IN-DEPTH SURVEY REPORT

OF

ELECTRO-COATINGS
HOUSTON, TEXAS

Survey Conducted By:
Stephanie E. Spottswood
Dennis O'Brien, P. E., C.I.H.
Alfred A. Amendola, P.E.
Kenneth Martinez

Date of survey:
August 11-13, 1981

Report Written By:
Stephanie E. Spottswood

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

PURPOSE OF SURVEY: To evaluate engineering control technology used at Electro-Coatings, a hard chrome electroplating establishment.

EMPLOYER REPRESENTATIVES CONTACTED:

J. Michael Sale, General Manager, Southern Region
Rod Hall, Manufacturing Manager, Houston Operations
William Atcheson, Sales and Marketing Manager
Walter Lund, Plant Manager
Clifton Garrett, Plant Superintendent.

EMPLOYEE REPRESENTATIVES CONTACTED: Non-Union.

ABSTRACT

An in-depth control technology survey was conducted at the Electro-Coatings electroplating facility in Houston, Texas during August 11-13, 1981. This company is involved in the hard chrome plating of oil field drilling equipment and printing rollers. Assessments of control technology, including ventilation design, control monitoring and work practices were made during this visit. Analysis of workplace air samples indicated that employee exposures to hexavalent chromium were controlled to 0.006 mg/m^3 and exposures to sulfuric acid were controlled to 0.055 mg/m^3.

Introduction

The National Institute for Occupational Safety and Health (NIOSH) is charged with the responsibility to conduct research and develop criteria for preventing exposure of workers to harmful chemical and physical agents. In response to this mandate, NIOSH has instituted a major effort to prevent occupational health problems through the application of control technology in the workplace. This control technology research program involves industry-wide engineering assessments in which effective options for the solution to occupational health problems are evaluated and documented.

NIOSH has initiated an assessment of engineering control technology in electroplating operations, where control measures exist for known chemical hazards, but a systematic study of their effectiveness has not been undertaken.

The Electro-Coatings facility was selected because it is a small scale, but high volume hard chrome plating operation with a well-designed ventilation system. Also, preliminary survey findings[1] indicated good use of engineering controls for minimizing employee exposure to hexavalent chromium and sulfuric acid.

Plant Description

This plating operation is located in an industrialized city in the Southwest. The climate in this locale is typically warm and humid, with temperatures ranging from 40°F in the winter months to above 100°F during the summer. The survey was conducted in mid-August, when temperatures averaged 85-90°F. The production area is housed in a 16 year-old building. The plating equipment and ventilation system have been installed within the last 8 years. The workforce is comprised of 11 employees: 10 platers and one production supervisor. The operation employs two work shifts; only the first shift was surveyed, which includes 5 platers. The company has no union, but an employee association represents all local company employees.

The shop plates a variety of parts used by the oil drilling industry, including pinion gear shafts, pump shafts, pump seats, pistons, turbine ends, hydraulic cylinder rods, compressor rods, manifolds and bumper housings. The shop also plates a large quantity of printing press rollers, a particularly large item, often up to 24" in diameter and 20' in length. The shop easily accommodates parts of these sizes.

The production area consists of one large open room, 9600 ft^2 in area. A schematic plant layout is presented in Figure 1. There are a total of six thermostatically controlled chrome plating tanks. Of these, four were included in the survey. The two along line #1 (tanks A and B) are each 24 feet long, 4 feet wide and 7 feet deep. They are exhausted by two slot hoods along the long sides of both tanks, with plenums at the ends.

Two chrome plating tanks occupy line #2 (tanks C and D). These are each 10 feet long by 3 1/2 feet wide by 7 feet deep with an exhaust slot on one long side. The tanks are covered with a hard plastic lid which rests 6-8 inches above the top front of the tank. These covers were designed to reduce chromic acid loss from misting at the surface.

The plating lines are divided into 17 stations; each station is supplied current by a separate rectifier. The tanks are constructed of steel with "Koroseal"^{R} lining. The pits beneath the tanks are lined with acid-resistant bricks.

During the plant survey, the indoor temperature ranged from 90^o-96^oF and the relative humidity was 60%.

Process Description

Most of the parts to be plated are received at the plant with freshly-machined surfaces, usually from the company's machine shop. They are palletized and transported by truck to the plating facility. At the plating shop, the smaller parts are usually sand-blasted in a fully-enclosed cabinet. Larger parts are sand-blasted in a separate blasting building where an air-supplied respirator is provided for employee protection. Parts are then transferred to a "staging area" where they are masked (portions not to be plated are taped), affixed to a copper-carrying lead anode and racked on a rod for precleaning.

The precleaning step involves manual application of an abrasive cleanser to the surface to be plated followed by a fresh water rinse. The part to be cleaned is removed from the holding rod and the attached anode is hooked onto the overhead hoist for loading into the clear water rinse tank.

After the abrasive scrub and rinse, the part is subjected to a reverse-etch for 3-5 minutes. The part is immersed in a chromic acid plating solution and the current is reversed to remove smut, accelerate cleaning and provide a more active surface for plating. After reverse-etching, the polarity is reversed and the part is hard chrome plated. The approximate plating time in the chrome tanks is 15-16 hours. While the part is submerged in the tank, the plater prepares another part for processing.

The desired chrome thickness can range from 0.001 to 0.05 inch. When the part has attained the required thickness, it is removed by overhead hoist and transferred to a clear water holding tank for rinsing. The part remains in the holding tank for approximately one hour. It is then returned to the "staging area" where the anode and tape are removed. The part is then palletized and shipped back to the machine shop for final grinding, buffing and finishing.

