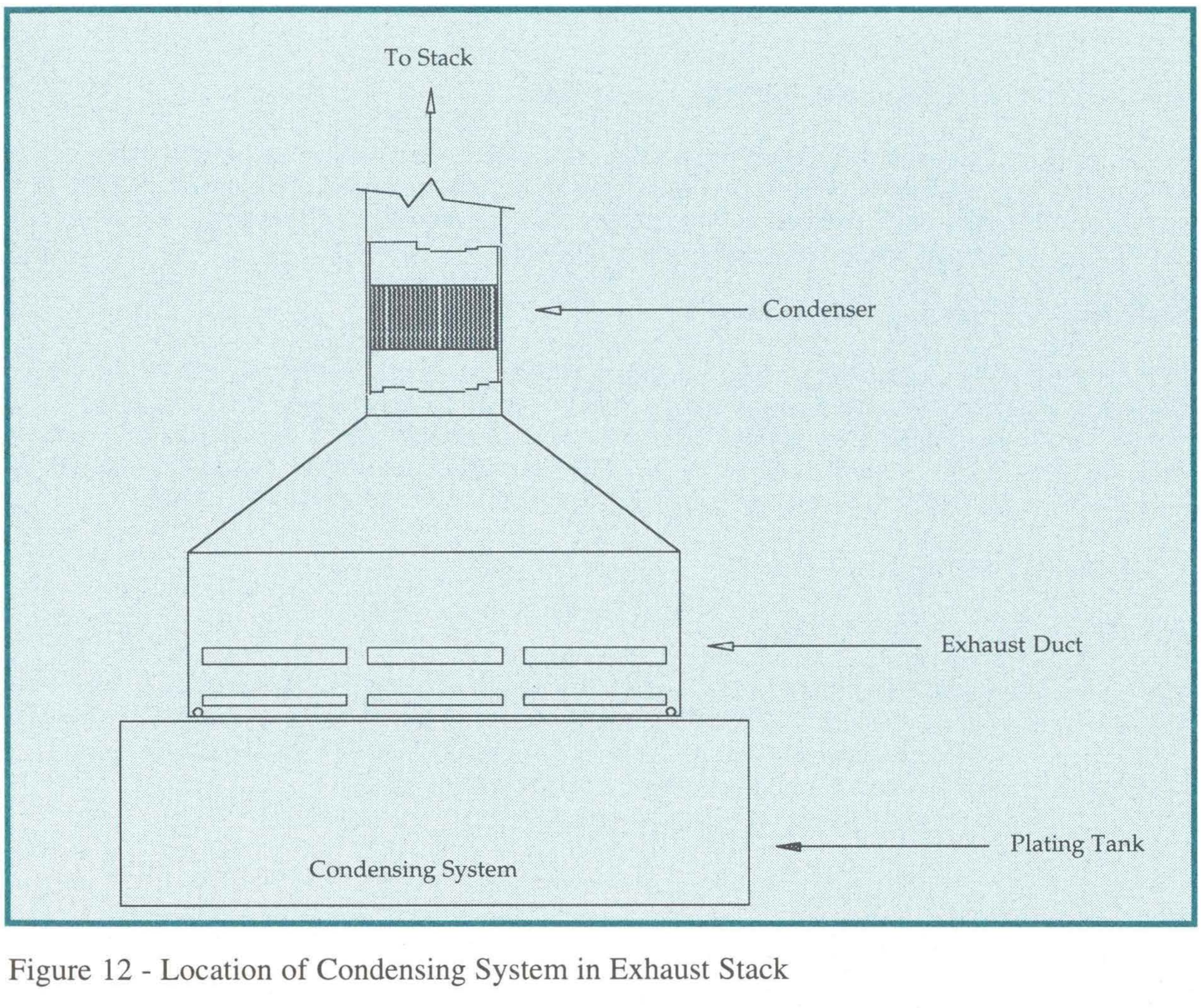

Figure 12 - Location of Condensing System in Exhaust Stack

Combined Technology Systems

Baffle System and Floating Plastic Balls

To implement this combination, the balls are used in the bath to cover the surface of the tank, while the baffle is placed in the front end of existing exhaust duct work. The balls could be confined to a "mesh type" bag to keep them from being trapped in recessed areas.

Considerations

Combining these two technologies can significantly reduce emissions from chromium electroplating, potentially up to 93 percent. The amount of evaporation of chromium-laden mist is reduced via the floating balls. This reduced amount of mist generated is sent through the directional changes of the baffles, where still more of the mist is trapped and returned to the bath. In other words, the chromium mist which is not trapped by the balls, escapes to the exhaust, and is trapped in the baffle system and directed back towards the plating bath. Combining these technologies does not require much additional effort, while the chrome removal rate can increase significantly.

Condensing Coil System and Floating Plastic Balls

The addition of condensing coils to the plastic balls can further reduce chromium emissions. Although this combination of emission reduction strategies was not tested, the condenser is expected to trap about 23 percent of what passes through the balls. Once again, the cost, installation, and maintenance of a condensing unit would be minimal.

Baffle and Condensing Coil System

Installing the system requires placing the baffle within the existing exhaust duct work, while placing the condenser in front of the baffle. The order of air flow would be through the condenser, through the baffle and out the stack. Therefore, any chromium which does not condense on the condenser is trapped in the baffle system. The exhaust fan speed may need to be increased, since there have been two air flow restrictions added to the system.

