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IN-DEPTH SURVEY REPORT

OF

U. S. CHROME
FOND DU LAC, WISCONSIN

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Division of Physical Sciences and Engineering
Engineering Control Technology Branch
4676 Columbia Parkway
Cincinnati, Ohio 45226

PURPOSE OF SURVEY:	To evaluate engineering control technology used in a production plating and cleaning operation
DATE OF SURVEY:	September 14 - 17, 1981
EMPLOYER REPRESENTATIVES CONTACTED:	Jack Kivi, Plant Manager
EMPLOYEE REPRESENTATIVES CONTACTED:	Non-union
STANDARD INDUSTRIAL CLASSIFICATION OF PLANT:	3471
ANALYTICAL WORK PERFORMED BY:	Mary E. Cassinelli DPSE, NIOSH UBTL, Salt Lake City, Utah

ABSTRACT

An in-depth control technology survey of a plating and cleaning operation was conducted at a production hardchrome plating shop. Cylinder bores of 2- and 6-cylinder aluminum engine blocks are hardchrome plated. The plant employs 18 workers on two shifts with four workers involved in plating operations. The operation utilizes a cleaning line, three production hardchrome plating tanks, and a chrome strip tank. The primary airborne hazards are chromic acid (hexavalent chromium), sulfuric acid, nitric acid/nitric oxide, and hydrofluoric acid. The in-depth study consisted of the assessment of the overall control system, primarily local exhaust ventilation and some work practices.

INTRODUCTION

This relatively new hardchrome plating production shop plates chrome to the inside cylinder bores of outboard marine engines. The plant was studied to evaluate lateral and push-pull exhaust ventilation for acid cleaning tanks and two-sided exhaust ventilation for hardchrome plating tanks. The survey was conducted in a northern state in late summer with morning temperatures 40 to 50^{o}F, and afternoon temperatures 65 to 75^{o}F. The 10,000 square foot plating shop is two years old and has a production force of 18 persons, 10 on day shift and 8 on the swing shift. Shifts are 10 hours per day, four or five days per week.

The production is confined strictly to the cleaning and plating of engines for marine outboard motors. Engine blocks are all cast aluminum with either 2 or 6 cylinders. The entire engine is cleaned in acid while only the inside cylinder bores are chrome plated.

PROCESS

The aluminum cylinder blocks are delivered by forklift truck in cargo skids. The blocks are cleaned in caustic, inspected, cold water rinsed, dipped in hot acid (mixture of acids), rinsed, dipped in nitric acid, rinsed, zincated (zincate delays oxidation of the aluminum), and rinsed. The operator stays with the hoist and blocks along the entire cleaning line. After cleaning, the 2-cylinder blocks are hand carried to the chrome tank, loaded on a fixture, plated, swung out of the tank, rinsed off by hose and placed in a cold water rinse tank. The blocks are honed, inspected, laystalled (roughed-up to allow oil to adhere to cylinder wall), inspected, and shipped to the customer.

Six cylinder blocks are handled in the same manner except the blocks are moved to the plating tank using a hoist.

There is also a strip tank for removing all chrome from the engine block aluminum surface. The strip tank is used only for blocks that need rework.

The plating area is shown in Figure 1. In the center of the picture is the cleaning line and the vertical exhaust duct for the acid tank ventilation system. The chrome plating tanks are along the back wall as is the round vertical exhaust duct for the chrome plating ventilation system. The ceiling height in the building is 24-feet; all rectification as well as lateral ventilation ducts are located in the basement. In the winter, heated air is supplied to the building by a make-up air unit high on the North wall. The plant installed two 8-inch-diameter vinyl ducts with fans to circulate the warmer air near the ceiling. Air near the ceiling is blown down through the ducts and discharged 2-feet above the floor. This system has raised temperature at shoulder height by $8^{\circ}F$. One of the vinyl ducts is shown in the center of Figure 1.

Figure 1. Plating shop area.

A 44-inch-diameter fan in the roof provides general exhaust ventilation. In mild weather make-up air is supplied through open doors. The plating area layout is shown in Figure 2. The process tanks and their contents are as follows:

Tank	Type	Contents	Tank	Type	Contents
1	Rinse	Water	11	Rinse	Water
2	Cleaner	Caustic	12	Rinse	Water
3	Acid dip	Acid	13	Strip tank	Chromic acid
4	Acid dip	Acid	14	Rinse	Water
5	Rinse	Water	15	Rinse	Water
6	Nitric Dip	Acid	16	Steel strip	Hot alkaline cleaner
7	Rinse	Hot water	17	Rinse	Water
8	Rinse	Water	18	Chrome plate	Chromic and sulfuric acid
9	Rinse	Water	19	Chrome plate	Chromic and sulfuric acid
10	Zincate	Alumon-EN	20	Chrome plate	Chromic and sulfuric acid

HAZARD ANALYSIS

The primary hazards for hardchrome plating operations are chromic and sulfuric acids and for cleaning operations, sulfuric acid, nitric acid, and nitric oxides, and hydrofluoric acid. Chromic acid is chromium trioxide (chromic acid anhydride) and its aqueous solutions. Hexavalent chromium exists in solution with hydrogen ions and is considered to be in the non-carcinogenic form. Airborne hexavalent chromium compounds can cause irritation of the respiratory tract, ulceration, and perforation of the nasal septum, epistaxis, skin ulceration, chronic asthmatic bronchitis, and eye injury. Chromic acid can cause cracks or breaks in the skin which are commonly referred to as "chrome holes" or "chrome ulcers." Chromic acid mist may also discolor the teeth and tongue.[1-5]