The chrome plating solutions contain chromic acid (chromium trioxide) and a small amount of sulfuric acid giving a ratio of 100:1 (33 oz/gal chromic acid, 0.33 oz/gal sulfuric acid). Chrome bath temperatures range from 125^0-130^0F.

Hazard Analysis

The hazards of concern at the operation include sulfuric acid and chromic acid mists. Concentrated sulfuric acid is highly irritating to the eyes and mucous membranes. Dilute sulfuric acid is an irritant to skin and mucous membranes, and may cause irreparable corneal damage and blindness.[2,3]

Local effects of chromic acid include dermatitis upon skin exposure, and pulmonary sensitization. Chromic acid is also corrosive to the skin and mucous membranes of the upper respiratory tract.

Systemically, acute exposures to chromic acid mist may cause coughing and wheezing, headache, dyspnea, pain upon deep inspiration, fever, and loss of weight. Additionally, electroplaters are particularly susceptible to a variety of symptoms including lacrimation, inflammation of the conjunctiva, nasal itch and soreness, nosebleed, ulceration and perforation of the nasal septum, nasal congestion, chronic asthmatic bronchitis, dermatitis and skin ulceration, laryngeal mucosa inflammation, skin discoloration, and dental erosion. Although rare, hepatic injury has been reported from exposure to chromic acid used in plating baths.[2,3]

Evaluation

To evaluate control effectiveness, personal, tank and area samples were taken during the first shift, for three consecutive days. Five personal samples for hexavalent chromium (CrVI) and sulfuric acid were collected daily to assess each employee's 8-hour time-weighted average exposure. Tank samples for CrVI, total chromium and sulfuric acid were collected daily at fixed locations around the perimeter of the plating tanks. General area samples for CrVI were collected at three distinct locations within the plant, away from the plating tanks. These sampling locations are indicated in Figure 1.

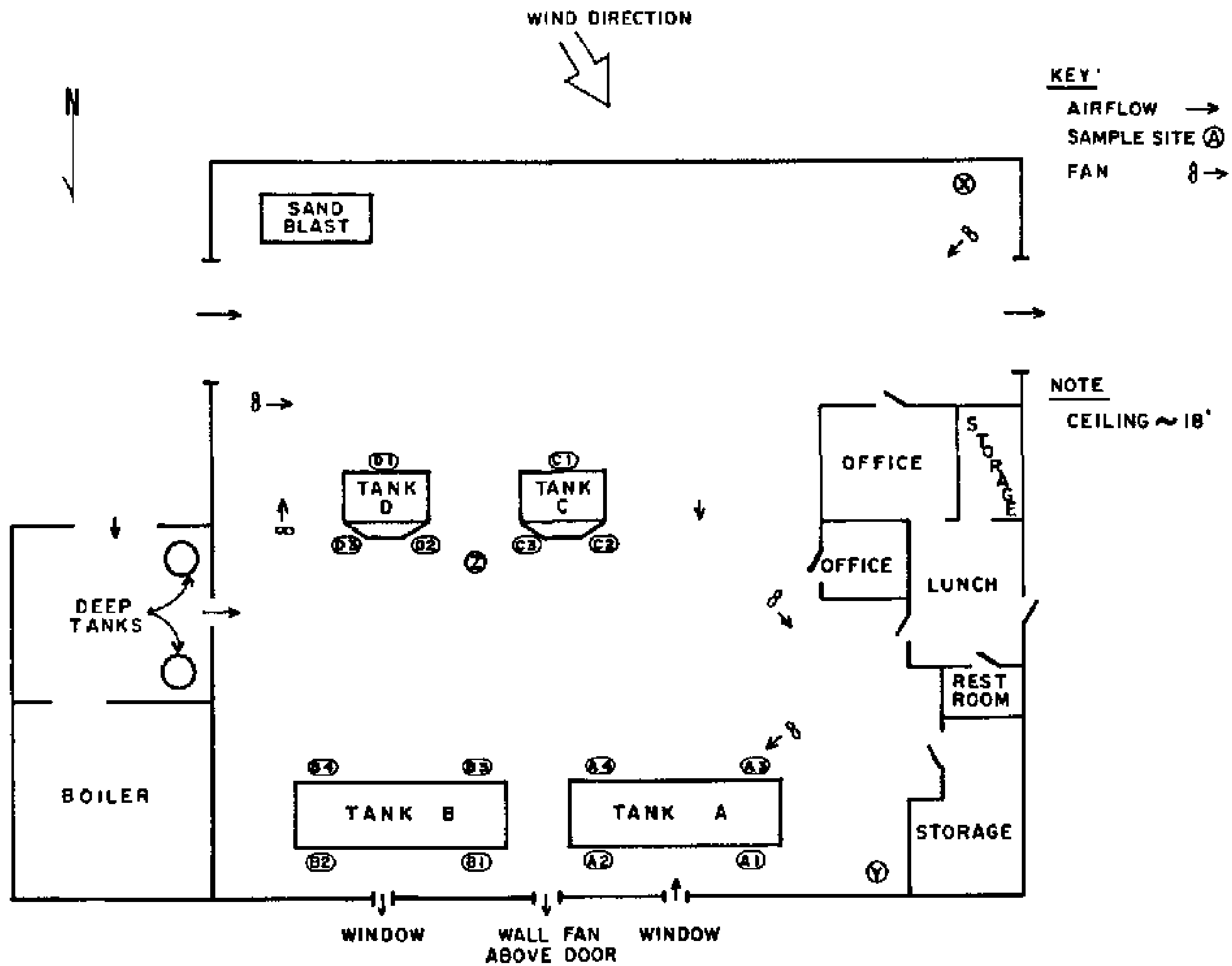

Figure 1. **SAMPLE LOCATIONS AND SHOP PLAN** Scale 1/10" = 2'

CrVI was collected using 37 mm diameter, 5μm pore size polyvinylchloride filters in closed-face casettes, with MSA Model G sampling pumps operated at 2.0 L/min. The samples were analyzed colorimetrically according the NIOSH method No. P&CAM 169[4].

