106-17b

IN-DEPTH SURVEY REPORT
OF
AMERICAN AIRLINES PLATING FACILITY

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National Institute for Occupational Safety and Health
Cincinnati, Ohio

PURPOSE OF SURVEY:	To evaluate occupational health hazard control measures used in an aircraft maintenance plating facility.
DATE OF SURVEY:	December 7-10, 1981
EMPLOYER REPRESENTATIVES CONTACTED:	Mr. R. D. Heston, Manager of Machine Processing Mr. John Doshier, Plating Shop Supervisor Mr. John Flynn, Safety Director Mr. Mach Hay, Safety Engineer
EMPLOYEE REPRESENTATIVES CONTACTED:	Mr. Carl Gulley, Shop Steward, UAW Local 514
STANDARD INDUSTRIAL CLASSIFICATION CODE:	372: Aircraft and Parts
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Abstract

An in-depth survey was conducted at the American Airlines Maintenance and Engineering Center as part of a NIOSH study evaluating measures to control occupational health hazards associated with the metal plating industry. This American Airlines plating facility, employing approximately 25 workers, is primarily engaged in plating hard chromium, nickel and cadmium on aircraft engine and landing gear parts. Six tanks were studied, including an electroless nickel tank.

Area and personal samples for chromium, nickel, cadmium, and cyanide were collected. Ventilation airflow and tank dimensions were measured, and data was recorded on plating operations. The relationships between air contaminants emitted, local exhaust ventilation flow rate, tank size, and plating activity were evaluated.

Personal exposures were found to be within NIOSH Recommended Standards. Area concentrations around two tanks, which had low values of exhaust rate per square foot of tank area, were relatively high with respect to exposure standards. Covering one of these tanks dramatically reduced the area concentrations around the tank. This tank is illustrative of the disruptive effects of strong, uncontrolled, air currents across the surface of marginally ventilated tanks. An insufficient amount of supplied make-up air caused air currents within this shop from air streaming through open doorways from other areas of the building.

INTRODUCTION

The American Airlines Maintenance and Engineering Facility plating shop was surveyed as part of the NIOSH Control Technology Assessment of the Metal Plating Industry. Many of the solutions used for the ionic deposition of metals present potential hazards to the workers. The proper use of control measures can reduce these hazards to safe levels. Thus, NIOSH is evaluating the effectiveness of occupational health hazard control techniques employed in selected plating shops.

American Airlines was identified as an establishment in which exposures to plating hazards were generally well-controlled. Local exhaust ventilation is installed on most of the tanks. Some of the tanks have covers in addition to the ventilation.

The operation is housed in a large room (approximately 13,000 square feet) within a much larger building. Depending on the workload, between 20 and 30 platers are employed in the shop. Approximately one third of this total works the night shift. A typical workload is approximately 4000 shop orders per month, with usually one part per order. The layout of the shop, showing the tanks evaluated in this survey, is diagrammed in Figure 1.

There are six plating lines in the south end of the shop, identified alphabetically A through F and arranged in three parallel pairs, containing a total of approximately 80 tanks. There are also some tanks in a smaller area at the north end of the shop. Between these two plating areas is work space for masking, fitting fixtures, and light shop work. Abrasive blasting, shot-peening, buffing and grinding, and machining operations are performed in other areas of the building. A laboratory for analyzing plating bath concentrations is located adjacent to the main doorway to the shop. Office space, a break area, washroom facilities, and vending machines are also situated just outside this same doorway.

The tanks are set on concrete ventilation-duct tunnels constructed on the basement floor. The floors of the shop and the aisles between the paired rows are reinforced concrete; however, the area around the perimeter of each tank, as well as between the two lines of each paired row, is open to the basement and covered by a steel grating.

The concrete ventilation ducts run through the basement to each end of the rectangular room, then rise through large, round, metal ducts to fans on the roof. The tanks at the north end are exhausted through a separate system with risers in the adjacent room. Two of the large risers at the south end draw air from the basement through fans in the ceiling. A large heating and comfort ventilation system duct with numerous vents runs the length of the room up in the ceiling space.

Tank B-10 is the largest of the hard chrome tanks, holding over 1000 gallons of plating solution. It has a two-sided lateral exhaust ventilation system. The slot on each side is actually a series of seven slots approximately 12 inches long and 2 inches wide. The slots are set back from the edge of the tank about 3 inches, but an overhang of the hood above the slots extends out to the edge of the tank.

Tank D-1 contains an electroless nickel bath. It has both a two-side ventilation system and a full cover. Its ventilation system consists of a single slot on each side, approximately two inches wide, running the length of the tank. A two-piece cover is hinged to the ventilation manifold box on each side. It extends beyond the front and rear edges of the tank, but leaves an open space of about one square foot at each end. Pieces plated in this tank undergo reciprocating oscillation.

Tank E-1 is the nickel strip tank. It also has both a two-sided ventilation system and a full cover. The two-piece cover, hinged in the middle and along one side, extends the length of the tank except for about six inches at one end of the tank where steam pipes and the stirring device are located. However, the exhaust ventilation slot on each side extends a few inches beyond the edge of the tank at this end.

