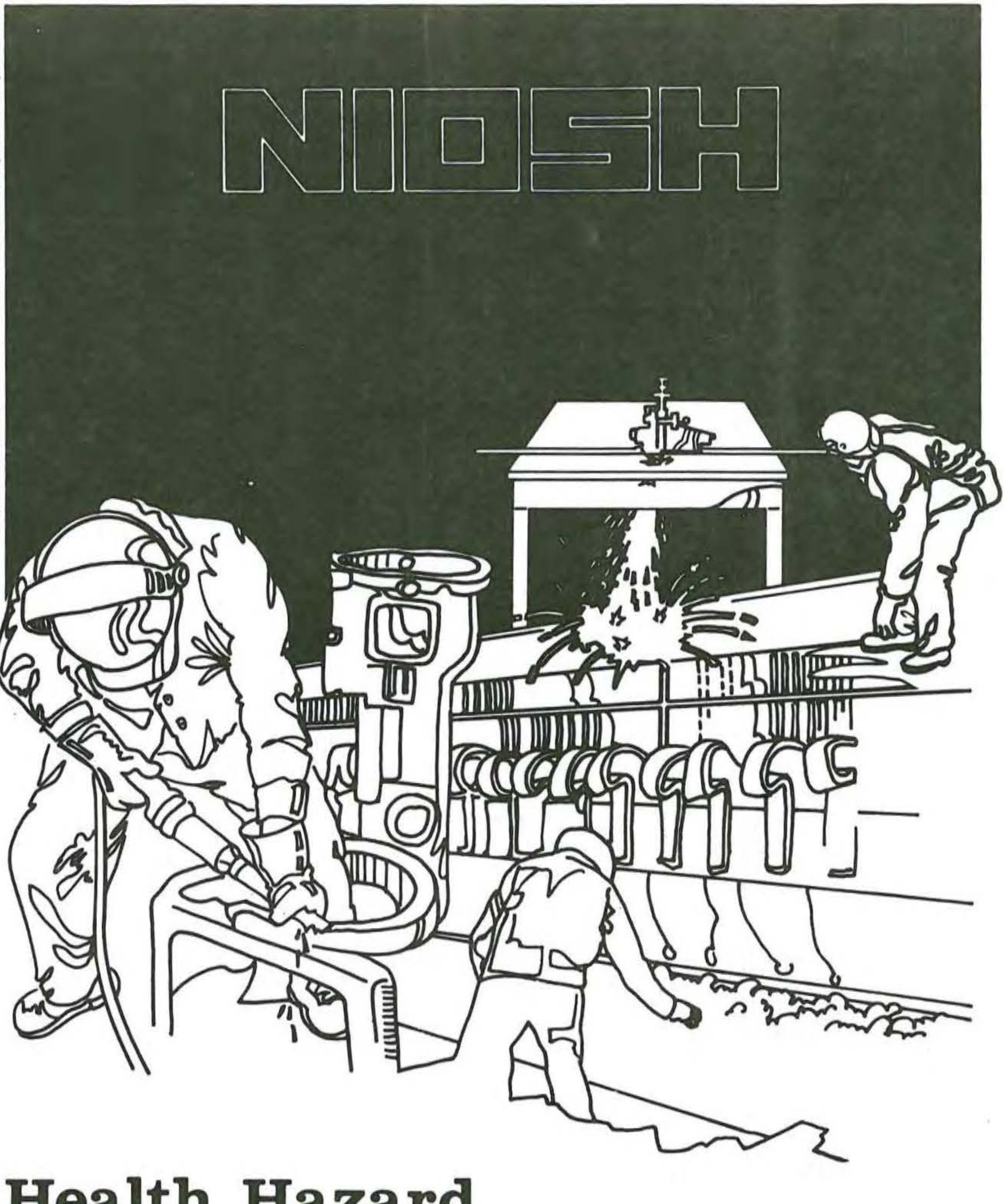
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public [illegible] Service
Centers for Disease Control ■ National Institute for Occupational Safety and Health

NIOSH



Health Hazard Evaluation Report

HETA 82-191-1267
ENGINEERED AIR SYSTEMS, INC.
ST. LOUIS, MISSOURI

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

HETA 82-191-1267
FEBRUARY 1983
ENGINEERED AIR SYSTEMS, INCORPORATED
(FORMERLY AMERICAN AIR FILTER COMPANY)
ST. LOUIS, MISSOURI

NIOSH INVESTIGATORS:
James M. Boiano, I.H.
Tar-Ching Aw, M.D.

I. SUMMARY

On April 1-2, 1982, a health hazard evaluation was conducted by the National Institute for Occupational Safety and Health (NIOSH) at Engineered Air Systems, Incorporated (formerly American Air Filter Company), St. Louis, Missouri. The evaluation focused on workers acutely exposed to sulfur dioxide (SO_2) following an industrial accident.

On the morning of March 18, 1982, SO_2 was released during chemical clean-up of a dip tank containing spent chromic acid solution. Sodium bisulfite, added to the tank as part of a disposal procedure, caused the evolution of SO_2 and subsequent evacuation of 148 workers in the plant. Air sampling for SO_2 the following day by the company's insurance carrier did not reveal detectable levels of SO_2 in the work area, indicating that the gas had dissipated overnight.

Twenty-seven percent of the employees (i.e., 40 workers) in the work area around the dip tanks were seen at the local hospital and/or by the company physician. The main symptoms experienced were cough (78%), chest discomfort (78%), and irritation of the throat (78%) and eyes (50%). Residual symptoms present two weeks after the incident include cough (8%), chest discomfort (30%), and irritation of the throat (18%) and eyes (4 workers). Nineteen chest X-rays were obtained and evaluated, out of the 28 done within two weeks of the incident. These chest X-rays did not show any chemical pneumonitis nor bronchopneumonia. The pulmonary function tests showed that one out of 28 results reviewed was abnormal, a finding which may not be associated with SO_2 exposure since results of similar tests done prior to the incident were unavailable for comparison. Other laboratory test results provided to NIOSH showed no recurrent pattern of abnormalities.

On the basis of the information obtained during the investigation, NIOSH has determined that a health hazard due to acute overexposure to sulfur dioxide occurred at American Air Filter Company on March 18, 1982. However, results of available medical tests did not show significant changes consistent with SO_2 exposure among the affected workers. Recommendations to prevent similar incidents from occurring in the future are presented in Section VIII of this report.

