IN-DEPTH SURVEY REPORT
OF
VALLEY CHROME PLATERS
BAY CITY, MICHIGAN

Survey Conducted By:

John W. Sheehy
James H. Jones
Vincent D. Mortimer, Jr.
Daniel R. Kemme

Report Written By:
Vincent D. Mortimer, Jr.

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Engineering Control Technology Branch
Division of Physical Sciences and Engineering
National Institute for Occupational Safety and Health
Cincinnati, Ohio

PURPOSE OF SURVEY:

To evaluate occupational health hazard control measures used in a plating job-shop.

DATE OF SURVEY:

27 April - 1 May 1981

EMPLOYER REPRESENTATIVES CONTACTED:

Mr. Thomas Knight, Owner/Manager

STANDARD INDUSTRIAL CLASSIFICATION:

3471: Plating and Polishing

ANALYTICAL WORK PERFORMED BY:

John Palassis, DPSE/MRSB, NIOSH
James W. Carter, DPSE/MRSB, NIOSH
Ceola H. Moore, DPSE/MRSB, NIOSH
UBTL, Salt Lake City, Utah

Abstract

An in-depth survey was conducted at Valley Chrome Platers in Bay City, Michigan in conjunction with a NIOSH study evaluating measures used to control the occupational health hazards associated with metal plating industry. Valley Chrome is a small job shop, employing four platers, engaged exclusively in hard chrome, industrial plating. It was surveyed primarily to evaluate the two-sided local exhaust ventilation systems for the hard chrome plating tanks. Eight tanks were studied, including a large automated line.

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

Environmental concentrations were found to be within OSHA standards despite a generally low level of ventilation relative to tank size and plating load. Blanketing the surface of each tank with small, floating, plastic spheres may be a factor in controlling plating emissions.

BAY CITY IN-DEPTH SURVEY REPORT

INTRODUCTION

The Valley Chrome plating facility was surveyed as part of the NIOSH Control Technology Assessment of the electroplating industry. The solution of chromic acid and sulfuric acid used in hard chromium plating presents 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.

Valley Chrome was identified as an establishment in which exposures to the hazards of chrome plating were generally well-controlled. Valley Chrome is a small job shop, employing four platers, engaged exclusively in hard chromium plating for a variety of industries. There are eight tanks, including a large automated line. All plating tanks have local exhaust ventilation, but there are differences in age, size, and air handling capabilities of the various systems.

The operation is housed in a single-story, concrete block building built by this company in 1960. The layout of the shop is shown in Figure 1. The original plating shop, an old, wood-frame building next to the current shop, is now used as a place for eating lunch and changing clothes.

Tanks 11, 12, 13, and 14 are similar in size and configuration, and are grouped together near the front of the plant. Tanks 11 and 12 are paired together, aligned along their long axis, with a water rinse tank between them. Tanks 13 and 14 are arranged in the same manner, and a row of pretreatment and rinse tanks lies between the two plating rows. The rectifiers are situated on a shelf behind the tanks, with the controls and gauges on the front face accessed by reaching over the tank. (See Figures 2 and 3.)

The ventilation systems for these tanks consist of a single-slot hood on each side of the tank. Each hood manifold box extends from the plenum to the midpoint of the combined length of each tank, including part (but not necessarily half) of the intervening rinse tank. A 14-inch duct rises from the plenum to a separate fan on the roof. The axial-type fans have 1/2 to 1 horsepower motors isolated in a "duo-duct" arrangement.