Sulfuric acid (H_2SO_4) is a colorless, odorless liquid soluble in water and alcohol. Concentrated sulfuric acid can cause rapid damage to mucous membranes, is exceedingly dangerous to the eyes, and can burn and char the skin and mouth. Diluted H_2SO_4 is irritating to the skin and may cause scarring of the skin and blindness. Sulfuric acid can cause etching of dental enamel

Figure 2

and edema of the lungs and throat. Chronic exposure can lead to health problems such as emphysema and rhinorrhea.[6,7]

Nitric acid is a colorless, yellow or red fuming liquid with an acrid, suffocating odor. It causes eye, mucous membrane and skin irritation; delayed pulmonary edema; pneumonitis; bronchitis; and dental erosion. Its extremely corrosive nature can produce burns and ulcers of the skin, eye, and mucous membranes.

Nitrogen dioxide is a dark brown gas that can irritate the eyes and nasal passages and produce an acid taste. Acute exposures may produce death preceeded by symptoms of weakness, a cold feeling, nausea, abdominal pain, coughing, severe cyanosis, accelerated heart action, and convulsions. In some cases, nitrogen dioxide may produce dyspnea, cyanosis, vomiting, vertigo, and unconsciousness without pulmonary edema.

Nitrogen oxide (or nitric oxide) is a colorless gas that is rapidly oxidized in the presence of oxygen. Because it oxidizes to other oxides of nitrogen such as nitrogen dioxide (which is a more serious hazard), it is a significant contaminant when found in the workplace. Methemoglobinemia may be caused by nitrogen oxide.[6,7,8,9]

Hydrofluoric acid or hydrogen fluoride (HF) is a primary irritant of the eyes, skin, mucous membranes and lungs, and can produce chemical and dermal burns. Chronic exposure may result in nose bleeds. Fluoride burns can result in systemic poisoning by absorption of fluoride through the skin. Inhalation of high levels of elemental or acid fluorine can cause bronchospasm, pulmonary edema, gastrointestinal symptoms, chest pain, lung damage, and death.[6,8]

EVALUATION

Control effectiveness was determined by the collection and analysis of air samples collected over a 3-day period. Personal samples for Chromium VI, sulfuric acid, and nitric acid/nitric oxide were collected each day during the day shift. Area samples were collected for the above substances plus total chromium and hydrofluoric acid at fixed locations on the front lips of the acid tanks, above the surface of the plating baths, on the perimeter of the plating tanks, and in the general room air. Personal samples were collected for 7 to 8 hours; area samples were collected for 2 to 8 hours.

Hexavalent chromium was collected using closed-faced cassettes with 37 mm polyvinyl chloride filters of 5 um pore size and MSA Model G personal pumps operating at 2.0 Lpm and analyzed colorimetrically using NIOSH Method No. P&CAM 169.[10]

Total chromium was collected using closed-faced cassettes with 37 mm mixed cellulose ester filters of 0.8 um pore size and MSA-Model G personal pumps operated at a flow rate of 2.0 Lpm. Analysis was performed using atomic absorption spectroscopy according to NIOSH Method No. P&CAM 173.[10]

Sulfuric, nitric, and hydrofluoric acids were collected using 7 mm diameter silica gel tubes and DuPont 200 and DuPont 4000 personal pumps operating at 200 cc/m and analyzed using ion-chromatography according to NIOSH Method No. P&CAM 339.[11] Nitric oxides, collected along with nitric acid, is converted to nitric acid and is included as part of the nitric acid concentration. Each MSA and DuPont pump was calibrated with filters or tubes in line using a bubble buret. Nitric and hydrofluoric acids were also collected using liquid media tubes and analyzed as described above (NIOSH Method No. P&CAM).

Air velocity and total airflow were determined for each of the tanks. Air velocities were measured at the face of the acid hood and in the plating tank slots using a Kurz hot wire anemometer; total airflow discharged by the local exhaust systems, the general exhaust fan, and the push air supply blower (for the acid line) were measured. Smoke tubes were used to qualitatively evaluate local exhaust ventilation.

PERSONAL EXPOSURE

Two employees were sampled for three days to determine exposures to Chromium VI, sulfuric acid, and nitric acid. The results are shown in Table 1. The maximum exposure to Chromium VI of 0.001 mg/m^3 was far below the NIOSH recommended standard of 0.025 mg/m^3. The two platers spent almost all of 9/15, more than half of 9/16, and several hours on 9/17 in the plating area. The decrease in production from 9/15 to 9/17 may account for the decrease in exposures to Chromium VI from 9/15 to 9/17. Under any circumstances, including full production, exposures to hexavalent chromium should be below the NIOSH recommended health standard.

Table 1. Employee exposure (mg/m^3).

Employee		Chromium VI	Sulfuric Acid	Nitric Acid
Worker A:				
	9/15	0.001	0.04	0.08
	9/16	0.001	0.04	0.14
	9/17	0.0002	0.05	0.57
Worker B:				
	9/15	0.001	0.04	0.10
	9/16	0.0002	0.04	0.04
	9/17	0.0004	0.05	0.64
Mean		0.0006	0.04	0.26
NIOSH Recommended[1]		0.025	1.0	5.
OSHA PEL[2]		0.100	1.0	5.
TLV[3]		0.050	1.0	5.