This system has not yet been tested.

PTAPS Applied Research Plans

The new technologies discussed in this section are being tested on a pilot scale in a 500 gallon chrome plating tank at the PTAPS applied research facility. One of the goals of this research is to determine the ability of the new technologies to meet EPA standards. Results of this testing will be incorporated into the next issue of this guide.

Chapter 5

Choosing a Chromium Emission Reduction Strategy

Chromium Emission Reduction
for
Electroplaters and Anodizers

Choosing a Chromium Emission Reduction Strategy

In the previous two sections a number of technologies have been presented for reducing chromium emissions. The decision to use a particular technology or combination of technologies is crucial in meeting CAAA requirements and maintaining economic competitiveness. Before making this decision, it is important that each technology, or combination of technologies, be evaluated to ensure that whatever system is selected, it will achieve the desired results. When evaluating the various chromium emission control technologies, the following factors should be considered:

- regulatory emission standards for the specific type of plating or anodizing
- the type of objects being plated or anodized
- the existing configuration of the affected tanks
- installation and operating costs of individual control technologies
- effectiveness of individual control technologies
- space constraints within the facility

The following tables compare parameters for many of the emission control technologies previously discussed in the manual.

Table 2

Installation and Operating Costs

Technology	Purchase Cost	Annual Operating Costs
Floating balls	$500	N/A
Mist suppressants	$300	$300
Wetting agents	$300	$300
Mesh pad mist eliminator	$50,000	$16,000
Chevron blade mist eliminator	$40,000	$16,000
Packed bed scrubber	$45,000	$15,000
Venturi scrubber	$100,000	$20,000
Baffle system	$1,000	N/A
Condensing Coil	$2,000	$1,000

When selecting a control technology, it is important to know how much emission reduction is necessary in order to meet CAAA requirements. The most accurate method for determining uncontrolled emissions of chromium is through stack sampling and analytical testing. However, this is rather expensive when the object is to simply get a basic idea of how much chromium is being exhausted. Instead, using two equations and information from typical operating parameters, a facility can get a general idea of the chromium concentration in the exhaust.

To roughly calculate the amount of chromium emitted from the operating tank, the following equation can be used:

$$\text{Eq. 1} \quad Cr(mg) = 49{,}000 + \{0.0016*I*t*(Vol)\}$$

where Cr = milligrams of chromium emitted prior to a control device; I = the amperage; t = plating time; and vol = the plating tank volume in liters.

To further calculate the emission concentration in the same units as the CAAA requirements, the volume of exhaust must be incorporated:

$$\text{Eq. 2} \quad Cr(mg/scm) = Cr/(v*t*0.02832)$$

where Cr = milligrams per standard cubic meter of chromium emitted prior to a control device (from the first equation); v = the blower exhaust rate in cfm; and t = the plating time in minutes.

As an example, the uncontrolled emissions from the PTAPS testing tank were calculated as 3.7 mg per standard cubic meter of exhaust air.

By first determining the concentration of chromium in exhaust emissions, a facility is better able to select a control technology that will perform the emission reduction without excessive costs. Table 3 summarizes the effectiveness of many available control technologies. If a facility only needs a 65% emission reduction to achieve compliance, it is not necessary to purchase the more efficient technologies. Purchase of unnecessary equipment is not a wise business choice and reduces available capital, and may increase operation and maintenance costs.

Table 3

Emission Reduction Capabilities

Technology	Emission Reduction
Floating balls	70%
Mist suppressants	95%
Wetting agents	95%
Mesh pad mist eliminator	99%
Chevron blade mist eliminator	95-98%
Packed bed scrubber	95%
Venturi scrubber	95%
Baffle system	76%$^{+}$
Condensing Coil	23%*

$^{+}$Based on lab scale testing *Estimated

As noted in table 4, many current control technologies generate wastewater during operation. This wastewater must be treated through the facility's wastewater treatment system prior to disposal through a sanitary sewer. The alternative is to collect the wastewater and manage it as a hazardous waste. Both of these options for waste management can be cost prohibitive, especially for smaller businesses.

Table 4

Regulated Waste Generation

Technology	Waste Type
Floating balls	none
Mist suppressants	none
Wetting agents	none
Mesh pad mist eliminator	wastewater
Chevron blade mist eliminator	wastewater
Packed bed scrubber	wastewater
Venturi scrubber	wastewater
Baffle system	none
Condensing Coil	none

Some control technologies can be installed and operated within the existing exhaust duct, or within the plating or anodizing tank. Other technologies are separate prefabricated pieces of equipment. These prefabricated units must be tied in to existing exhaust systems. These units do need to be indoors, so roof-mounting is not a viable option. Space requirements for many of these units can be a serious problem, especially if there is not any space available overhead.

Many of these prefabricated units also require electrical power, a water supply, and a wastewater discharge outlet. Each of these requirements should be addressed at the facility to determine whether:

- there is enough space to house the unit
- there is the appropriate electrical supply available
- water can be adequately supplied
- wastewater can be removed and treated before discharge

Installation and operating costs, effectiveness in meeting regulatory requirements, and waste generation are three important aspects of chromium emission reduction. Regardless of the final decision, each of these factors should be carefully considered when selecting a control technology.

To keep up to date on chromium air emission issues, request the free Point Source quarterly newsletter from the Program for Toxic Air Pollutant Studies at 800-422-3109.