KEYWORDS: SIC 348 (Ordnance and Accessories), sulfur dioxide, sodium bisulfite, chromic acid, respiratory symptoms.

II. INTRODUCTION

On March 29, 1982, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Assistant Director of Safety and Health, International Brotherhood of Boilermakers, Iron Ship Builders, Blacksmiths, Forgers, and Helpers to conduct a health hazard evaluation at the American Air Filter Company, St. Louis, Missouri. The requestor asked NIOSH to evaluate workers who were acutely exposed to sulfur dioxide on the morning of March 18, 1982. The gas was evolved during chemical treatment of a dip tank solution prior to its disposal. In addition, the union expressed their concern about the possibility of other contaminants being generated during the treatment process.

NIOSH investigators conducted a combined environmental and medical evaluation at the plant on April 1-2, 1982. A letter was sent to the company and the union on April 16, 1982, summarizing the evaluation and presenting preliminary recommendations.

III. BACKGROUND

Engineered Air Systems, Incorporated, St. Louis, Missouri, employs 120 salaried and 150 production workers in the manufacture of environmental air control systems and ground support equipment for the Department of Defense. April 1, 1982 marked the first day the plant was operating under new ownership, purchasing the facility from American Air Filter Company.

At about 10:30 a.m. on March 18, 1982, workers attempting to clean out and desludge a dip tank containing spent chromic acid solution inadvertently produced sulfur dioxide (SO_2) while treating the solution with sodium bisulfite. (The bisulfite addition was part of a disposal procedure developed by Oakite Products, Inc., for chromium containing waste solutions.) Within a short period of time, workers quenched the reaction, but not before the SO_2 spread throughout the work area resulting in the evacuation of the plant. To prevent the possibility of further contamination, the dip tank was covered and vented outdoors. By 11:30 a.m., the plant was shut down and workers were sent home for the rest of the day. Some of the workers were taken to the local hospital and others were followed-up and evaluated by the company physician.

The following day, an industrial hygienist with the company's insurance carrier conducted an air sampling survey at the plant. Samples were collected for sulfur dioxide, and for total and hexavalent chromium. Concentrations of these contaminants were below the analytical limits of detection.

On March 25 (one week after the incident) the company hired a private consultant to collect additional air samples for SO_2. Spot measurements taken at various locations in the vicinity of the tank were nondetectable. Two samples taken inside the covered dip tank revealed levels of 5 and 7 ppm.

At the time of the NIOSH evaluation on April 1-2, 1982, the dip tank still remained covered and vented.

The weekend following the NIOSH visit, the company made another attempt to clean out the dip tank. The operation was completed without incident.

IV. METHODS

A. Environmental

NIOSH was notified 11 days after the incident, during which time environmental sampling had been conducted on two separate occasions with negative findings. Therefore, NIOSH did no further sampling but instead focused on collecting background and technical information relating to the March 18th incident. Information was obtained concerning the characteristics of the dip tank at the time of the incident, chemicals and procedures used in the treatment process, and standard operating procedures for the proper use of the specific Oakite products used to treat the spent chromic acid solution.

In order to address the question of whether other contaminants were generated in addition to SO_2, a chemist with the Division of Physical Sciences and Engineering, NIOSH, was contacted to discuss the chemistry of the reaction, given the chemicals used.

B. Medical

A medical questionnaire, dealing with symptoms experienced after exposure to the SO_2, was administered to all 40 employees seen by a physician. This included 20 workers who were seen at St. John's Mercy Hospital on March 18th and 20 workers who were subsequently seen by the company physician over the next one week. Results of chest X-rays, pulmonary function tests, and other investigations done in conjunction with this incident were obtained and evaluated.

V. EVALUATION CRITERIA

Sulfur Dioxide

Sulfur dioxide (SO_2) is a colorless, water-soluble gas which forms sulfurous acid (H_2SO_3) on contact with moisture. This reaction may occur on the mucous membranes lining the respiratory tract following inhalation of the gas. Acute inhalation causes immediate irritation of the respiratory tract and constriction of the respiratory air passages. This presents as cough, breathlessness, a choking sensation, and chest tightness or discomfort. Such effects are usually reversible on removal from further exposure.

Atmospheric levels of 1 to 3 ppm (parts per million) have been reported to cause severe narrowing of the respiratory air passages.[1] There is varying sensitivity among different individuals to the broncho-constricting effects of SO_2. Repeated exposure to 10 ppm have caused nosebleeds among exposed workers.[2] Acute inhalation of large amounts of sulfur dioxide can result in death from asphyxia.[3] Survivors can suffer from chemical bronchopneumonia and bronchiolitis obliterans (narrowing and inflammation of the small airways), which may be fatal after a few days. Bronchial asthma can also result following acute exposure to SO_2.[4]

In descriptions of the effects of ambient air pollution, SO_2 and other air pollutants have been said to contribute to or aggravate acute nonspecific upper respiratory tract disease, chronic bronchitis, emphysema, and lung cancer. These are usually the effects of long-term chronic exposure rather than single acute exposures.

NIOSH recommends that exposures to sulfur dioxide not exceed an 8-hour time-weighted average of 0.5 parts per million (ppm). The current OSHA standard is 5 ppm for an 8-hour TWA exposure.

VI. RESULTS

A. Environmental

The procedure used during the disposal treatment initiated on March 18th was developed by Oakite Products, Inc. It basically requires the use of two chemicals, sodium bisulfite and calcium hydroxide, with titration tests conducted before and during the operation to indicate acid strength and/or reaction endpoints. The purpose of the sodium bisulfite was to convert the hexavalent chromium to the disposably acceptable trivalent form. The calcium hydroxide was used to precipitate the trivalent chromium out of solution so that the liquid and sludge (precipitate containing heavy metals) could be properly handled for subsequent disposal.

The disposal treatment involved the addition of 400 lbs of sodium bisulfite into a 1100 gallon capacity dip tank (dimensions: 9.5'x5.0'x4.5'), containing approximately 500 gallons of a mixture of chronic, hydrofluoric, and nitric acids. The solution was at room temperature and was mildly agitated by air bubbles produced from a hose connected to a compressed air source. The bisulfite was mixed with water and pumped as a slurry into the tank in two - 200 lb batches. After the second batch was added, sulfur dioxide was liberated. Within a short period of time, workers terminated the reaction by adding calcium hydroxide to the tank.