1. NIOSH/OSHA Occupational Health Guidelines for Chemical Hazards.[12]
2. 29 CFR 1910
3. ACGIH TLV Book

Sulfuric acid exposures were very low with all personal samples below detectable limits and less than one-twentieth the allowable limit. Sulfuric acid exposures are possible from both the chromic acid plating tanks and the mixed acid tanks. The low employees exposures indicate sulfuric acid emissions from the individual plating tanks or the mixed acid tanks are low, which in turn indicate good control of sulfuric acid for these tanks.[2]

Nitric acid/nitric oxide personal exposure data averaged 0.26 mg/m^3 or 1/20th of the allowable limit. The highest exposure on 9/17 was 0.64 mg/m^3, or 1/8th the standard. These data indicate very good control of nitric acid/

nitric oxide emissions from the mixed acid tank and the nitric acid tank especially during normal production on 9/15 and 9/16. Highest nitric acid/nitric oxide exposures were on 9/17 when production was slowest. The highest levels on 9/17 resulted in part from a work practice where the mixed acid tank (3) was pumped out into a drainage trough below the tanks for about 30 minutes. This created strong burning acid fumes in the area of the acid line.

GENERAL VENTILATION

The roof ventilation fan was measured to exhaust 13,000 cfm. This provides 3 to 4 air exchanges per hour in the production area. (There is no make-up air supply unit.) During the survey, the roof exhaust fan was on except the morning of 9/17. Make-up air was supplied through open doors on 9/15, and half-open doors on 9/16. On 9/17 the doors were closed in the a.m. (cool weather), and opened in the afternoon. The general area samples for Chromium VI (Table 2) show average concentrations on 9/17 to be three times the concentration on 9/15 and twice the concentration on 9/16. This increase in Chromium VI concentrations can probably be attributed to shutting off the roof fan and closing the doors during the a.m. of 9/17. This bit of data is indicative of the benefits of general exhaust ventilation in reducing airborne chemicals in the workplace.

Table 2. General area sample concentrations - Chromium VI (mg/m^3).

Date	Sample Location			
	GA #1	GA #2	GA #3	Mean (daily)
9/15	.0005	.0005	.0010	.0007
9/16	.0005	.0008	.0020	.0011
9/17	.0007	.0027	.0032	.0022
Mean (ea. sta.)	.0006	.0013	.0021	
Overall Mean				.0013

ELECTROPLATING TANK 13

Tank 13 is a reverse chrome strip tank 3-feet by 7-feet by 4-feet-deep, equipped with two-sided exhaust ventilation. the exhaust slots are along the 7-foot dimension and are 1-1/2-inches-wide. Fumes are exhausted through expanding-type plenums on the sides of the tank to a single plenum on the South end of the tank and are discharged downward to a lateral duct in the basement. There are no covers on the tank, nor are plastic balls used.

The chrome strip bath contains 33 oz/gal chromic acid and is at room temperature. Cylinder blocks that need rework are placed in the bath, the block becomes the anode, and the cathode is a piece of iron (the reverse of the chrome plating). The blocks are stripped of all chrome down to the aluminum surface. The chrome strip is operated at 6 volts and 800 to 1,000 amps.

Tank 13 was operated on only one day for 2 hours. The part, a 6-cylinder block, was hung in the center of the tank. Two area air samples were taken during operations; one sample was located 4-inches from the West edge of the tank on top of the 1-1/2-inch ventilation slot, the other sample was located 5 inches from the South edge of the tank. (The exhaust slots are along the East and West edges of the tank.)

Airflow Measurements

Total exhaust volume and exhaust rate for this tank were 1,160 cfm and 56 cfm/ ft^2 (Table 3). Industrial Ventilation[13] recommends an exhaust rate of 175 cfm/ft^2 for free-standing tanks with hoods along two parallel sides when stripping chromium. The exhaust rate for Tank 13 was 1/3rd the recommended value.

Slot velocities were very uniform on both sides of the tank and ranged from 700- to 900-feet per minute.

Table 3. Airflow measurements.

Tank	Q Exhaust Air (cfm)	Q/A Exhaust Rate (cfm/ft^2)	Recommended[13] Exhausted Rate (cfm/ft^2)
13	1,160	56	175
18	3,960	99	250
19	2,940	74	250

Air Sampling Results

The two area samples taken on Tank 13 showed Chromium VI levels of 0.004 mg/m^3 (above a ventilation slot) and less than 0.001 mg/m^3 (South end of tank - no exhaust slot). Both samples are well below the NIOSH recommended level of 0.025 mg/m^3 for Chromium VI (non-carcinogenic).

Discussion

The very limited data indicates very good control of chromic acid mists from chrome stripping operations at an exhaust rate of only 60 cfm/ft^2 using two-sided local exhaust ventilation for a 3-foot-wide tank.

ELECTROPLATING TANK 18

Tank 18, shown schematically in Figure 3, is a hardchrome plating tank equipped with two-sided exhaust ventilation. The tank is 10-feet by 4-feet by 3-feet deep and contains a solution of 33 oz/gal chromic acid and 0.33 oz/gal sulfuric acid. Bath temperature is 136 to 140^{o}F. During production the solution is vigorously agitated. Tank 18 has 8 rectifiers, each providing current for a 6-cylinder block and a 9th rectifier for a dummy load. The ventilation system consists of 2-inch slots along both sides of the 10-feet dimension. Air is exhausted through the slots to both ends of the tank, then downward through a lateral duct (Figures 3a and 3b), to the 36-inch-diameter chromic acid exhaust stack. The liquid level of the bath is 3-inches below the slot. No plastic balls or mist suppressants are used in the bath.

