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MODERN PLATING CORPORATION
FREEPORT, ILLINOIS

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I. SUMMARY

On January 9, 1986, the National Institute for Occupational Safety and Health (NIOSH) was requested to evaluate employee exposures to chemicals used in electroplating operations at Modern Plating Corporation, Freeport, Illinois.

Following the completion of an OSHA investigation, NIOSH investigators conducted an initial survey visit in April 1986. A medical survey was conducted in June 1986, during which confidential medical interviews were conducted with the employees. An environmental survey was conducted in July 1986, during which personal breathing zone and area air samples were collected for inorganic acids, cyanides, metals, and trichloroethylene.

The results of the air samples collected for sulfuric acid, hydrochloric acid, cyanides, cadmium, chromium, nickel, copper, iron, zinc, trichloroethylene were all found to be below the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs). With the exception of a personal sample collected for cadmium on a lab technician, all of the samples were also below the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs). NIOSH recommends that cadmium, nickel, certain forms of hexavalent chromium, and trichloroethylene be considered potential human carcinogens, and exposure be reduced to the lowest feasible level (LFL).

The results of the medical questionnaires did not reveal the presence of any chronic health problems among the workers. Several employees did complain of acute respiratory irritation attributed to instances of addition of chemical to plating tanks and inadequate ventilation.

The environmental results represent the conditions at the time of the survey. Any changes in production or operating conditions may result in changes in the airborne contaminant concentrations. Also, several of the electroplating lines were not operational during the survey, and are not reflected in these results. In particular, the hard chrome line was not operating, and was not scheduled to be operated in the future. Due to the toxicity of chromium compounds and the degree of misting generally associated with this type of operation, a thorough assessment of employee exposures should be made if use of this line is resumed.

On the basis of the data collected during this survey, it has been determined that a potential health hazard existed from airborne exposure to cadmium for a laboratory technician. Although OSHA standards were not exceeded at the time of the survey NIOSH recommends that exposures to cadmium, chromium (VI) compounds, nickel, and trichloroethylene should be reduced to the lowest feasible level. Recommendations for engineering controls, personal protective equipment and work practices, designed to reduce employee exposures, are contained in this report.

KEYWORDS: SIC 3471, Electroplating, Metal Cleaning, Trichloroethylene, Metals, Cadmium, Chromium (VI), Nickel, Cyanide, Inorganic Acids.

II. INTRODUCTION

On January 9, 1986, NIOSH received a confidential request for a health hazard evaluation at the Modern Plating Corporation, Freeport, Illinois. The requestor was concerned with employee exposures to various chemicals used in electroplating operations at the plant and employee complaints of headaches, mucous membrane irritation, and nasal sores.

Concurrent with the NIOSH request, a similar request was filed with the Occupational Safety and Health Administration (OSHA) for an inspection of the facility. Following completion of the OSHA inspection, NIOSH investigators conducted an initial survey visit to the facility on March 21, 1986. An opening conference was held with representatives of plant management and the local union. During this survey, background information was obtained related to the basis of the request and the nature of plant operations. Following this meeting, a walk-through survey of the electroplating areas was conducted. On June 19, 1986, a medical survey was conducted at the facility and confidential employee interviews were conducted. An environmental survey was conducted on July 29 and 30, 1986. The results of the environmental samples were provided to the company and the requestor by letter on September 18, 1986, and August 6, 1987.

III. BACKGROUND

A. Plant History, Workforce, and Employee Duties

Modern Plating Corporation, Freeport, Illinois, has been involved in electroplating operations for over 50 years, and has been at its present location since 1961. The company provides electroplating services for a variety of customers who require specialized plating for their products. At the time of the survey, the plant employed 87 salaried and hourly staff. The majority of the plant production operations were carried out on the day shift, with limited operations occurring on the afternoon and evening shifts.

The duties of the production employees may vary depending on the degree of automation of the electroplating lines. On the more automated plating lines, the parts are passed through the various plating tanks on conveyor driven racks. On these lines, the employees generally are located at the "head end" of the lines to load the parts and at the "tail end" of the lines to remove the plated parts and check the condition of the finished product. On the manual plating lines, in addition to loading and unloading the racks or baskets, the employees are also required to move the parts from tank to tank, usually with the help of an overhead hoist. For all of the plating lines, it is periodically necessary for employees to enter the plating tank area to check the operating conditions of the plating baths and to maintain the solutions as needed.

B. Plant Operations

Several different types of electroplating processes were carried out at Modern Plating Corporation, including nickel, chrome, brass, copper, and zinc. A detailed listing of the electroplating operations which were present at the time of the survey is presented in Table 1. In lieu of providing a detailed discussion of each of the specific types of electroplating, due to the basic similarities of these processes, a general overview of the basic processes is provided below.