Total chromium was collected using 37 mm diameter, 0.8 μm pore size mixed cellulose ester filters in closed-face casettes, with MSA Model G pumps operated at 2.0 L/min. These samples were analyzed by Atomic Absorption Spectrophotometry according to NIOSH Method No. P&CAM 152[4].

Sulfuric acid was collected using 7 mm diameter silica gel tubes and DuPont 200 sampling pumps operated at 200 cc/min. The samples were analyzed by ion chromatography according to NIOSH Method No. P & CAM 310[4].

Ventilation Measurements

Air velocity and air flow measurements were taken to evaluate the plant's engineering controls. Air velocities were measured using a Kurz Model # 441 hot wire anemometer. Velocity measurements were made in the horizontal plane above tanks A and B, near the centerline, and vertical plane at the front and sides of tanks C and D, and at the slots of the exhaust hoods. Velocities were averaged and the total volume of air discharged through each exhaust hood was determined. Pitot traverse readings were made in the ductwork using a 5/16 inch diameter Dwyer Model 160-48 pitot tube and inclined manometer.

Table 1. Operating Parameters

Tank	Date	Time	Bath Temp °F	Volts	Amps	Surface Area(in^2)	Current Density(A/in^2)
A	8/11	a.m.	125-130	4	100	36	2.8
		a.m./p.m.	"	6	1350	580	2.3
		p.m.	"	4.2	620	220	2.8
	8/12	a.m.	"	3.8	640	320	2
		p.m.	"	6	700	390	1.8
	8/13	a.m.	"	3.4	150	76	2.0
		a.m.	"	5.8	1000	500	2.0
		p.m.	"	3.4	100	40	2.5
B	8/11	a.m.	"	4.5	450	360	1.3
		a.m.	"	8	650	374	1.7
		a.m./p.m.	"	8.2	250	126	2.0
		p.m.	"	6.8	650	280	2.3
		p.m.	"	9.2	5600	3150	1.8
	8/12	a.m.	"	6	700	360	1.9
		a.m.	"	5.5	500	240	2.1
		a.m.	"	6.8	125	63	2
		p.m.	"	7.4	150	76	2
	8/13	a.m.	"	8	400	187	2.1
		p.m.	"	5.5	700	360	1.9
C	8/11-8/13 Not Plating						
D	8/11	a.m.	"	7.6	4400	2000	2.2
		p.m.	"	7.4	1000	500	2
	8/12	p.m.	"	7.5	4400	2180	2

Electroplating Tanks A & B

Tanks A & B, shown schematically in Figure 2, are located adjacent to each other in the north side of the plant. Each tank is equipped with a local exhaust hood. The exhaust air is vented through two 2-inch slot hoods along parallel sides of the tank and then through 18-inch wide plenums extending along the length of each tank. Exhaust air flows laterally to an end take-off hood to a 36-inch diameter duct which exhausts to the roof. Tanks A and B are pictured in Figures 3 and 4.

Operating Parameters

Tank operating parameters, including bath temperature, voltage, amperage, part surface area, and current density, were recorded for comparison purposes. These parameters are presented in Table 1.

