21 Air Pollution Control Technology

Introduction

The control of emissions to the air under the Clean Air Act of 1990 requires the metal finisher to comply with emission standards from specific processes, such as hard chromium plating, decorative chromium plating, chromic acid aniodizing, and vapor degreasing. In addition, most states enforce regulations that are generally vague. A typical clause states, "No person shall discharge from any source whatsoever such quantities of air contaminants or other material that cause injury, detriment, nuisance, or annoyance to any considerable number of persons or to the public, or which cause or have a natural tendency to cause injury or damage to business or property." States, and sometimes counties or cities, typically also have emission limits imposed on various metal finishing exhaust stacks. As a result of these requirements and OSHA worker protection requirements, many metal finishing processes require both ventilation and control.

A well-operating ventilation system will reduce fugitive emissions (those to which a worker will be exposed) below regulated PELs. A well-operated emission control system, such as a fume scrubber or a mesh pad mist elimination system, will reduce stack emissions below levels regulated by the U.S. Environmental Protection Agency, the state EPA, or a local municipality.

Design of Ventilation Equipment

In general, the design and installation of the ventilation and/or scrubbing equipment required to meet both government pollution control and health regulations should be left to professionals. However, to ensure cost-effective choices and allow the manager to evaluate the existing ventilation system, the basic design requirements are outlined on the following pages.

Control the Environment

The processing area should be closed as much as possible to eliminate cross drafts and to allow the airflow to be directed from the source of the emissions to the capture devices (hoods).

By confining the process within an enclosure or room, general room air movement can be achieved with a high degree of efficiency. Air is flowed from the air make-up system past the operating personnel, providing relatively clean air to breathe. It then travels across the source of contamination and is collected on the opposite side. The smaller the enclosed volume, the greater the efficiency of the ventilation system.

Hood Design

Hood selection is determined by:

- Size and configuration of the parts to be processed
- Temperature of the processing solution
- Height to which the part is lifted to clear the tanks

In general, downdraft hoods along the sides of tanks work well in capturing surface contamination. However, because these hoods require a generally low profile so parts can pass over them to adjacent tanks, they are not the most efficient for high temperature solutions where steam is present or in capturing the fumes coming off the parts as they are lifted from the tanks.

The updraft open face or updraft multislot hoods have a much greater capture area, thus producing a higher bank of airflow. This type is better suited for heated tanks and fume removal from parts as they are lifted from the tank.

A line of updraft type hoods, spread out over a long distance, thereby creating a high cross-sectional laminar airflow through the facility, is far more efficient than a series of low profile opposing hoods.

Make-up Air

For any ventilation system to work, there must be a make-up system that replaces the air being removed from the room. This make-up volume should be less than the amount of air being vented in order to keep the area under negative pressure. This is necessary to keep airborne contamination from escaping into adjacent areas and to maintain a uniform laminar flow in the facility.

Like the ventilation system, the introduction of make-up fresh air should be distributed over the widest area possible in order to provide for sweeping the sides of the rooms.

Ventilation Ducts

Many cities require fire-retardant materials such as fiber glass in the construction of ducts and sprinkler systems to protect ducts from fire. Before installation, verify that material such as polyvinyl chloride (PVC) is allowed.

General duct installation practices can be found in the American National Standards Institute (ANSI) Z9.1 standard *Open-Surface Tanks— Ventilation and Operation*, which has been incorporated into OSHA regulations as of late 1998.

A good rule of thumb is that duct velocity should be 25,000–28,000 feet per minute (fpm) in all drops, and 1,000–2,500 fpm in all trunk lines. If these velocities are maintained, it might not be necessary to use dampers to balance the system. If they cannot be maintained, dampers should be installed. In either case, the important control parameter is called the "control velocity," which is the speed of the air withdrawn from the process at the slot of the exhaust hood. ANSI Z9.1 details how to obtain the correct capture velocities, which must be determined for each process that is exhausted. The standard also allows you to determine whether a given process actually requires an exhaust hood (local exhaust) or if general room air ventilation is considered adequate. The following is a simplified description of the procedure used under ANSI Z9.1 for determining the control velocity required for a specific process.

Determination of Control Velocity

This section provides guidance on how to use ANSI Z9.1 to determine the control velocity and whether a process requires ventilation, with a few examples.

