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From: Commanding Officer, Naval Energy and Environmental Support Activity

Subj: LESSONS LEARNED FOR VENTILATION SYSTEMS AT ELECTROPLATING FACILITIES

Ref: (a) NEESA FY93 Workplan/Program V:K7FW-1 NAVOSH

Encl: (1) NEESA 66-82, Lessons Learned for Ventilation Systems at Electroplating Facilities
(2) NEESA Products and Services

1. Per reference (a), we are forwarding enclosure (1) for your use. Enclosure (1) is the second in a series of lessons learned from our industrial ventilation system surveys for the Navy.

2. Electroplating facilities have the most complex industrial ventilation systems in the Navy. Enclosure (1) details some common problems encountered. These problems include a lack of general maintenance, crossdrafts, unbalanced ventilation systems, and incorrect design.

3. Enclosure (2) is an overview of NEESA products and services.

4. Our Indoor Air Management Division provides engineering and information/data management support. Our services include industrial ventilation system engineering, testing, troubleshooting, design review and training. Our asbestos management team performs surveys, assessments, abatement action consultation, and training. We also manage the Deficiency Abatement Program Management Information System, which includes EFD/claimant report production and providing training/guidance documents.

5. Our contact is Ms. Jill Hamilton, Code 112F1, at DSN 551-4892 or commercial (805) 982-4892.

George D Wandrocke
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By direction

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NEESA 66-82 JULY 1993

LESSONS LEARNED FOR VENTILATION SYSTEMS AT ELECTROPLATING FACILITIES

NAVAL ENERGY AND ENVIRONMENTAL SUPPORT ACTIVITY

Port Hueneme, California 93043-5014

NEESA 66-82 JULY 1993

LESSONS LEARNED FOR VENTILATION SYSTEMS AT ELECTROPLATING FACILITIES

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EXECUTIVE SUMMARY

Electroplating facilities have the most complex industrial ventilation systems in the Navy. Their design, construction, and system maintenance is crucial to the safety and health of plating shop personnel. From 1986 to 1992, the Naval Energy and Environmental Support Activity (NEESA) performed 13 industrial ventilation tests at various Naval electroplating facilities.

This paper details some common problems encountered. The percentages given below reflect the number of shops out of the 13 tested with one or more of the corresponding general problems. The percentages do not represent a deficient system, but rather particular problem areas.

1. Eighty-five percent of the shops lack general maintenance. We found one or more of the following: holes in the duct work, broken dampers, broken fan belts and couplings, and worn out fan bearings. Without maintenance any mechanical system will eventually fail. It is essential that Public Works and plating shop personnel develop and implement a preventative maintenance program.

2. Fifty-four percent of the shops have improperly designed or operated replacement air systems. The system either does not supply enough air, or is incorrectly balanced. Additionally, velocity of the supply air is too high, which disrupts the hood's ability to capture contaminants.

   The design and operation of the replacement air systems are critical to the effectiveness of the exhaust system. Follow industrial ventilation design criteria for replacement air systems. Do not use general heating, ventilation, and air conditioning (HVAC) criteria. HVAC criteria does not apply to industrial ventilation systems.

   Contact a certified Testing, Adjusting and Balancing (TAB) company for assistance in balancing existing replacement air systems.

3. Forty-six percent of the shops had crossdrafts and turbulent air. Open doors and windows, pedestal fans, and improperly designed replacement air systems cause crossdrafts and turbulence. Effective capture of contaminant cannot be obtained under these conditions.

   Install baffles on the tanks to block any crossdrafts as much as possible. Place signs on entrances to remind personnel to keep doors closed. Install plastic curtains in front of all garage doors or where necessary to block crossdrafts. Remove all pedestal fans. Ensure the room static pressure remains between -0.02 and -0.06 inches water gauge (wg).

4. Thirty-eight percent of the shops had unbalanced ventilation systems. Too much air is exhausted through some hoods and not enough through others. Blast gates are improperly adjusted.

Exhaust system balancing is difficult. Contact a certified TAB company for assistance in balancing the exhaust systems.

5. Thirty-one percent of the shops had incorrectly designed exhaust systems. Design errors include: selecting hazard classifications incorrectly, specifying duct diameters too large, excluding fan system effects from the design, and configuring the stack to distribute exhaust effluent inside the building's eddy zone.