Based on discussions with the NIOSH chemist, there was a possibility that other contaminants such as hydrogen fluoride, chromic acid mist, and nitric acid mist could have been formed during the upset condition. Their presence would primarily be dependent on whether localized heating or bubbling was present in the tank after the bisulfite was added. If these contaminants were evolved, it is suspected that they would have been present in much lower concentrations than the SO_2.

B. Medical

The characteristics of the 40 employees seen are as follows:

	Those Seen At Hospital On The Same Day	Those Subsequently Seen By The Company Physician
Age	median: 42.5 years range: 23-57 years	median: 39.5 years range: 21-54 years
Sex	14 males, 6 females	16 males, 4 females
Race	14 whites, 6 blacks	15 whites, 5 blacks

These 40 workers were all in the factory premises around the area of the dip tanks (i.e., painting, production, and assembly areas) at the time of the release of the SO_2. (A diagrammatic representation of the location of the dip tanks and an estimate of the number of workers in each area on the morning of the incident is presented in Figure 1). There were 148 workers in the plant on March 18th. Hence, 27% of the workers were seen by a physician in connection with the incident. These 40 workers consisted of 21 welders, 12 subassembly workers, and seven other staff members including maintenance and supervisory personnel.

1. Symptoms Experienced

The commonest symptoms experienced by the 40 workers interviewed were:

Symptom	No. of Workers with Symptom	Percent
cough	31	78
chest discomfort	31	78
throat irritation	31	78
eye irritation	20	50

Other symptoms mentioned were abdominal cramps, nasal irritation, nausea, and headache.

Cough was productive of sputum in 45% of those with cough. The duration of cough was:

Duration of Cough	Number of Workers	Percent	Number of Smokers	Number of Non-smokers
A day or less	12	39	7	5
>1 day to 1 week	8	26	3	5
>1 week to 2 weeks	8	26	2	6
>2 weeks	3	10	2	1

Note: There is no significant difference in the smoking history when workers with different durations of cough are compared.

Chest discomfort - this was described mainly as a sensation of tightness in the chest by 31 of the 40 workers (78%). A few workers mentioned actual chest pain. The duration of chest discomfort was:

Duration of Chest Discomfort	Number of Workers	Percent
A day or less	6	19
>1 day to 1 week	6	19
>1 day to 2 weeks	7	23
>2 weeks	12	39

Irritation of the eyes was reported by nine workers. This was of short duration in five workers, and was still present two weeks after the incident in four workers. Eighteen workers reported sore throat or dryness of the throat. In seven of these cases (39%), the symptom persisted for more than two weeks.

Amongst all 40 workers seen, those seen at the hospital on the same day tended to have more symptoms than those subsequently seen by the company physician. This is an expected observation, since those more severely affected would have been taken to the hospital for immediate treatment.

2. Clinical Investigations and Laboratory Tests

All 40 individuals seen had one or more of the following tests:

a. Chest X-ray
b. Pulmonary function test
c. Hematology and blood chemistry
d. Arterial blood gases
e. Electrocardiograms (EKG)

Chest X-rays - all 20 of those seen at the hospital, and eight out of 20 of those seen by the company physician had chest X-rays. NIOSH was provided with X-ray reports for only 19 individuals. Seventeen were reported as normal and two had calcified granulomas (a finding unrelated to SO_2 exposure). There was no report of chemical pneumonitis nor bronchopneumonia.

Pulmonary function tests (PFT's) - 36 of the 40 workers seen had PFT's. NIOSH was provided with PFT results for 28 individuals. The number of repeat PFT's after the incident varied from one to five for each individual. The PFT results for the 28 individuals provided showed that the first PFT's were done within a week of the incident for 19 individuals, and within the second week following the incident for nine individuals.

Analysis of these PFT results showed that 27 out of 28 (96%) had FEV_1/FVC (forced expiratory volume in one second divided by forced vital capacity) ratios of 70% or more. Values less than 70% indicate airways obstruction.[5] One worker had an FEV_1/FVC ratio of 53% on the day after the incident. Two repeat tests done within a week showed the ratio to be 38% (four days later) and 53% (six days later). The chest X-ray was normal. This worker is a smoker and does not have a history of obstructive airways disease. In the absence of PFT results prior to the incident it is uncertain whether in this one individual the reduction in FEV_1/FVC ratio is related to SO_2 exposure.

Other results - hematology and clinical chemistry results for eight workers were made available to NIOSH. This included six workers seen at the hospital and two seen by the company physician. Arterial blood gases were done for two patients and EKGs for three. No recurrent pattern of abnormalities were noted in these results.

VII. DISCUSSION AND CONCLUSIONS

A. Environmental

The reaction between sodium bisulfite and a strong acid is a common method of preparing sulfur dioxide.[6] Chromic, hydrofluoric, and nitric acids are readily reduced by the bisulfite to produce their respective acid salts, sulfur dioxide, and water, as illustrated in the following chemical equations:

$$2NaHSO_3 + H_2CrO_4 \rightarrow Na_2CrO_4 + 2SO_2 + 2H_2O$$

$$NaHSO_3 + HF \rightarrow NaF + SO_2 + H_2O$$

$$NaHSO_3 + HNO_3 \rightarrow NaNO_3 + SO_2 + H_2O$$

The reaction product of SO_2 was not unexpected as it was designed to reduce the hexavalent chromium present in the solution. What was unexpected, though, was the fact that the SO_2 was evolved from the solution and into the work environment.

The cause of the airborne evolution of large amounts of SO_2 is not known. It appears that, based on the information obtained, the lack of adequate mixing during the addition of the sodium bisulfite was a likely factor in its release. This situation could have caused localized heating which favors the liberation of SO_2 and possibly other contaminants. A similar situation would occur if the bisulfite was added to the solution too quickly. During the treatment what may have appeared to be a typical addition rate was probably too fast considering the reportedly poor mixing conditions.

B. Medical

The symptoms experienced by the workers seen at the hospital and by the company physician are consistent with those previously described for sulfur dioxide exposure.[3,4] The effects in this case are mild to moderate since some workers had symptoms lasting for a short duration, and others were still having symptoms two weeks after the incident. Complete data on clinical investigations and laboratory tests were not available. Hence, it is not possible to document all the clinical and biochemical effects experienced. Of the available results, the chest X-rays showed no radiological features of delayed pulmonary effects. The pulmonary function tests had some abnormalities in FEV_1 and FVC, the significance of which is difficult to interpret in the absence of previous PFT results.