To determine the control velocity, refer to the following references and:

1. Obtain the "Hazard Class" for the chemicals in the process tank. This can be obtained from the ANSI Z9.1 standard. If you can find your process and obtain a hazard class, skip steps 2–6. If Table B.3 of ANSI Z9.1 does not list your process, you need to get the following information and arrive at a hazard class using the method described over the next few pages.
2. The Permissible Exposure Limits (PELs) or Threshold Limit Values (TLVs®) of the major pollutants and hazardous ingredients in the process tank: PELs for common air contaminants are established by OSHA (29 CFR 1910.100). TLVs are published by the American Conference of Governmental Industrial Hygienists (ACGIH), which publishes a booklet containing these values. The cost is about $15.

   Note: if OSHA and ACGIH disagree on the PEL/TLV value applicable to a pollutant, the OSHA PEL supersedes the TLV. You can also consult with the supplier of the chemical products or the MSDS (material safety data sheet). For our examples, the PEL for chromic acid mist is 0.1 mg/m^3, while the PEL for nickel as a soluble compound is 1 mg/m^3.

3. The boiling point of the process solution, in degrees Fahrenheit (°F): This typically is found in the MSDS. Most metal finishing tanks are near enough to 212°F that this value can be used.
4. The flash point, which is normally >212°F for all water-based processing solutions, also can be found in the MSDS for the processing chemicals.
5. The relative evaporation rate: This is a rating of how fast the liquid in the process evaporates. Data can be found in the *Electroplating Engineering Handbook* and *Industrial & Engineering Chemistry* by A.K. Doolittle (Vol. 27, page 1169). Fast = 0–3 hours for complete evaporation, medium = 3–12 hours, slow = 0–50 hours, and nil = >50 hours. You may also find these data in the MSDS.
6. The gassing or misting rating for the process: One source for this information is Engineering Plate 161, issued by the New York State Department of Labor, Division of Industrial Hygiene and Safety Standards. Another source is Chapter 3700 of the *Environmental Conservation Handbook*, published by the New York State Department of Environmental Conservation. If the process you are evaluating is not listed in either of these sources or in ANSI Z9.1, you will need to contact your

Table 1. Determination of Hazard Class
(If ANSI Z9.1 Does Not Provide It)

Hazard Potential	PEL/TLV Gas/Vapor, ppm	Mist mg/m3	Flash Point, °F
A	0-1	0-0.1	------
B	11-100	0.11-1.0	<100
C	101-500	1.1-10	100-200
D	>500	>10	>200

Table 2. Misting/Gassing/ Evaporation Rating

Rate	Temp °F	Degrees Below Below Boiling °F	Relative Evaporation	Gassing
1	>200	0-20	Fast	High
2	150-200	21-50	Medium	Medium
3	94-149	51-100	Slow	Low
4	<94	>100	Nil	Nil

chemical supplier or consultant/professional engineer for a professional estimate of the gassing rate.

Once you have the hazard class from ANSI Z9.1 or the information indicated in steps 2–6 on any given process, you can determine whether the tank needs ventilation and how much ventilation it requires, as shown to the left.

Hazard Potential Rating

From Table 1, the hazard potential of a specific process is determined. The hazard potential is a rating (A, B, C, or D) based on the OSHA PEL or the ACGIH TLV for either gas/ vapor or mist, depending on which is emitted by the process. The rating also depends on the flash point, but this rarely is an issue for metal finishing processes. If the properties of the process yield conflicting hazard ratings, you should use the most hazardous rating. Thus, if a process contains two toxic metals — one that has a PEL of 0.1 mg/ m^3 and the other with a PEL of 1.1 mg/m^3 — then the hazard rating is "A", not "C".

As an example, hexavalent chromium plating has a hazard potential class rating of "A" due to toxicity (PEL for chromic acid mist is 0.1 mg/m^3). A sulfamate nickel-plating tank would have a hazard potential class rating of "B" due to the PEL of 1.0 mg/m^3 for soluble nickel mist.

Misting/Gassing/Evaporation Rating

From Table 2 of ANSI Z9.1 a gas, vappor, or misting rating can be obtained. As shown in the table, a rating of 1 is assigned to a process that operates above 200°F, or is 0–20 °F below the boiling point, or has a fast evaporation rating or a high level of gassing (mist formation due to gas bubbles).

In the examples of the previous chart, the chromium plating process has a rate of gas or mist evolution that is "high," yielding a gassing rate of "1". The nickel plating process (sulfate process, using soluble anodes) has a gassing rating of "nil" for a rating of "4" in Table 2.