Actual operating parameters during the survey are presented in Table 4. Tank 18 was operating below normal production because of a lack of available 6-cylinder blocks. Nonetheless, there was production in the tank with highest production on 9/15 tapering off to 9/17.

Table 4. Tank parameters.

Tank No.	Date	Volts	Amps	% of Sampling Time Plating	Watts DC	Surface Area Plated (sq. in.)	Bath Temp. °F
18	9/15	8	4,500	60	22,000	1,026	140
18	9/16	8	1,700	90	12,000	342	140
18	9/17	8	1,700	60	8,000	342	140
18	Max. Prod. Possible	8	11,500	90	83,000	—	—
19	9/15	6.8	7,900	90	48,000	1,520	140
19	9/16	6.8	7,900	90	48,000	1,520	140
19	9/17A	6.0	1,900	90	10,000	320	140
19	9/17P	6.0	3,500	70	15,000	640	140
19	Max. Prod. Possible	7.0	8,700	90	55,000	—	—

Airflow Measurements

Airflow measurements for Tank 18 are shown in Table 3. Total exhaust volume was 3,960 cfm or 99 cfm/ft^2. Industrial Ventilation[13] recommends 250 cfm for chromic acid plating solutions (in freestanding tanks not against a wall or baffle with hood along two parallel sides and tank width/length ratios of 0.25 to 0.49). The exhaust rate is equal to 40 percent of the recommended level. The tappered two-sided hoods provided even exhaust ventilation with slot velocities along the South side 1.13 times slot velocities on the North side.

Air Sampling Results

Air sampling data for Tank 18 is presented in Table 5 and air sampling locations are shown in Figure 4. the average overall concentrations were 0.004 mg/m^3 for Chromium VI, 0.006 mg/m^3 for total chromium, and 0.06 mg/m^3 for sulfuric acid. These data indicate the air concentrations for these substances are well below the NIOSH recommended levels as well as the legal (OSHA PEL) limits (although area samples can only be used to estimate compliance with the legal standard, they are a valuable indicator of effectiveness of the control system for the plating tanks.)

Table 5. Workplace air concentrations (mg/m^3) - Area samples - Tank 18.

Sample Location	No. of Samples	Chromium VI	Total Chromium	Sulfuric Acid
Tank 18 - 1	3	0.004	0.006	0.06
Tank 18 - 2	3	0.002	—	—
Tank 18 - 3	3	0.006	—	—
Mean		0.004	0.006	0.06

The data also shows there were only small differences in Chromium VI concentration among the three sampling locations for Tank 18. Chromium VI levels did increase substantially from 9/15 and 9/16 to 9/17. Average Chromium VI levels were less than 0.001 mg/m^3 on 9/15 and 9/16 and 0.011 mg/m^3 on 9/17, a tenfold increase.

General area sample Chromium VI concentrations taken at two locations approximately 10-feet from Tank 18 are presented in Table 2. The average Chromium VI concentration at locations GA1 and GA2 was 0.001 mg/m^3. This compares with an average Chromium VI concentration for Tank 18 of 0.004 mg/m^3.

Figure 4. Tank 18 - area sample locations (top view).

Discussion

The area sample results (Table 5) for Tank 18 indicate two-sided exhaust ventilation for a 4-foot-wide tank provided excellent control of Chromium VI, total chromium, and sulfuric acid emissions at the production rates shown in Table 4.

The highest production rate of the survey occurred on 9/15 when the average Chromium VI concentration for the three area samples was less than 0.001 mg/m^3. Increasing the production rate to the maximum possible (which is 2-1/2 times the production on 9/15) would most likely increase Chromium VI levels, however, the increased levels are expected to be well below NIOSH recommended Chromium VI concentration of 0.025 mg/m^3. (The maximum production would occur at 83,000 watts at $140^{o}F$ with eight 6-cylinder blocks being plated.)

The highest Chromium VI concentration for a single sample was 0.17 mg/m^3 on 9/17 at Station 3, the East-end of the tank. The relatively higher level is due to the fact an engine block was plated at the East-end of the tank on 9/17, but not on 9/15 or 9/16, and that room air currents may interfere with the ventilation at that end of the tank. In other words, the exhaust rate appears very good for the tank as a whole, but the ventilation over certain areas of the tank may not be adequate in the presence of even light room air currents.

Total Chromium and sulfuric acid emissions were easily controlled by ventilation. Sulfuric acid levels were essentially the same from day to day. Total chromium levels were five times greater on 9/17 than on 9/15. This may be attributed to good general room ventilation on 9/15; while during the morning of 9/17, the general ventilation fan was off and the doors which allow make-up air to enter the building were closed.

ELECTROPLATING TANK 19

Tank 19 is a hardchrome plating tank used in the production plating of 2-cylinder aluminum blocks. The tank shown schematically in Figures 3a and 3b is identical to Tank 18. The tank is 10-feet by 4-feet by 3-feet deep, and is equipped with two-sided exhaust ventilation. The two parallel slots are along the 10-foot length of the tank and are 2-inches-wide. Air is exhausted through the slots to both ends of the tank (Figure 3a) and downward to exhaust ducts in the basement. There were no covers on the tanks and plastic balls and fume suppressants are not used. Liquid level in the tank was 6- to 7-inches below the exhaust slots.