C. General Discussion of Electroplating

1. Metal Pretreatment

Prior to electroplating, a thorough cleaning of the surface of the workpiece or metal stock is required in order to ensure the proper adherence of the plating metal to the base metal. Commonly used pretreatment processes include solvent, acid, and alkaline cleaning. The process of solvent cleaning or vapor degreasing uses an organic solvent to remove grease, lubricants, and soluble soils. Acid solutions are used to remove layers of metal oxides. The process of removing thick layers of oxide is referred to as pickling. The process of removing thin oxide layers is referred to as bright dipping. Alkaline solutions are used to remove oils and solid soils from workpiece surfaces through their detergent action. Certain alkaline cleaners (electrolytic types) can be agitated by gas bubbles to enhance their effectiveness. Tanks or baths containing the pretreatment solutions are located at the beginning of each plating line. The particular arrangement and types of substances used is determined by the particular needs of the metal to be plated. A water rinse tank usually is located between each of these tanks.¹

2. Electroplating

Electroplating is an electrochemical process by which a metallic layer is deposited on a base metal through the action of an electrical current. Although different methods of electroplating exist, the process usually involves the use of an anode (composed of the metal to be plated), a cathode (composed of the part to be plated), and an electrolytic solution (containing metallic salts of the metal to be plated and acids, alkaline materials and other additives to impart stability or functional properties to the solution, e.g. brighteners). The application of an electrical current, usually from a low voltage DC power supply, causes a migration of the metal ions from the electrolyte solution to the cathode where they are deposited on the base metal. Metal from the anode then dissolves into the solution to replace the metal ions as they are depleted from the electrolyte.^{1,2}

During electroplating, the electric current passes through the plating solution resulting in the deposition of the plated metal on the cathode. However, inefficiencies in the electrochemical process result in a portion of the current causing the dissociation of water at the electrodes. This results in the release of hydrogen and oxygen gas bubbles which, as they rise to the surface of the tank, entrain plating solution droplets. These droplets are carried into the atmosphere and form a mist. The degree of misting from a particular operation often can be predicted by the current efficiency of the plating solution. In hard chromium plating, the current efficiency may be as low as 12% to 15%, resulting in severe misting; while in nickel plating, current efficiencies may run as high as 95% to 98%, resulting in much less misting.¹

D. Environmental Monitoring, Personal Protection, and Engineering Controls

Environmental monitoring by the company was carried out on a monthly basis. This consisted of the collection of detector tube samples for acetic acid, ammonia, carbon monoxide, chlorine, chromic acid mist, cyanide, hydrochloric acid, hydrogen cyanide, nitric acid, sulfuric acid, sulfur dioxide, and trichloroethylene. Personal protective equipment used by the employees included safety glasses, which were required when placing parts in the tanks. In addition, aprons, goggles, faceshields, rubber gloves, and respirators (for chromic acid) were made available to the chemical technicians who maintain the plating baths. Local exhaust ventilation also was present on several of the plating lines.

IV. MATERIALS AND METHODS

Prior to conducting the NIOSH evaluation, the results of the OSHA inspection conducted in January/February 1986 were reviewed. Although some general safety and health citations were issued following OSHA inspection, no overexposures to any air contaminants were found. In order to determine if further evaluation by NIOSH was necessary, an initial survey was conducted on March 21, 1986. Based on the information collected during this survey, it was decided that a medical survey would be conducted to determine if employees were experiencing any work-related health problems. Additional environmental sampling also would be conducted to further document the airborne contaminant levels.

A. Medical Survey

On June 19, 1986, a medical survey was conducted at the facility. Confidential interviews were conducted with each of 33 production employees who work in the plant. A questionnaire was used to obtain information regarding the employees work history and the presence of any general or work related health problems.

B. Environmental Survey

On July 29 & 30, 1986, an environmental survey was conducted during which personal samples (obtained near the employee's breathing zone) and general area samples (obtained in the immediate vicinity of the plating tanks) were collected to assess the airborne concentrations of the various contaminants. The selection of substances to be included in the sampling protocol was based on a consideration of the types of contaminants which could be released from the various processes, their toxicity, and the potential for employee exposure. A brief discussion of the specific rationale for the inclusion of substances in the sampling protocol is provided below.

1. **Metals** - Since a significant portion of the mist generated above electroplating baths generally consists of metal salts composed of the plating metal and the anionic constituent of the bath, the airborne concentrations of these substances were evaluated.² The sampling methodology which was used allowed for the analysis of multiple metals on each sample.
2. **Acid mists** - Airborne exposures to acid mists were evaluated due to the extensive use of acids in the various pretreatment and electroplating solutions. Since a number of different acids were present in the various metal pretreatment and plating baths, a sampling methodology was used which allowed for the analysis of multiple acid components on each sample.
3. **Cyanides** - Due to their high acute toxicity and widespread use in electroplating operations, samples were collected for airborne cyanides. These included both cyanide salt mists and hydrogen cyanide, both of which can be generated from electroplating processes.
4. **Organic Solvents** - Since trichloroethylene was used as a solvent in degreasing operations, air samples for this substance were also collected.

All samples were collected using battery-powered pumps which were attached by tygon tubing to the collection media. A complete listing of the sampling media, flow rates, analytical methodology and limits of detection is provided in Table 2. Specific information regarding the locations and durations of sample collection is provided in Tables 3 through 6.

V. EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week, for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a preexisting medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects often are not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and, thus, potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent becomes available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLV's), and 3) the U.S. Department of Labor/Occupational Safety and Health Administration (OSHA) occupational health standards [Permissible Exposure Limits (PEL's)]. Often, the NIOSH recommendations and ACGIH TLV's are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLV's usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used. The NIOSH-recommended exposure limits (REL's), by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is required by the Occupational Safety and Health Act of 1970 (29 USC 651, et seq.) to meet those levels specified by an OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits (STEL's) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high, short-term exposures.

A summary of the evaluation criteria and the major health effects of the substances evaluated in this survey are presented in Table 7.

VI. RESULTS

A. Medical

A total of 33 employee questionnaires were evaluated. Among these employees, no chronic work related health

effects or nasal perforation were noted. There were, however, several employees who complained of episodic mucous membrane irritation. These symptoms most commonly were associated with the addition of new acid to the plating baths in the areas in which the employees were working and when the local exhaust ventilation did not appear to be working properly.

B. Environmental Survey

1. Inorganic Acids

The results of the air samples collected for inorganic acids are presented in Table 3. All samples were analyzed for sulfuric and hydrochloric acid. Sulfuric acid was not detected in any of the ten personal samples above the limit of quantitation of 7 micrograms (ug) per sample. Hydrochloric acid was detected in 9 of the 10 personal samples, at TWA concentrations ranging from 0.05 to 0.22 milligrams per cubic meter of air (mg/M^3), with a mean of $0.13 \text{ mg}/\text{M}^3$. These results are below the OSHA PEL and the ACGIH TLV of $7 \text{ mg}/\text{M}^3$ as an 8-hour TWA. There is no NIOSH REL for hydrochloric acid.

2. Cyanides

The results of the air samples collected for cyanides are presented in Table 4. TWA concentrations of total cyanide in the six area samples collected ranged from 0.04 to $1.6 \text{ mg}/\text{M}^3$, with a mean of $0.66 \text{ mg}/\text{M}^3$. These concentrations are below the NIOSH REL, the OSHA PEL, and the ACGIH TLV of $5 \text{ mg}/\text{M}^3$ for cyanide as an 8-hour TWA. It should be noted that these samples are area samples which were collected adjacent to plating tanks where highest cyanide concentrations would be expected. Actual employee exposures would be expected to be much lower.

The analytical method used during this survey collects both particulate cyanide salts (on a filter) and hydrogen cyanide gas (in an impinger). While the NIOSH REL is expressed as the total amount of cyanide present in either of these forms, the OSHA and ACGIH specify separate criteria for HCN and cyanide salts. Although only a relatively small portion of the cyanide was found in the particulate form on the filter media, it is probable that some of the particulate material (cyanide salts) may have formed hydrogen cyanide (which would be particularly true under acidic conditions) where it would be trapped in the impinger. Since it is not possible to determine exactly the degree to which this might have occurred, the more restrictive OSHA and ACGIH criteria for cyanide salts have been applied in this instance.

3. Metals

The results of the air samples collected for metal analysis are presented in Table 5. The samples analyzed included four personal samples collected for employees working on electroplating lines, five area samples collected near plating baths at various electroplating lines, and one personal sample collected for a lab technician involved in various non-plating activities.

Cadmium was measured at TWA concentrations ranging from less than the limit of detection ($< \text{LOD}$) of $1 \text{ ug}/\text{sample}$ to $0.027 \text{ mg}/\text{M}^3$ in the four personal samples collected for the electroplaters, at TWA concentrations ranging from $< \text{LOD}$ to $0.0020 \text{ mg}/\text{M}^3$ in the five area samples, and at a TWA concentration of $0.196 \text{ mg}/\text{M}^3$ for the lab technician. NIOSH recommends that cadmium be considered a potential human

carcinogen, and exposure be reduced to the lowest feasible level (LFL).³ All of the results are below the OSHA PEL of 0.2 mg/M³, and with the exception of the sample collected for the lab technician, are below the ACGIH TLV of 0.05 mg/M³, as an 8-hour TWA.

Chromium was measured at TWA concentrations ranging from less than the limit of detection (<LOD) of 1 ug/sample to 0.0046 mg/M³ in the four personal samples collected for the electroplaters, at TWA concentrations ranging from <LOD to 0.0023 mg/M³ in the five area samples, and at a TWA concentration of 0.0046 mg/M³ for the lab technician. These results are below the OSHA PEL of 0.1 mg/M³, and the ACGIH TLV of 0.05 mg/M³, as an 8-hour TWA. Analysis of two additional area samples specifically for hexavalent chromium revealed TWA concentrations ranging from less than the limit of quantitation (<LOQ) of 0.2 ug/sample to 0.0034 mg/M³, which are also below the OSHA and ACGIH criteria.