VIII. RECOMMENDATIONS

1. A maintenance program should be established whereby the chromic acid dip tank is cleaned and desludged. The frequency with which this procedure should be done (according to Oakite Products, Inc.) is when the trivalent chromium concentration exceeds twice that of the hexavalent form as determined by routine titration monitoring.

2. Because of the relatively high toxicity of chromium compounds, the chromic acid dip tank should be equipped with local exhaust ventilation similar in concept to the pickling tank system suggested in VS-504 (Figure I). Design specifications and considerations, and an example of how to calculate airflow requirements for such a system, is presented in Appendix I.

3. Future attempts for the disposal treatment of spent chromic acid solution should preferably be done during the weekends when the factory workers are not present. Adequate ventilation and mixing should be ensured and workers involved provided with appropriate respirators, which provide protection against SO_2. Only trained personnel, aware of the chemical reaction, should participate in such a procedure. These recommendations should also apply to contractors employed in this purpose.

IX. REFERENCES

1. Doull J, Klaassen CD, Amdur MD (eds) (1980). Cassarett and Doull's Toxicology - the Basic Science of Poisons, 2nd Edition, MacMillan Publishing Co. Inc., New York, pp. 610.

2. National Institute for Occupational Safety and Health. NIOSH/OSHA occupational health guidelines for chemical hazards. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1981. (DHHS (NIOSH) publication no. 81-123).

3. National Institute for Occupational Safety and Health. Occupational diseases: a guide to their recognition. Revised ed. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1977. (DHEW (NIOSH) publication no. 77-181).

4. National Institute for Occupational Safety and Health. Criteria for a recommended standard: occupational exposure to sulfur dioxide. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1974. (DHEW publication no. (NIOSH) 74-111).

5. National Institute for Occupational Safety and Health. Manual of Spirometry in Occupational Medicine. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1981.

6. Siebring BR. Chemistry - The MacMillan Company, Collier - MacMillan Canada, Ltd, Toronto, Canada, 1967, pp. 278.

7. American Conference of Governmental Industrial Hygienists. ACGIH industrial ventilation: a manual of recommended practice. ACGIH Committee on Industrial Ventilation: Lansing, Michigan, 1982.

X. AUTHORSHIP AND ACKNOWLEDGEMENTS

Report Prepared by:	James M. Boiano Industrial Hygienist Industrial Hygiene Section
	Tar-Ching Aw, M.D. Medical Officer Medical Section
Acknowledgement:	John Palassis Chemist Division of Physical Sciences and Engineering
Originating Office:	Hazard Evaluations and Technical Assistance Branch Division of Surveillance, Hazard Evaluations, and Field Studies
Report Typed By:	Debra A. Lipps Jacqueline Grass Clerk-Typist Industrial Hygiene Section

XI. DISTRIBUTION AND AVAILABILITY OF REPORT

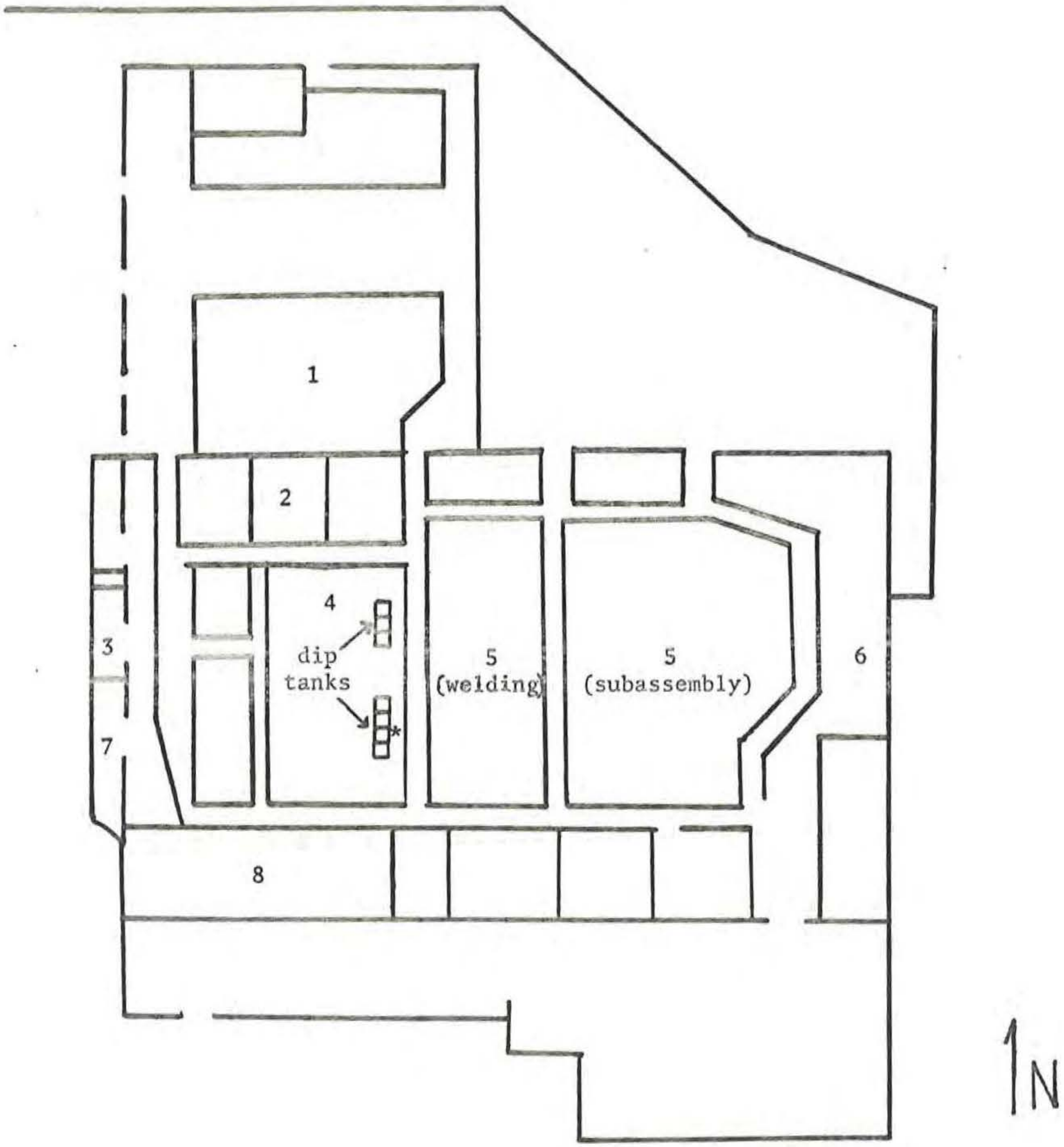
Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from NIOSH Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. Engineered Air Systems, Incorporated, St. Louis, Missouri
2. American Air Filter, Incorporated, Louisville, Kentucky
3. IBBISBBFH, National Headquarters, Kansas City, Kansas
4. IBBISBBFH, Local 1012, St. Louis, Missouri
5. Oakite Products, Incorporated, Berkeley Heights, New Jersey
6. NIOSH, Region VII
7. OSHA, Region VII