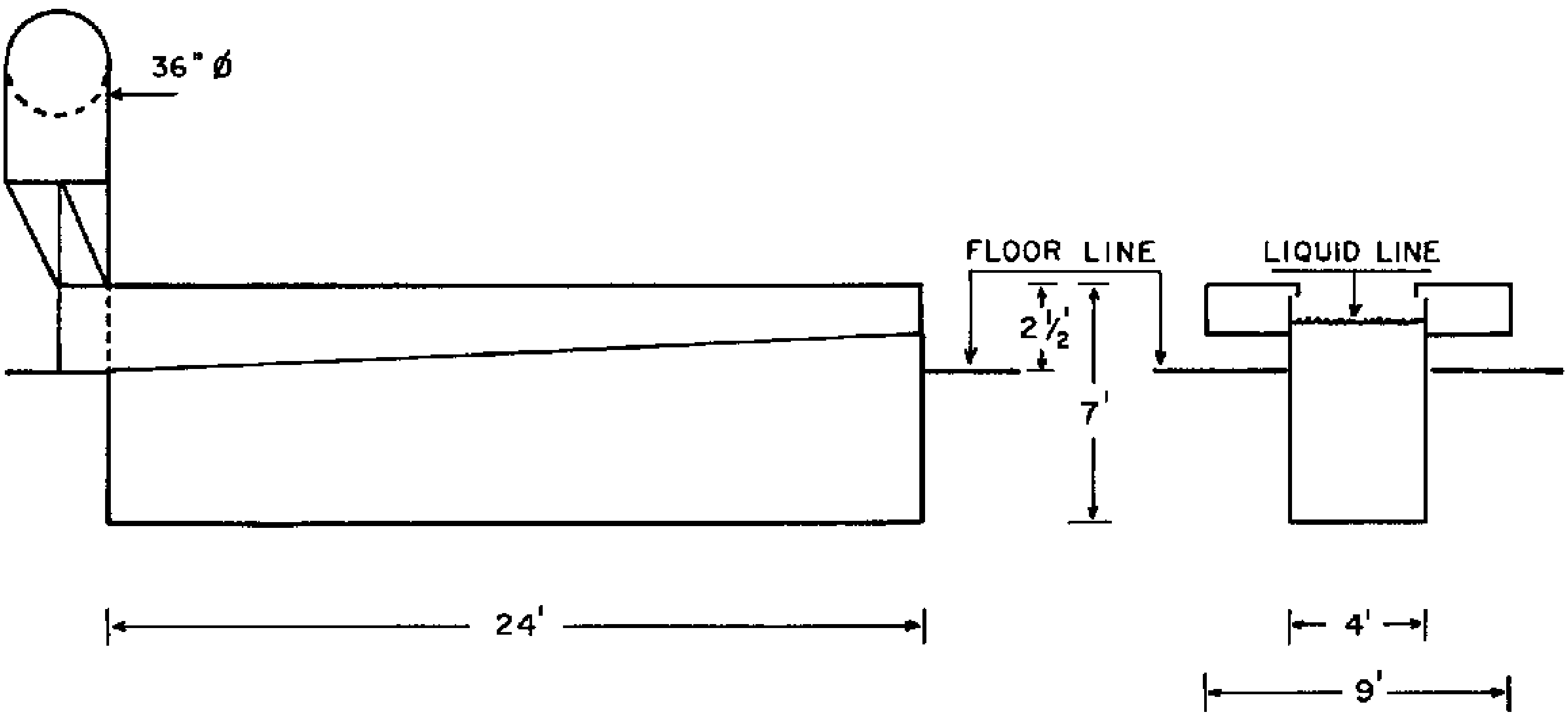

Figure 2. GENERAL ARRANGEMENT, TANK AND HOOD, TANKS A - B

Scale $2/10'' = 1'$

Table 2. Airflow Measurements

Tank	Q Exhaust Air (cfm)	Q/A Exhaust Rate (cfm/ft2)	Control Velocity (ft/m) Mean	 Std. Dev.
A	13650	142	158	68
B	16900	176	69	26
C	1500*	43	113	29
D	2850*	81	134	70

*from pitot traverse

Airflow Measurements

Air velocity measurements for tanks A and B are presented in Table 2. The average capture velocities were 158 fpm for tank A and 69 fpm for tank B. Capture velocity measurements were made in a horizontal plane several inches above the surface of each tank. Total airflow to the hood measured at 13,650 cfm for tank A (142 cfm/ft^2) and 16,900 cfm for tank B (175 cfm/ft^2) by means of a pitot tube traverse.

Air Sampling Results (Tanks A and B)

Tank and area sampling results for hexavalent chromium and total chromium are reported in Table 3. Mean concentrations of all contaminants are within the maximum levels allowed by OSHA[5] and recommended by the ACGIH[6] for an 8-hour exposure to these substances.

Discussion

The low concentrations of hexavalent chromium and total chromium can be attributed to effective local exhaust ventilation of the plating operation. Changes in plating rates and current applied over the range experienced (100-5600 amps) did not appear to influence the hexavalent chromium, total chromium, or sulfuric acid air concentrations at these very low levels.

Table 3
Air Sampling Results - Hexavalent Chromium

Location	No. Of Samples	Mean Concentration (mg/m^3)	Concentration Range (mg/m^3)
Tank A	11	0.003	0.0002 - 0.0096
B	12	0.002	0.0002 - 0.0095
C	9	0.001	0.0002 - 0.0032
D	9	0.002	0.0002 - 0.0064
Area X	9	0.001	0.0002 - 0.0009
Y	3	0.002	0.0002 - 0.0052
Z	3	0.004	0.0002 - 0.0125

Table 4

Air Sampling Results - Total Chromium

Location	No. Of Samples	Mean Concentration (mg/m^3)	Concentration Range (mg/m^3)
Tank A	2	0.006	0.003 - 0.009
B	3	0.007	0.003 - 0.010
C	3	0.005	0.003 - 0.010
D	3	0.005	0.003 - 0.012

Table 5

Air Sampling Results - Sulfuric Acid

Location	No. Of Samples	Mean Concentration (mg/m^3)	Concentration Range (mg/m^3)
Tank A	3	0.052	0.050 - 0.056
B	3	0.054	0.053 - 0.055
C	3	0.053	0.051 - 0.056
D	3	0.064	0.053 - 0.081

Electroplating Tanks C and D

Tanks C and D, shown in Figure 5, are covered with large plastic lids to prevent mist or vapor evolution. These tanks are located near an open door which creates interferring cross drafts in this area. The tanks are equipped with 1 1/2 inch slotted hoods with an 18 inch plenum which extends the length of the tanks. Air is exhausted through a 36-inch duct which exhausts to the roof. Tanks C and D are also pictured in Figures 6 and 7. Operating parameters are included in Table 1.

Airflow Measurements

Air velocity measurements for Tanks C and D are presented in Table 2. The average capture velocities were 113 fpm and 134 fpm for Tanks C and D, respectively. Capture velocity measurements were made in the vertical plane of the front and side edges of each tank with the covers down in place. Total airflow to the hood was determined from pitot tube traverse of the exhaust duct. Total airflow for Tank C was 1500 cfm (43 cfm/ft^2) and for Tank D, 2850 cfm (81 cfm/ft^2).