The plating bath contains 33 oz/gal of chromic acid and 0.33 oz/gal of sulfuric acid and is operated at $140^{o}F$. The bath is vigorously agitated. Operating parameters during the survey are presented in Table 4. Production in Tank 19 was near a maximum on 9/15 and 9/16 but much lower on 9/17.

Airflow Measurements

The total exhaust volume and exhaust rate for Tank 19 were 2,940 cfm and 74 cfm/ft^2 as shown in Table 3. The exhaust rate is only 30 percent of 250 cfm/ft^2 recommended in Industrial Ventilation[13] for chromic acid plating solutions.

Slot velocities taken along the East side of the tank were about 16 percent higher than along the West side of the tank. Slot velocities were very consistent along the 10-feet length of both sides of the tank.

Air Sampling Results

Air samples were collected above the surface of the chromic acid bath (before ventilation) and on the perimeter of the tank (after ventilation). The sampling locations for Tank 19 are shown in Figure 5 and the air sampling results in Table 6. Chromium VI concentration for the samples taken on the perimeter of tank following ventilation control averaged 0.011 mg/m^3 with the highest level at Station 4. This data indicates very good control of Chromium VI emissions. The average Chromium VI levels for all the perimeter sample locations were less than the NIOSH recommended maximum level of 0.025 mg/m^3.

Table 6. Workplace air concentrations (mg/m^3) - Tank 19 - area samples.

Sample Location	Chromium VI Mean	Chromium VI Std. Dev.	Total Chromium Mean	Total Chromium Std. Dev.	Sulfuric Acid Mean	Sulfuric Acid Std. Dev.	No of Samples
Above liquid surface							
1	0.31	0.34	0.22	0.18	1.70	1.87	6*
2	2.49	1.55	--	--	--	--	6
Mean (for tank)	1.4	1.6					
On tank perimeter							
3	0.002	0.002	0.004	0.002	0.05	0.01	3
4	0.025	0.021	--	--	--	--	3
5	0.004	0.001	--	--	--	--	2**
Mean (for tank)	0.011	0.016					

* Sulfuric acid value based on 5 samples.
**Sample on 9/16/81 not included because it was located above liquid surface.

Figure 5. Tank 19 - area sample locations (top view).

Samples were collected 7- to 13-inches above the surface of the chromic acid bath at two locations in the middle of the tank (Figure 5) to quantify the rate of emissions. At Station 2, chromium VI emissions averaged 2.5 mg/m^3, while at Station 1 average Chromium VI levels were only one-eighth as high. Chromium VI levels were reduced from 0.31 mg/m^3 at location 1 inside the tank to 0.002 mg/m^3 at location 3 (after ventilation), a 99.4 percent reduction, and Chromium VI was reduced from 2.5 mg/m^3 at Station 2 inside to 0.004 mg/m^3 at Station 5 outside, a 99.8 percent reduction. The overall concentration inside (before the control) was 1.4 mg/m^3 and outside (after control) was 0.011 mg/m^3 for an overall reduction of 99.2 percent.

Total chromium concentrations averaged 0.22 mg/m^3 inside the tank (Station 1) and 0.004 mg/m^3 after the ventilation (Station 3). The 0.004 mg/m^3 is well below the NIOSH recommended level and the OSHA PEL of 0.5 mg/m^3. The data shows a 98 percent reduction in total chromium levels from inside to outside the tank.

Sulfuric acid concentrations were 1.7 mg/m^3 inside the tank and less than 0.05 mg/m^3 outside the tank. The concentration of less than 0.05 mg/m^3 is well below the NIOSH recommended standard and the OSHA PEL for sulfuric acid. The data also shows a reduction in sulfuric acid of more than 97 percent from inside to outside the tank.

Discussion

Chromium VI samples taken after the ventilation control averaged 0.011 mg/m^3 and none of the sample locations had average Chromium VI concentrations greater than the NIOSH recommended standard of 0.025 mg/m^3. This indicates very good control of Chromium VI emissions. Furthermore in this particular operation the plater spends a maximum of 25 percent of the time near the chromic acid tanks so his exposure should be proportionately lower. The Chromium VI concentrations shown here for this tank were most likely close to maximum because the tank was near maximum production for most of the survey.

The results also indicate that the relatively low ventilation rate of 74 cfm/ft^2 is satisfactory for a 4-foot-wide tank using two-sided exhaust ventilation with an estimated 48,000 watts of power. The 74 cfm/ft^2 exhaust rate is much less than the 250 cfm/ft^2 recommended in Industrial Ventilation.[13]

The data further shows that Chromium VI concentrations were 2 to 3 orders of magnitude lower just after the ventilation than in the space (inside the tank) 6- to 12-inches above the chromic acid bath.

Total chromium and sulfuric acid levels were easily controlled at the exhaust rate of 74 cfm/ft^2.

ACID LINE

The location of the acid line is shown in Figure 1. The acid line is comprised of 12 tanks and a 1/4-inch thick polypropylene exhaust hood (shown in Figure 6) extending from Tank 2 to Tank 6. The contents of the 12 tanks are as follows.