According to ANSI Z9.1, the rating needs to be modified for certain equipment such as vapor degreasers. A modern, well-operated vapor degreaser can be given a gas, vapor, or mist rating of "4". A vapor degreaser operating in "average" condition is rated "3," while a poorly operated degreaser may be assigned a rating of "2" or "1."

ANSI also assigns the following gassing rating to these common metal-finishing processes:

- **High.** Nitric acid bright dip, chromium plating, anodizing aluminum, stripping zinc in acid, and satin finishing of aluminum
- **Medium.** Pickling of steel, alkaline cleaning of aluminum (cold), strike plating
- **Low.** Cyanide plating, phosphoric pickling, phosphating, tin plating (stannate solution)

Table 3. Determining The Required Control Velocity

Hazard Class	Control Velocity For Lateral Exhaust ft./min.
A1, A2	150
A3, B1, B2, C1	100
B3, C2, D1	75
A4, C3, D2	50
B4, C3, D2	General Room Ventilation

Determination of Control Velocity

In our example, the hazard class rating for chromium plating is A1, while the nickel plating process has a hazard class rating of B4. Using Table 3 of ANSI Z9.1 (partially shown above), and the dimensions of the plating tank, we can obtain the control velocity in feet per minute required for each plating tank.

From Table 3 of ANSI Z9.1, the specified capture velocity of a combination of hazard "A" and gassing rating "1," is 150 fpm for a lateral exhaust hood in an undisturbed location. The ANSI Z9.1 standard has other control velocities for other types of exhausts, but we are using lateral exhaust since it is the most common. You would need to increase this capture velocity value if you have cross drafts around the plating tank or if the loading dock door is nearby. Note that the capture velocity is not the ventilation rate (cfm) — it is the speed at which air must be moving at the opening of the hood in order to capture emitted fumes and mist. The ventilation rate will be calculated shortly.

Table 4. Determining The Ventilation Rate

Tank With Lateral Exhaust Hood Against Wall Or Baffled					
Control Velocity,	Ventilation Rate, cfm per ft^2 For The Following Aspect (W/L) Ratios:				
fpm	0-0.09	0.1-0.24	0.25-0.49	0.5-0.99	1.0-2.0
50	50	60	75	90	100
75	75	90	110	130	150
100	100	125	150	175	200
150	150	190	225	250	250

Example, 2 x 4 ft. tank, requiring 150 fpm control velocity: 250 x 2 x 4 = 2000 cfm.

For the B4 process (nickel plating, soluble anodes, no air agitation) note that general room ventilation is considered sufficient. Therefore, if such a tank is ventilated, it is not required by regulation and energy could be wasted.

Determination of the Actual Ventilation Rate

To determine the ventilation rate (cfm) required for a process tank, first divide the width of the tank, by the length. For example, a tank that is 2 feet wide and 4 feet long would have a ratio of 2/4 = 0.5. Based on this ratio and the control velocity, look up the cfm per square foot exhaust rate required. This can be found in Table 4 of ANSI Z9.1. Part of the data in Table 4, for a tank against a wall with a hood along one side, is shown in the chart.

In our example from the previous page, the required control velocity was 150 fpm. For this control velocity, and a width-to-length ratio of 0.5, Table 4 of ANSI Z9.1 indicates that the tank would require 250 cfm per square foot of tank surface area if the tank were up against a wall. The total exhaust rate for a 2- × 4-foot tank against a wall would then be 250 × 2 × 4 = 2000 cfm.

Note: Table 4 of ANSI Z9.1 contains additional data for tanks that are not against a wall (free-standing tanks) and for tanks exhausted from two sides.

There is more to ventilating a process than we have covered, but the procedure above can be used to quickly determine if a process is adequately ventilated or if a process requires ventilation at all.

Blowers

The backward curved centrifugal blower has evolved as the most economical, most quiet, and most easily maintained blower for low-pressure ventilation systems. In-line blowers, in contrast, are generally noisier and very difficult to maintain. Radial blowers are noisy and are high-energy users. They are not recommended in large sizes due to the high risk of self-destruction, which may be caused by their comparatively high top speeds.

Composite Mesh Pad Emission Control Systems

Composite mesh pad (CMP) systems consistently outperformed wet scrubbers in emission tests performed by EPA. The most effective design consists of a vessel that incorporates three or four mesh pads in series and a precontrol device. The pads typically consist of polypropylene monofilament woven or knitted into the mesh configuration.