Tank E-10 is a sulfamate nickel tank. Pieces plated in this tank undergo reciprocating oscillation, but there is no air agitation. This tank does not have local exhaust ventilation.

Tanks F-7 and F-10 are similar in size and configuration except that F-10 is 2 feet shorter and 3 feet deeper. Both have two-sided local exhaust ventilation, with the slots set back about 3 inches from the edge of the tank liner insert which contains the plating bath. The plating solution in each tank is filtered, but there is no agitation of the piece(s) being plated or the bath.

The platers which comprise the work force are generally quite experienced, averaging 19 years of plating employment. For the day shift, the years of experience range from 7 to 30 (average of 20); and for the night shift crew from 1 to 35 with an average of 17. The median for all three groupings in 20 years. The workers usually rotate assignments.

PROCESS DESCRIPTION

Each part undergoes some surface preparation before being plated. This pretreatment will consist of some combination of shot-peening, abrasive blasting, degreasing, descaling, pickling, etching, alkaline cleaning, and stripping along with numerous rinses. Some of these procedures are performed in other sections of the facility.

Areas not to be plated are "stopped-off" with some sort of masking agent. Wax and an adhesiveless plastic tape are two commonly used types. Some pieces are fitted with fixtures to better distribute the electric field and achieve a more uniform deposition of metal. Parts are manually placed into the tanks, using an overhead hoist for large parts. After plating, the pieces are rinsed, any fixtures and "stop-offs" are removed, and depending on the specified procedure for the part, high-strength steel pieces may be heat treated in an oven at 375°F for 12 (chromium) or 23 hours (nickel and cadmium).

Every tank is not used everday. Some are used only for certain types of pieces, and some must wait for a full load. Some tanks are used everyday, but only for a little while, such as for flash or strike plating. Other tanks are in almost constant use, plating large pieces for long periods of time. The overall plating workload is dependent on the level of activity (flying hours) of the airline.

Tank B-10 contains 32 oz/gal chromic acid and 0.34 oz/gal sulfuric acid, typical of the all hard chrome tanks in the shop. The bath is maintained at around 120°F by steam coils in the bath. Most plating is performed at a current density of approximately 2 amps per square inch, and a deposition rate of 0.0005 to 0.0008 inches per hour.

The electroless nickel tank utilizes a proprietary bath, Enplate Ni-419. The composition is adjusted for a nickel metal concentration of 0.7 to 0.8 oz/gal and a pH of 5.2. This bath is operated at 180-190°F, and a load of pieces plates for 1 to 2 hours.

The nickel strip solution contains 8 oz/gal of nitrobenzene sulfonic acid and 12 oz/gal of sodium cyanide. A load of pieces usually soaks in the agitated bath, at 140°F, for about 20 hours.

Tank E-10 contains 60 oz/gal nickel sulfamate, less than 1 oz/gal nickel chloride, 6 oz/gal boric acid, and a trace of an antipitting agent. Nickel metal content is controlled to 10-12 oz/gal and the pH is kept between 4 and 4.5. The bath is maintained between 110 and 120°F.

The two cadmium tanks, F-7 and F-10, are similar in bath composition except that one (F-7) contains brighteners. Both are room-temperature baths adjusted to achieve a cadmium metal concentration of from 3-5 oz/gal and a total cyanide (as sodium cyanide) to cadmium ratio of 4. Most pieces plate only a few minutes, often using hand held electrodes for holes and other internal surfaces.

These bath compositions are summarized in Table 1.

Table 1
Composition of Tank Solutions

Tank	Bath Description	Composition
B-10	Hard chrome plating	32 oz/gal chromic acid 0.34 oz/gal sulfuric acid
D-1	Electroless nickel plating	ENPLATE Ni-419 (0.7-0.8 oz/gal nickel metal)
E-1	Nickel strip	8 oz/gal nitrobenzene sulfonic acid 12 oz/gal sodium cyanide
E-10	Sulfamate nickel plating	60 oz/gal nickel sulfamate 0.75 oz/gal nickel chloride 6 oz/gal boric acid 0.05 oz/gal antipitting agent
F-7	Bright cadmium plating	3-5 oz/gal cadmium metal 11.7-17.5 oz/gal total cyanide (As sodium cyanide) 1.5-2.5 oz/gal sodium hydroxide brightening agent(s)
F-10	Dull cadmium plating	3-5 oz/gal cadmium metal 11.7-17.5 oz/gal total cyanide 1.5-2.5 oz/gal sodium hydroxide

HAZARD ANALYSIS

The primary hazards from the hard chrome plating operation are chromium and sulfuric acid. From nickel plating, the potential hazard is metallic nickel and soluble nickel compounds; from the nickel strip bath, cyanide and nickel; and from cadmium plating, both cadmium and cyanide. These substances may be present in the air due to the generation of mist from the plating bath. Workers also come in contact with these substances in liquid form when handling the parts being plated, when adding chemicals to the tanks, when performing maintenance operations on the tanks, and when draining the tanks.