The NIOSH criteria document for chromium (VI) recommends a REL of 0.025 mg/M³ for non-carcinogenic forms of chromic acid and mono and dichromates (dichromates) of hydrogen, lithium, sodium, potassium, rubidium, cesium, and ammonia.⁴ However, in several studies, soluble forms of chromium (VI) have been associated with excess lung cancers.¹ While these studies are not conclusive, it would be prudent to reduce exposure to all forms of chromium (VI) as low as possible.¹

Copper was measured at TWA concentrations ranging from less than the limit of detection <LOD of 1 ug/sample to 0.0042 mg/M³ in the four personal samples collected for the electroplaters, at TWA concentrations ranging from <LOD to 0.0025 mg/M³ in the five area samples, and at a TWA concentration of 0.016 mg/M³ for the lab technician. These results are below the OSHA PEL and ACGIH TLV of 1.0 mg/M³ as an 8-hour TWA, for copper salts. There is no NIOSH REL for copper salts.

Nickel was detected at TWA concentrations ranging from 0.0012 mg/M³ to 0.0052 mg/M³ in the four personal samples collected for the electroplaters, at TWA concentrations ranging from <LOD to 0.0052 mg/M³ in the five area samples, and at a TWA concentration of 0.039 mg/M³ for the lab technician. NIOSH recommends that nickel be considered a potential human carcinogen, and exposure be reduced to the lowest feasible level.⁵ All of the results are below the OSHA PEL and ACGIH TLV of 1.0 mg/M³, as an 8-hour TWA.

Iron and zinc were detected in these samples; however, as evidenced by the data contained in Table 5, their concentrations were far below their respective evaluation criteria.

4. Trichloroethylene

Table 6 presents the results of the area samples collected for trichloroethylene. TWA concentrations of 82.1 and 84.2 parts of trichloroethylene per million parts of air (ppm) were detected in long-term samples collected in the two samples. Since employees were only in the area of these tanks on a few brief occasions throughout the day, these values would not be representative of personal exposures. However, NIOSH considers trichloroethylene to be potentially carcinogenic and recommends reducing exposure to the lowest feasible limit.⁶ The OSHA standard for trichloroethylene is 100 ppm, and the ACHIH TLV for trichloroethylene is 50 ppm, as an 8-hour TWA.

VII. DISCUSSION AND CONCLUSIONS

The results of the environmental samples collected for cyanides and inorganic acids were all found to be below their respective evaluation criteria. However, several metals which NIOSH considers to be potentially carcinogenic (cadmium, chromium (VI), and nickel) were detected in both personal and area samples. The highest concentrations of these metals were found in the sample collected for the lab technician. This individual was not working on the plating lines, but was involved in a number of activities in other areas of the plant, including one activity described as "sludge treatment." While the exact nature of his activities is not known, it would be prudent to evaluate his job tasks carefully to determine his potential exposures.

The sample results indicated that the electroplaters also were exposed to low concentrations of potentially carcinogenic substances (cadmium, chromium, nickel). While the concentrations measured were below the OSHA PEL's and ACGIH TLV's, NIOSH recommends that exposure to these substances be reduced as much as possible. In instances where these materials cannot be substituted by substances with a lower order of toxicity, engineering controls, such as local exhaust ventilation, provide the most suitable means of exposure control.

Several of the employees working at the plating lines reported episodic symptomatology indicative of acute mucous membrane irritation. These episodes were often related to periods when new solutions were prepared in the plating tanks, or when local exhaust ventilation on certain plating tanks was not functioning properly. Whenever possible, for those tanks which are not equipped with local exhaust ventilation, chemical additions should be made during shifts when that particular line and adjacent lines are not operational. Care should be taken to ensure that the individual responsible for chemical addition is wearing the appropriate respiratory, face, hand, and body protection.

During the survey, several plating lines were noted to have either damaged or ineffective local exhaust ventilation. Examples include: 1) damage to a slot exhaust hood on the nickel chloride tank on Line 13, 2) no air movement into the slot hood on the chromic acid tank on Line 8, and 3) a damaged hood above a hydrochloric acid tank on Line 4. It would be prudent to provide ongoing attention to maintaining and improving the local exhaust ventilation systems within the plant. Control of process emissions by this method would result in a reduction of employee exposures and the risk of developing any chronic health problems. This also might reduce the episodes of acute respiratory irritation which were reported. Properly designed and functioning local exhaust systems also would be beneficial in other ways. An example of this would be the additional protection that would be afforded in the event of changes in operating conditions (i.e., increased bath temperatures or current densities) or process components which might result in either an increase in the concentrations or toxicity of the emissions. An efficient exhaust ventilation system would help to minimize the hazard that might occur from the accidental mixing of incompatible chemicals (i.e., acids and cyanide salts) that would release hydrogen cyanide, a highly toxic gas. Further, a properly designed and maintained local exhaust system would operate more efficiently, and thus reflect a cost savings over a poorly designed system.

The use of personal protective equipment is another area which should receive increased attention. During the survey, one employee was observed working at a plating tank without wearing eye protection. Since many of the chemicals used in plating operations are capable of causing severe burns or irritation upon direct contact with the skin or eyes, the appropriate eye protection should be worn. Each task must be evaluated carefully for this potential hazard. The selection of personnel protective equipment should be based on the potential for solution contact with any portion of the body. In instances where an employee's hands may come into direct or indirect contact with the plating solutions, the proper type of glove should be used to provide a suitable degree of impermeability to the particular solution. Ongoing training and supervision also is necessary to ensure that the proper personal protective equipment is selected and worn by the

employees during these tasks.