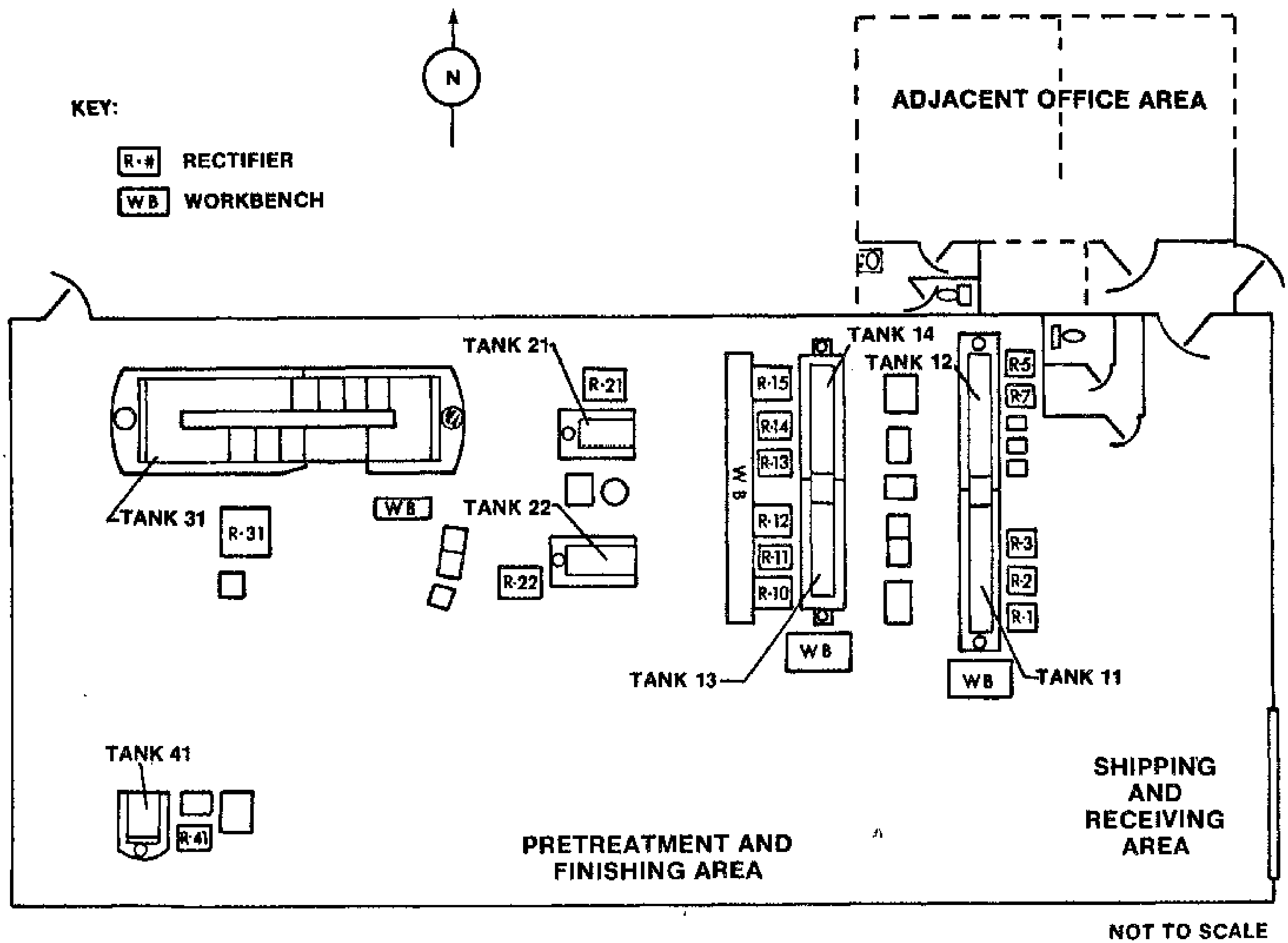

Figure 1. Floor Plan of Plating Shop

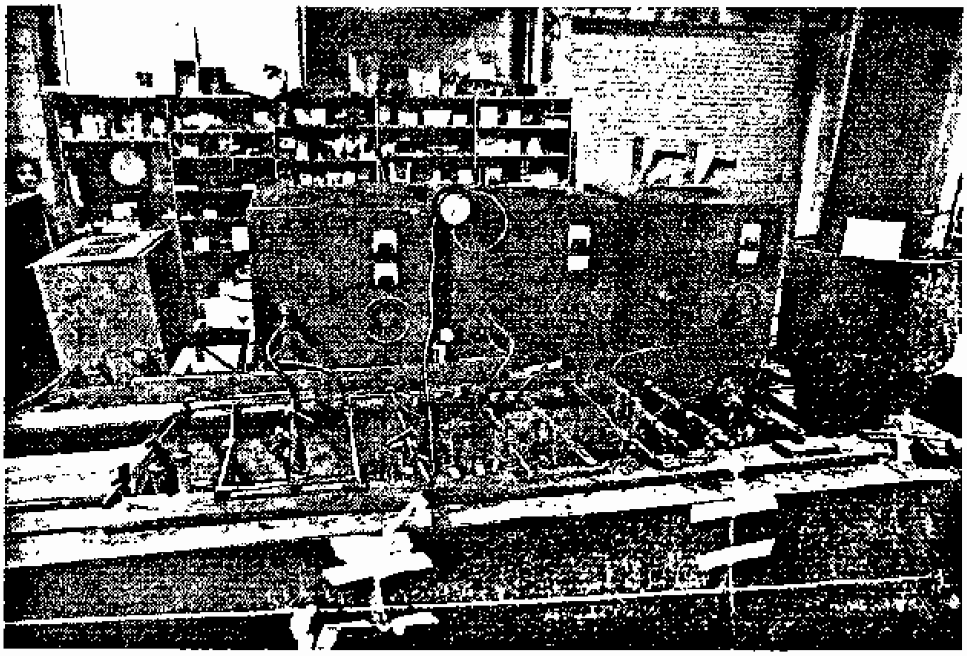

Figure 2a. Tank 11

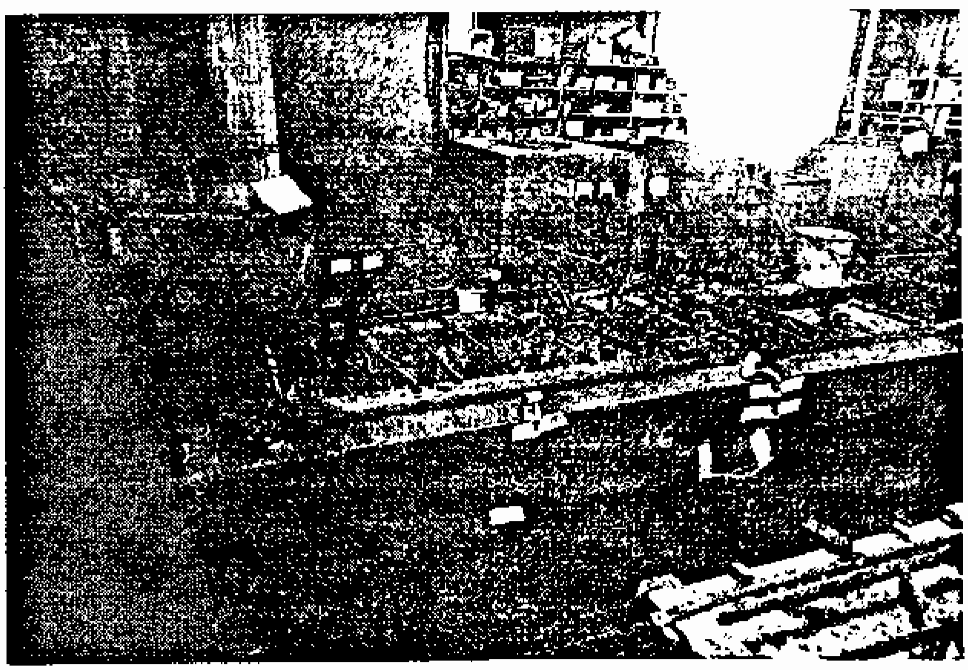

Figure 2b. Tank 12

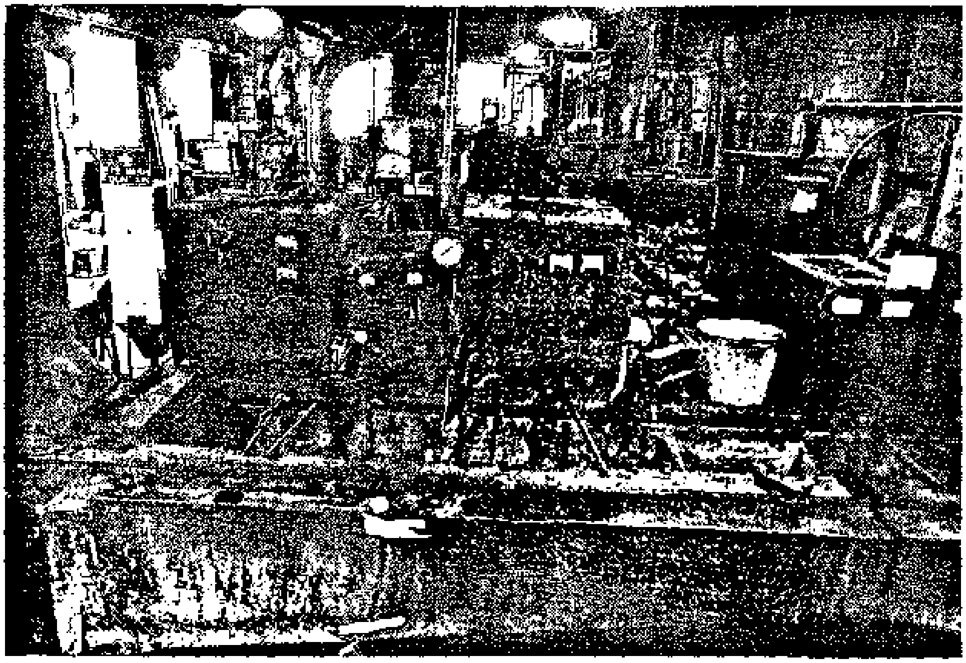

Figure 3a. Tank 13

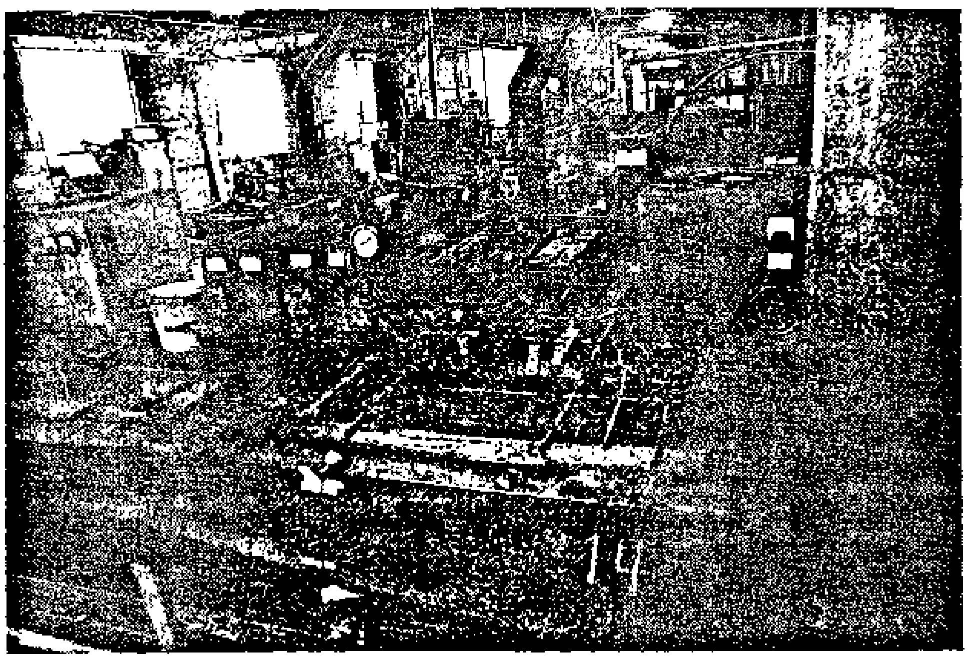

Figure 3b. Tank 14

The ventilation systems for the two pairs differ in the design of the riser take-off. Tanks 11 and 12 have a large rectangular plenum with the duct rising from the top of the plenum box without a taper. Tanks 13 and 14 have a smaller plenum box with the duct rising from a triangular transition box jutting from the back of the main plenum.