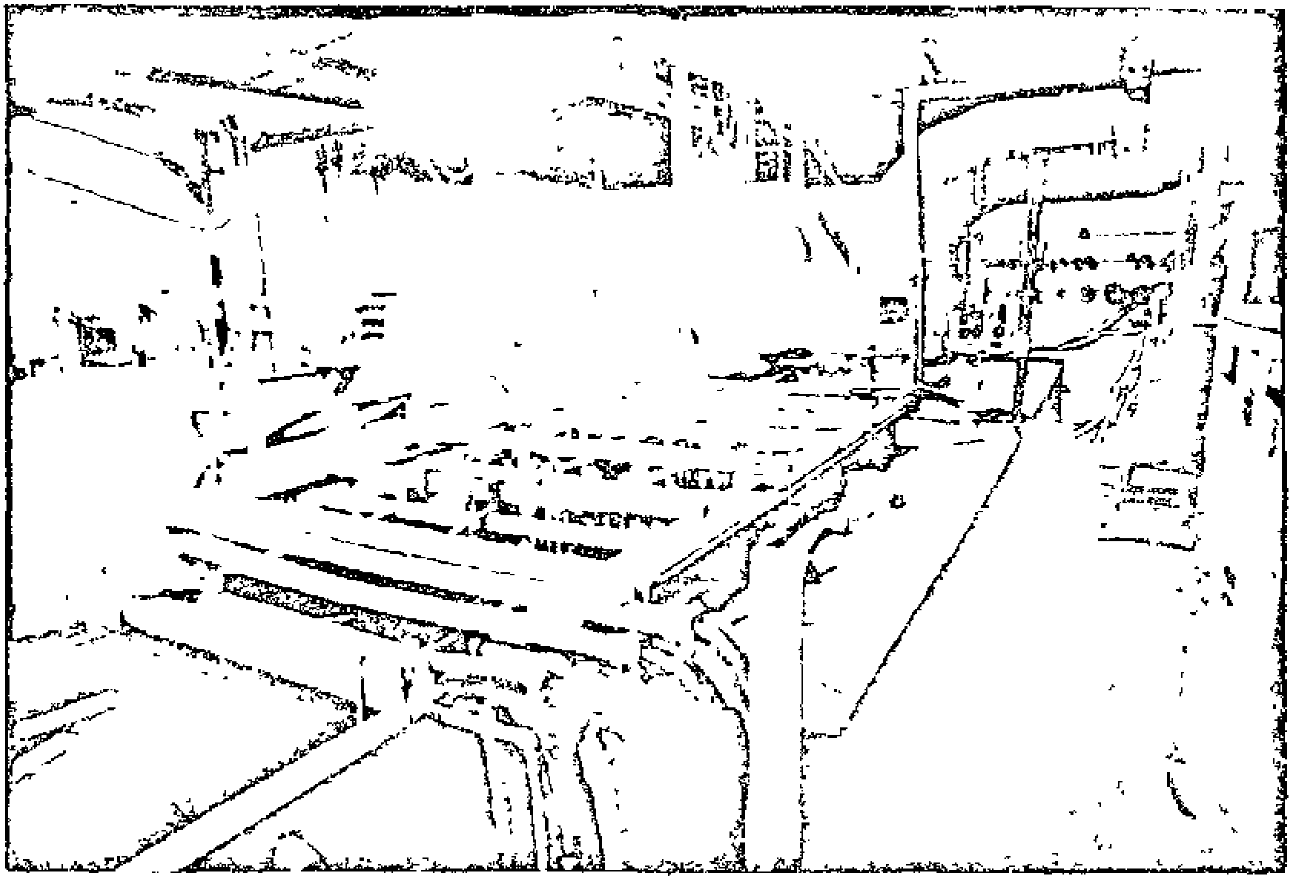

Figure 3: Tank A - Hood and duct viewed from east

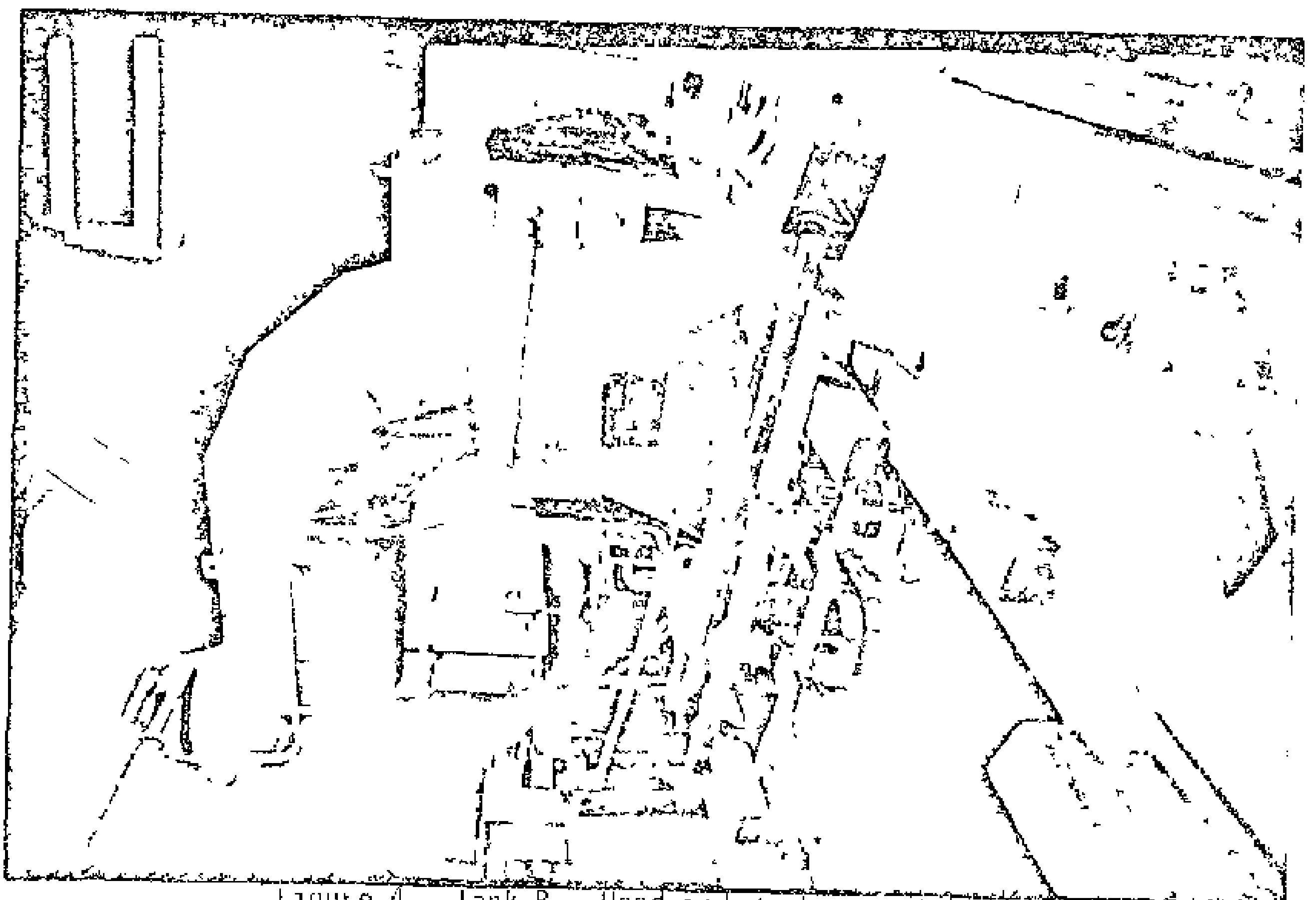