Tank No.	Description	Constitutents	Concentration	Temp ^{o}F
1	Rinse	Water	--	Room
2	Caustic cleaner	Sodium hydroxide	8 oz/gal	150
3, 4	Acid	Hydrogen fluoride	13%	Room
		Sulfuric acid	22%	--
		Nitric acid	43%	--
5	Rinse	Water	--	Room
6	Acid	Nitric acid	50%	Room
7, 9	Rinse	Water	--	Room
8	Rinse	Water	--	150
10	Alumon	Alumon-EN (caustic)	20%	Room
11, 12	Rinse	Water	--	Room

Figure 6. Acid cleaning line and exhaust hood.

Tanks 3 and 4 are interchangeable and are used alternately. The tank not being used is covered.

The polypropylene exhaust hood (Figure 6) is 118-inches-long and extends along the right 14-inches of Tank 2, all of Tanks 3, 4, and 5, and the left 20-inches of Tank 6. Tanks 2 to 6 are each 24-inches-wide (dimension along the hood), 36-inches-long (front to back), and 3-feet-deep. A side view of the hood and Tanks 2 to 6 are shown in Figure 7. The exhaust hood is 10-inches-wide with baffles at 10-inch centers. Fumes are exhausted downward through the plenum to the basement, through a short horizontal section, and then upward through a 2-foot-square vertical duct, equipped with a wet (water and caustic) scrubber. Polypropylene balls (1-1/2-inches) have been added to the scrubber to break up the air stream to allow the acid to drop out. Before using the polypropylene balls enough acid mist was discharged through the stack to create a puddle on the roof with a pH of 3 to 4.

The 1/4-inch polypropylene exhaust system replaced metal hood and PVC ducts previously used on the acid line. In 1-1/2 years of operation the metal hoods had corroded and the square PVC duct broke at welds causing leaks and odors. The acid line ventilation system is completely separate from that of the chrome line.

Airflow Measurements

Airflow measurements for the acid line ventilation system are presented in Table 7. The total exhaust volume for the hood was 2,000 cfm. The exhaust volumes for Tanks 3 and 6 were 410 and 320 cfm. (It should be noted the exhaust hood extends beyond the left and right edges of Tank 3. This should have the effect of improving the ventilation.) The exhaust rates for the two tanks were from 69 to 54 cfm/ft^2, approximately 1/4th the exhaust rate recommended in Industrial Ventilation.[13]

Table 7. Airflow measurement - acid line.

Type of Ventilation	Q (cfm)	Q/A (cfm/ft^2)	qo (cfm)	qo/Q	Q/A Recommended
Exhaust Only					
Entire hood	2,000	68	--	--	--
Tank 3	410[1]	69	--	--	250
Tank 6	320[2]	54	--	--	250
Push/Pull					
Entire Hood	2,000	68	45	.02	--
Tank 3	410	69	11	.03	--

1. The exhaust hood extends beyond right and left of tank.
2. Exhaust hood extends beyond right edge of tank.

Smoke tube measurements on Tank 3 showed rapid capture of emissions at 2-feet from exhaust hood (exhaust ventilation only). At 3-feet from the exhaust hood, smoke a few inches below the edge of the tank was captured, while smoke 1- to 2-inches above the tank was not captured.

On 9/15, exhaust ventilation only was used, but on 9/16 the acid line was adapted for push-pull ventilation. Total air supplied by the push-pull was measured to be 45 cfm. The supplied air volume for Tank 3 was 11 cfm or 3 percent of the exhaust volume. Push air was not supplied to Tank 6.

Air Sampling Results

Area samples for sulfuric, nitric (plus nitric oxide), and hydrofluoric acid were taken on mixed acid Tank 3 for 2 days. The samples were taken at two stations, 2- to 3-inches outside of the front corners of the tank (see Figure 6). The results are presented in Table 8. Sulfuric acid concentrations averaged 7.3 mg/m^3 with exhaust ventilation only and 4.4 mg/m^3 with push-pull ventilation. These area samples exceed by several time the standard for personal exposure to sulfuric acid of 1 mg/m^3. Nitric acids/nitric oxide concentrations were 0.8 mg/m^3 with (exhaust ventilation only) and 0.5 mg/m^3 (push-pull ventilation). These values are below the NIOSH recommended level and OSHA standard of 5.0 mg/m^3 for nitric acid. (The NIOSH recommended maximum concentration and the OSHA standard for nitric oxide is 30 mg/m^3). Area samples for hydrogen fluoride averaged 2.0 mg/m^3 (exhaust ventilation only) and 1.1 mg/m^3 (push-pull ventilation) which is just below the recommended maximum HF concentration for personal samples of 2.5 mg/m^3.

Table 8. Workplace air concentrations (mg/m^3) - Acid line.

Sample Location	Date	No. of Samples	H_2SO_4	NO/HNO_3	HF	Notes
Tank 3	9/15	2	7.3	0.76	2.0	Exhaust only
Tank 3	9/16	2	4.4	0.48	1.1	Push-Pull
Percent reduction			40	37	44	(a)

(a) Reduction in airborne concentrations when changing from exhaust only to push-pull ventilation.

The data shows that the use of push/pull ventilation decreased the average acid concentration by approximately 40 percent compared to exhaust ventilation only. (It should be noted the general exhaust ventilation system operated on both 9/15 and 9/16.)