Tanks 21 and 22, pictured in Figure 4, are positioned near the middle of the shop, separated by a tank containing cleaner and a rinse tank. They appear to be about the same size; however, Tank 21 is 8 feet deep, while Tank 22 is less than 2-1/2 feet deep. A large rectifier for each tank is located on the floor along side the tank.

With approximately the same surface area, the ventilation systems for these two tanks are similarly sized. The ventilation exhaust ducts from these two tanks join at the roof into a common system. The combined duct then passes through a scrubber to a centrifugal fan with a rectangular discharge.

The automated line, Tank 31, is a large rectangular structure containing about 30 linear feet of plating trough, approximately 2 feet wide, in the shape of a big "U." Completing the rectangular channel are pretreatment and rinse tanks and a space to remove and to insert racks into the mechanized cycle (Refer to Figure 5.) Its large rectifier stands on the floor off to the side of the tank.

The entire plating traverse, except for the bottom of the "U," is paralleled by a single-sided slot hood. Due to the U-shape of the plating portion of the tank, the ventilation system resembles the two-sided hoods on the other tanks. The two manifolds are joined by a plenum which is ventilated by a duo-duct, axial fan mounted just above the plenum.

Tank 41, shown in Figure 6, is a cubical tank, with 3-foot sides, situated in the southwest corner of the building. Along side it, in a row, are a rinse tank and a cleaner tank which was not being used at the time of the survey. A platform has been constructed in front of these elevated tanks to provide worker access. The rectifier is situated along side the tank, behind the rinse tank.

Tank 41 is outfitted with the newest two-sided ventilation system. The manifold box on each side leads into the plenum through a channel with a smooth inner radius. This system is constructed entirely of polyvinyl-chloride sheeting with "welded" seams. A separate tube-axial (duo-duct) fan is located on the roof.