All of these agents can act directly on the skin, the eyes, and linings of the nose and throat. The principal route of entry for chronic effects is inhalation; however, chromium and cyanide may also enter the body through the skin and from eating food exposed to mist or dust laden with the contaminant.

Much has been written on the potential hazards of these substances. There is no attempt here to present all known data, merely some pertinent information in summary form.[1]

Chromic Acid

Chromic acid is an aqueous solution of chromium trioxide (CrO_3), a dark red, odorless solid. It may cause corneal injury if splashed in the eyes, and, if swallowed, stomach and kidney problems. From short-term exposure, chromic acid mist may cause severe irritation of the nose, throat, and lungs. Skin exposure may result in ulceration of the skin.

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[1] One source for a comprehensive review with references is the NIOSH/OSHA Occupational Health Guideline for Chemical Hazards (NIOSH Publication 81-123).

Repeated or prolonged exposure to chromic acid mist may cause ulceration and perforation of the nasal septum. Respiratory irritation may occur with symptoms resembling asthma. Liver damage with yellow jaundice has been reported. A skin rash may develop from prolonged contact or an allergic reaction. Erosion and discoloration of the teeth has been attributed to chromic acid exposure.

Although some forms of chromium are considered carcinogenic, chromic acid is currently not considered one of them. However, papillomata (benign tumors of the mucous membrane) of the oral cavity and larynx were found in 15 of 77 chrome platers exposed for an average of 6.6 years to chromic acid mist at air concentrations of approximately 0.4 mg/m^3 chromium.

Annual medical examinations are advised. Emphasis should be placed on observation for changes in the mucous membranes of the upper respiratory tract, ulceration of the skin, and evidence of tumors of the respiratory tract and lungs.

The Occupational Safety and Health Administration (OSHA) has ruled that an employee's exposure to chromic acid and chromates (i.e. Chromium VI) shall not exceed at any time a ceiling concentration of 0.1 milligram of chromium per cubic meter of air. An employee's exposure to soluble chromic and chromous salts (i.e. total chromium) in any 8-hour work shift of a 40-hour work week shall not exceed the time-weighted average of 0.5 mg/m^3. NIOSH has recommended that the permissible exposure limit for non- carcinogenic chromium VI be reduced to 0.025 mg/m^3 averaged over a work shift of up to 10 hours per day, 40 hours per week, with a ceiling limit of 0.05 mg/m^3 averaged over any 15-minute period. For the carcinogenic chromium VI compounds, NIOSH has recommended a permissible exposure limit of 0.001 mg/m^3. Chromium trioxide is not currently believed to be carcinogenic.

Sulfuric Acid

Sulfuric acid (H_2SO_4) can affect the body if it is inhaled or if it comes in contact with the eyes or skin. It can also affect the body if it is swallowed. The extent of the effects depends somewhat on how concentrated the acid is. Concentrated sulfuric acid destroys tissue through an extensive dehydrating action, while the dilute form is primarily an irritant due to its acid properties.

Sulfuric acid mist can severely irritate the eyes, nose, throat, and skin. Splashes of concentrated acid in the eyes or on the skin may cause blindness and severe burns. Repeated or prolonged exposure may cause erosion of the teeth, soreness of the mouth, and difficulty breathing. Chronic inflammation of the skin or irritation of the eyes may be caused by over-exposure to sulfuric acid.

The current OSHA standard for sulfuric acid is an 8-hour time-weighted average of 1.0 mg/m^3. NIOSH has recommended that the permissible exposure limit be 1.0 mg/m^3 averaged over a work shift of up to 10 hours per day, 40 hours per week.

Cadmium Dust

Generally, cadmium dust (whether from the metal, the oxide, or various salts) is odorless. The chief warning properly is dryness and irritation of the respiratory tract followed in a few hours by nausea and diarrhea. These nonspecific symptoms are insufficient to warn of exposures which may cause systemic poisoning and damage to the lungs. If enough is inhaled from an acute exposure, after a delay of several hours a person may develop shortness of breath, coughing, chest pain, sweating, chills, and weakness.

Possible effects from repeated or prolonged exposure include loss of sense of smell, ulceration of the nose, difficulty breathing, kidney damage, and mild anemia. Exposure to cadmium may be associated with an increased incidence of prostate cancer in man. Periodic pulmonary function testing, urinalysis, and examination of the prostate gland are recommended for medical surveillance. The urine should be checked for the presence of low molecular weight proteins in addition to standard measures.

The current OSHA permissible exposure limit (PEL) for cadmium dust (as cadmium) is 0.2 mg/m^3 averaged over an 8-hour shift, with a ceiling level of 0.6 mg/m^3. NIOSH has recommended that the standard be reduced to 0.04 mg/m^3 of cadmium averaged over a workshift of up to 10 hours with a ceiling limit, averaged over a 15-minute period, of 0.2 mg/m^3.