The nitric acid dip, Tank 6, was sampled for three days for nitric acid/nitric oxides. The results are presented in Table 9. Samples were taken at locations 2- to 3-inches out from the front corners of the tank. The HNO_3/NO_x levels ranged from 0.05 to 2.8 mg/m^3 and averaged 1.3 mg/m^3, which is less than the recommended maximum level for nitric acid of 5 mg/m^3. The average concentration at Station 2 was almost three times that of Station 1.

Table 9. Workplace air concentrations (mg/m^3). Nitric oxide/nitric acid (NO_x/HNO_3).

Location	No. of Samples	Concentration	Notes
Tank 6			
Station 1	3	0.7	(1)
Station 2	3	1.9	(2)
Mean		1.3	

1. Exhaust hood across from Station 1.
2. Exhaust does not extend to the right of the tank across from Station 2 (see Figure 6).

Discussion

Sulfuric acid area sample concentrations at Tank 3 were as much as 11 times that recommended for personal exposure to sulfuric acid. However, all the samples were taken only a few inches from the edge of the tank and it would require the operator to hold his head this close to the tank for an entire shift to receive this exposure. Nevertheless, a fair amount of sulfuric acid fumes are not being captured, and the ventilation system should be rated as less than adequate for the mixed acid tank.

The following recommendations should improve the ventilation system for Tank 3 and the other acid tanks.

1. Turn the tanks 90^{o} so the air is drawn across the narrower 24-inch dimension rather than the 36-inch dimension. Smoke tube tests indicate excellent capture at 24-inches from the hood but not at 36 inches from the hood.

2. An increased exhaust volume may help slightly. (Industrial Ventilation recommends 250 cfm/ft^2 which is much greater than the 70 cfm/ft^2 measured.) About a 20 percent increase in exhaust volume could be achieved by closing off a 20-inch portion of the exhaust hood along Tank 5, a rinse tank.

3. A push-pull system based on very limited data appears to upgrade the ventilation system from an inadequate to an adequate system.

The quantity of supply air for the push-pull ventilation system must be carefully controlled, too much air supply could actually increase fumes from the tank.

The nitric oxide/nitric acid and hydrogen fluoride emissions from Tank 3 were satisfactorily controlled and push-pull ventilation appeared to control these substances better than exhaust ventilation only.

Exhaust ventilation for Tank 6 was adequate to control nitric oxide/nitric acid. The airflow rate of 54 cfm/ft^2 appears adequate although it is less than 1/4th that recommended by Industrial Ventilation.[13] One flaw in the ventilation system is the hood does not extend to the right edge of Tank 6. This may account for the threefold increase in nitric oxide/nitric acid concentrations between the left (Station 1) and the right (Station 2) sample locations. The hood should extend 4- to 6-inches beyond the right edge of the hood (the extra inches allow for bowing of the plastic tanks and for emissions caused by indoor air currents moving from left to right.) Push-pull ventilation was not tested for Tank 6.

SUMMARY

Personal samples taken on two platers showed very good control of hexavalent chromium and sulfuric acid from hardchrome plating tanks and good control of sulfuric and nitric acid from acid cleaning tanks. Area samples taken on the chrome plating tanks showed excellent control of hexavalent chromium, total chromium, and sulfuric acid emissions. Exhaust ventilation rates as low as 75 cfm/ft^2 from two-sided exhaust hoods satisfactorily controlled plating emissions. Area samples taken both in the air space above the chromic acid baths and on the perimeter of the plating tanks, showed the local exhaust ventilation system reduced hexavalent chromium levels by more than 99 percent and sulfuric acid levels by 97 percent.

Area samples taken on the mixed acid tank (containing HF, H_2SO_4, and HNO_3) showed the one-sided local exhaust ventilation did not fully capture sulfuric acid emissions. Smoke tube measurements showed very good capture of smoke at 2-feet from the exhaust hood, but failed to capture smoke at 3-feet from the hood above the edge of the tank. (The tank dimension perpendicular to the hood is 3-feet.) The addition of push air supply to create a push-pull system resulted in a small reduction in sulfuric acid fumes.

Limited data showed two-sided exhaust ventilation adequately controlled hexavalent chromium emissions from a chrome strip tank.

The low exposure levels to hexavalent chromium and acids in the plant were due to not only good local exhaust ventilation but also to: (1) low density of plating and cleaning tanks, (2) high ceilings, and (3) general exhaust ventilation. The benefit of general exhaust ventilation was demonstrated when the roof exhaust fan was turned off the morning of the last day of the survey. General area samples showed hexavalent chromium levels two to three times higher on the last day of the survey than on the previous two days when the roof exhaust fan was operating. (Also, production levels were lowest on the last day of the survey.)

The results from this study also show that a threefold increase in plating production did not appear to affect hexavalent chromium levels on the perimeter of the tanks or in the general room air.

Extrapolation of the exposure data in the study to what would be expected during maximum production indicates existing ventilation would be adequate to protect workers; nevertheless, this plant would be an excellent candidate for testing the hypothesis that higher plating production increases emissions and worker exposure. Such a follow-up study should be conducted when the plant is at maximum production.

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APPENDIX A.
Air Sampling Data (U. S. Chrome)

Table A1. Personal samples.