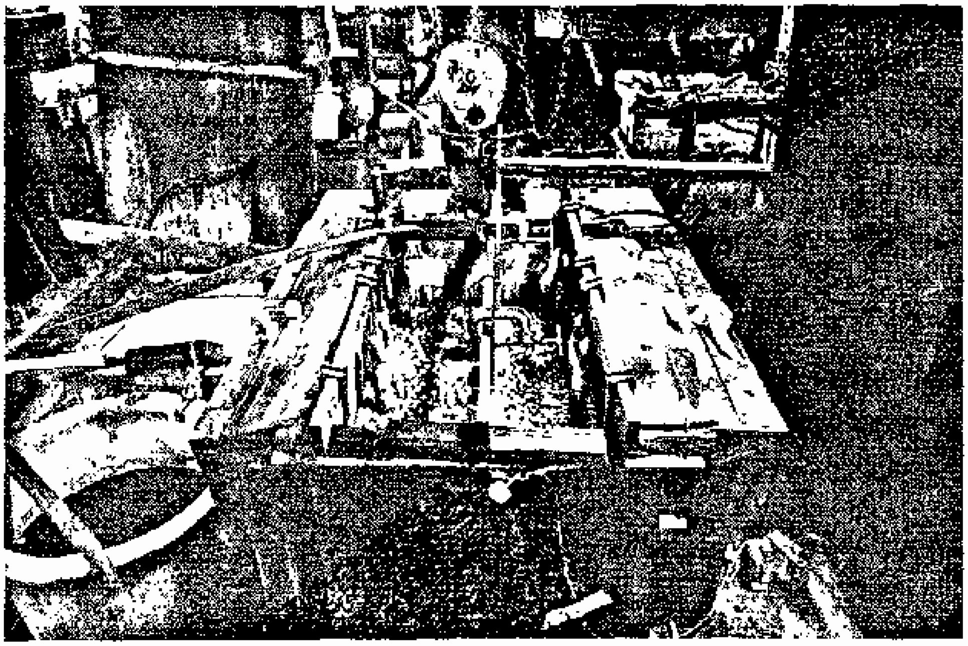

Figure 4a. Tank 21

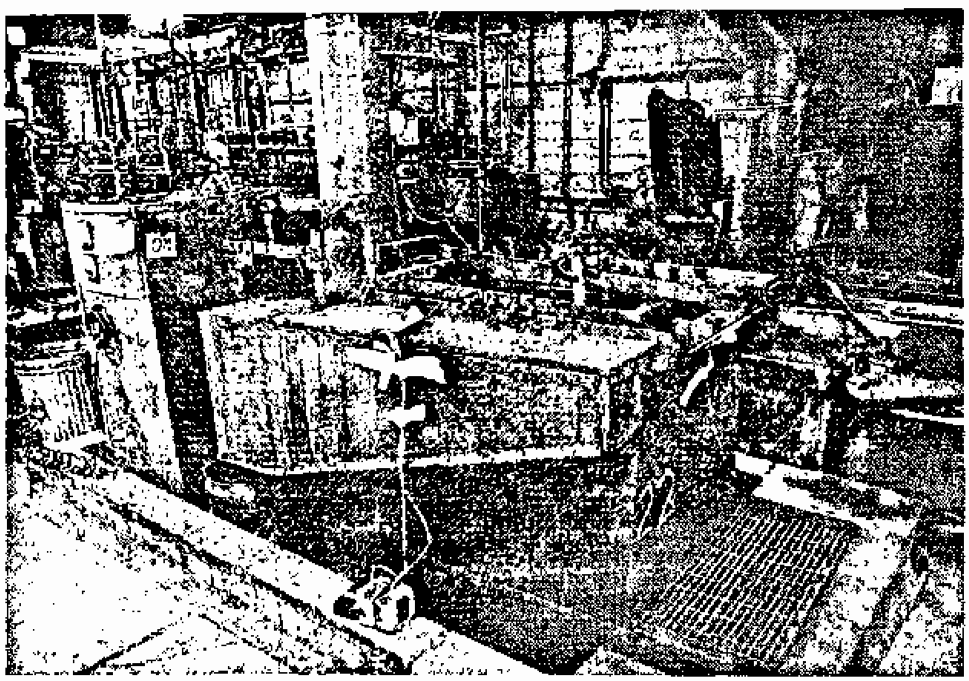

Figure 4b. Tank 22

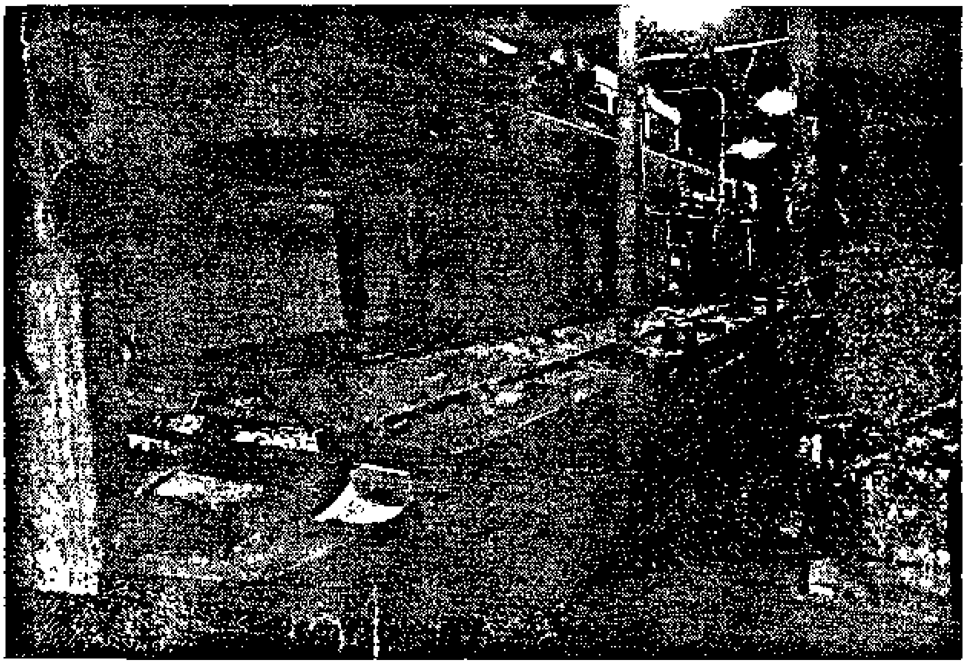

Figure 5. Tank 31

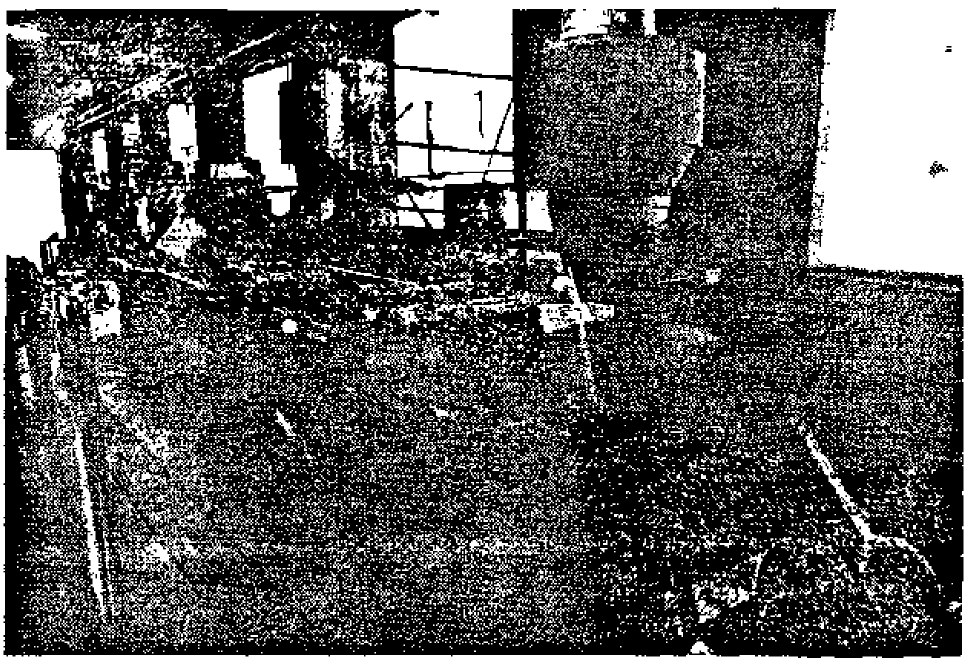

Figure 6. Tank 41

Four full-time platers work a single shift, five days per week. Their years of plating experience range from 7 to 21. The owner/manager spends a good deal of time in the shop, performing some of the plating. The only other employee, a part-time (30 hr/wk) bookkeeper, works almost entirely in an adjacent office area.

The survey was conducted during a period of mild weather, with outside daytime temperatures in the 50's and 60's. The temperature inside the building was around 70° F with approximately 55% relative humidity. The doors were open some of the time during the survey, a condition common during pleasant weather.

PROCESS DESCRIPTION

The parts to be plated are received at the front of the shop. Before being plated, most pieces undergo some surface preparation, such as stripping, grit blasting, and cleaning in acid, alkaline, and/or electrolyzed solution. Areas not to be plated are masked with cellulose acetate butyrate hot-dip and/or some type of tape. The parts are then manually loaded into a plating tank using an overhead hoist for large parts. In the process of removing a piece from the tank after the desired thickness has been plated, the chromic acid is rinsed off over the tank. This is followed by a still-water rinse and removal of the masking agents. High-strength steel is then baked in an industrial oven at 350° F to relieve the stresses that may have developed during plating. To finish the job, the part may be given a light coating of an oil/water emulsion to prevent rusting of the unplated surfaces.

The plating solution in tanks 11, 12 and 31 contained 25 oz/gal chromic acid and 0.23 oz/gal sulfuric acid. The other five tanks contained 40 oz/gal chromic acid and 0.40 oz/gal sulfuric acid. All plating tanks are maintained at around 125° F, heated by gas burners underneath the tanks.

Cleaning tanks contain 8 oz/gal of Haviland Anokleen 2-S, which consists of approximately 40% caustic soda (sodium hydroxide). Some of these tanks are electrolyzed and operated in a reverse current mode. The stripping solution contains 8 oz/gal of sodium hydroxide. The acid solutions are a 5% sulfuric acid dip, an acid etch containing 8 oz/gal oxalic acid, and a pickling solution with 1 part HCl to 2 parts water. This information is summarized in Table 1, and the locations of these tanks are shown in Figure 7.