For the purpose of informing the 40 affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

FIGURE I

Schematic of Plant Layout Indicating the Location of the Dip Tanks and Distribution of Workers Present on March 18th by Work Area



Area	No. of Workers
① Assembly	31
② Machine-Shop	2
③ Testing	3
④ Painting	8
⑤ Production	23
⑥ Sheet-Metal	21
⑦ Crating	8
⑧ Assembly	31

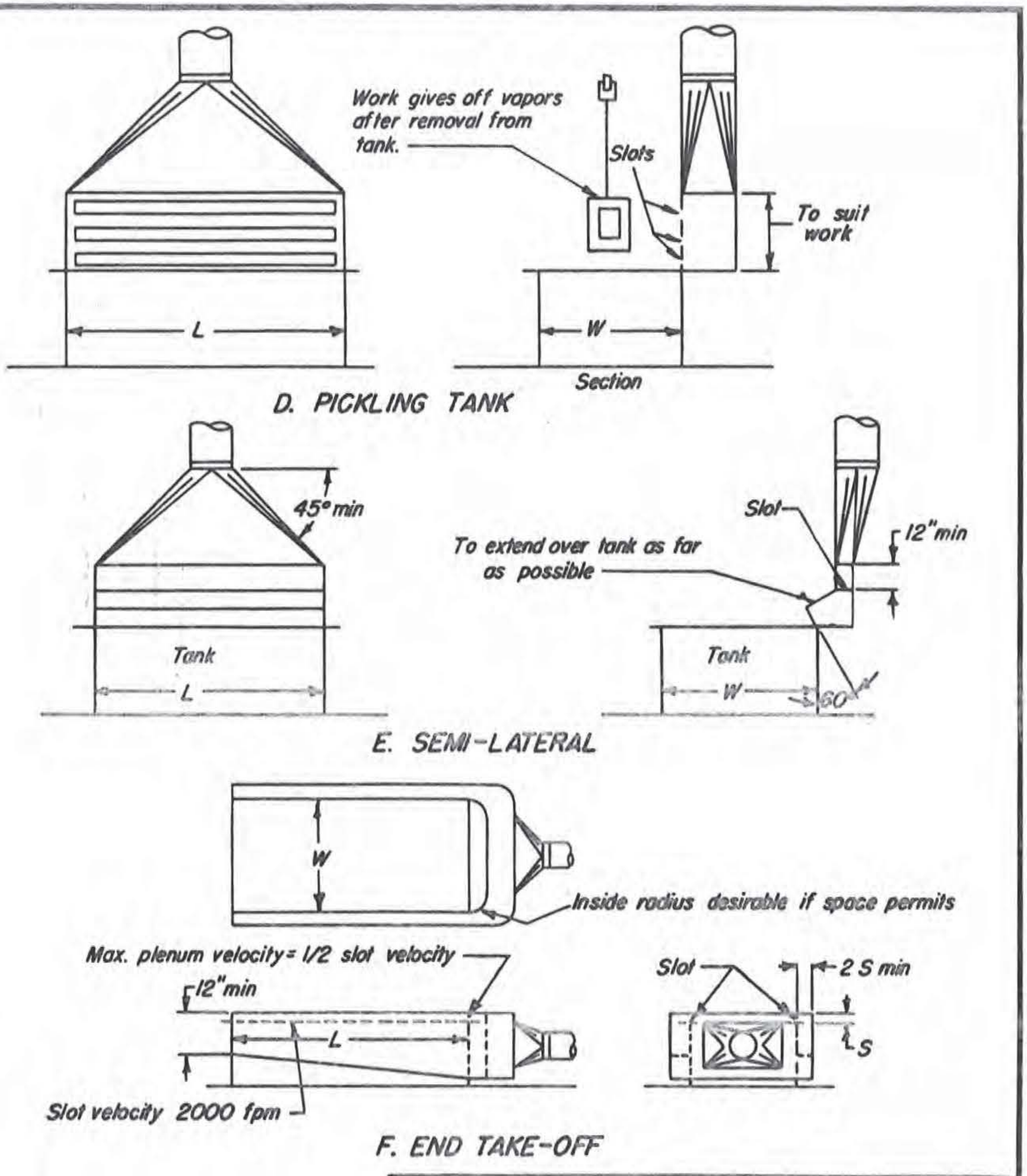
Not shown on map:

⑨ Stores - 7 workers
⑩ Maintenance - 6 workers
⑪ Inspection - 8 workers

NOTES: (1) work areas are "blocked off" for illustration and do not indicate the presence of partitions
(2) chromic acid dip tank is identified by asterisk

FIGURE 2

SPECIFIC OPERATIONS



AMERICAN CONFERENCE OF
GOVERNMENTAL INDUSTRIAL HYGIENISTS

OPEN SURFACE TANKS

DATE	1-66	VS-504

Source: see Reference 7

APPENDIX I

SPECIFIC OPERATIONS

OPEN SURFACE TANK DESIGN DATA

A. Duct velocity = any desired velocity (usually 1000-1200 fpm)

B. Entry loss = 1.78 slot VP plus duct entry loss.

C. Maximum plenum velocity = $\frac{1}{2}$ slot velocity.

D. Slot velocity = 2000 fpm unless distribution provided by well-designed, tapered takeoff.

E. Provide ample area at small end of plenum.

F. If L = 6 feet or greater, multiple takeoffs are desirable.
If L = 10 feet or greater, multiple takeoffs are necessary.