The best mesh pad configurations use the largest monofilaments with the largest void spaces as the first stage, with the following stages using incrementally decreasing monofilament sizes and void spaces. This configuration facilitates removal of mist in stages based on particle size. It also provides protection of the highest efficiency stages, which are most prone to pluggage, by the “precontrol” stages up front.

Mesh pad systems work by the principle of inertial impaction (i.e., particles must be traveling with sufficient velocity to impact and adhere to the surface of the media). The efficiency of the pads is determined to a specific mist particle size. Mist particles of varying sizes are collected by the specific stages designed to collect that particle size and through periodic wash-down, the mist is flushed off the media and is drained from the unit to be sent to waste treatment or to be recycled to the process tank.

The vessel (chamber holding the pad(s)) design is critical to the capability of the device to meet emission standards. Because high efficiency mesh pads have high collection efficiencies on microscopic particle sizes (some configurations remove 99 percent at 1 micron), they also create high-pressure drops in inches of water. If pads are not properly “sealed” into the vessel wall, the pressure drop can cause the gas stream to follow the “path of least resistance” around the media, creating bypass and causing excess emissions. Drain lines must be sealed (or trapped) to prohibit bypass through the units drain manifold. Vessels also must incorporate a well-designed wash-down spray system to periodically clean the media and prevent pluggage, or chromic acid buildup.

Vessels must be designed for easy wash-down. They also should be designed with accessible pressure taps to accommodate flexible tubing from a differential pressure gauge, enabling daily monitoring and recording of the device's pressure drop. The differential pressure gauge should be easily accessible, whether located on the vessel itself or in a remote panel. The vessel also must incorporate accessible inspection doors to allow quarterly inspections of the media.

EPA's technology study concluded that the overall removal efficiency of composite mesh pad systems was directly correlated to the inlet loading of mist. Higher removal efficiencies were achieved in systems where inlet loading was considered high (e.g., 10 milligrams per ampere hour for a plating process). Lower removal efficiencies resulted when inlet loadings were lower.

The media used to capture emission particles may use a monofilament with a specific structure in pyramid, flat, or round cross section. Filaments may be randomly distributed or in specific order. Filament diameters range from 2–40 mils in cross section. Each style has its own performance characteristics:

- Coarse styles
  —High liquid-handling capacity
  —Pluggage resistance
  —Efficient on 10 micron particles and greater
- Medium styles
  —Reasonable liquid-handling capacity
  —Less pluggage resistance
  —Efficient to 3–5 microns
- Finer styles
  —Low liquid-handling capacity
  —High pluggage potential
  —Efficient to 1–3 microns

Modern designs incorporate complex composite pads composed of several styles of fiber diameters composite mesh pads, yielding liquid-handling capacity in the first and final stages and high removal efficiencies. It was discovered that the best approach is to design for removal of chromium droplets in stages by particle size. Therefore, the newer designs use the largest monofilament at the scrubber inlet and gradually incorporate smaller monofilaments toward the outlet. The largest monofilaments remove the majority of particles while protecting the smaller monofilaments from saturation (clogs).

Most composite mesh pad designs incorporate three or four pads in series:

- Stage #1 — 10 microns and greater
- Stage #2 — 3–5 microns
- Stage #3 — 1 /micron
- Stage #4 — Re-entrainment chamber

Principles of Operation

Stage 1. Inertial Impaction — Larger Droplets

Chromium mist is evacuated from tanks by the local exhaust system and delivered to the first stage of the mist elimination system by the ductwork. The particles travel through the ductwork at velocities of 3,000–3,200 fpm. The mist stream enters the first stage of the mesh pad system at 500 fpm. The velocity reduction is accomplished by providing a chamber with a larger cross-sectional area than the ductwork. The particle velocity must be high enough to prevent the droplets from following the gas stream around each fiber. The largest chromium droplets inertially impact with Stage 1 (which contains the largest monofilament) and most particle sizes above 8–10 microns are collected.

Stage 2. Interception

Smaller droplets are carried around the Stage 1 fibers and into Stage 2. Stage 2 contains large-to-medium and medium-to-finer monofilament and most particle sizes 3–5 microns are collected.

Wash-Down and Irrigation

Wash-down requirements can vary due to conditions of inlet loading, hours of operation, atmospheric conditions, etc. Wash-down and irrigation of the mesh pad system is critical to the success of the system in meeting emission regulations.