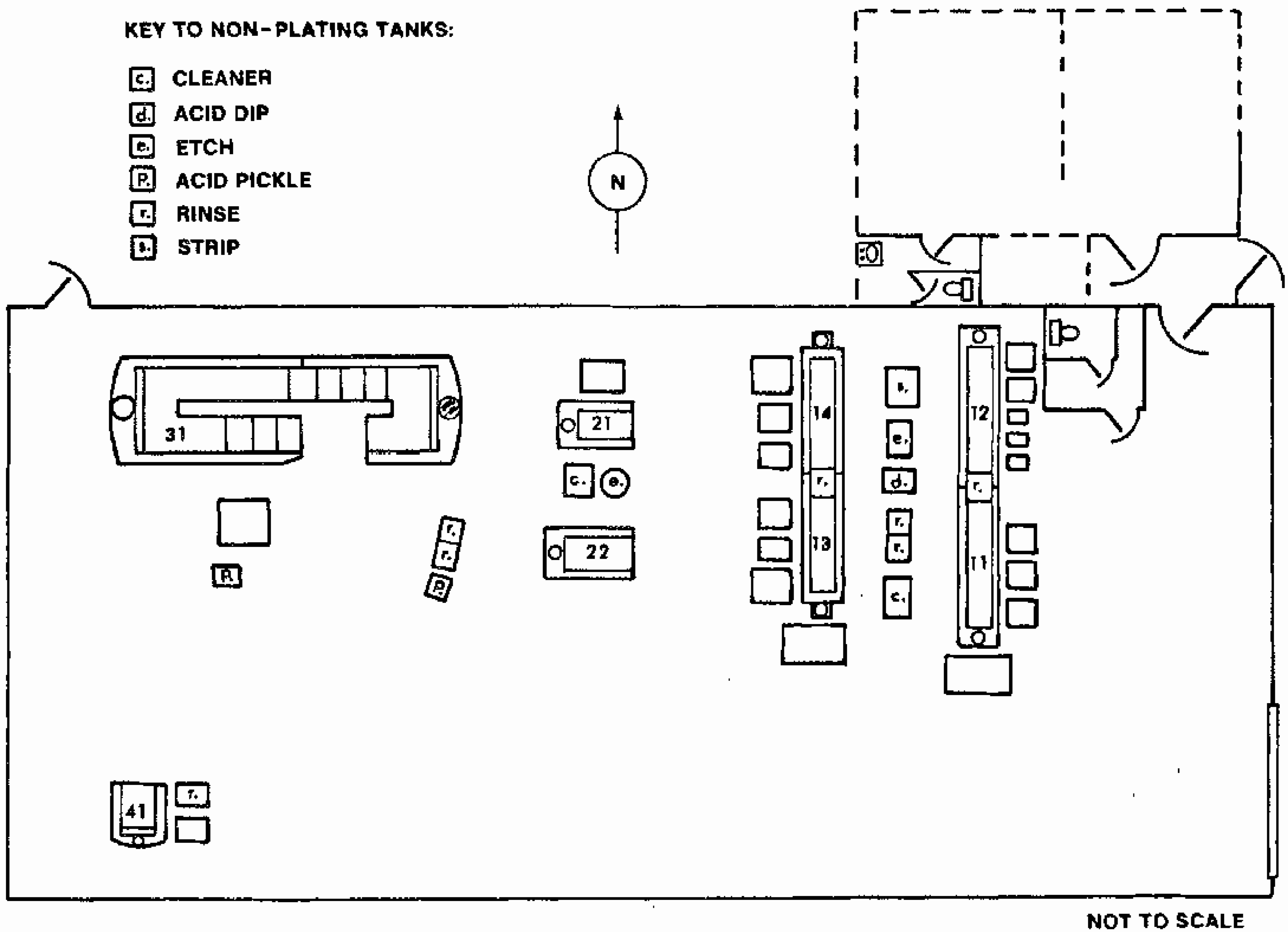

Figure 7. Location of Plating and Non-Plating Tanks

Table 1. Composition of Tank Solutions

Tank	Solution Description	Composition
11	chrome plating bath	25 oz/gal chromic acid 0.23 oz/gal sulfuric acid
12	chrome plating bath	same as tank 11
13	chrome plating bath	40 oz/gal chromic acid 0.40 oz/gal sulfuric acid
14	chrome plating bath	same as tank 13
21	chrome plating bath	same as tank 13
22	chrome plating bath	same as tank 13
31	chrome plating bath	same as tank 11
42	chrome plating bath	same as tank 13
(a)	acid pickle	1 part hydrochloric acid 2 parts water
(b)	strip	8 oz/gal sodium hydroxide trace of wetting agent
(c)	cleaner	8 oz/gal Haviland Anokleen 2-S (contains caustic soda)
(d)	acid dip	5% sulfuric acid
(e)	etch	8 oz/gal oxalic acid trace of wetting agent
(f)	rinse	water

All the tanks have polypropylene spheres, approximately an inch in diameter, floating on the surface. Enough spheres are in each tank to completely cover the surface, reducing the effective surface area for the emission of air contaminants from the tank, as well as heat loss.

All of the tanks except 41 have boards extending from the ventilation slot-box out over the tank as much as six inches. On Tanks 11, 12, 13, and 14, these boards support (and electrically isolate) the cathode and anode bars. These boards somewhat reduce the area through which the ventilation system draws air from outside the tank and concentrates the air flow more in the center of the tank. Generally, the boards do not hinder the movement of pieces into or out of the tanks, but they are removable if necessary.

HAZARD ANALYSIS

The primary hazards from the hard chrome plating operation are chromium and sulfuric acid. These substances may be present in the air due to the generation of mist from the plating bath. Workers also come in contact with the substances in liquid form when handling the parts being plated when adding chemicals to the tanks, when performing maintenance operations to the tanks and ventilation system and when draining the tanks. Both of the agents can act directly on the skin, the eyes, and the linings of the nose and throat. Chromium may also enter the body through the skin and from eating food exposed to chromium-laden dust or mist.

Much has been written on the potential health hazards of these substances. There is no attempt here to present all known data, merely some pertinent information in summary form.[1] The pertinent NIOSH/OSHA Occupational Health Guidelines are appended to this report.

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.

Repeated or prolonged exposure to chromic acid mist may cause ulceration and perforation of the nasal septum. Respiratory irritation may occur

[1] NIOSH/OSHA Occupational Health Guidelines for Chemical Hazards, NIOSH Publication 81-123.

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.

EVALUATION METHODS

To determine the effectiveness of the controls used in this hard chrome electroplating operation, both area and personal air samples for chromium and sulfuric acid were collected for the duration of the work shift on three consecutive days. An estimate of the airborne concentration of the substance of interest can be computed by dividing the amount collected on the filter by the volume of air drawn through the sampling device. Air velocities in front of the slot hoods and total air flow exhausted from each tank were measured, and dimensions were obtained for all tanks and ventilation systems. Information on the plating operations was recorded 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 um pore size and personal pumps operated at a flow rate of 2 liters of air per minute. These samples were analyzed for chromium VI using NIOSH method P&CAM 169[2], a colorimetric procedure. The sampling for total chromium was similar except that 37 mm mixed cellulose ester filters with a pore size of 0.8 um were used. These samples were analyzed for chromium according to NIOSH method P&CAM 152[2], using atomic absorption spectroscopy. For all chromium samples, either MSA Model-G or DuPont P-4000 pumps were used.

Personal and area samples for sulfuric acid were collected in 7 mm diameter silica gel tubes using DuPont P-200 pumps operated at a flow rate of 200 milliliters of air per minute. These samples were analyzed for sulfuric acid using ion chromatography. NIOSH method P&CAM 339[3], a procedure for the analysis of sulfuric acid collected on silica gel, was followed.

[2]NIOSH Manual of Analytical Methods, Vol. 1 (Second Edition), NIOSH Publication 77-157A.
[3]NIOSH Manual of Analytical Methods, Vol. 7, NIOSH Publication 82-100.

Area samples were placed at fixed locations around the plating tanks. All but a few room air samples were positioned close to the edge of the tanks, above the slot if located on a ventilated side. Chromium VI was sampled for at all locations. Total chromium and sulfuric acid samples were only collected at one sampling site for each selected tank. No samples were collected for total chromium on tanks 13 and 14. Sulfuric acid samples were not collected on tanks 13, 14 and 31 nor at the general room air sites.

Breathing zone personal samples, both filter cassettes and silica gel tubes, were clipped to the collar, on the front side 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 on all production workers present each day of the sampling period.

Total air flow through each ventilation system was measured either in the vertical duct or at the discharge on the roof by taking velocity readings for equal-area segments. Either a pitot tube or a 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 the flow at that point.

Air velocities were also measured for each tank at the slot and at the centerline of the tank or at some intermediate points. These measurements were taken using either a Sierra Model 440 or a Kurz Model 441 hot-wire anemometer. Slot air velocity measurements were taken at approximately one-foot intervals, except for tank 41 which was divided into six-inch intervals. Two readings were taken at each interval, one for the top half of the slot and one for the bottom half.

Since the velocity readings were taken for equal-area sections, an average slot velocity can be computed by adding all the velocity readings for each tank and dividing by the number of readings. An approximation of the volume flow rate may be calculated by multiplying this average velocity by the total slot area for each tank.

This same procedure was performed for the make-up air system.
The makeup air velocity was measured both at the intake (outdoors, at ground level on the north side of the building) and at the outlets inside the shop.

During the three days of sampling, information was recorded on the pieces being plated in each tank and the corresponding rectifier parameters. The information gathered included bath temperature, rectifier voltage and current, surface area of piece being plated, desired thickness or plating rate, and the period of time each piece would be in the tank.

RESULTS

Personal Sampling

The average workshift employee exposures to chromium VI are given in Table 2; the daily time-weighted average concentrations to which each employee was exposed are reported in Table A-1, appended to this report. All the chromium VI levels are less than one-fourth the NIOSH recommended workshift limit for the non-carcinogenic form of chromium VI. Two of the hexavalent chromium samples and one for total chromium were reported to be below the detectable limits of the analytical procedure. All the personal samples for sulfuric acid were below the analytical limits of detection, the values averaging less than 0.1 mg/m^3, approximately one-tenth the recommended standard.

Table 2. Averaged Workshift Exposures to Chromium VI

Job Description	Number of Values Averaged	Average Exposure mg/m^3	Range of Exposures mg/m^3
Automatic line	3	0.004	0.002 - 0.006
General Plating	5	0.002	$<$ 0.001 - 0.003

Plater A ran the automated line when it was operating during our survey, and worked elsewhere in the shop when the automatic line was idle. Platers B and C worked the other tanks and are considered together in Table 2 under the category of "General Plating." All employees are capable of operating any of the tanks, but these are their usual assignments. Plater C did not work the second day of sampling. A fourth employee was not present during the week of the survey.

Area Samples

The average daily chromium VI concentrations for each tank are given in Table 3. The concentrations at each of the sampling sites, shown in Figure 8, are listed in Appendix A. (See Tables A-2, A-3, and A-4) Many of the amounts were reported to be below the detectable limits of the analytical procedure.