Figure 4 Tank B - Hood and duct viewed from west

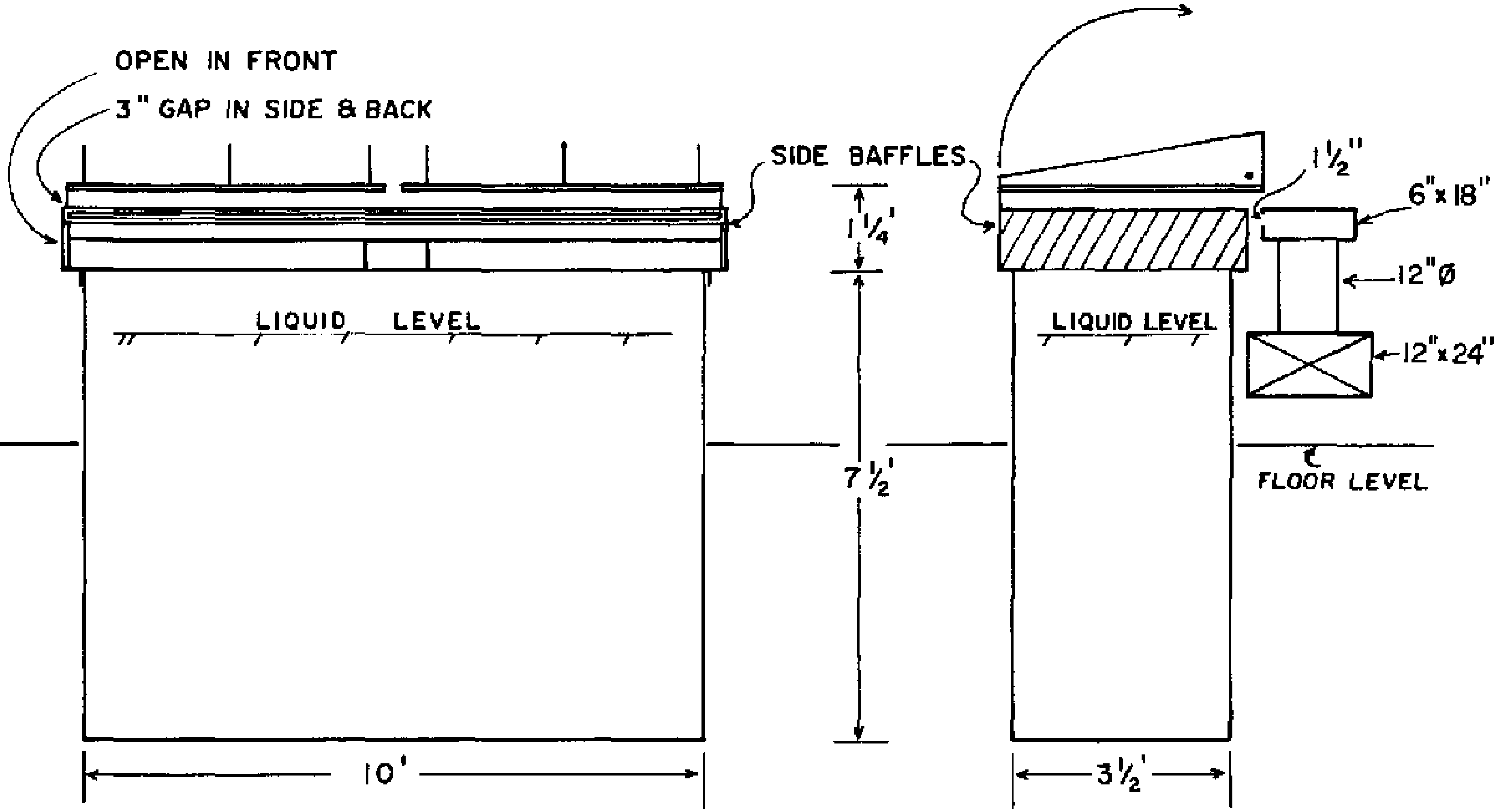

Figure 5. GENERAL ARRANGEMENT, TANK & HOOD WITH COVER, TANKS "C" AND "D".