   Follow exhaust system design criteria outlined in Military Handbook 1003/17, Industrial Ventilation Systems, and Industrial Ventilation, A Manual of Recommended Practices, by the American Conference of Governmental Industrial Hygienists.

Section III details common problems encountered at the electroplating facilities tested. Recommended solutions are given. Well written criteria for good design, construction, and operation is readily available. Additionally, to ensure consistent design, establish a design review process. Have Industrial Hygiene and Safety professionals, and NEESA review designs. NEESA is designated as the center of expertise in industrial ventilation. By using the criteria, reviewing designs, learning from past mistakes, and working together, we can eliminate ventilation problems at naval electroplating facilities.

I. INTRODUCTION

In 1983, the Chief of Naval Operations (CNO) recognized the need for improvements in Navy industrial ventilation systems. CNO directed the Naval Facilities Engineering Command (NAVFAC) to establish an engineering group at the Naval Energy and Environmental Support Activity (NEESA) to investigate and correct industrial ventilation deficiencies. In 1990, NAVFAC designated NEESA as the Navy's center of industrial ventilation expertise. In this capacity, we produce guidance documents, review designs, test ventilation systems, and conduct design training.

From 1986 to 1992, we tested 13 industrial ventilation systems at various electroplating facilities throughout the Navy:

1. To evaluate system performance and recommend improvements to comply with Occupational Safety and Health Administration (OSHA) standards.

2. To provide baseline system performance data. Against which, future measurements are compared to verify system performance. Title 29, Labor, Code of Federal Regulations, Part 1910 - General Industry Standards, Section 94(d)(8) (29 CFR 1910.94(d)(8)) requires this baseline testing.

3. To obtain "hands on" experience to enhance our understanding of specific ventilation design requirements and to develop our expertise further.

4. To provide design engineers; public works personnel, and ROICC/OICC offices with a "lessons learned" package identifying navy-wide deficiencies in industrial ventilation.

5. To provide recommendations to improve systems to meet design and performance standards.

This document details some common problems encountered in plating shops throughout the Navy. By compiling a list of common problems and defining the solutions, we can eliminate these problems in future electroplating facilities.

II. BACKGROUND

During the cleaning and electroplating of metal parts, workers are potentially exposed to acid mists, caustic vapors, hexavalent chromium and cadmium fumes, and other hazardous chemicals. Local exhaust ventilation hoods are used to capture contaminants and carry them away from the workers breathing zone. Figure 1 shows typical exhaust hoods found in plating shops.

OSHA 29 CFR 1910.1000 defines permissible exposure limits for contaminants found in plating shops. OSHA 29 CFR 1910.1000 also requires that engineering controls (i.e., local exhaust ventilation) be designed, built, and maintained to prevent worker exposures above permissible limits.