Table 3. Average Chromium VI Concentrations for Each Tank

Tank	28 April		29 April		30 April	
	Concentration mg/l	No. of samples	Concentration mg/l	No. of samples	Concentration mg/l	No. of samples
11	0.001	2	0.006	3	0.032	3
12	0.002	3	0.020	3	0.006	3
13	0.002	2	0.002	2	0.002	1
14	0.002	2	0.007	2	0.005	1
21	0.005	3	0.007	3	0.013	3
22	0.003	3	0.010	3	0.032	3
31	0.047	2	0.025	2	0.020	1
41	0.002	3	0.002	3	0.005	3
General	0.002	2	0.002	2	0.003	2

It must be noted that these area samples were taken to evaluate the effectiveness of control measures. Since the workers move from one area to another, these area sample concentrations are not directly comparable to work-shift standards for employee exposure. It can, however, be informative to compare area concentrations with ceiling limits, even though the sampling periods may differ. If a time-weighted average area concentration is high with respect to the ceiling limit value, it is possible that an employee's

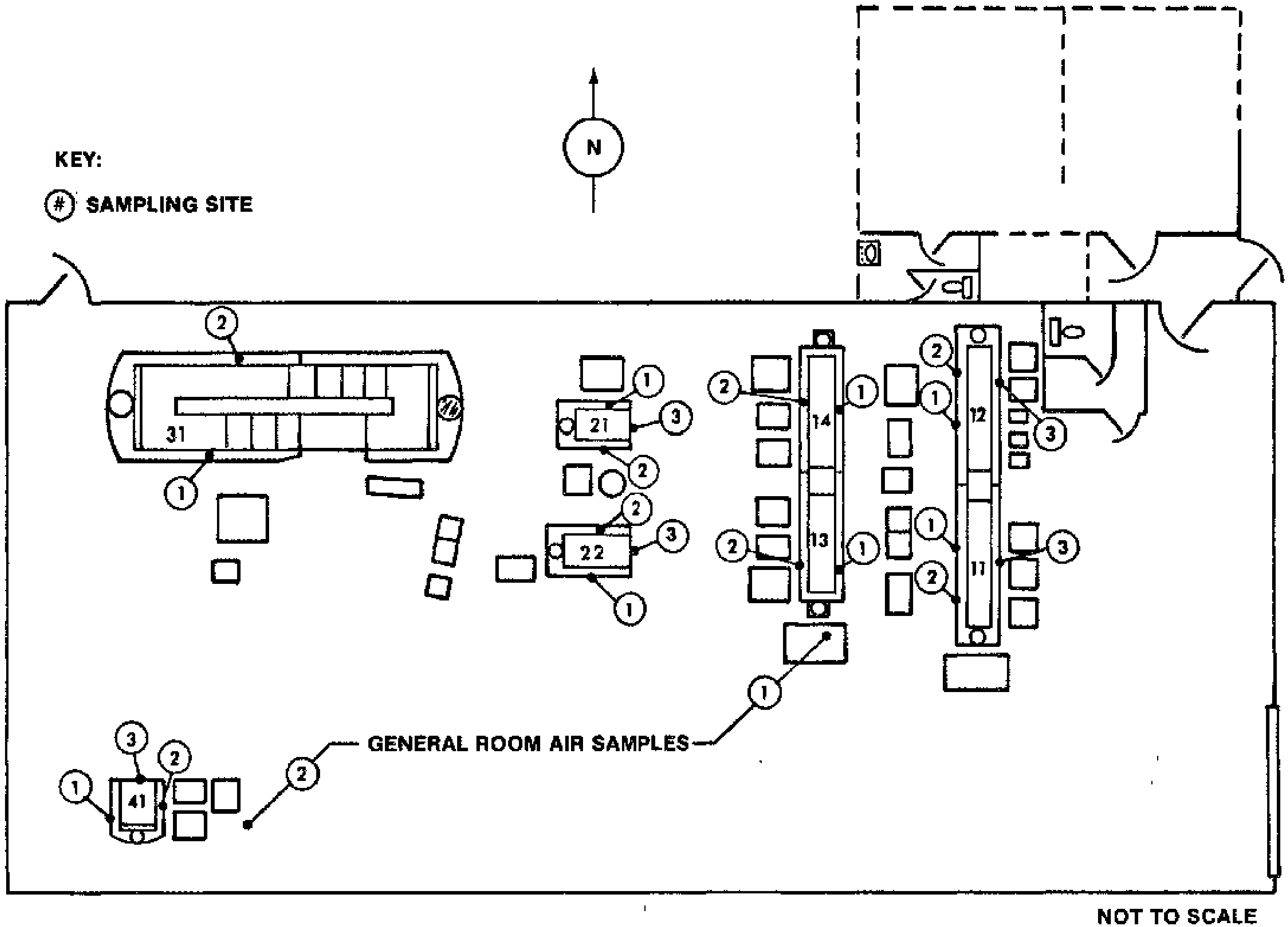

Figure 8. Location of Sampling Sites

exposure would have exceeded the ceiling limit if his breathing zone was close to the sampling site for a sufficient 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.

None of the chromium VI concentrations exceeded the OSHA ceiling level, although some of the individual concentrations were close. Three of the individual area concentrations were greater than the NIOSH recommended ceiling concentration. It must be noted that it is unlikely that an employee's breathing zone would be close to an individual area sampling site for an appreciable period of time. None of the average tank values exceeded either ceiling limit.

Airflow Measurements

From the ventilation data compiled in Table A-5, the exhaust volume flow rate for each tank is presented in Table 4 along with the tank area and the ratio of ventilation rate to surface area. The actual volume exhausted through the slots may be slightly less due to air drawn through holes and cracks in the system. These values are difficult to measure.

Table 4. Ventilation Airflow
Relative to Surface Area of Tanks

Tank	Surface Area, ft^2	Flow rate ft^3 /min	Rate/area cfm/ft^2
11	13.5	1200	89
12	13.5	1600	119
13	11.0	1400	127
14	13.3	1200	90
21	10.0	700	70
22	12.0	2200	183
31	100.0	3000	30
41	9.0	2100	233

The flow rate per square foot of tank surface area is an important design parameter. Many years ago, 100 - 150 cfm/ft^2 may have been the "rule of thumb" for all plating tank ventilation.[4] Currently, for open surface chromium plating tanks, the Industrial Ventilation Manual[5] recommends a value of 250 cfm/ft^2. Only Tank 41 is within 10% of this recommended value. Almost all the other tanks are less than half this value.

But probably more important than the ventilation rate to surface area ratio, is the emission of contaminants from each tank and the control of these emissions above the tank. The average capture velocities are presented in Table 5. Only tank 41 is close to the 150 ft/min recommended in the Industrial Ventilation Manual for open surface tanks containing chromium plating solutions. However, on this tank, many of the velocity readings were not perpendicular to the face of the slot. A number of readings for the other tanks also exhibited this condition. This may indicate an interfering air current over the top of the tank.

In determining the average slot-velocity, differences were noted from one end to the other of each slot on most of the tanks and between the two sides of the hood on some tanks (see Table 6). The largest variations were on tank 11. The slot velocity at the plenum end was almost six times the slot velocity measured at the other end of the hood. Also on this tank, the average velocity for the front slot was 930 feet per minute compared to only 380 for the rear slot. Tank 41 was one of the most uniform The slot velocity at the duct end is only approximately 13 percent greater than the slot velocity at the other end; and the two sides have average velocities of 2060 and 1920 ft/min, differing by less than 8 percent.

Table 6. Average Slot Velocity Values At Opposite Ends of the Manifold Boxes For Two Tanks

	Tank 11		Tank 41	
	front slot	rear slot	left slot	right slot
Plenum end	1100	780	2100	1800
Other end	260	60	1850	1600
Difference	840	720	250	200

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

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

Table 5. Average Capture Velocities

Over Surface of Tanks

Tank	Depth of surface in.	Distance from slot in.	Capture Velocity ft/min average	Capture Velocity ft/min range
11	6	12[a]	25	15- 45
12	6	6	45[b]	20- 95
13	6	12[a]	35	20- 70
14	6	6	35[b]	20- 70
21	8	6	30	20- 60
22	6	6	70[b]	25-100
31	8	12	55	20-130
41	6	6	130[b]	80-190

a. One set of measurements made at centerline of tank, 12 in. from both slots.

b. For many of the readings, maximum velocities were not perpendicular to slot face.