The environmental results presented in this report represent only the conditions present at the time of the survey. Therefore, any changes in production rates or operating conditions may result in changes in the airborne contaminant concentrations. In addition, several of the electroplating lines were not operational at the time of the survey, and are not reflected in the survey results. In particular, the hard chrome line was not operating, and was not scheduled to be operated in the future. Due to the toxicity of chromium compounds and the degree of misting generally associated with this type of operation, a thorough assessment of employee exposures should be made if use of this line is resumed.

VIII. RECOMMENDATIONS

Due to the fact that electroplating operations pose a variety of hazards from several different types of substances, a comprehensive health and safety program which minimizes exposure to all substances is necessary. In order to be effective, such a program should address proper planning, employee education, engineering and administrative controls, personal protective equipment, work practices, and personal hygiene. While the company has in place several key elements of this program, ongoing attention in each of these areas is necessary to further reduce the potential health hazards from these chemicals. The following recommendations are made to help further reduce employee exposures.

- 1) The existing ventilation system for the plating lines should be evaluated for major deficiencies which could adversely affect the performance of the overall system (i.e., damaged and non-functioning hoods). The correction of existing deficiencies, including the installation of new local exhaust ventilation, should take into consideration standardized design practices such as those provided in the American Conference of Governmental Industrial Hygienists "Industrial Ventilation", the American National Standards Institute "Practices for Ventilation and Operation of Open-Surface Tanks", and the Occupational Safety and Health Administration "General Industry Standards".^{7,8,9}
- 2) Local exhaust ventilation systems should be evaluated periodically for their effectiveness. This should include the use of smoke tubes or other suitable methods in order to evaluate qualitatively the airflow characteristics at the individual tanks. This evaluation should include the effects of room air currents and other external sources of air disturbance on the the ventilation system's performance. A quantitative evaluation of system performance should be made following any major changes or revisions in the systems to ensure that minimum recommended exhaust rates are achieved.⁷
- 3) In instances where engineering controls are not feasible and respirator use is necessary (i.e., maintenance work, tank cleaning, or other infrequent short periods of exposure), employees should be provided with a properly selected and fitted respirator. A respiratory protection program should be put into place that meets the requirements provided in the OSHA "General Industry Standards", 29 CFR 1910.134.⁹
- 4) Face shields, chemical goggles, splash aprons, arm coverings, gloves, and boots should be made readily available to the employees. Individual job tasks should be evaluated carefully, and the selection of the appropriate type(s) of protective equipment should be based on the potential for skin or eye contact with the various solutions. The employees should receive periodic training and adequate supervision to ensure the proper use of this equipment.

- 5) Employees should be encouraged to use work practices that minimize the risk of exposure at all times. This includes practices such as closing plating tank covers whenever possible. All tanks and storage containers should be labeled clearly and accurately to allow for easy identification of their contents and should be immediately re-labeled to reflect any changes in the solutions. Strict attention should be given to instructing employees as to the proper methods of storage and use of reactive chemicals. The "Electroplating Engineering Handbook" provides a discussion of the special precautions that need to be taken when reactive chemicals such as cyanides are being used.¹⁰
- 6) Proper personal hygiene procedures should be stressed for all personnel working on the electroplating lines. Hands should be washed regularly, particularly after contact with any of the solutions. Any skin problems (i.e., dermatitis) should be reported promptly to management and proper corrective actions should be taken. Regular housekeeping should be emphasized in the plating tank area, and the employee lunch room. Eating, drinking, or smoking should not be allowed in the vicinity of the plating lines.
- 7) Non-routine operations, such as those performed by the laboratory technician, should be evaluated carefully for exposure potential. Standard operating procedures should be prepared for all activities which may involve exposure to toxic substances. Such procedures should specify the appropriate work practices, engineering controls, and personal protection, to be used during these activities.

IX. REFERENCES

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XI. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

Copies of this Determination Report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, Information Resources and Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days the report will be available through the National Technical Information Services (NTIS), Springfield, Virginia. Information regarding its availability through NTIS can be obtained from the NIOSH publications office at the Cincinnati, address. Copies of this report have been sent to the following:

- A. Requestor
- B. Modern Plating Corporation
- C. U. S. Department of Labor, OSHA - Region V
- D. NIOSH Regional Offices/Divisions

For the purposes of informing the affected employees, copies of the report should be posted in a prominent place accessible to the employees, for a period of 30 calendar days.