G. Tank width (W) means the effective width over which the hood must pull air to operate (i.e., where the hood face is set back from the edge of the tank, this set back must be added in measuring tank width).
If W = 20 inches, slot on one side suitable.
If W = 20 to 36 inches, slots on both sides are desirable.
If W = 36 to 48 inches, slots on both sides are necessary unless all other conditions are optimum.
If W = 48 inches or greater, local exhaust is not usually practical. Enclosure is best.

It is not practicable to ventilate across the long dimension of a tank whose ratio $\frac{W}{L}$ exceeds 2.0. It is undesirable to do so when $\frac{W}{L}$ exceeds 1.0.

H. Liquid level to be at least 6 inches below top of tank.

I. Hood types A, C, D and E are preferred--plenum acts as baffle to room air currents.

J. Provide enclosures or removable covers on tank if possible.

K. Provide ductwork with cleanouts and drains and corrosion-resistant coating if necessary. Use flexible connection at fan inlet.

L. Install baffles to reduce crossdrafts. If impossible, increase control velocity by vector analysis. Baffle is a vertical plate the same length as tank and with top of plate as high as tank is wide. If exhaust hood is on side of tank against a building wall or close to it, it is perfectly baffled.

Volume Calculation for Good Conditions (No crossdrafts, adequate and well-distributed makeup air):

1. Determine hazard potential from Table 5-5-1 using information from Threshold Limit Value, Solvent Flash Point, Solvent Drying Time Tables in Appendix or Table 5-5-6.
2. Determine contaminant evolution rate from Table 5-5-2 employing number denoting highest range (see Table 5-5-6).
3. From Table 5-5-3 choose minimum control velocity according to hazard potential, evolution rate and hood design (see Table 5-5-5 for typical processes).
4. From Table 5-5-4 select the cfm/sq ft for tank dimensions and tank location.
5. Multiply tank area by value obtained from Table 5-5-4 to calculate required air volume.

Example Problem:

Given: Chrome Plating Tank 6' × 2.5'.
High production decorative chrome.
Free standing in room.
No cross drafts.

a. Tank Hood. See VS-503. Use hood "A" along 6' side. Hood acts as baffle.
W = 2.5'
L = 6.0'
W/L = 0.42

b. Component - Chromic Acid

Hazard potential: A (From Table 5-5-1; From Appendix: TLV = 0.1 mg/m^3
Flash point = Negligible)
Rate of Evolution: 1 (From Table 5-5-2; From Table 5-5-6; Gassing rate = high)
Class: A-1
Control Velocity = 150 fpm (From Table 5-5-3)
Minimum Exhaust Rate = 225 cfm/ft^2 (From Table 5-5-4; Baffled tank, $\frac{W}{L}$ = 0.42)
Minimum Exhaust Volume = 225 × 15 sq ft = 3375 cfm

Source: see Reference 7

APPENDIX I (Con'td)

INDUSTRIAL VENTILATION

c. **Hood Design**

Design slct velocity = 2000 fpm

$$\text{Slot Area} = \frac{Q}{V} = \frac{3375 \text{ cfm}}{2000 \text{ fpm}} = 1.69 \text{ sq ft.}$$

$$\text{Slot Width} = \frac{A}{L} = \frac{1.69 \text{ sq ft}}{6 \text{ ft}} = 0.28 \text{ ft} = 3.375 \text{ in.}$$

$$\text{Plenum depth} = (2)\,(\text{slot width}) = (2)(3.375) = 6.75''$$

$$\text{Duct area} = \frac{Q}{V} = \frac{3375 \text{ cfm}}{2500 \text{ fpm}} = 1.35 \text{ sq ft.}$$ Use 16 in. duct, area = 1.396 sq ft.

$$\text{Final duct velocity} = \frac{Q}{A} = \frac{3375}{1.396} = 2420 \text{ fpm}$$

$$\begin{aligned} \text{Hood SP} &= \text{Entry loss} + \text{Acceleration} \\ &= 1.78\ VP_s + 0.25\ VP_d + 1.0\ VP_d \text{ (see Section 4)} \\ &= (1.78 \times 0.25'') + (0.25 \times 0.37'') + 0.37'' \\ &= 0.45 + 0.09 + 0.37 \\ \text{Hood SP} &= 0.91'' \end{aligned}$$

TABLE 5-5-1—DETERMINATION OF HAZARD POTENTIAL

HAZARD POTENTIAL	HYGIENIC STANDARDS		FLASH POINT (See Appendix)
	Gas and Vapor (See Appendix)	Mist (See Appendix)	
A	0-10 ppm	0-.1 mg/M^3	—
B	11-100 ppm	.11-1.0 mg/M^3	Under 100 F
C	101-500 ppm	1.1-10 mg/M^3	100-200 F
D	Over 500 ppm	Over 10 mg/M^3	Over 200 F

TABLE 5-5-2—DETERMINATION OF RATE OF GAS, VAPOR OR MIST EVOLUTION

Rate	Liquid Temperature of	Degrees Below Boiling Point	Relative Evaporation* (Time for 100% Evaporation)	Gassing**
1	Over 200	0-20	Fast (0-3 hours)	High
2	150-200	21-50	Medium (3-12 hours)	Medium
3	94-149	51-100	Slow (12-50 hours)	Low
4	Under 94	Over 100	Nil (Over 50 hours)	Nil

---

*Dry Time Relation (See Appendix).
Below 5 - Fast, 5-15 - Medium, 15-75 - Slow, 75-over - Nil.

**Rate of gassing depends on rate of chemical or electrochemical action and therefore depends on the material treated and the solution used in the tank and tends to increase with: (1) Amount of work in the tank at any one time; (2) Strength of the solution in the tank; (3) Temperature of the solution in the tank; and (4) Current density applied to the work in electrochemical tanks.