Cyanide

Cyanide salts, and the hydrogen cyanide produced when these salts come in contact with acids or moisture, may have a faint almond odor; however, due to the toxicity of the cyanide ion in the body, neither eye or nasal irritation nor odor detection provide an adequate wrarning of cyanide exposure. Inhalation or ingestion of cyanide salts may cause death due to cessation of cellular respiration. Sufficient cyanide may be absorbed through the skin, especially if there are cuts or damage to the skin, to cause fatal poisoning.

Acute exposure may be rapidly fatal, or may be marked by weakness, dizziness, headache, and nausea, possibly followed by convulsions, unconsciousness, and death, depending on the degree of cyanide intoxication. The dust of cyanide salts is irritating to the eyes, nose, and skin, especially in the presence of moisture such as tears and sweat. Generally, there are no known major health effects from chronic exposure to cyanide. However, cyanide salts are corrosive, and skin ulceration may develop from repeated or prolonged low level exposure. The OSHA PEL for cyanide is an 8-hour time-weighted average of 5 mg/m^3 of cyanide and, for hydrogen cyanide, 10 parts of HCN gas per million parts of air (equivalent to 11 mg/m^3 HCN) averaged over an 8-hour shift. NIOSH has recommended that these standards be changed to a ceiling limit of 5 mg/m^3 of cyanide averaged over a 10-minute period.

Nickel

Metallic nickel and nickel compounds are generally odorless substances with poor warning properties of overexposure. Health effects are manifested primarily as skin and respiratory disorders. Nickel itself is not very toxic if swallowed, but its soluble compounds are.

Skin contact may result in a sensitization dermatitis often called "nickel itch". The initial itching may be followed (up to many days later) by reddening and ulceration of the skin or an eczema-like rash. The dermatitis may be cleared up after removal from contact with the source of the nickel; but subsequent, low-level exposures to nickel will cause an outbreak of skin irritation. This sensitization phenomenon may extend to the respiratory tract. Nickel has been implicated in certain cancers among nickel refinery workers, but cases attributed to exposures from metal plating applications are rare and no definitive relationship has been established.

The current OSHA standard for nickel metal and its soluble compounds is 1 mg/m^3 averaged over an 8-hour workshift. NIOSH recommends that nickel be regulated as an occupational carcinogen, and that the standard be lowered to 0.015 mg/m^3 averaged over a work shift of up to 10 hours per day.

EVALUATION METHODS

To determine the effectiveness of the controls used in this shop, both area and personal samples for the hazardous substances were taken on three consecutive days. An estimate of the airborne concentration of the substance of interest can be caluculated by dividing the amount collected on the filter by the volume of air drawn through the sampling device. Total air flow for each tank sampled and air velocities at the face of the slot hoods of these tanks were measured. Notes were taken on the plating operations in these tanks for the three days of sampling.

Personal and area samples for hexavalent chromium were collected using closed-face cassettes with 37 mm polyvinylchloride membrane filters of 5 m pore size and MSA Model-G personal pumps operated at a flow rate of 2 liters of air per minute. These samples were analyzed for chromium VI using NIOSH P&CAM 319[2], a colorimetric procedure.

The sampling for nickel, cadmium, total chromium, and cyanide was similar except that 37 mm mixed cellulose ester filters with a pore size of 0.8 m were used. When analyzed separately, total chromium collected was determined using NIOSH P&CAM S-323[3], an atomic absorption spectrophotometric (AAS) method. When amounts for each of some combination of nickel, cadmium, and/or total chromium were desired, NIOSH P&CAM 173[4] (an AAS method) was used. Particulate cyanide was analyzed for using an ion-specific-electrode, direct-potentiometric procedure, NIOSH P&CAM S-250[3].

Area samples for sulfuric acid were collected in 7 mm diameter silica gel tubes using DuPont P-200 pumps operated at a nominal flow rate of 200 milliliters of air per minute. All the sulfuric acid samples were lost before they could be analyzed.

[2] NIOSH Manual of Analytical Methods, Volume 6, NIOSH Publication 80-125.

[3] NIOSH MOAM, Vol 3, Pub 77-157C.

[4] NIOSH MOAM, Vol 1, Pub 77-157A.

Area samples were placed at fixed locations in the room and around the tanks. On tanks B-10, F-7 and F-10, samples were placed above the surface as well as above the slot to roughly estimate the concentration differential related to the ventilation. On all tanks, samples were also taken on unventilated sides, further indicating the quality of control.

For the personal samples, the filter cassettes were clipped to the collar, on the front of the work shirt. This placed them in the breathing zone, only a few inches below the face, in a manner so as not to interfere with the workers activities. These samples were taken for the duration of the shift (except during the lunch break) for three platers working the tanks being sampled each day of the sampling period.