Measuring the air flow through the vents into the shop yields a value of approximately 14,000 cubic feet per minute. This agrees well with the 13,400 cfm of total ventilation system air flow, calculated by summing the individual tank ventilation rates. This is consistant with the fact that neither a positive nor negative pressure condition (which would indicate that substantially more or less air is being pumped into the building than is being exhausted by the ventilation system) existed in this shop.

Pláting Procéss Parameters

Acid mist emission is a function of the product of the plating current and the duration of plating. The relevant plating parameters are given in Table 7. Only the time during which pieces were being plated in a tank on which samples were being collected has been included. The products of each current level and the time the piece(s) plated at that setting have been summed. An "average current" value has been calculated as an aid for differentiating between situations where a high load was applied for a short time versus a low level of plating for a longer time. For days on which certain data items were uncertain, no values are given.

DISCUSSION

Employee A spent over half his time on the automatic line, at the work bench loading parts to be plated onto special racks and removing plated pieces from the racks. At the bench, he is exposed essentially to general room air.

In addition to placing racks on the rail to be moved into the automated sequence and taking racks off the rail at the conclusion of the plating cycle, a number of manual interventions were performed by the worker, occasionally necessitating his climbing up on top of the unit. This activity provided his greatest exposure to the acid mist, potentially in excess of recommended ceiling limits, although for probably less than a tenth of the work shift.

Employees B and C also performed a number of tasks not directly involving the plating tanks: preparing pieces for plating and processing them after being plated. These activities (performed mostly along the south wall, see Figure 1, and in the front portion of the shop) would expose them to the general room air, mixed with outside air when the overhead door was open.

Table 7. Plating Parameters Relavent to Acid Mist Emission

Tank	Date	Total Time hr:min	Cumulative Current-Time Product, Amp-hr	Average Current, Amp.
11	28	6:50	800	120
	29	7:00	2000	290
	30	7:35	1600	210
12	28	1:30	280	190
	29	1:30	75	50
	30	:30	75	150
13	28	1:55	240	130
	29	7:00	910	130
	30	6:00	1000	170
14	28	5:25	700	130
	29	7:20	820	110
	30	:30	5	10
21	28	6:05	6100	1000
	29	7:30	1250	1700
	30	4:30	4500	1000
22	28	2:10	350	160
	29	7:25	1200	160
	30	7:45	1200	150
31	28	4:30	7300	1600
	29	5:00	9000	1800
	30	5:00	9600	1900
41	28	6:00	2400	400
	29	7:20	2900	400
	30	7:00	2200	310

However, some of their time was spent directly over the tanks, tending the pieces being plated. On tanks 11, 12, 13, and 14, operations involving the rectifiers required the worker to lean over the tank. This was not the case on tanks 21, 22 and 41 (nor 31), as the rectifiers were placed off to one side of the tanks rather than immediately behind them. Here again, this activity providing the most direct exposure to the acid mist probably comprised less than a tenth of the work shift.

Tanks 11, 12, 13, and 14

These tanks, similar in appearance, are fairly well controlled, although chromium concentrations above Tanks 11 and 12 were relatively high on two of the three sampling days for each tank. These elevated levels do not correlate well with the observed plating load, but variability in the determination of local concentrations and inadequate observations of plating activity may be masking the true relationship. The boards above the slot only extend over the tank about two inches beyond the plane of the slot, and probably contribute little to the effectiveness of the ventilation.

The ventilation systems on these tanks are not in good condition. There are holes in the hoods, cracks in the seams, and some of the slots are narrowed from being dented or becoming clogged. The manifold boxes and vertical ducts are well designed in that drainage is provided to prevent accumulation of liquid chromic acid.

Tanks 21 and 22

An imbalance of ventilation airflow exists between tank 21 and tank 22. Tank 21 only receives one-fourth of the combined flow. The total chromium results (Table A-2) and the capture velocity data (Table 5) suggest that the ventilation of tank 21 is insufficient; although the chromium VI area concentrations do not clearly support this. The measured flow rate of less than 600 cfm gives this tank the lowest ventilation to surface area ratio (except for the automatic line). The boards above the slots on these tanks extend up to four inches over the tanks, perhaps enough to slightly improve the ventilation flow pattern.

Tank 31

This tank is not well-controlled as indicated by the high chromium concentrations. (See Tables 3, A-2, and A-3.) This is effectively a two-sided ventilation system on a 20-foot long, 5-foot wide tank. The approximately 3000-cfm flow rate is insufficient for a tank this size. The boards which extend up to 6 inches over the tank probably improve the effectiveness appreciably in this situation. However, additional measures are necessary to achieve better control of the emissions from this tank.

Tank 41

The ventilation of this tank is adequate for its size. Although it is the smallest tank, it has the highest ventilation flow rate. The air sampling results and capture velocity values reflect this. The presence of a make-up air vent immediately over this tank may be a factor in these results. The downward flow of make-up air may be responsible for the disturbance in capture velocity orientation, but by blowing down it may help, rather than hinder, the capture of acid mist emissions from this tank.

General Shop Area

The ambient concentrations in the shop are aided substantially by the generous provision of make-up air. The infusion of make-up air allows the local exhaust ventilation to work at maximum efficiency. The additional air also provides dilution ventilation, reducing the effective airborne concentration of the contaminants which are not captured by the local exhaust ventilation.

Personal Protective Equipment

All platers wore "bump" hats (a smaller, lighter type of hardhat), safety glasses, and steel-toed shoes while in the shop. Gloves were available and used much of the time, especially when removing pieces from a plating bath. Work clothes were supplied and laundered by the shop. Powered, overhead hoists were used for lifting all large pieces.

CONCLUSIONS AND RECOMMENDATIONS

Personal time-weighted average chromium and sulfuric acid levels are below the corresponding OSHA Permissible Exposure Limits and the NIOSH recommended standards despite low capture velocities and insufficient ventilation rates relative to tank surface area according to current recommended practice. The use of plastic spheres, the high rate of general exhaust ventilation from the make-up air supply, and the boards partially covering the sides of the tank above the slots may contribute to the acceptable levels of contaminants in the air around the tanks.

The data does not show much correlation of the sampling results with plating activity. Considering that most tank samples were taken above the slots, this lack of correspondence indicates that, generally, the control measures effectively limit the emission of acid mist into the shop. Had the controls not been as effective in handling tank emissions, increases in plating load would have been consistently reflected in area samples. For instance, the chromium VI area concentrations at site 3 (a non-ventilated site) of Tank 22 was higher (although not proportionally) on the 2 days when the cumulative current-time product was higher; however, sufficient data is not available here to evaluate the relationship. Isolated excursions of single sampling site concentrations may be due in part to small but significant differences in the positioning of the samples.

It is possible that working directly over a tank (especially one which is marginally ventilated) 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 must work directly over a tank for more than a few minutes, either the plating current should be interrupted or the worker should wear proper respiratory protection.

Tank 41 has the best sized ventilation system in the shop. It should be used as much as possible for the pieces with large areas to be plated and those requiring long plating times at relatively high current levels.

Many of the tanks have higher air flow rates through the slots at the end of the tank closest to the vertical duct. This condition is most pronounced on Tanks 11, 12, and 14. When possible, keeping the heavy plating activity at the plenum-end of these tanks will take advantage of better ventilation.

It is not evident from our observations why tank 21 has a much lower flow rate than tank 22. The blastgate for Tank 21 appears to be fully open; however, some clogging of the slots on this tank was noted. Although the sampling results did not clearly indicate that this imbalance creates a problem, the depth of tank 21 and the corresponding plating activity probably warrant it a greater share of the total ventilation. This ventilation system should first be checked for clogging, and cleaned out if necessary. (This is recommended on a regular basis for all tanks in the shop.) If this does not correct the imbalance, the blastgates should be adjusted to balance the air flow through the system closer to half of the total flow rate.