Source: see Reference 7

APPENDIX I (Con'td)

SPECIFIC OPERATIONS

TABLE 5-5-3—MINIMUM CONTROL VELOCITY (FPM) FOR UNDISTURBED LOCATIONS

Class (See Tables 5-5-1 and 5-5-2)	Enclosing Hood		Lateral Exhaust (See VS-503-504) (Note 1)	Canopy Hoods (See Fig. 4-14 & VS-903)	
	One Open Sides	Two Open Sides		Three Open Sides	Four Open Sides
A-1, and A-2 (Note 2)	100	150	150	Do not use	Do not use
A-3 (Note 2), B-1, B-2 and C-1	75	100	100	125	175
B-3, C-2, and D-1 (Note 3)	65	90	75	100	150
A-4 (Note 2), C-3, and D-2 (Note 3)	50	75	50	75	125
B-4, C-4, D-3 (Note 3), and D-4 ADEQUATE GENERAL ROOM VENTILATION REQUIRED (See Sec. 2)					

Notes: 1. Use aspect ratio to determine air volume, see Table 5-5-4 for computation.
2. Do not use canopy hood for Hazard Potential A processes.
3. Where complete control of hot water is desired, design as next highest class.

TABLE 5-5-4—MINIMUM RATE, CFM PER SQUARE FOOT OF TANK AREA FOR LATERAL EXHAUST

Required Minimum Control Velocity, fpm (From Table 5-5-3)	Cfm per sq ft to maintain required minimum control velocities at following $\frac{\text{tank width}}{\text{tank length}}\left(\frac{W}{L}\right)$ ratios.				
	0.0-0.09	0.1-0.24	0.25-0.49	0.5-0.99	1.0-2.0 Note 2
Hood against wall or baffled (See Note 1 below and Note L, Pg. 5.65). See VS-503 A and C, VS-504 D and E.					
50	50	60	75	90	100
75	75	90	110	130	150
100	100	125	150	175	200
150	150	190	225	[250] Note 3	[250] Note 3
Hood on free standing tank (See Note 1). See VS-503 B and VS-504 F.					
50	75	90	100	110	125
75	110	130	150	170	190
100	150	175	200	225	250
150	225	[250] Note 3	[250] Note 3	[250] Note 3	[250] Note 3

Notes: 1. Use W/2 as tank width in computing W/L ratio for hood along centerline or two parallel sides of tank. See VS-503 B and VS-504 F.

2. See Notes F and G. Pg. 5-65.

3. While bracketed values may not produce 150 fpm control velocity at all aspect ratios, the 250 cfm/ft^2 is considered adequate for control.

Source: see Reference 7

INDUSTRIAL VENTILATION

TABLE 5-5-5
Typical Processes
MINIMUM CONTROL VELOCITY (fpm) FOR UNDISTURBED LOCATIONS

Operation	Contaminant	Hazard	Contaminant Evolution	Lateral Exhaust Control Velocity See VS-503-504	Collector Recommended
Anodizing Alum.	Chromic-Sulf. Acids	A	1	150	X
Alum. Bright Dip	Nitric+Sulf. Acids	A	1	150	X
	Nitric+Phosphoric Acids	A	1	150	X
Plating -					
Chromium	Chromic Acid	A	1	150	X
Copper Strike	Cyanide Mist	C	2	75	X
Metal Cleaning (Boiling)	Alkaline Mist	C	1	100	X
Hot Water (If Vent Desired)					
Not Boiling	Water Vapor	D	2	50*	
Boiling		D	1	75*	
Stripping -					
Copper	Alkaline-Cyanide Mists	C	2	75	X
Nickel	Nitrogen Oxide Gases	A	1	150	X
Pickling - Steel	Hydrochloric Acid	A	2	150	X
	Sulfuric Acid	B	1	100	X
Salt Solution (Bonderizing & Parkerizing)					
Not Boiling	Water Vapor	D	2	50*	
Boiling		D	1	75*	
Salt Baths (Molten)	Alkaline Mist	C	1	100	X

*Where complete control of water vapor is desired, design as next highest class.

TABLE 5-5-6—AIRBORNE CONTAMINANTS RELEASED BY METALLIC SURFACE TREATMENT, ETCHING, PICKLING, ACID DIPPING AND METAL CLEANING OPERATIONS

Process	Type	Notes	Component of Bath which May be Released to Atmosphere (13)	Physical and Chemical Nature of Major Atmospheric Contaminant	Class (12)	Usual Temp. Range-F
Surface Treatment	Anodizing Aluminum		Chromic-Sulfuric Acids	Chromic Acid Mist	A-1	95
	Anodizing Aluminum		Sulfuric Acid	Sulfuric Acid Mist	B-1	60- 80
	Black Magic		Conc. Sol. Alkaline Oxidizing Agents	Alkaline Mist, Steam	C-1	260-350
	Bonderizing	1	Boiling Water	Steam	D-2,1 (14,15)	140-212
	Chemical Coloring		None	None	D-4	70- 90
	Descaling	2	Nitric-Sulfuric, Hydrofluoric Acids	Acid Mist, Hydrogen Fluoride Gas, Steam	B-2,1 (15)	70-150
	Ebonol		Conc. Sol. Alkaline Oxidizing Agents	Alkaline Mist, Steam	C-1	260-350
	Galvanic-Anodize	3	Ammonium Hydroxide	Ammonia Gas, Steam	B-3	140
	Hard Coating Aluminum		Chromic-Sulfuric Acids	Chromic Acid Mist	A-1	120-180
	Hard Coating Aluminum		Sulfuric Acid	Sulfuric Acid Mist	B-1	120-180
	Jetal		Conc. Sol. Alkaline Oxidizing Agents	Alkaline Mist, Steam	C-1	260-350
	Magcote	4	Sodium Hydroxide	Alkaline Mist, Steam	C-3,2 (15)	105-212
	Magnesium Pre-Dye Dip		Ammonium Hydroxide-Ammonium Acetate	Ammonia Gas, Steam	B-3	90-180
	Parkerizing	1	Boiling Water	Steam	D-2,1 (14,15)	140-212
	Zincete Immersion	5	None	None	D-4	70- 90

Source: see Reference 7

APPENDIX I (Con'td)