Total air flow was measured in the duct connecting the ventilation system plenum to a concrete duct in the basement and in each of the main ducts leading out of the room. Either a pitot tube or a TSI Model-1650 hot wire anemometer was used for these measurements. An estimate of the flow rate can be calculated by computing the average velocity and multiplying by the cross-sectional area of flow at that point. Air velocities were also measured for each tank at the slots and, on tanks D-1 and E-1, at the openings remaining with the covers in the closed position. These measurements were taken for approximately six-inch intervals with the hot-wire anemometer. Two readings were taken at each interval, one for the top half of the slot and one for the bottom half.

During the three days of sampling, information was recorded on tank operation. For tank B-10, this included area being plated, rectifier parameters, and the time during the sampling period that plating was in progress for each piece or combination of pieces in the tank.

RESULTS

Personal Samples

The average workshift employee exposures to the various substances are given in Table 2; the daily time-weighted average concentrations which each sampled plater was exposed to are reported in Table A-1, appended to this report.

Table 2
Average Workshift Employee Exposures

Work Area	Substance	Number of Values Average	Average Concentration mg/m^3	Range of Exposures mg/m^3
Lines A, B & C	Chromium VI	3	0.0012	0.002 - 0.003
Lines D, E & F	Total Chromium	4	0.004	0.003 - 0.004
Lines D, E & F	Nickel	4	0.004	0.003 - 0.006
Lines D, E & F	Cad,ium	4	0.002	0.002 - 0.003
Lines D, E & F	Cyanide	2	0.001	0.001 - 0.002

Plater A was involved strictly in hard chrome plating during our survey. Having other job assignments in the shop; he did not spend all his time around tank B-10, but he was the only plater working that tank during our day-shift sampling.

Plater B's assignments during our survey included the electroless nickel tank, which was operated on Tuesday and Thursday. He was also involved in nickel (sulfamate) electroplating, as well as other tasks, including some contact with the nickel stripping operation.

Plater C was primarily occupied with cadmium plating. He also had some involvement with the nickel strip operation.

None of the sampled concentration values exceeded either the OSHA Permissible Exposure Limit or the NIOSH Recommended Standards. In fact, all but 4 of the individual samples were reported to be below the detectable limits of the analytical procedures.

Area Samples

The average daily area concentrations for each substance are given in Table 3. The concentrations at each of the sampling sites, shown in Figure 2, are listed in the appendix. (See Table A-2) Many of the amounts collected on the filters were reported to be below the detectable limits of the analytical procedures. Results from site 3 on tank B-10, sites 2 and 4 on tank D-1, site 2 on tank E-1, and site 3 for tanks F-7 and F-10 were not used for daily tank averages if they exceeded any other tank value. The filters at these sites were positioned to collect contaminant laden air which would eventually be removed by the local exhaust ventilation, and the concentrations at these points would not be indicative of net tank emissions.

Table 3
Average Daily Area Concentrations

	12/8/81		12/9/81		12/10/81	
	mg/m^3	N	mg/m^3	N	mg/m^3	N
			Chromium VI			
Tank B-10	2.9	3	0.6	3	0.007	3
			Total Chromium			
Tank B-10	6.1	1	1.4	1	< 0.008	1
Room Air	0.01	4	0.006	3	< 0.004	2
			Nickel			
Tank D-1	0.7	2	----	-	0.3	2
Tank E-1	< 0.004	2	----	-	< 0.004	2
Tank E-10	< 0.004	2	< 0.003	2	< 0.004	2
Room Air	< 0.004	4	< 0.003	3	< 0.003	2
			Cadmium			
Tank F-7	< 0.002	3	< 0.002	2	< 0.002	2
Tank F-10	----	-	< 0.002	1	< 0.002	2
Room Air	< 0.002	4	< 0.002	3	< 0.002	2
			Cyanide			
Tank E-1	----	-	< 0.001	2	----	-
Tank F-10	----	-	< 0.001	1	----	-
Room Air	----	-	< 0.001	1	< 0.001	2

It must be noted that these area samples were taken to evaluate the effectiveness of the control measures. Since workers move from one area to another and their breathing zones are not at tank level, these tank sample concentrations are not directly comparable to work-shift standards for employee exposure. It can, however, be informative to compare area concentrations with ceiling limit standards, even though the sampling periods may differ. If a time-weighted average area concentration is high with respect to the ceiling limit value for that substance, it is possible that an employee's exposure would have exceeded the ceiling limit if his breathing zone was close to the sampling site for the requisite amount of time. This identifies areas (although not all such areas) where employees should be cautious about working for more than brief periods of time.

All of the chromium VI concentrations for tank B-10 on the first two days, except those for the sampling site on the south end of the tank, exceed the ceiling limits specified in both the NIOSH recommended standard and the current OSHA standard. None of the individual site concentrations for tank B-10, except the one directly over the surface, exceeded either ceiling limit on the third day of sampling.

None of the cadmium concentrations exceeded either the OSHA or the NIOSH recommended ceiling limits. None of the cyanide concentrations exceeded even a thousandth of the NIOSH recommended ceiling limit. There are no ceiling limit values for nickel and total chromium.