In addition to tank 31 being the least effectively ventilated tank, it also exhibits a ventilation system design flaw: the fan is placed inside the building. With this arrangement, if any holes or cracks develop in the duct after the fan, the exhausted air stream may be "pushed" out into the shop. The fan would be better mounted on the roof, with the end of the discharge at least 5 feet above the surface of the roof to escape surface air currents.

In the meantime, the portions of the slots above the rinse tanks on the automatic line may be blocked off, forcing more air to come through the area of the slot which ventilates the plating bath. The boards extending from above the slots should be retained, and replaced if they deteriorate. If the fan is replaced, a more efficient fan with a higher rating should be considered. A design flow rate of 10,000 to 15,000 cfm would be necessary to reach the 100 to 150 cfm/ft^2 range, comparable to the other tanks.

Table A-1. Results of Personal Sampling for Chromium VI, Total Chromium, and Sulfuric Acid

Employee	Day mo/day/yr	Duration of Sampling hr:min	Air Volume of Sample liters	Calculated Concentration mg/m³
		Chromium VI		
Plater A	4/28/81	7:52	944	0.004
	4/29/81	7:58	956	0.002
	4/30/81	7:55	950	0.006
Plater B	4/28/81	7:59	958	0.001
	4/29/81	7:52	944	0.003
	4/30/81	7:42	924	0.002
Plater C	4/28/81	7:59	958	0.001
	4/30/81	7:46	932	0.002
NIOSH Recommended (Time-weighted average) standard				0.025
		Total Chromium		
Plater A	4/29/81	7:58	956	0.005
Plater B	4/28/81	7:59	958	0.007
Plater C	4/30/81	7:46	932	0.005
OSHA TWA PEL				0.5
		Sulfuric Acid		
Plater A	4/28/81	7:52	868	0.12
	4/30/81	7:53	979	0.10
Plater B	4/29/81	7:52	859	0.12
	4/30/81	7:41	973	0.10
Plater C	4/28/81	7:59	1011	0.10
OSHA (TWA) PEL				1.0
NIOSH Recommended (TWA) Standard				1.0

Table A-2. Individual Sampling Site, Chromium VI Concentrations

		28 April			29 April			30 April		
Tank	Site	hr:min	liters	mg/m^3	hr:min	liters	mg/m^3	hr:min	liters	mg/m^3
11	1	6:52	824	< 0.001	7:41	922	0.014	7:37	914	0.014
	2	6:43	806	< 0.001	7:35	910	< 0.002	7:36	912	< 0.002
	3	6:42	804	—[a]	7:40	920	0.003	7:36	912	0.079
12	1	6:33	786	< 0.003	7:42	924	0.038	7:41	922	0.010
	2	6:30	780	0.002	7:40	920	0.015	7:44	928	0.015
	3	6:28	776	0.003	7:42	924	0.006	7:45	930	0.003
13	1	6:34	788	< 0.003	7:43	926	0.002	7:36	912	—[a]
	2	6:36	792	< 0.001	7:40	920	0.002	7:35	910	0.002
14	1	6:32	784	< 0.003	7:42	924	0.002	7:39	918	—[a]
	2	6:30	780	0.001	7:45	930	0.013	7:41	922	0.005
21	1	6:09	738	< 0.003	7:27	894	0.002	7:37	914	0.027
	2	6:19	758	0.001	7:22	884	0.002	7:39	918	0.005
	3	6:05	730	0.011	7:27	894	0.017	7:39	918	0.008
22	1	6:04	728	< 0.001	7:25	890	0.002	7:42	924	0.004
	2	6:01	722	0.004	7:26	892	0.007	7:42	924	< 0.001
	3	5:58	716	0.004	7:26	892	0.020	7:42	924	0.092
31	1	6:56	832	0.066	8:00	960	0.023	7:26	892	—[a]
	2	6:53	826	0.028	8:00	960	0.027	7:29	898	0.020
41	1	5:58	716	< 0.003	7:20	880	0.002	7:41	922	0.004
	2	5:57	714	0.003	7:16	872	0.002	7:36	912	0.007
	3	5:57	714	0.001	7:17	874	0.003	7:36	912	0.005
General	1	6:33	786	< 0.001	7:12	864	0.002	7:15	870	0.001
Room Air	2	6:20	380	< 0.003	7:14	868	0.001	5:54	708	0.004

a. Sample was not available for analysis.

Table A-3. Individual Sampling Site,

Total Chromium Concentration

		28 April			29 April			30 April		
Tank	Site	hr:min	liters	mg/m^3	hr:min	liters	mg/m^3	hr:min	liters	mg/m^3
11	1	6:49	818	< 0.006	7:42	924	0.032	7:37	914	--
12	1	6:34	788	< 0.006	7:39	918	0.056	7:41	922	0.010
21	1	6:10	740	0.027	7:27	894	0.025	7:37	914	0.036
22	1	6:04	728	< 0.007	7:25	890	< 0.006	7:42	924	0.011
31	1	6:56	832	0.089	8:00	960	0.039	7:26	892	0.191
41	1	5:57	714	< 0.007	7:21	882	< 0.006	7:41	922	< 0.005
General Room Air	1	6:33	786	< 0.006	7:12	864	< 0.006	7:15	870	< 0.006

Table A-4. Individual Sampling Site,

Sulfuric Acid Concentrations

		28 April			29 April			30 April		
Tank	Site	hr:min	liters	mg/m^3	hr:min	liters	mg/m^3	hr:min	liters	mg/m^3
11	1	6:49	89.6	<0.11	7:34	89.9	<0.11	7:39	91.8	<0.11
12	1	6:34	74.9	0.15	7:42	92.4	<0.11	7:44	91.4	<0.11
21	1	6:10	76.9	<0.13	7:29	89.8	<0.11	7:37	89.1	<0.11
22	1	6:04	73.1	0.15	7:24	89.2	<0.11	7:42	92.9	<0.11
41	1	5:56	65.8	<0.15	7:21	88.6	<0.11	7:37	85.9	<0.11

Table A-5. Ventilation System Data

Tank	Tank Dimensions ft.	Slot Length in.	Number of slots	Slot Width in.	Average Slot Velocity ft/min.	Airflow Measurement Site	Area of Flow in.^{2}	Average Velocity ft/min.	Flow rate at this Location ft^3/min.
11	6.75 x 2	99	2	1.5	660	Duct	150	1200	1200
12	6.75 x 2	99	2	1.5	500	Duct	150	1500	1600
13	5.5 x 2	88	2	2	400	Duct	150	1300	1400
14	6.67 x 2	88	2	2	550	Duct	150	1200	1200
21	4 x 2.5	48	2	1.5	560	--	-	--	700[a]
22	4 x 3	48	2	2	1300	--	-	--	2200[a]
21&22		-	-	-	--	Combined Discharge	280	1500	2900
31	20 x 5	237	2	2	530	Discharge minus rain cap	310	1400	2931 3000
41	3 x 3	36	2	2	2000	Discharge minus rain cap	250	1200	2100

a. These values were prorated using estimates of flow rates for tanks 21 and 22 calculated by multiplying the average slot velocity by the total slot area.

APPENDIX B

In addition to collecting the sample of interest, a number of the filters (41 out of 96) had been covered by a uniform, grey coating. Almost three-fourths of these were from Tanks 11, 12, 13, and 14. A few of the samples were withheld for the Measurements Research Support Branch of NIOSH to determine the nature of the coating.

The exact identity of the coating on the filters could not be determined. It is felt that the coating is not directly related to plating bath emissions.

The particles were too small for optical microscopy. Qualitative x-ray fluorescence (XRF) did not reveal any elements above fluorine on the periodic table (a limitation of the method) which could be found only on filters with the coating. Energy-dispersive X-ray analysis indicated they might include aluminum silicates, calcium-phosphorous and calcium-potassium silicates, and iron. This contradicted the XRF analysis, as all these elements are above fluorine on the periodic table. There may be a relation here to the material used for grit blasting.

Low-temperature ashing consumed the coating in less than 30 minutes, supporting a suspicion that the coating may be a carbon-based residue from the gas-burners used to heat the tanks.