Chromium droplets must stay moist or wetted to maintain their size and enhance collection. Dried-out particles tend to shrink in size, are more difficult to collect, and cause clogging of the mesh pads.

Note: Some CMP systems have run completely dry and performed quite well on gas streams with high moisture content, but many hard chromium plating conditions require *continuous* irrigation on one or more of the stages. The remaining stages typically are flushed periodically with wash water that is returned to the plating tank to make up evaporative losses.

Typical manufacturers recommended wash-down requirements are as follows (automatic wash-down timers/systems should be used due to the high frequency of wash-downs):

- Stage 1: Continuous irrigation but at low volume approximately ¼–½ gpm per square foot of pad cross section. If continuous wash-down is not feasible due to a low evaporative loss in tank, a calculation should be performed to maximize periodic wash-down duration and frequency.
- Stage 2: 2–4 times a shift for approximately 20–25 seconds.
- Stage 3: 4–8 times a shift for approximately 20–25 seconds.
- Stage #4: Re-entrainment chamber does not typically require wash-down.

Precontrol Devices

Precontrol devices typically consist of a single mesh pad in a smaller vessel designed to maintain an exhaust velocity of 600 fpm. They are mounted just above or close to the exhaust hood "in line" with ductwork, or they can be mounted directly into the exhaust hood. They are valuable for two reasons: 1) They reduce the inlet loading into the main control device; and 2) they collect the majority of the largest emission droplets at the source, keeping the ductwork cleaner and minimizing wear and possible leaks.

Wet Packed Bed Scrubbers

A wet packed bed scrubber should have complete draining capabilities, a wash-out system, automatic level controls, flow monitors, pH controls, and an overflow system for solution changes. Construction of the unit should allow ease of maintenance.

Wet packed bed scrubbers are designed typically for absorption of emissions that are present in an exhaust in the form of a gas (HCL–NH_3, NOX, SO_2, etc.), but they can also lower mist emissions. Packed bed scrubbers use a packing media to distribute a scrubbing solution that contacts the gas and promotes "mass transfer" of gas into the liquid (scrubbant). The scrubbant may be water, but often is a chemical solution that has greater affinity for absorption of the undesirable gas. Chromium emissions from plating processes are in the form of a mist not a gas; therefore, wet scrubbers work mechanically as wet collectors, not gas absorbers, on such emissions.

Wet scrubbers consist of:

- Vessel designed to handle a flow velocity of 500 fpm or below
- Bed of random packing (media) typically 1–3 feet in depth
- Spray chambers and a recirculation system to continuously saturate the packing
- Mist elimination system (usually a mesh pad) to remove re-entrained scrubbant

The most effective designs of packed bed scrubbers use either cross flow (horizontal flow) or counter current (vertical flow). The principle behind removal of gases in a wet scrubber is "gas absorption" (i.e., the absorption of specific constituents of the gas stream by dissolving them into the scrubbing solution).

The final stage of the scrubber must be an effective mist eliminator to prevent re-entrained scrubbing solution from entering the atmosphere. The two most common mist eliminator designs are chevron baffle angles and mesh pads. The chevron baffles are designed to create abrupt directional changes in the airstream, thereby impinging wet particles onto the baffles surface or catchment. Chevron baffles are typically effective on the larger range of particle sizes (i.e., 12–100 microns), and because their pluggage potential is minimal they are considered low maintenance.

Mesh pad eliminators, used in wet scrubbers, usually consist of woven or knitted polypropylene monofilament, either in a random or specific configuration. They work by mechanical impingement and are velocity dependent. The particle to be collected must be traveling with sufficient velocity to impact and adhere to the fiber. These are designed for specific particle size removal depending on the diameter of the monofilament, the designed void spaces, and the number of mesh layers used. Smaller monofilaments and tighter void spaces are obviously more efficient in removing smaller particle sizes (1–3 microns), but the down side is they have a greater potential for pluggage and require more maintenance and care. Therefore, the most logical scrubber mesh pad eliminator design is a filament diameter and void space that is large enough to minimize the pluggage potential and have a functional liquid-handling drainage capacity. This type of mesh pad configuration is usually effective on particle sizes 5–10 microns in diameter.

A variety of packing materials for packed bed scrubbers are available, such as:

- Palil rings
- Cascade mini rings
- Saddles
- Spheres
- Tri-pack
- Tellerettes
- Polyhedron-Lanpac
- Multiple drip points (pincushion) Nupac

The best packing materials typically are determined by trial and error or experience.