Airflow Measurements

From the ventilation data compiled in Table A-3, the exhaust volume flow rate for each ventilated tank is presented in Table 4; along with the area of the plating bath surface and the ratio of the ventilation rate to surface area. The flow rate per square foot of tank area is an important design parameter. Many years ago, 100-150 cfm/ft^2 may have been the "rule of thumb" for all plating ventilation.[5] Currently, the Industrial Ventilation Manual[6] recommends a value of 250 cfm/ft^2 for open surface chromium plating tanks. There are no recommended values for the proprietary baths used for the electroless nickel and nickel strip operations at American Airlines, and only adequate general ventilation is required for cyanide/cadmium and sulfamate/nickel without air agitation.

Table 4
Ventilation Airflow Relative to Tank Surface Area

Tank	Surface Area, ft^2	Flow Rate ft^3/min.	Rate/Area cfm/ft^2
B-10	29	2200	76
D-1	13	1100	85
E-1	15	2100	140
E-10	27	---	---
F-7	19	2600	140
F-10	14	2200	160

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[5] Burgess, Recognition of Health Hazards in Industry. John Wiley & Sons, New York, 1981.

[6] Industrial Ventilation - A Manual of Recommended Practice, (16th Edition), American Conference of Governmental Industrial Hygienists Committee on Industrial Ventilation, 1980.

In determining the average slot velocity, differences were noted from one end of the tank to the other. (See Table 5.) The range of these variations is typified by Tanks B-10 and F-10.

Table 5
Average Slot Velocity Values at Opposite Ends of the Manifold Boxes for Two Tanks

	Tank B-10		Tank F-10	
	Front Slot	Rear Slot	Front Slot	Rear Slot
Plenum end	1750	1800	2000	2200
Other end	950	1000	1600	1500
Difference	800	800	400	700

The total amount of air exhausted from the shop was determined by measuring a velocity profile in each of the large round ducts at the end of the concrete traces. A total volume rate of 440,000 cfm was measured, including the two ducts (one of which was not operating at full capacity) exhausting air from the basement.

With such a large exhaust volume rate and no supplied make-up air (other than a small (unknown) quantity of comfort ventilation) a considerable amount of air was drawn through any openings into the plating shop. For one doorway, a large overhead door in the southwest corner of the shop, the airflow was estimated to be 40,000 cfm. This value was calculated by multiplying the size of the opening by the average velocity measured with a hot-wire anemometer.

Plating Process Parameters

Acid mist emission is a function of the product of the plating current, the duration of plating, and the inefficiency of the plating bath. Although this relationship is used here only for hard chrome plating, it is generally true for all plating baths. Some relevant plating parameters for tank B-10 are given in Table 6. Only the time during which pieces were being plated while samples were being collected has been included.

Table 6
Plating Parameters for Tank B-10

Date	Plating Time hr	Cumulative Current-Time Product, Amp-hr	Average Current Density Amp/in^2	Cumulative Power-Time Product, Watt-hr
8	6.8	3400	1.5	20,000
9	6.1	1800	1.9	13,000
10	3.8	1500	1.8	6,600

For the other tanks, information was recorded on the loads of parts in each tank during the sampling periods. We were informed that approximately twice as much was plated in the electroless nickel tank on Thursday as on Tuesday; the tank was not used on Wednesday. Approximately the same workload was processed through each of the other tanks for each of the three sampling days.

DISCUSSION

Only two tanks, B-10 and D-1, had relatively high area concentration values. Nevertheless, none of the measured employee exposures exceeded even an action level of one-half the NIOSH Recommended Standard. Two of the three chromium VI exposure values for plater A were less than the NIOSH proposed standard of 0.001 mg/m^3 for the carcinogenic form of hexavalent chromium. The room air concentrations are also low with respect to the NIOSH Recommended Standards, except for one sample near B-10. Tank B-10 exhibited high chromium VI concentrations at the northeast corner of the tank when the surface was not covered. This was consistent with a prevailing air current emanating from an often-open doorway in the southwest corner of the room; however, it is not known that keeping this doorway closed when not in use would allow the ventilation system to control emissions from this tank. Considerably less air is exhausted through the slots at the north end of the tank, so there could be an escape of bath emissions with no air currents moving over the top of the tank. Even if the slot velocity profile were uniform, the quantity of air being exhausted from B-10 would probably be insufficient for a hard chrome tank with this much surface area. Air from the center of the tank is not drawn to the sides, but allowed to rise where interferring air currents can push it over an edge of the tank.

When the surface was covered on the third sampling day, the concentrations at the sampling sites around the tank were reduced substantially as is shown in Table 7. The cover restricts the area through which the ventilation system must daw its supply air, creating higher control velocities at all places where chromic acid mist might escape.

It would be possible for changes in sampled concentrations around the edge of a tank to be caused by changes in the amount of plating. Two filters were placed at sampling site 3, less than a foot above the surface, near the center of the tank, to measure the acid mist given off by the plating bath. The "gasing" or mist generated by the plating bath is proportional to the product of the current applied and the duration of plating and the inefficiency of the bath. The values in Table 7 are the amounts collected on the filters, divided by this "gasing" value. The constancy of the tabulated values for site 3 indicates that, although the plating load in tank B-10 varied over the three days of sampling, the acid mist emission changed accordingly. Therefore, the dramatic drop in the concentrations at the other sites on the third day must be the result of placing a cover over the tank.