TABLE 1
Some Potential Emissions of Metal Pretreatment and Electroplating Processes
 Modern Plating Corporation, Freeport, Illinois

Line Number	Line Description	Some Component(s) of the Baths Which May be Released into the Atmosphere
1	Black Oxide	alkaline mist, hydrochloric acid
2	Phosphate	sulfuric, hydrochloric, and phosphoric acids, antimony, cyanide
3	Zinc Hoist	alkaline mist, hydrochloric acid, zinc, chromium*
4	Cadmium Automatic	trichloroethylene, hydrochloric acid, cadmium, cyanide, chromium*
5	Organic Coater	stoddard solvent
6	Nickel Hoist**	sulfuric acid, nickel, cyanide, chromium* copper, zinc
7	Zinc Automatic	hydrochloric acid, cyanide, sodium hydroxide, zinc, chromium*
8	Stevens Automatic	sulfuric acid, nickel, chromium*, trichloroethylene
9	Zinc Jessup Barrel	hydrochloric acid, zinc, chromium*
10	Auto-Chromater	chromium*, sulfuric and acetic acids
11A	Hand-Chromater	chromium*, nitric and formic acids
11B	Pickle Line	hydrochloric acid
12	Jessup Cad Barrel	hydrochloric acid, cadmium, cyanide
13	Side Barrel Line	hydrochloric and sulfuric acids, nickel, cyanide, copper, zinc, cadmium, formaldehyde
14	Nickel Barrel	hydrochloric acid, nickel, cyanide, copper, zinc, chromium*
15	Zinc VIP**	hydrochloric, nitric, sulfuric, and acetic acids, zinc, chromium*
16	Laquer Room**	miscellaneous solvents
17	Lead Coating	lead, nitric acid
18	Degreaser**	trichloroethylene
19	Pan Line	nitric acid, chromium*

* Includes chromic acid and/or other forms of chromium, i.e., chromates

**Not operational at the time of the survey

TABLE 2
Sampling and Analysis Methodology

Modern Plating Corporation
 Freeport, Illinois
 July 30, 1986

Substance	Collection Media	Flowrate (LPM)	Analysis	Detection Limit (ug/sample)	NIOSH Reference Method
INORGANIC ACIDS (Sulfuric, Hydrochloric)	Silica Gel Tubes	0.2	Ion Chromatography	4.0	7903
CYANIDE AEROSOL (salts) and CYANIDE GAS (HCN)	0.8-um AA Filter followed in-line by Bubbler containing 10 ml 0.1 N KOH	1.0	Ion-Specific Electrode	0.1	7904
		1.0	Ion-Specific Electrode	0.1	7904
TRACE METALS	0.8-um AA Filter	1.5	Inductively Coupled Plasma, Atomic Emission Spectroscopy	1.0	0600
TRICHLOROETHYLENE	Charcoal Tube	0.2	Gas Chromatography	10	1003

Reference: National Institute for Occupational Safety and Health. NIOSH Manual of Analytical Methods, Volumes 1 & 2, Third Edition. Cincinnati, Ohio: National Institute for Occupational Safety and Health 1984. [DHEW(NIOSH) Publication No. 84-100].

TABLE 3
Results of Personal Breathing-Zone Air Samples Collected for
Hydrochloric and Sulfuric Acids
 Modern Plating Corporation
 Freeport, Illinois
 July 30, 1986

<u>Job Title/ Line Number*</u>	<u>Sample Duration (minutes)</u>	<u>Sample Volume (Liters)</u>	<u>TWA Concentration Hydrochloric Acid (mg/M3)</u>	<u>TWA Concentration Sulfuric Acid (mg/M3)</u>
Plater/Line 14	449	88.2	0.14	< LOD
Plater/Line 11A	450	88.0	0.10	< LOD
Plater/Line 2	440	93.6	0.20	< LOQ
Plater/Line 1	440	85.6	0.22	< LOD
Plater/Line 13	453	86.6	0.05	< LOD
Plater/Line 3	434	77.4	0.19	< LOD
Plater/Line 8	414	84.9	< LOQ	< LOD
Plater/Line 7	419	82.5	0.10	< LOD
Plater/Line 12	358	69.4	0.06	< LOD
Lab Technician	409	78.7	0.08	< LOQ
NIOSH Recommended Exposure Limit			NA	1.0
OSHA Permissible Exposure Limit			7.0	1.0
ACGIH Threshold Limit Value			7.0	1.0

Abbreviations and Key

TWA - Time-weighted average concentration (all sample results are expressed as a TWA for the duration of sample collection).

mgM³ - milligrams of contaminant per cubic meters of air

<LOD - Less than the limit of detection: 2 micrograms/sample for sulfuric acid and 1 microgram/sample for hydrochloric acid.

<LOQ - Less than the limit of quantitation: 7 micrograms/sample for sulfuric acid and 3 microgram/sample for hydrochloric acid. (Substances with this notation were detected, but not in high enough concentrations to reliably quantitate.)