Scale $4/10" = 1'$

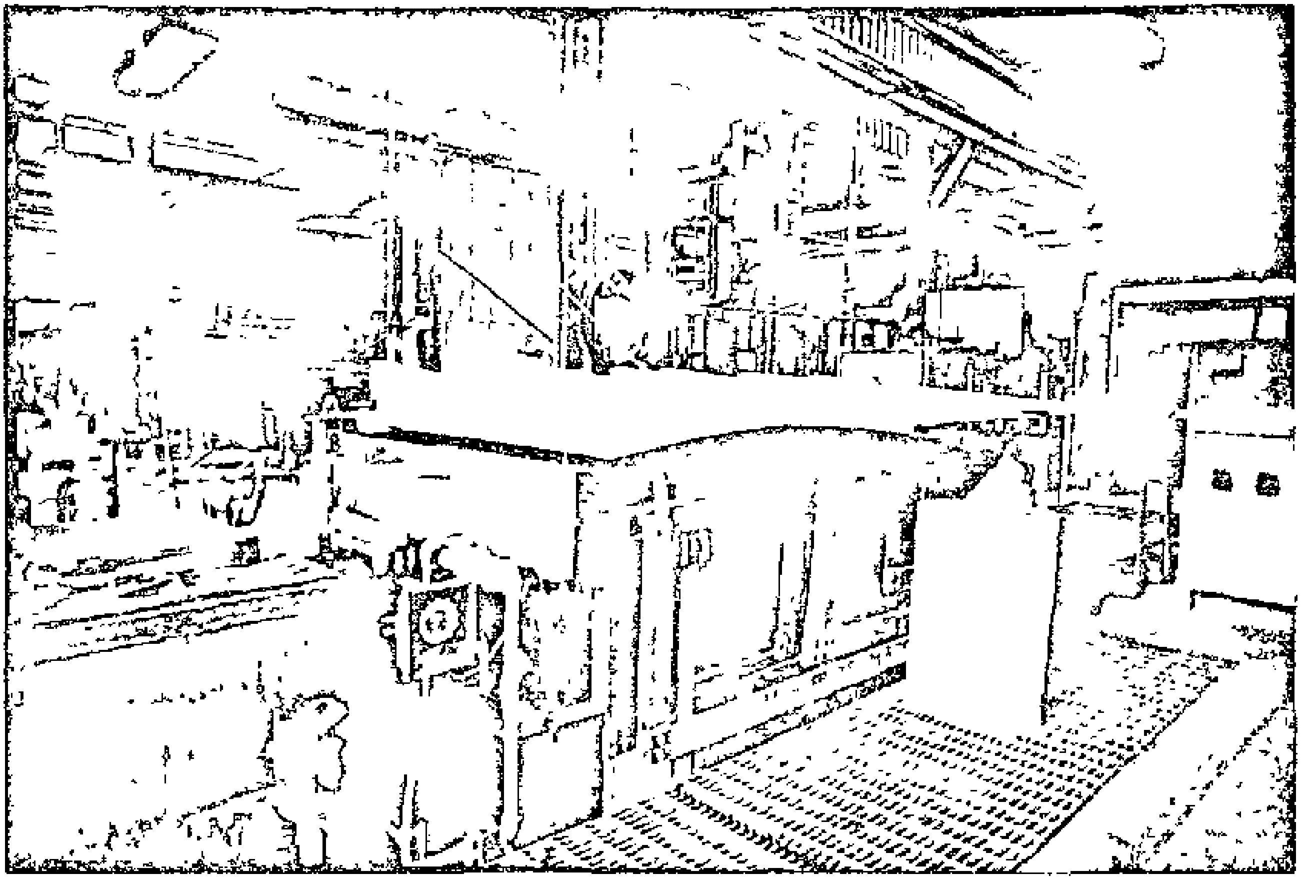

Figure 6. Tank C - front view with cover

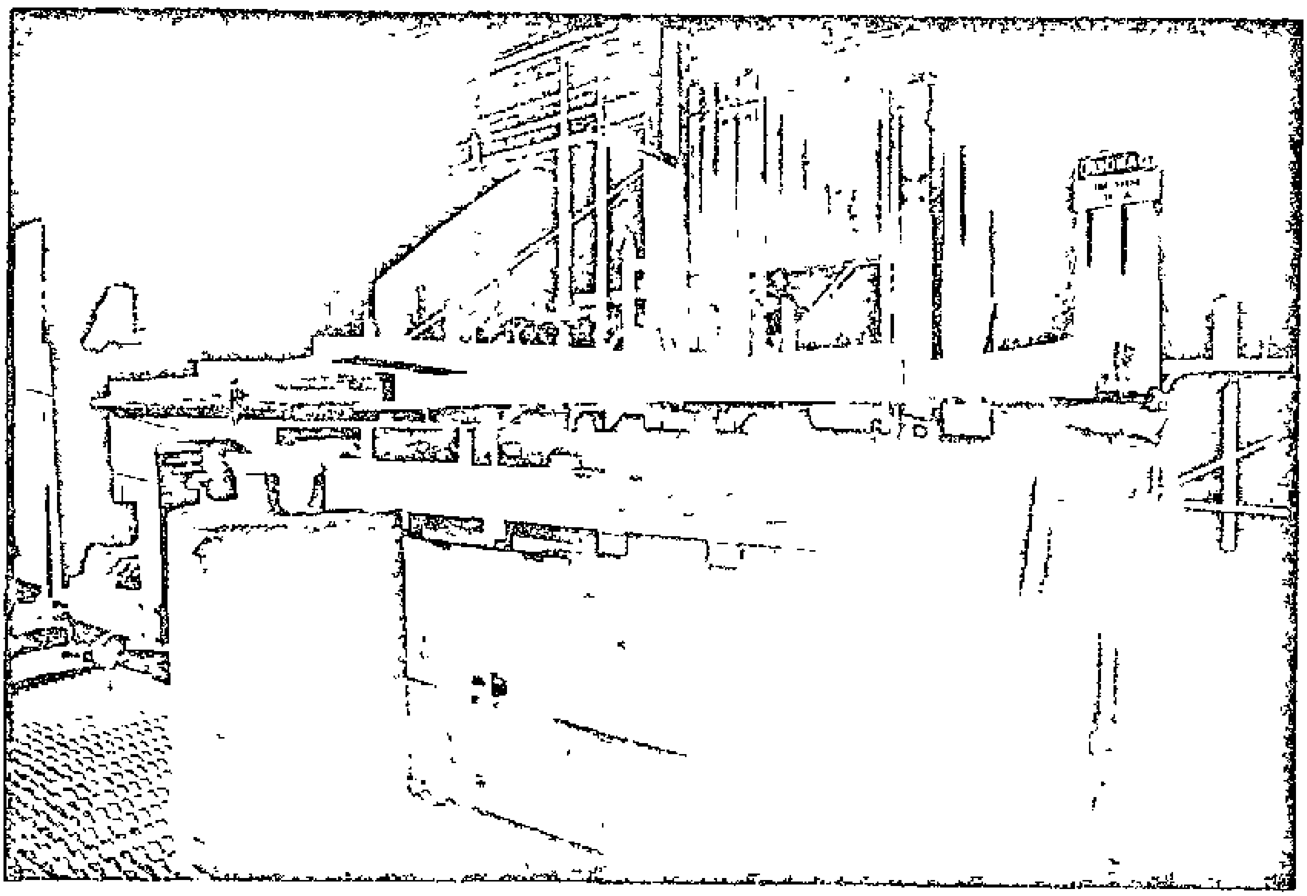

Figure 7. Tank D - front view with cover

Air Sampling Results (Tanks C and D)

Results of area and tank sampling for hexavalent chromium and total chromium are reported in Table 3, 4 and 5. Mean concentrations of all contaminants are within the maximum levels allowed by OSHA[5] and recommended by ACGIH[6] for an 8-hour period.

Discussion

The excellent control of hexavalent chromium and total chromium at Tank D can be attributed to effective local exhaust ventilation of the plating operation. The exhaust rates measured, however were well below the ACGIH recommended rates (250 cfm/ft^2) for control of chromic acid or sulfuric acid mists. Effective control was largely due to the presence of the covers. Control would be seriously comprimised by operating the tanks with the lids raised. However, the evolution of these mists was well controlled, as indicated by the low airborne concentrations of these substances. No plating was performed in Tank C during the survey; however, the exhaust hood was functioning to permit measurement of the air flow.

Personal Monitoring

Airborne levels of hexavalent chromium and total chromium in the breathing zone of the platers are reported in Table 6. The breathing zone samples were collected for the duration of the 8-hour day shift.

Mean concentrations of all personal exposures to CrVI were well below the maximum allowed by OSHA[5] and less than 25% of the level recommended by NIOSH[6] for an 8-hour time-weighted average exposure. Mean concentrations for personal exposures to sulfuric acid were one-twentieth the OSHA PEL and the NIOSH recommended concentration.

Discussion