Table 7

Chromic Acid Mist Generation with Respect to Plating Load

Site	12/8/81	12/9/81	12/10/81
1	3.1	0.52	0.005
2	8.6	2.4	0.002
3	4.1	4.4	3.6
4	0.091	0.058	0.019
5	0.28	0.19	0.005

Tank D-1 is equipped with hinged metal covers which are kept closed most of the time. However, a relatively high concentration value was obtained for the sample on the front of the tank on Thursday. The high values on Tuesday are not considered typical, since the damper on the D-1 duct in the basement had inadvertently closed.

Even when full flow to this system was restored, there was still considerably less air exhausted through the front portion of the slots than the rear. Also, it must be noted that the area at the ends, not enclosed by the covers, is approximately twice the ventilation slot area and about one sixth of the tank surface area. There may be some short circuiting of the ventilation supply air to this tank, even with the covers in place.

Tank E-1 is well-controlled. With the cover up, slot velocities were all in the 1000 to 2000 feet per minute range. Control velocities at the openings with the cover in place were all greater than 600 ft/min. Even the concentrations above the surface under the cover were below the detectable limits.

Tank E-10 had no detectable concentrations of nickel, even without ventilation. Being a high efficiency bath, not much mist generation was expected.

Tanks F-7 and F-10 differed not only in size but in the type and amount of plating. There were no detectable concentrations for F-7, even directly above the surface. On F-10, only the two samples above the surface showed detectable amounts. Both were below the NIOSH Recommended Standards.

From the presence of strong air currents into the shop through open doorways and the suction on doors into the room, it was evident that the plating shop was under a negative pressure condition, It is a physical fact that the same amount of air which leaves the room must enter the room. Thus, when the inflow of air is insufficient, the outflow of air is restricted. And the high volume-flowrate inflow streams can set up air flow patterns within the room.

In some situations, a small negative or positive pressure is desired to control the leakage of air from one room to another. Preventing the flow of air out of this plating shop need not be a major concern. Except for some elevated chromium concentrations in the south end (especially the southeast corner) of the shop, the concentrations of potential occupational health hazards sampled for were below detectable limits. It may be a good idea to maintain a slight negative pressure; but with the present situation, the ventilation system is rendered less effective working against such a large negative pressure.

Since the platers spend only a small portion of the day directly over the tanks, the bulk of their exposures are to the general room air. Strong air currents compound this situation. For instance, a plater who spent most of his day just beyond the northeast corner of B-10 may have a relatively high exposure.

Appropriate items of personal protective equipment (face shields, aprons, gloves, etc.) were observed being worn on a number of occasions. These devices are especially important while loading and unloading tanks to protect the workers from possible splashes if a piece would be dropped in the plating bath. Powered, overhead hoists were used for lifting all large pieces.

Protective headgear were not observed in use. It is a good work practice to wear some type of hard hat and steel-toed shoes when handling large heavy pieces.

CONCLUSIONS AND RECOMMENDATIONS

Personal time-weighted average exposures to chromium, cadmium, nickel and cyanide are below the corresponding OSHA permissible exposure limits and the NIOSH Recommended Standards despite some relatively high tank emissions and a general deficiency of supplied make-up air. Most of the tanks are well-controlled, with good capture even along the center line of the tank.

It is possible that working directly over a hard chrome tank (especially one with high plating loads and marginal ventilation) when plating is in progress may expose an employee to concentrations in excess of recommended ceiling limits. This undesirable work practice should be avoided. If an employee (including maintenance personnel) must work directly over such a tank for more than a few minutes, either the plating current should be turned off or the worker should wear proper respiratory protection, in addition to other appropriate personal protective devices.

All of the tanks we measured had higher air flow rates through the slots at the plenum end of the tank closest to the vertical duct leading from the tank. When possible, keeping the heavy plating activity at this end of the tank will take advantage of better ventilation.

Outside make-up air should be mechanically supplied into the shop to relieve the high level of negative pressure. The present exhaust ventilation rate of approximately 120,000 cfm should then increase somewhat. A value in the range of 125,000 to 150,000 cfm, including the comfort ventilation, would be a good initial design value. It is possible that some of this air could be supplied by recirculation (consistent with current recommended practices) especially from the ducts exhausting from the basement area. Some of this may also be provided from other parts in the building as long as this air is moved by fans (although not floor fans) and not solely by natural drafts through open door ways.