SPECIFIC OPERATIONS

TABLE 5-5-6—CONTINUED

Process	Type	Notes	Component of Bath which May be Released to Atmosphere (13)	Physical and Chemical Nature of Major Atmospheric Contaminant	Class (12)	Usual Temp. Range-F
Etching	Aluminum		Sodium Hydroxide-Soda Ash-Trisodium Phosphate	Alkaline Mist, Steam	C-1	160-180
	Copper	6	Hydrochloric Acid	Hydrogen Chloride Gas	A-2	70- 90
	Copper	7	None	None	D-4	70
Pickling	Aluminum		Nitric Acid	Nitrogen Oxide Gases	A-2	70- 90
	Aluminum		Chromic, Sulfuric Acids	Acid Mists	A-3	140
	Aluminum		Sodium Hydroxide	Alkaline Mist	C-1	140
	Cast Iron		Hydrofluoric-Nitric Acids	Hydrogen Fluoride-Nitrogen Oxide Gases	A-2,1 (15)	70- 90
	Copper		Sulfuric Acid	Acid Mist, Steam	B-3,2 (15)	125-175
	Copper	8	None	None	D-4	70-175
	Duralumin		Sodium Fluoride, Sulfuric Acid	Hydrogen Fluoride Gas, Acid Mist	A-3	70
	Inconel		Nitric, Hydrofluoric Acids	Nitrogen Oxide, HF Gases, Steam	A-1	150-165
	Inconel		Sulfuric Acid	Sulfuric Acid Mist, Steam	B-2	160-180
	Iron and Steel		Hydrochloric Acid	Hydrogen Chloride Gas	A-2	70
	Iron and Steel		Sulfuric Acid	Sulfuric Acid Mist, Steam	B-1	70-175
	Magnesium		Chromic-Sulfuric, Nitric Acids	Nitrogen Oxide Gases, Acid Mist, Steam	A-2	70-160
	Monel and Nickel		Hydrochloric Acid	Hydrogen Chloride Gas, Steam	A-2	180
	Monel and Nickel		Sulfuric Acid	Sulfuric Acid Mist, Steam	B-1	160-190
	Nickel Silver		Sulfuric Acid	Acid Mist, Steam	B-3,2 (15)	70-140
	Silver		Sodium Cyanide	Cyanide Mist, Steam	C-3	70-210
	Stainless Steel	9	Nitric, Hydrofluoric Acids	Nitrogen Oxide, Hydrogen Fluoride Gases	A-2	125-180
	Stainless Steel	9,10	Hydrochloric Acid	Hydrogen Chloride Gas	A-2	130-140
	Stainless Steel	9,10	Sulfuric Acid	Sulfuric Acid Mist, Steam	B-1	180
	Stainless Steel Immunization		Nitric Acid	Nitrogen Oxide Gases	A-2	70-120
	Stainless Steel Passivation		Nitric Acid	Nitrogen Oxide Gases	A-2	70-120
Acid Dipping	Aluminum Bright Dip		Phosphoric, Nitric Acids	Nitrogen Oxide Gases	A-1	200
	Aluminum Bright Dip		Nitric, Sulfuric Acids	Nitrogen Oxide Gases, Acid Mist	A-2,1 (15)	70- 90
	Cadmium Bright Dip		None	None	D-4	70
	Copper Bright Dip		Nitric, Sulfuric Acids	Nitrogen Oxide Gases, Acid Mist	A-2,1 (15)	70- 90
	Copper Semi-Bright Dip		Sulfuric Acid	Acid Mist	B-2	70
	Copper Alloys Bright Dip		Nitric, Sulfuric Acids	Nitrogen Oxide Gases, Acid Mist	A-2,1 (15)	70- 90
	Copper Matte Dip		Nitric, Sulfuric Acids	Nitrogen Oxide Gases, Acid Mist	A-2,1 (15)	70- 90
	Magnesium Dip		Chromic Acid	Acid Mist, Steam	A-2	190-212
	Magnesium Dip		Nitric, Sulfuric Acids	Nitrogen Oxide Gases, Acid Mist	A-2,1 (15)	70- 90
	Monel Dip		Nitric, Sulfuric Acids	Nitrogen Oxide Gases, Acid Mist	A-2,1 (15)	70- 90
	Nickel and Nickel Alloys Dip		Nitric, Sulfuric Acids	Nitrogen Oxide Gases, Acid Mist	A-2,1 (15)	70- 90
	Silver Dip		Nitric Acid	Nitrogen Oxide Gases	A-1	70- 90
	Silver Dip		Sulfuric Acid	Sulfuric Acid Mist	B-2	70- 90
	Zinc and Zinc Alloys Dip		Chromic, Hydrochloric Acids	Hydrogen Chloride Gas (If HCl attacks Z_n)	A-4,3 (15)	70- 90
Metal Cleaning	Alkaline Cleaning	11	Alkaline Sodium Salts	Alkaline Mist, Steam	C-2,1 (15)	160-210
	Degreasing		Trichloroethylene-Per-chloroethylene	Trichloroethylene-Per chloroethylene Vapors	B (16)	188-250
	Emulsion Cleaning		Petroleum-Coal Tar Solvents	Petroleum-Coal Tar Vapors	B-3,2 (15)	70-140
	Emulsion Cleaning		Chlorinated Hydrocarbons	Chlorinated Hydrocarbon Vapors	(17)	70-140

Notes: 1 Also Aluminum Seal, Magnesium Seal, Magnesium Dye Set, Dyeing Anodized Magnesium, Magnesium Alkaline Dichromate Soak, Coloring Anodized Aluminum
2 Stainless Steel before Electropolishing
3 On Magnesium
4 Also Manodyz, Dow-12
5 On Aluminum
6 Dull Finish
7 Ferric Chloride Bath
8 Sodium Dichromate, Sulfuric Acid Bath and Ferrous Sulfate, Sulfuric Acid Bath
9 Scale Removal
10 Scale Loosening
11 Soak and Electrocleaning
12 Class as described in Section 2 for use in Table 5-5-3 based on hazard potential (Table 5-5-1) and rate of evolution (Table 5-5-2) for usual operating conditions. Higher temperatures, agitation or other conditions may result in a higher rate of evolution.
13 Hydrogen gas also released by many of these operations.
14 Rate where essentially complete control of steam is required. Otherwise, adequate dilution ventilation may be sufficient.
15 The higher rate is associated with the higher value in the temperature range.
16 For vapor degreasers, rate is determined by operating procedure. See YS-501.
17 Class of operation is determined by nature of the hydrocarbon. Refer to Appendix A.

Source: see Reference 7

DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
CENTERS FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
ROBERT A. TAFT LABORATORIES
4676 COLUMBIA PARKWAY, CINCINNATI, OHIO 45226

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

Third Class Mail

U.S.MAIL

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF HHS
HHS 396