NA - No applicable evaluation criteria

* Arbitrary Line Number - Refer to Table 1 for more descriptive information

TABLE 4
Results of Area Air Samples Collected for Hydrogen Cyanide

Modern Plating Corporation
 Freeport, Illinois
 July 30, 1986

<u>Sample Location/ Line Number*</u>	<u>Sample Duration (minutes)</u>	<u>Sample Volume (Liters)</u>	<u>TWA Concentration Cyanide (mg/M3)</u>
Next to cadmium cyanide bath/Line 13	180	180	1.00
Next to copper cyanide bath/Line 13	180	180	1.12
Next to cadmium cyanide bath/Line 12	180	180	1.61
Next to copper cyanide bath/Line 14	180	180	0.18
Next to sodium cyanide bath/Line 7	180	180	0.04
Next to cadmium cyanide bath/Line 4	180	180	0.07
NIOSH Recommended Exposure Limit			5.0
OSHA Permissible Exposure Limit			5.0
ACGIH Threshold Limit Value			5.0

Abbreviations and Key

TWA - Time-weighted average concentration (all sample results are expressed as a TWA for the duration of sample collection).

mg/M³ - milligrams of contaminant per cubic meter of air

* Arbitrary Line Number - Refer to Table 1 for more descriptive information

TABLE 5
Results of Environmental Samples Collected for Trace Metals
 Modern Plating Corporation, Freeport, IL (July 30, 1987)

<u>Sample Type</u>	<u>Sample Description/ Line Number</u>	<u>Sample Time (minutes)</u>	<u>Sample Volume (Liters)</u>	<u>TWA Concentration (Milligrams Per Cubic Meter of Air)</u>					
				<u>Cadmium</u>	<u>Chromium</u>	<u>Copper</u>	<u>Iron</u>	<u>Nickel</u>	<u>Zinc</u>
Personal	Plater/Line 13	453	906	0.0017	0.0012	0.0042	0.014	0.0014	0.0031
Personal	Plater/Line 11A	450	900	0.027	0.0046	0.0022	0.048	0.0012	0.045
Personal	Plater/Line 3	437	874	<LOD	<LOD	<LOD	0.0055	0.0013	0.0040
Area	Near baths/Line 7	419	838	<LOD	<LOD	0.0017	0.0095	0.0024	0.0050
Area	Near baths/Line 8	414	828	<LOD	<LOD	<LOD	0.0088	0.0022	0.0029
Area	Near baths/Line 12	358	716	0.0018	<LOD	0.0025	0.029	0.0018	0.0087
Personal	Plater/Line 14	147	368	<LOD	<LOD	0.0033	0.011	0.0052	0.0071
Area	Near baths/Line 10	320	640	0.0020	0.0023	<LOD	<LOD	<LOD	0.0019
Area	Near baths/Line 8	313	626	<LOD	<LOD	<LOD	0.0045	0.0032	0.0024
Personal	Lab Technician	409	818	0.196	0.046	0.016	0.064	0.039	0.17
NIOSH Recommended Exposure Level				LFL	0.025	NA	NA	LFL	NA
OSHA Permissible Exposure Limit				0.2	1.0	1.0	15.0	1.0	15.0
ACGIH Threshold Limit Value				0.05	0.05	1.0	1.0	1.0	10.0

Abbreviations and Key

TWA - Time-weighted average concentration (results are expressed as a TWA for the duration of sample collection).

* Arbitrary Line Number - Refer to Table 1 for more descriptive information

NA - No applicable evaluation criteria

LFL - Lowest Feasible Level

TABLE 6
Results of Area Air Samples Collected for Trichloroethylene

Modern Plating Corporation
 Freeport, Illinois
 July 30, 1986

<u>Sample Location/ Line Number</u>	<u>Sample Duration (minutes)</u>	<u>Sample Volume (Liters)</u>	<u>TWA Concentration Trichloroethylene (ppm)</u>
Next to degreasing tank /Line 18	59	9.11	5.1
Next to degreasing drum /Line 4	58	11.58	1.6
NIOSH Recommended Exposure Limit			LFL
OSHA Permissible Exposure Limit			100
ACGIH Threshold Limit Value			50

Abbreviations and Key

TWA - Time-weighted average concentration (all sample results are expressed as a TWA for the duration of sample collection).

ppm - parts of contaminant per million parts of air

* Arbitrary Line Number - Refer to Table 1 for more descriptive information

LFL - Lowest Feasible Level

Table 7
Evaluation Criteria and Health Effects Summary

SUBSTANCE	EVALUATION CRITERIA			PRIMARY HEALTH EFFECTS
	NIOSH REL	OSHA PEL	ACGIH TLV	
<u>Hydrogen Chloride</u> (Hydrochloric acid)	NA	7 mg/M ³ (C)	7 mg/M ³ (C)	High concentrations are very corrosive to eyes, skin, and mucous membranes. Skin contact with concentrated or HCL)HCL solutions can cause burns, and repeated contact with dilute solutions can cause dermatitis. Inhalation can result in burning, choking, coughing, laryngitis, bronchitis, pulmonary edema, and death. Long-term exposure may cause erosion of the teeth. ^{11,12}
<u>Sulfuric acid</u> (H ₂ SO ₄)	1 mg/M ³	1 mg/M ³	1 mg/M ³	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 sulfuric acid is irritating to the eyes, nose, throat, and skin and may cause scarring of the skin and blindness. Inhaled sulfuric acid can cause irritation of the eyes, nose, and throat, etching of dental enamel and edema of the lungs and throat. ^{11,12}
<u>Cyanides (as CN)</u>	5 mg/M ³ (10-min)	5 mg/M ³ (skin)	5 mg/m ³ (skin)	HCN when inhaled or cyanide salts when ingested can cause immediate collapse. High concentrations of cyanides can cause death due to chemical asphyxia. Lower concentrations can cause dizziness, headaches, weakness, confusion, nausea, and vomiting. Other effects are slow gasping respiration and eye and skin irritation. HCN gas has a bitter almond odor and can cause nose and upper respiratory tract irritation. ^{11,12}
<u>Hydrogen Cyanide</u> (HCN)	5 mg/M ³ (10-min)	11 mg/M ³	10 mg/M ³ (C)(skin)	