Adding Composite Mesh Pads to an Existing Wet Scrubber

A packed bed scrubber in good shape can be used as a first stage in a higher efficiency mesh pad control device. The mesh pad section can be mated to the outlet side of the wet scrubber. A minimum of two pads consisting of larger filaments in the up stream to protect subsequent layers and fine monofilament in the down stream for coalescing should be used as an add-on.

Monitoring Equipment

Clean Air Act regulations for hard chromium platers or decorative chromium platers who choose not to use a fume suppressant require composite mesh pad systems to employ pressure-drop devices for monitoring pressure drop and recording it once a day (±1 inch water column). Most manufacturers recommend that each stage have the capability for pressure-drop monitoring. This is easily accomplished with a magnahelic gauge, a gauge that reads pressure drop in inches of water, can be equipped with 4–20 milliamp transmitter and set points, and can send a signal to a process controller for recording or alarm. Pressure-drop monitoring can also be done with a photohelic gauge, which is similar to a magnahelic gauge but is equipped with set points and a 110-volt output for system shutdown or to energize an alarm.

The same regulations require pack bed scrubber operators to monitor pressure drop and inlet gas velocity once a day. Gas velocity is monitored using an air velocity magnahelic gauge reading in inches of water and feet per minute, connected to a pitot tube traversing the inlet duct diameter.

O&M Plans

(for Hard Chromium Plating Installations)

Under the Clean Air Act, the owner or operator of a hard chromium-plating tank must prepare an operation and maintenance plan. The plan shall be incorporated by reference into the source's Title V permit and must specify the operation and maintenance criteria for the hard chromium-plating tank, the add-on air pollution control device, and the process-and-control system monitoring equipment. It shall also include a standardized checklist to document the operation and maintenance of this equipment.

The plan must specify procedures to be followed to avert equipment or process malfunctions due to poor maintenance or other preventable conditions. It must include a systematic procedure for identifying malfunctions of process equipment, add-on air pollution control devices, and process and control system monitoring equipment, and for implementing corrective actions to address such malfunctions.

If the operation and maintenance plan fails to address or inadequately addresses an event that meets the characteristics of a malfunction at the time the plan is initially developed, the owner or operator must revise the operation and maintenance plan *within 45 days* after such an event occurs.

If actions taken by the owner or operator during periods of malfunction are inconsistent with the procedures specified in the operation and maintenance plan, such actions will be recorded and shall be reported *within two working days* after commencement. This report shall be followed by a letter, within seven working days after the end of the event, unless the owner or operator makes alternative reporting arrangements.

The owner or operator of a hard chromium-plating tank shall keep the written operation and maintenance plan on record after it is developed to be made available for inspection, upon request, by the EPA or control authority for the life of the plating tank or until the tank is no longer subject to these regulations. In addition, if the operation and maintenance plan is revised, the owner or operator shall keep previous (i.e., superseded) versions of the operation and maintenance plan on record to be made available for inspection, upon request, for a *period of five years* after each revision to the plan.

Maintenance of Mesha Pad Systems and Scrubbers

Maintenance Considerations for Composite Mesh Pad Systems

Due to the clogging potential of high efficiency mesh pads and the thick consistency of chromium plating solutions, these mist eliminators must be thoroughly maintained and washed down frequently on a consistent schedule. If wash-down is neglected for too long, the contaminants can solidify deep inside the pads containing smaller monofilaments, and flushing of the pad then becomes ineffective. At that point, removal of the pad from the vessel for manual cleaning is the only option. This can be difficult, especially on larger units and can be avoided if a proper wash-down schedule is faithfully executed. A magnahelic or photohelic gauge should be used to monitor the pressure drop of each stage of the eliminator. If the gauge readings begin to increase, that stage should be washed down immediately for the duration specified by the manufacturer.

A control panel for automatic timed wash-down of the mesh pads is a good idea. It consists of a 3- or 4-channel, 365-day timer clock to initiate the wash-down, timer relays on each stage for wash duration, and solenoid valves plumbed into the eliminator's spray chamber piping. This is a simple way of ensuring that flushing of these mesh pads is not neglected.