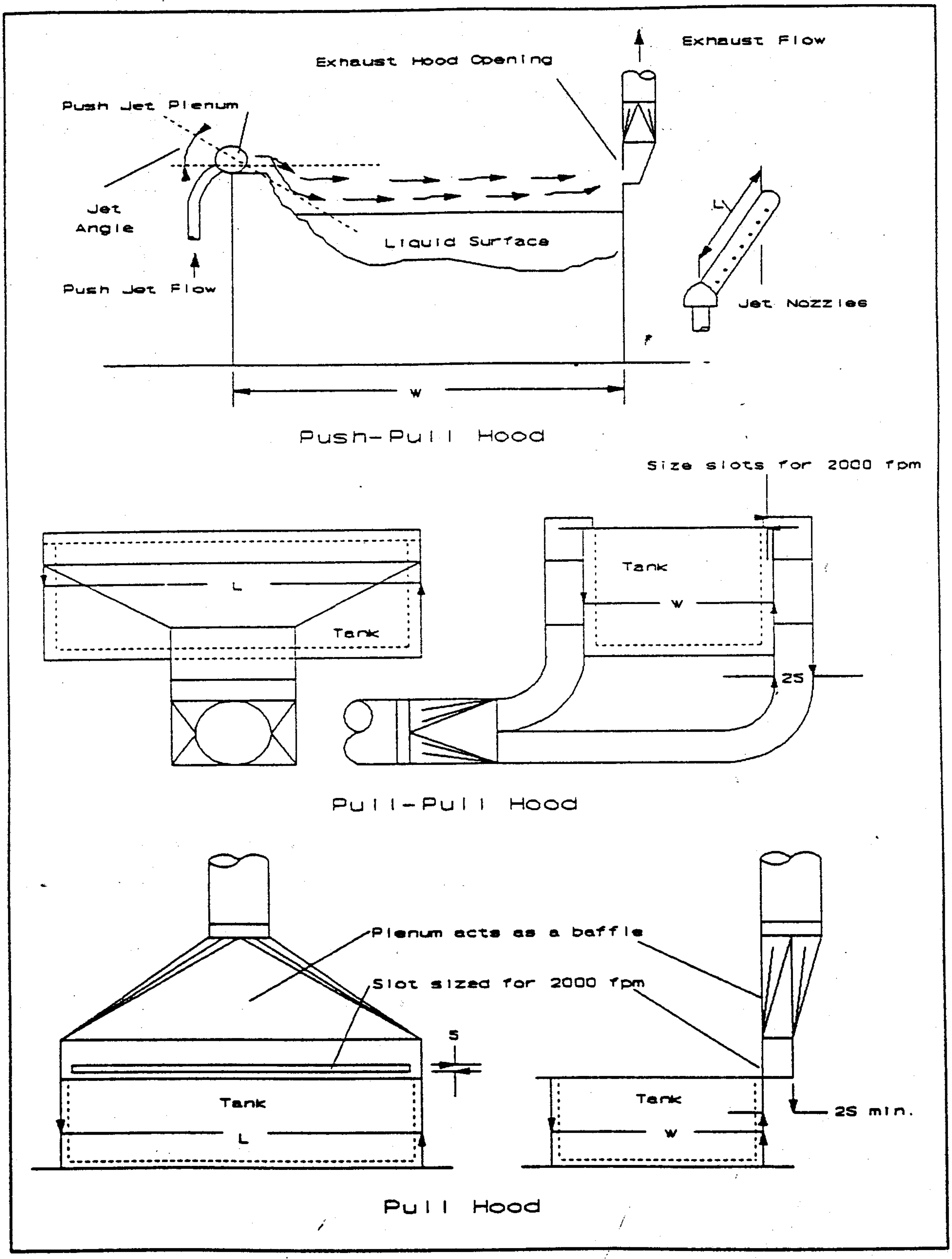

Figure 1. Exhaust Hood Configurations

OSHA further regulates open surface tanks under Title 29, Code of Federal Regulations, Part 1910.94 (d). OSHA 29 CFR 1910.94(d)(8) requires baseline and periodic testing. OPNAVINST 5100.23C, Navy Occupational Safety and Health Program Manual, Chapter 5, requires ventilation systems to meet or exceed those design standards stated in Industrial Ventilation, A Manual of Recommended Practice, by the American Conference of Governmental Industrial Hygienists (ACGIH) and Military Handbook 1003/17, Industrial Ventilation Systems. Criteria in this report are based on these documents.

III. FINDINGS AND SOLUTIONS

A. DESIGN

1. **FINDING:** Duct size is improperly specified. MIL-HDBK-1003/17 recommends a minimum transport velocity of 2500 feet per minute (fpm) for plating shops, to prevent contaminants settling in the duct work. Settled contaminants can cause system deterioration through duct corrosion and plugging.

   ACGIH allows transport velocities of 1000 to 2000 fpm. We have found these do not prevent contaminate settling.

   SOLUTION: Size the duct work to obtain a minimum transport velocity of 2500 fpm. We found that this transport velocity reduces the amount of contaminants settling in the duct work.

2. **FINDING:** Exhaust stacks are incorrectly designed, allowing exhaust effluent to re-enter the facility through the replacement air intakes. Recirculation of the air can cause an accumulation of contaminants in the workplace. The stack configurations that adversely affect the performance of the fan cause a system effect. The systems effects reduce fan efficiency. Account for system effects during design for proper fan selection.

   SOLUTION: Install "no loss" stackheads on the exhaust fan outlets (Figure 2). Discharge exhaust effluent outside the buildings eddy zone to provide adequate dispersion and to prevent exhaust air from re-entering the facility (Figure 3).

3. **FINDING:** Required flow rates for individual tanks are improperly calculated due to the following: hazard classification is designated incorrectly; baffles are specified in the design, but are not installed; tank dimensions are different from the design dimensions; and tank contents are different from the design specifications. These parameters are in the equation to determine the flow rate.