The effective control of tank contaminants in the platers' breathing zones can be attributed to good local exhaust ventilation and to good work practices. Additionally, doors to the plant remained open during the summer, providing some natural dilution ventilation. When these doors are closed during the winter months exposures may be higher.

Table 6
Employee Exposure

Employee	Job Title	No. of Days Sampled	8-Hour TWA Concentrations (mg/m^3) Chromium VI	Sulfuric Acid
#1	Plater	3	0.005	0.053
#2	"	3	0.001	0.052
#3	"	3	0.002	0.053
#4	"	3	0.002	0.055
#5	"	3	0.003	0.053
Mean Exposure			0.003	0.053
OSHA PEL[5]			0.10	1.0
ACGIH TLV[6]			0.05	1.0
NIOSH Rec.[7]			0.025	1.0

Work Practices

Employee work practices were observed to determine their contribution to the overall effectiveness in controlling exposures[8]. To avoid skin contact with chromic acid solutions, employees usually wore protective gloves during the dipping and removal of parts from the plating tanks. Employees who were engaged in manual activities (e.g., masking of parts prior to plating), frequently washed their hands in a clear water tank provided for that purpose.

Generally, platers used hand-operated overhead hoists for transferring parts in and out of the tanks. However, on occasion, workers were observed standing on the side plenum of a tank to guide a part into the tank. Such a practice would increase the opportunity of mist inhalation and should be avoided.

Conclusions

Four hard chrome plating tanks were evaluated at this plant, all locally ventilated with single-slotted lateral or semi-lateral exhaust hoods. The data gathered indicate low airborne levels of hexavalent chromium and sulfuric acid as well as low personal exposures. This plant has demonstrated that safe and healthful working environments within electroplating operations involving potentially harmful chemical agents can be achieved with the use of effective engineering control technology, good work practices, and effective management.

References

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