Worker	Date	Time	Vol.	Time Weighted Average Exposure Over 8-Hour Workday: Hexavalent Chromium (mg/m^3)	Sulfuric Acid (mg/m^3)	Nitric Acid (mg/m^3)
A	9/15/81	478	956	0.0010	—	—
	9/15/81	478	96	—	0.04	0.08
	9/16/81	493	986	0.0008	—	—
	9/16/81	493	103	—	0.04	0.14
	9/17/81	415	830	0.0002	—	—
	9/17/81	415	86	—	0.05	0.57
B	9/15/81	479	958	0.0008	—	—
	9/15/81	479	95	—	0.04	0.10
	9/16/81	484	968	0.0002	—	—
	9/16/81	484	101	—	0.04	0.04
	9/17/81	406	812	0.0004	—	—
	9/17/81	406	85	—	0.05	0.64

Table A2. Area samples - acid line.

Location	Date	Time	Vol.	Hydrogen Fluoride (mg/m³)	Sulfuric Acid (mg/m³)	Nitric Acid** (mg/m³)
				Time Weighted Average Exposure Over 8-Hour Workday		
Tank 3: Station 1						
	9/15/81	478	97	3.02	11.84	0.81
	9/16/81	448	95	2.05	8.06	0.43
		445	445	--	--	0.30*
	9/17/81	347	69	2.23	4.93	0.82
		322	322	1.22*	--	1.37*
Tank 3: Station 2						
	9/15/81	477	92	1.05	2.84	0.72
		430	430	2.72*	--	1.16*
	9/16/81	448	90	0.24	0.74	0.52
		444	444	1.22*	--	1.25*
	9/17/81	346	73	0.55	2.49	0.59
		322	322	0.24*	--	0.74*
Tank 6: Station 1						
	9/15/81	467	96	--	--	0.094
	9/16/81	485	99	--	--	0.051
	9/17/81	360	74	--	--	2.03
Tank 6: Station 2						
	9/15/81	466	90	--	--	0.356
	9/16/81	483	100	--	--	2.5
	9/17/81	360	76	--	--	2.76

* Liquid media samples (all others are silica gel).
**Includes oxides of nitrogen.

Table A3. Area samples - hexavalent chromium.

Worker/Location	Date	Time Weighted Average Exposure Over 8-Hour Workday: Sample Time (min)	Sample Vol. (liters)	Hexavalent Chromium (mg/m^3)
		Chrome Plating Samples		
Tank 18: Station 1				
	9/15/81	455	910	0.0007
	9/16/81	491	982	0.002
	9/17/81	406	812	0.01
Tank 18: Station 2				
	9/15/81	454	908	0.0004
	9/16/81	493	986	0.0002
	9/17/81	308	616	0.01
Tank 18: Station 3				
	9/15/81	456	912	0.0007
	9/16/81	491	982	0.0002
	9/17/81	402	804	0.02
Tank 19: Station 1				
	9/15/81 a.m.	344	688	0.09
	9/15/81 p.m.	112	224	0.02
	9/16/81 a.m.	235	470	0.09
	9/16/81 p.m.	235	470	0.23
	9/17/81 a.m.	201	402	0.95
	9/17/81 p.m.	219	438	0.46
Tank 19: Station 2				
	9/15/81 a.m.	336	672	0.33
	9/15/81 p.m.	109	218	3.62
	9/16/81 a.m.	229	458	1.31
	9/16/81 p.m.	242	484	2.27
	9/17/81 a.m.	195	390	2.82
	9/17/81 p.m.	217	434	4.61
Tank 19: Station 3				
	9/15/81	445	890	0.0002
	9/16/81	461	922	0.001
	9/17/81	409	818	0.004

Table A3. Area samples - hexavalent chromium. (cont'd)

		Time Weighted Average Exposure Over 8-Hour Workday		
Worker/Location	Date	Sample Time (min)	Sample Vol. (liters)	Hexavalent Chromium (mg/m^3)
Tank 19: Station 4				
	9/15/81	434	868	0.0007
	9/16/81	157	314	0.04
	9/17/81	410	820	0.04
Tank 19: Station 5				
	9/15/81	434	868	0.003
	9/16/81	240	480	0.14
	9/17/81	401	802	0.005
Tank 13: Station 1				
	9/16/81	126	252	0.004
Tank 13: Station 2				
	9/16/81	116	232	0.0009
		General Area Samples		
Station 1				
	9/15/81	410	820	0.0002
	9/16/81	471	942	0.0002
	9/17/81	383	766	0.0007
Station 2				
	9/15/81	481	962	0.0002
	9/16/81	438	876	0.0008
	9/17/81	383	766	0.003
Station 3				
	9/15/81	409	818	0.001
	9/16/81	444	888	0.002
	9/17/81	205	410	0.003

Table A4. Area samples - total chromium.

Location	Date	Time Weighted Average Exposure Over 8-Hour Workday: Sample Time (min)	Sample Vol. (liters)	Total Chromium Concentration (mg/m^3)
		Chrome Plating Samples		
Tank 18: Station 1				
	9/15/81	454	908	.002
	9/16/81	491	982	.004
	9/17/81	309	618	.015
Tank 19: Station 1				
	9/15/81 a.m.	344	688	.09
	9/15/81 p.m.	112	224	.04
	9/16/81 a.m.	235	470	.10
	9/16/81 p.m.	235	470	.16
	9/17/81 a.m.	201	402	.50
	9/17/81 p.m.	219	438	.41
Tank 19: Station 3				
	9/15/81	444	888	.003
	9/16/81	454	908	.002
	9/17/81	409	818	.006