   Also, the design flow rate is calculated using the wrong effective width. The effective width is equal to half the tank width for pull-pull hoods and the entire tank width for pull hoods.

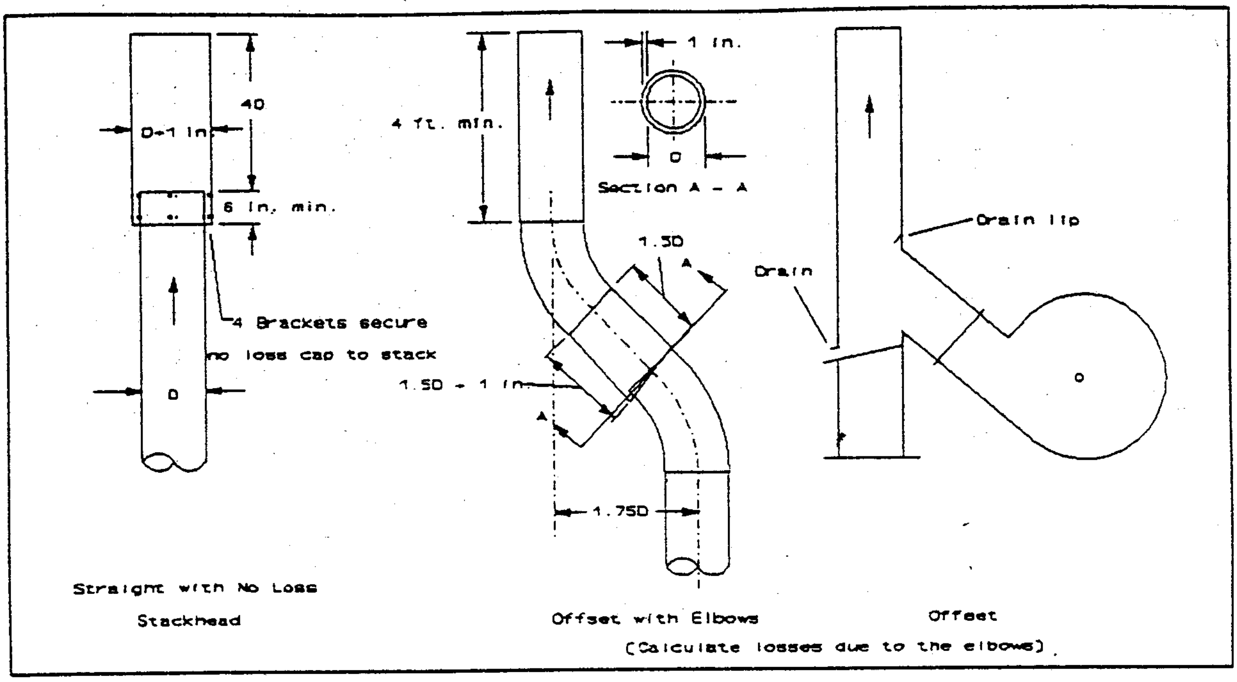

Figure 2. Exhaust Stack Designs

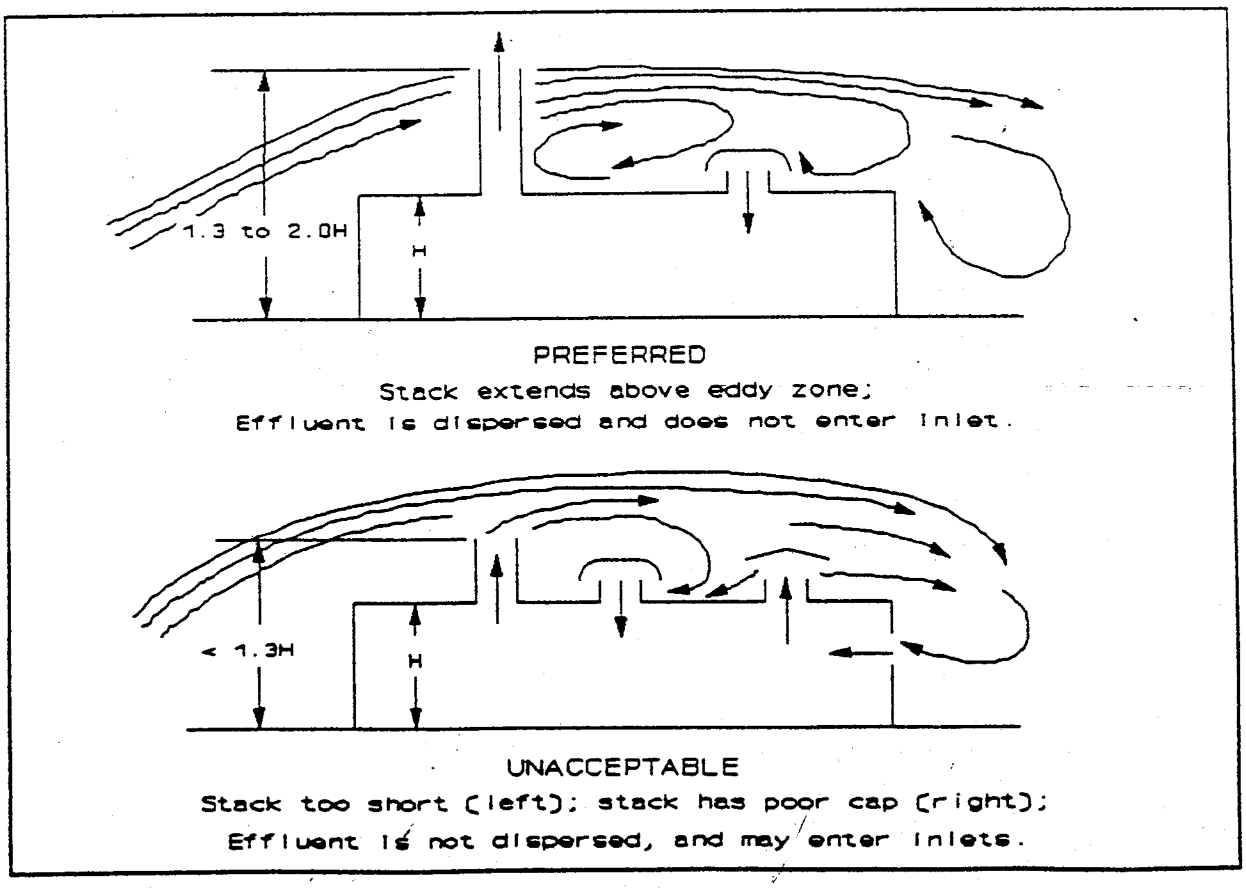

Figure 3. Stack Height Relative to Eddy Zone

SOLUTION: Determine hazard classifications for the individual tanks using criteria given in 29 CFR 1910.94 (d)(2). Calculate the required flow rate in accordance with OSHA 29 CFR 1910.94. See MIL-HDBK-1003/17 or the ACGIH Manual for additional information on calculating required flow rates.

Design modifications are common during most construction projects. Changing the design factors, such as tank dimensions and contents, impact the required volumetric flow rate. Recalculate flow rates and rebalance the system based on the as built features of each tank. Contact your Engineering Field Division or NEESA for help in determining required flow rates.

B. EXHAUST SYSTEM

1. **FINDING:** The exhaust system is not balanced due to improperly set blast gates. The system exhausts excessive air in certain areas and insufficient air in other areas. The total volumetric flow rate for the system is equal to the flow rates for all the hood connected to the system. The flow rate through each hood is designed to provide adequate capture over the surface of the tank.

   SOLUTION: Balance the system using an air balancing company certified by either the Associated Air Balancing Council or the National Environmental Balancing Bureau. Adjust blast gates to obtain the required exhaust flow rate for each hood. When balancing the systems, consider the required flow rate as the minimum amount of air to be exhausted.

   Lock blast gates in place upon final adjustment to prevent movement. Paint blast gates, in a contrasting color, for visual verification that gate has not moved.

2. **FINDING:** The principal advantage of the push-pull system over a pull-pull system is the reduced exhaust air volume. Reduced air volumes result in energy savings. In push-pull systems, a plane of air is pushed across the surface of the tank. The push-air moves contaminants above the tank surface and carries them toward the exhaust hood.

   The most common error in operating a push-pull system is providing excess push-air. Excessive push-air causes turbulence at the entry to the exhaust plenum, disrupting the hood's effectiveness to capture contaminants. The excessive push-air carries contaminants past the hood and into other work spaces. Too little push-air, often caused by clogged holes, allows contaminants to escape.