Table 7 (continued)

Evaluation Criteria and Health Effects Summary

SUBSTANCE	EVALUATION CRITERIA			PRIMARY HEALTH EFFECTS
	NIOSH REL	OSHA PEL	ACGIH TLV	
<u>Cadmium</u> (dust)	LFL	0.2 mg/M ³ 0.6 mg/M ³	0.05mg/M ³ 0.2 mg/M ³ (15 min)	Cadmium is an irritant to the respiratory tract. Inhalation of sufficiently large amounts of cadmium may cause coughing, chest pains, sweating and chills, followed by pulmonary edema. Cadmium may also cause kidney damage. Some cadmium compounds have been shown to cause excess lung cancer in human and animal studies. ^{3,12}
<u>Chromic Acid and Chromates</u> [for non-carcinogenic forms of Cr(VI)*]	0.025 mg/M ³ (LFL)	0.1 mg/M ³	0.05mg/M ³	In some workers, chromium compounds may act as allergens, causing dermatitis and pulmonary sensitization. In the hexavalent state [Cr(VI)], these compounds are irritating and corrosive to the skin and mucous membranes. Certain forms of hexavalent chromium have been found to cause respiratory cancer. ^{1,4}
<u>Copper salts (as CU)</u> (Including copper sulfate and cuprous chloride dust or mist)	NA	1 mg/M ³	1 mg/M ³	Copper salts act as skin irritants, causing itching, erythema, and dermatitis. They can also cause upper respiratory tract irritation, a metallic taste in the mouth, nausea, congestion of the nasal mucous membranes, salivation, vomiting, gastric pain, hemorrhagic gastritis, and diarrhea if introduced into the gastrointestinal tract. ^{11,12}
<u>Nickel</u>	LFL (0.015 mg/M ³)	1 mg/M ³ (soluble compounds)	0.1 mg/M ³	Skin sensitization is the most commonly seen toxic reaction to nickel and its compounds. Nickel is also an irritant to the eyes and mucous membranes of the respiratory tract. Due to concern about the potential carcinogenicity of nickel compounds, NIOSH recommends that occupational exposure to nickel be reduced to the lowest feasible level. ^{5,12}

*Includes chromic acid and mono and bichromates (dichromates) of hydrogen, lithium, sodium, potassium, rubidium, cesium, and ammonia. Refer to text for complete discussion of criteria.

Table 7 (continued)

Evaluation Criteria and Health Effects Summary

SUBSTANCE	EVALUATION CRITERIA			PRIMARY HEALTH EFFECTS
	NIOSH REL	OSHA PEL	ACGIH TLV	
<u>Iron Oxide (fume)</u>	NA	10 mg/M ³	5 mg/M ³	Inhalation of iron oxide fume can cause an apparently benign pneumoconiosis termed siderosis. ¹²
<u>Zinc Oxide (fume)</u>	5 mg/M ³	5 mg/M ³	5 mg/M ³	Inhalation of zinc oxide fumes may cause a metallic or sweet taste in the mouth, dryness and irritation of the throat, coughing at the time of exposure, and an influenza-like illness termed metal fume fever. ¹²
<u>Trichloroethylene</u>	LFL (25 ppm)	100 ppm 200 ppm (5-min) 300 ppm (P)	50 ppm 200 ppm (15-min)	Repeated skin contact may cause dermatitis. The vapor causes irritation of the eyes, nose, and throat. It can also cause central nervous system depression, with headache, dizziness, and other symptoms similar to alcohol intoxication. It has been shown to cause liver tumors in animals and is considered to be a suspect human carcinogen. ^{6,12}

ABBREVIATIONS AND KEY

All evaluation criteria are expressed as 8-hour (OSHA, ACGIH) or 10-hour (NIOSH) time-weighted averages (TWA's) unless a shorter duration of exposure is specified below the criteria. Those criteria noted with a "C" or "P" should not be exceeded at any time during the workshift.

Skin - Indicates a potential for contribution to the overall exposure through skin absorption.

LFL - Due to potential carcinogenicity, exposures should be reduced to the lowest feasible level. Values

appearing below the LFL designation usually indicate the lowest reliable limit of analytical detection at the time of the NIOSH recommendation.

mg/M³ - milligrams of contaminant per million parts of air

ppm - parts of contaminant per million parts of air

NA - No applicable standard or criteria