Most high efficiency eliminator designs incorporate access doors to remove the media for maintenance purposes. Although it can be a difficult job, removal and thorough cleaning of the media should be done at least annually, when production permits, as a preventive measure. Special care should be taken when reinstalling the media into the vessel, to ensure proper fit, and that no gaps are left between the media and the vessel's wall. Due to the high-pressure drop across the mesh pad, even the smallest gap could provide a path for bypass, and with the extremely low emission standards a gap could cause noncompliance.

Maintenance Considerations for Packed Bed Scrubbers

A new wet scrubber, with fresh recirculation solution and all components functioning properly, will obviously work at its designed efficiency. The main objective is to set up an effective maintenance schedule to keep the system functioning properly. The following maintenance objectives are relatively simple and should be faithfully executed:

- Scrubber spray chambers and nozzles should be regularly inspected (one to two times a week) to ensure that they are not plugged. As mentioned previously, if a portion of the packing remains dry, that portion is ineffective. Poor irrigation can also cause the packing section or mist eliminator to become plugged or fouled. Therefore, it is imperative that each nozzle sprays at its designed flow rate.
- The packing sections should be inspected often to ensure that solids are not building up, plugging portions of the pack. This could result in increased static pressure, reducing the ventilation rate, and could also prevent irrigation of other portions of the packed section, resulting in excess emissions. If buildup of contaminant on the packed section occurs, the scrubber recirculation tank should be drained and replenished with fresh water and perhaps an applicable solvent added. The packing section should then be flushed to break down trapped solids. This process may have to be repeated depending on the degree of the fouling present. If maintenance has been neglected and the severity of the pluggage is too great, the tedious job of removing and cleaning the packing must be done as a last resort. Most scrubber designs incorporate an access door or manway for this purpose. However, if maintenance inspections are done on a regular basis, this should not occur.
- The scrubber mist eliminator should also be regularly inspected. The catchment on a chevron baffle can become filled with solids, rendering it ineffective. The mesh pad eliminator is even more prone to pluggage. Although most scrubber

designs do not use a wash-down spray chamber for the mist eliminator, most designs provide access areas for spraying the eliminator manually with a hose, or for removal of the mesh pad eliminator for a more thorough cleaning. The scrubber recirculation system should be kept reasonably clean for several of the following reasons:

- To ensure that the solution is capable of gas absorption. (i.e., not scrubbing acid with acid, contaminant with contaminant, etc.)
- To minimize buildup of solids in packed and mist eliminator sections
- To prevent pluggage of spray chambers and nozzles

Most scrubber recirculation designs recommend a continuous addition of freshwater. The regulations require that this addition be made from the top of the packed bed. Up to 5 percent of total recirculation rate should be added to the recirculation tank and simultaneously overflowed to waste treatment. This serves to make up for evaporation of the recirculated solution occurring in the scrubber and to help keep the solution from becoming too contaminated. The recirculation tank should also be kept clean of sediment settling to the bottom of the tank. These solids are easily stirred up and will inevitably contribute to pluggage of spray nozzles, packing section, and the mist eliminator section.

Components for Preventive Maintenance

Inspection and maintenance of the wet scrubber system can be made easier with the addition of accessories to monitor scrubber operation and to ease the maintenance burden.

Pump Flow Meter

Any scrubber design has specifications for the required recirculation rate based on scrubber capacity, inlet concentration, packing depth, etc. Monitoring this recirculation rate gives the assurance that the designed flow rate is maintained for proper irrigation of the packed section at all times. The pump flow meter reads the number of gallons being sent to the scrubber from the pump discharge. It is calibrated to read the designed recirculation rate on either an analog or digital display. If the reading is lower than the designed recirculation rate, either the spray chamber or some spray nozzles are plugged.

Wye Strainer

The wye strainer is a simple, inexpensive filter installed in the piping between the pump discharge and the scrubber spray chamber. It simply collects particles from the recirculation flow that could potentially plug the spray system and perhaps the packing section. The advantage of the wye strainer is that it is much easier to clean than the spray chamber, nozzles, or packing.

Magnahelic Gauge

The magnahelic gauge is an analog gauge that gives constant reading of the pressure differential or pressure drop across a given medium. It is typically used to monitor the pressure drop across the scrubber packing media or mist eliminator. It can be mounted on the scrubber vessel or in a control panel in a remote location. It is usually connected to the scrubber vessel via ¼-inch plastic tubes from the gauge that penetrates the vessel on either side of the media being monitored. Certain types of random or structured packing and mesh pad configurations have specific designed pressure drops that when clean, based on their density, void fractions, irrigation rates, gas velocity, etc. If the magnahelic gauge readings begin to increase above designed pressure drop, it is a sure indicator that the contaminant is building up on the media and corrective action should be taken.