   SOLUTION: Specify a 20 percent adjustability in the push-air volume flow rate. Adjust the volume flow rate during balancing and lock the mechanism in place. The flow rate of the push-air should be 18.5 cfm per foot of tank length or 5 cfm per square foot of tank surface area.

   Design the holes in the push-air nozzle according to MIL-HDBK-1003/17. Keep holes clear to ensure sufficient air to push the contaminants into the exhaust system.

3. **FINDING:** The push-air plenum is placed several inches above the edge of the tank, allowing contaminants to escape into the worker's breathing zone.

   SOLUTION: Locate the push-air plenum as near the tank edge as possible. Design the push-air plenum to rest on the edge of the tank or install baffles to the edge of the tank.

4. **FINDING:** The push-air is disrupted by obstructions above the liquid surface in the tank. This causes the air to become turbulent, reducing the exhaust systems contaminant capture. This especially true for hard chrome plating tanks with conforming anodes.

   SOLUTION: Set the nozzle at the minimum angle necessary to clear nearby obstructions (0 to 20 degrees downward). Use pull-pull or pull type hoods for tanks with numerous built-in obstructions. Do not use a push-pull ventilation for hard chrome plating processes. Buss bars, hanging parts, and other obstructions will interfere with the air jets and decrease or eliminate the effectiveness of the ventilation system.

5. **FINDING:** The fluid level in the tank (freeboard) is too low for the push-pull system to operate properly.

   SOLUTION: Ensure the liquid level is never more than 8 inches from the top edge of the tank.

6. **FINDING:** Crossdrafts, from poorly designed replacement air systems, open doors, pedestal fans, and high negative room static pressures, interfere with the exhaust systems ability to capture contaminants.

   SOLUTION: Eliminate all crossdrafts by closing all windows and doors, and discontinuing use of pedestal fans. Also, proper design minimizes crossdrafts caused by replacement air systems. Balance the replacement air and exhaust systems to maintain a slight negative room static pressure of 0.04 ± 0.02 inches wg. Interlock the supply and exhaust fans to ensure they do not operate separately. Distribute the replacement air evenly as discussed in section C.

   Installing baffles also can help minimize crossdrafts. Use baffles to increase the hoods contaminate control and reduce energy consumption. Baffles reduce the required volumetric exhaust flow rate. See MIL-HDBK-1003/17 for baffle design.

7. **FINDING:** Tanks containing reactive substances are located close to each other. Cyanide and hydrochloric acid, when mixed produce hydrogen cyanide, a highly toxic gas. There is a high potential for accidental mixing of these chemicals when the tanks are placed next to each other. Mixture of the substances also may occur in the ventilation system or by accidental spillage.

SOLUTION: Clearly mark tanks containing reactive substances. Separate tanks containing reactive substances. Place signs on cyanide tanks that state, "DO NOT MIX WITH ACID." To prevent the mixing of cyanide and acids in the event of a tank rupture or spill, use sumps or berms to isolate areas the areas in accordance with OSHA 29 CFR 1910.94(d)(10). Do not connect substances constituting a fire, explosion, or chemical reaction hazard to the same exhaust system, per OSHA 29 CFR 1910.94(d)(7)(iii).

8. FINDING: Often empty tanks are still ventilated. This wastes energy.

   SOLUTION: Shut off the ventilation to the tanks not being used to save energy. Close the blast gates and lock in place. Balance the exhaust system associated with the tanks using a certified air balancing company. Reduce the fan speed or, if necessary, replace the fan to exhaust only the required volumetric flow rate for the system.

C. REPLACEMENT AIR SYSTEM. The design and operation of the replacement air system are critical components of a plating shop ventilation system. The exhaust systems of open surface tanks are very susceptible to crossdrafts. Poorly designed and operated replacement air systems can create crossdrafts up to 100 fpm.

1. FINDING: The building is under severe negative static pressure, due to more air exhausted than supplied. Negative pressures of up to 0.5 inches wg are created. Doors are difficult to open and a slam shut creating a safety hazard. Large crossdrafts are created from windows, cracks, and open doors.

   SOLUTION: Increase replacement fan speed to supply 90 to 95 percent of air exhausted. This will create a room static pressure, between -0.02 and -0.06 inches wg. Install variable speed supply fans and a room static pressure sensor to monitor changes in the room static pressure. The sensor modulates the speed of the replacement fan, which maintains the desired negative pressure.