Table A-1
Daily Results of Personal Sampling

Employee	Day Mo/dy/yr	Duration of Sampling hr:min	Air Volume of Sample liters	Calculated Concentration mg/m^3
		Chromium VI		
A	12/8/81	7:11	862	0.003
A	12/9/81	7:07	854	< 0.0002
A	12/10/81	5:25	650	0.0005
OSHA Permissible Exposure Limit (ceiling limit)			0.1	
NIOSH Recommended (time/weighted average) Standard				0.025
		Total Chromium		
B	12/8/81	6:56	832	< 0.004
B	12/10/81	5:45	690	< 0.004
C	12/8/81	7:08	856	< 0.004
C	12/9/81	7:28	896	< 0.003
OSHA (TWA) Permissible Exposure Limit				0.5
		Nickel		
B	12/8/81	6:56	832	0.006
B	12/10/81	5:45	690	< 0.004
C	12/8/81	7:08	856	< 0.004
C	12/9/81	7:28	896	< 0.003
OSHA (TWA) PEL			1.0	
NIOSH Recommended (TWA) Standard				0.015
		Cadmium		
B	12/8/81	6:56	832	< 0.002
B	12/10/81	5:45	690	< 0.003
C	12/8/81	7:08	856	< 0.002
C	12/9/81	7:28	896	0.002
OSHA (TWA) PEL			0.2	
NIOSH Recommended (TWA) Standard				0.04
		Cyanide		
B	12/9/81	7:06	852	< 0.001
C	12/10/81	5:22	644	< 0.002
OSHA (TWA) PEL			5.0	

Table A-2
Daily Area Sampling Results

Location	Site	12/8/81 hr:min	mg/m^3	12/9/81 hr:min	mg/m^3	12/10/81 hr:min	mg/m^3
				Chromium VI			
Tank B-10	1	7:55	3.0	6:41	1.2	4:02	0.004
	2	7:55	8.3	6:41	1.5	4:02	0.002
	3	7:56	4.0	6:37	2.8	4:06	3.0
	4	7:47	0.090	6:40	0.036	4:12	0.016
	5	7:38	0.28	6:40	0.12	4:12	0.004
				Total Chromium			
Tank B-10	2	7:49	6.1	6:41	1.4	4:02	< 0.008
	3	7:54	4.0	6:37	3.5	4:06	3.2
Room Air	1	8:34	0.005	-	-	-	-
	2	7:08	0.005	7:56	0.004	-	-
	3	7:07	0.033	8:05	0.012	6:17	< 0.004
	4	7:03	< 0.004	7:57	< 0.003	5:42	< 0.004
				Nickel			
Tank D-1	1	7:19	0.39	-	-	6:20	0.066
	2	7:21	0.65	-	-	-	-
	3	7:16	0.94	-	-	6:20	0.60
Tank E-1	1	6:40	< 0.004	-	-	6:25	< 0.004
	2	6:34	< 0.004	-	-	6:25	< 0.004
Tank E-10	1	7:05	< 0.004	7:59	< 0.003	6:10	< 0.004
	2	7:05	< 0.004	7:41	< 0.003	6:10	< 0.004
Room-Air	1	8:34	< 0.003	-	-	-	-
	2	7:08	< 0.004	7:56	< 0.003	6:17	< 0.004
	3	7:07	< 0.004	8:05	< 0.003	-	-
	4	7:03	< 0.004	7:57	< 0.003	5:42	< 0.004

Table A-2. Daily Area Sampling Results (Cont'd)

Location	Site	12/8/81 hr:min	mg/m^3	12/9/81 hr:min	mg/m^3	12/10/81 hr:min	mg/m^3
				Cadmium			
Tank F-7	1	7:35	<0.002	-	-	6:28	<0.002
	2	7:33	<0.002	7:47	<0.002	-	-
	3	7:33	<0.002	7:50	<0.002	6:28	<0.002
Tank F-10	1	-	-	7:33	0.015	-	-
	2	-	-	-	-	6:29	<0.002
	3	-	-	7:32	<0.002	6:28	<0.002
Room-Air	1	8:34	<0.002	-	-	-	-
	2	7:08	<0.002	7:56	<0.002	-	-
	3	7:07	<0.002	8:05	<0.002	6:17	<0.003
	4	7:03	<0.002	7:57	<0.002	5:42	<0.003
				Cyanide			
Tank E-1	1	-	-	7:56	<0.001	-	-
	2	-	-	7:56	<0.001	-	-
Tank F-10	1	-	-	-	-	6:29	0.004
	2	-	-	7:31	< 0.001	-	-
Room-Air	1	-	-	8:04	< 0.001	6:00	<0.001
	2	-	-	-	-	5:44	<0.001

Table A-3
Ventilation System Data

Tank	Tank Dimensions ft.	Total Slot Area in.	Number of Slots	Average Slot Velocity ft/min	Average Duct Velocity ft/min	Area of Flow ft^2	Flowrate at this Location ft^3/min
B-10	3.67 x 8	320	2	1350	1300	1.7	2200
D-1	3.33 x 4	140	2	790	1400	0.8	1100
E-1	3 x 5	180	2	1450	1400	1.5	2100
F-7	2.5 x 7.67	290	2	1530	1300	2.0	2600
F-10	2.5 x 5.67	220	2	1800	1500	1.5	2200