Photohelic Gauges

The photohelic gauge is similar to the magnahelic gauge except that it contains a set of relays that are available to perform a function (i.e., alarms, system shutdown, etc.). The set points are adjustable for a varied set of conditions (i.e., low airflow, pressure drop, etc.).

Materials of Construction for Ventilation Systems

The materials of construction to be used in the fabrication of ventilation systems will depend on the following factors:

- Corrosion and temperature resistance
- Flammability
- Ease of fabrication
- Initial cost and cost of installation
- System component: hood, duct, fan, or scrubber

Depending on the application, hoods and ductwork may be constructed of galvanized steel, asphalt or plastic-coated galvanized steel, rubber, redwood, or stainless steel. Because of their excellent long-term corrosion resistance, plastics such as PVC and polypropylene have been used successfully. When additional strength or high temperature resistance is required, the material of choice is usually fiber glass.

Corrosion and Temperature Resistance

As a general rule, the ventilation system component must be resistant to the solution that is being ventilated. The actual fume composition will depend on the amount of solution droplets leaving the surface of the solution and being carried into the system. In the case of chromium plating solutions, where the cathode efficiency is low and consequently a significant amount of hydrogen is generated at the cathode, the amount of chromic acid being carried into the ventilation system is substantial. On the other hand, where the cathode efficiency is comparatively high (e.g., decorative nickel plating), the amount of nickel sulfate, or chloride, carried into the system is relatively small. However, it is best to design the system as though the components were partially immersed in the plating solution to allow for the effect of additional oxygen at the surface.

Flammability

An essential consideration in the design of any ventilation system is the problem of flammability or combustibility. Since most plastics are combustible to varying degrees, this must be considered from the standpoint of the insurance costs and plant and personnel safety.

Fume/Mist Suppressants

Other methods can be used to reduce the fume generation from the surface of tanks and, thus, attempt to meet the severe limits now being promulgated. They may be divided into "mechanical" or "chemical" fume suppressants.

Mechanical Fume Suppressants

These devices are usually plastic balls or saucers made of polyethylene or pieces of tubing made of a rigid plastic and sealed at both ends. In both cases, they are placed as a blanket on the surface of the tank, where they act to block the emission of fumes or mist into the environment. Mechanical fume suppressants have the following disadvantages. They:

- Gradually break down in the various solutions
- Get sucked into the blower systems
- Get trapped on the parts or racks
- Increase the operating temperatures of certain solutions by reducing the cooling effect of evaporation
- Tend to pop out of the tank — saucers have a lesser tendency to do so

On the other hand, their efficiency in reducing fume emissions, when maintained in large enough quantities on the surface of the solution, has been measured as high as 95 percent. Therefore, serious consideration should be given to utilizing these materials when severe emission limitations must be met.

Chemical Fume Suppressants

These compounds are usually proprietary compositions of the wetting agent and/or foam producing type, which have been utilized in decorative chrome-plating operations. The wetting agent acts to reduce the size of the bubbles causing the mist or droplet generation. The foam-generating component produces a blanket on the surface of the solution, which acts as a physical barrier to the discharge of mist and fumes to the atmosphere. Some fume suppressants produce little or no foam and work simply by reducing the surface tension of the processing solution to a level at which the gas bubbles are so small they burst with only a small amount of energy, resulting in only traces of mist. Such fume suppressants were developed and are sold for hard chromium-plating applications, but they can also be used in other solutions. Some hard chromium platers have reported a greater degree of pitting problems when using fume suppressants, but most investigations into such problems have found that fume suppressants have little or no effect on pitting tendency. A trial may be required.

Initial quantitative tests with these materials are showing fume reduction efficiencies in the area of 95–98 percent. A combination of fume suppressant and a mechanical system based on floating media can often control emissions to greater than 98 percent efficiency. Combinations of fume suppressants and packed bed scrubbers have met the EPA emission standards for hard chromium plating in test installations studied by the Industrial Technology Institute.

Notes:

1) More detailed information on government regulations relating to air pollution may be found in the SFIC Regulatory Compliance Manual.
2) Mention of any equipment or process does not imply endorsement of that product by NAMF or the authors. Nor does it imply suitability for any specific application. Before utilizing any of the information in this document on any specific process or application, obtain professional assistance and guidance.

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