2. FINDING: a) The supply air system is not distribute equally. The total amount of air supplied is sufficient, but too much air is supplied to one area and not enough to another. This causes crossdrafts.

   b) Conventional HVAC type diffusers deliver large volumes of air at a high velocity. This causes turbulence which interferes with the exhaust systems ability to capture the contaminants.

   SOLUTION: Distribute replacement air evenly over a large area to create a low velocity laminar air flow into the shop.

We recommend two methods to distribute the replacement air. The first method delivers air to the room through perforated duct. The duct is perforated all around to minimize the exit velocity and "throw distance" from the duct. This method works very well for rooms with ceilings higher than 15 feet. For ceiling lower than 15 feet, possible turbulence or undesirable air currents can inhibit exhaust system performance.

For ceilings lower than 15 feet, or for even air distribution over a greater area, distribute the air through a perforated plate drop ceiling. Deliver the replacement air into the ceiling plenum through either perforated duct or large diffusers. This forces the air through the perforated plate drop ceiling and into the room. Plenum perforations range from 1/4 to 3/8 inch diameter with a velocity of 1000 fpm or less through the holes. Open area percentage for the perforated plate is 20% or less. Greater than 20% open area results in inferior distribution.

D. GENERAL MAINTENANCE

1. **FINDING:** System performance records often do not exist. Deterioration of ventilation system performance cannot be determined without baseline data or periodic monitoring.

   SOLUTION: Perform a baseline ventilation test, as required by OSHA 29 CFR 1910.94(d)(8)(i). Establish the correct operating data for hood static pressures, fan static pressures, system flow rates, fan speeds, motor speeds, clean filter static pressures, and air cleaning device static pressures.

   Ensure that the ventilation system performance is maintained at an acceptable level and design a monitoring system. Install magnehelic gauges on each hood to monitor hood static pressure. Locate the gauges either directly on the exhaust hood or on an annunciator panel near the room entrance. Mark the gauges to indicate the acceptable range. Shop personnel can determine immediately if the hoods static pressure goes outside the accepted range.

   Install magnehelic gauges to the supply fans, exhaust fans, filters, and air cleaning devices to monitor the static pressures. Locate the gauges on an annunciator panel. Mark the gauges to indicate the acceptable operating ranges. Also, install a magnehelic gauge to monitor room static pressure to that the proper quantity of replacement air is supplied.

2. **FINDING:** Lack of ventilation system maintenance is the most common problem found in plating shops. Maintenance records often do not exist. Accelerated wear occurs in the mechanical and electrical system components due to irregular maintenance. Often there is no continuity in maintenance practices due to changes in management.

   SOLUTION: Establish a preventive maintenance schedule. Include checking fan speed, belt tension and wear, and bearing lubrication in the maintenance schedule. Post a ventilation system maintenance log so shop personnel can easily determine when maintenance was last performed.

Inspect duct work quarterly for evidence of corrosion and damage. Check the hood static pressure and compare it to the baseline data to verify that hood flow rates are the same. Use a pitot tube and a manometer or a static pressure tap to obtain the hood static pressure readings. Do not base measurements on the attached magnehelic gauge in case of malfunction. If the hood static pressure has deviated by more than 20%, discontinue use of the tank, locate and fix the problem immediately.

IV. CONCLUSION

Design errors and lack of maintenance are the most common problems found in plating shop ventilation systems. Often these problems cause non-compliance with OSHA standards. Both plating shop designers and managers must be thoroughly familiar with OSHA regulations to ensure that the requirements are met.

Ensure consistent design through establishment of a design review process. Have Industrial Hygiene and Safety professionals, and NEESA (designated center of industrial ventilation expertise) review designs.

Over time, the shop's ventilation system will deteriorate. The keys to maintaining a good ventilation system are to identify and correct problems before the flow rate to each hood is affected. To verify system performance, compare flow rate measurements to baseline performance data. Quarterly inspections for duct work corrosion and damage, and flow rate verification are required by OSHA. The magnehelic gauges attached to the exhaust hoods, fans, and air cleaning devices are a method monitoring ventilation system performance between inspections.

V. ADDITIONAL PROBLEMS. Research is continuing in the following problem areas:

1. Liquid in the duct work due to backwash from the scrubber or entrainment and condensation in the duct work.

2. Compatibility of duct work material and adhesives with ventilated contaminants.

3. Greater efficiency air cleaning devices.