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I. SUMMARY

In November 1986, the National Institute for Occupational Safety and Health (NIOSH) received a request from the International Chemical Workers Union (ICWU) to evaluate employee exposures to chemicals used in the Metal Coated Fibers (MCF) Department at American Cyanamid in Wallingford, Connecticut. The request specified the employees' concerns of (a) dermatitis from exposure to nickel and synthetic graphite fibers, and (b) exposure to possible cancer-causing chemicals (methylene chloride and trichloroethane).

Between October and December 1987, environmental monitoring was done using both personal breathing zone and area air samples to characterize workers' exposure to chemicals in the MCF department. Environmental sampling revealed the following air concentration ranges, which are compared to their respective environmental exposure criteria (EC): methyl chloroform: 7.7 - 48.15 mg/m^3 (EC - 1910 mg/m^3, Occupational Safety and Health Administration (OSHA)), methylene chloride: 13.9 - 74.4 mg/m^3 (EC - lowest feasible level, NIOSH), nickel: 7.3 - 51.2 ug/m^3 (EC - 15 ug/m^3, NIOSH), synthetic graphite: 0.00003 - 0.23 mg/m^3 (EC - 10 mg/m^3, OSHA). Air supplied respirators were used where methylene chloride levels were measured; therefore, the air levels do not represent actual employee exposure.

During December 1987 and March 1988, a medical evaluation, including questionnaire, medical examination, and skin patch testing, was conducted. Fifty-six employees participated in the medical study; 31 had no workplace exposure to nickel solutions, sizing solutions or fibers; 19 were currently exposed; and 6 had previous but not current exposure. Seven employees had a work-related rash. MCF employees had a prevalence of work-related dermatitis 7 times that of non-MCF employees (RR = 7.04, 95% CI: 1.29, 38.6).

Twenty-three percent of participants reported a history of atopic (allergic) traits. Four of 5 atopic persons exposed to sizing compounds had a history of work-related rash, whereas none of the non-exposed atopic persons had such a rash. Only two employees had positive patch tests to nickel (2.5% and 5% solutions).

This study found excessive exposure to nickel and potential exposures to methylene chloride in the Metal Coated Fibers Department. This study also showed a positive relationship between occupational dermatitis and work in the MCF. This was observed, however, only for irritant dermatitis, not for allergic contact dermatitis. Furthermore, the relationship was statistically significant for workers with a prior history of atopic traits and appears to be due to exposures on the sizing line. Since it is not possible to identify persons at high risk with accuracy, all workers should be well trained in specific job assignments and monitored for the development of skin rash. Recommendations to reduce employee exposures to nickel and other chemicals are contained in Section VIII of this report.

Keywords: SIC 3471 (Electroplating, Plating, Polishing, Anodizing and Coloring), 3479 (Coating, Engraving, and Allied Services): plating, coating nickel, methylene chloride, trichloroethylene, synthetic graphite fibers

II. INTRODUCTION

In November 1986, NIOSH received a request from the International Chemical Workers Union (ICWU) concerning exposure of workers to nickel and nickel compounds, graphite fibers, methylene chloride, and methyl chloroform at the Metal Coated Fibers Department, Building 34, of the American Cyanamid Company in Wallingford, Connecticut. The union requested an evaluation of exposures resulting from the production of nickel-coated fiber, a new "high-tech" product for the electronic and computer industries. There was also concern regarding the carcinogenic potential of the chemicals listed above.

III. BACKGROUND

On April 2, 1987, a site visit was made to the plant by a NIOSH industrial hygienist and an epidemiologist. There was a preliminary meeting with the management personnel, both corporate and local, and the local union president and union steward. A walkthrough evaluation was conducted of Building 34, the location of the Metal Coated Fibers (MCF) Department.

Process

The MCF Department was started in November 1983 as a new business for commercial development and was constantly being modified. The first concept was to unwind graphite fiber as a continuous strand through plating tanks, plate nickel onto the fiber, dry it, and rewind it. Later, a second operation put other materials, such as epoxy resins, on the nickel-coated fiber and then cut the fiber into various sizes, some as short as 1/4 inch. The materials are used as lightning rods and also to add conductivity to computer housings and molded plastic materials.

Twenty-four employees worked in the MCF Department at the time of the first NIOSH visit (in April 1987): 12 production line workers, 3 supervisors, 1 quality control technician, 2 maintenance mechanics, 1 quality control supervisor, and 5 engineers. In the year prior to the first NIOSH visit, four people transferred out of the MCF Department, because of dermatitis. The MCF Department operates three shifts, five days per week.

During the April 1987 visit to Building 34, there were two plating lines operational, and one large plating line shut down for maintenance. The plating tanks throughout the operation are normally shut down one to two days every two weeks.
Plating lines 2 and 3 operate in a similar fashion. At one end there is a payout booth which contains as many as 12 spools of graphite fiber. The payout booth is acoustically lined and is ventilated through filters in the rear. The fibers move through a prewash section to the plating tanks, which are ventilated, to a rinse section, to hot rollers (to dry the thread), to a winder, which has sound-absorbing material on the back and sides and a ventilation system in the rear. The thread that comes across the system from the payout booth is called the tow. The number of fibers per tow varies considerably, and the diameters of the threads are measured in fibers per tow.

The spools are wound to a certain length and then packaged for shipment. The small line that was observed on April 2, 1987 produces an average 85,000 feet per shift of nickel-coated graphite fiber.

A third line contains a sizing operation, which coats an epoxy material on the tow. The epoxy carrier is methylene chloride (5% by volume). The company estimates that methylene chloride usage is five gallons per day. After the tow has been dipped, it proceeds through an enclosed drying line, which consists of a home-made enclosure with 8 entry ports of each side. At the time of the April visit, a portable hair dryer was inserted in each port to dry the fibers.

After the tow comes through the dryer, it goes either to a cutter, which cuts it into lengths several feet long, or through a chopper, which cut it to lengths as small as a quarter inch, called dry blend. Dry blend is blended with plastic and extruded to make plastic conductive. It can also be used for several other applications. This line was not operating when subsequent environmental surveys were done in October and December of 1987 and was to be phased out.

There is another, newer sizing operation beside the older unit. Here the sizing is mixed in an enclosed tank. The tow moves through the sizing and then through a large enclosed commercial dryer. From there it proceeds to an auxiliary chopper and is cut to size. The dry blend is placed in plastic bags, weighed, and packaged in large cardboard boxes for shipment. The bagging, weighing, and shipping operation is all done by hand.

Personal Protective Equipment

Work pants and shirts are provided daily. Hard hats, glasses, and safety shoes are also provided by the company and are required throughout the plant. On the plating line, the employees had a choice of whether to wear disposable coveralls over their work clothes. During the environmental investigations, all the employees observed wore the disposable coveralls, gloves, aprons, and boots. The plating tanks were provided with splash guards and exhaust ventilation. Half-face respirators (with dust and mist filters) were provided, but their use not required.

Employees are required to wear air supplied respirators, gloves, disposable coveralls, and aprons when accessing the mixing booth and sizing tank containing methylene chloride.

IV. EVALUATION DESIGN AND METHOD

Environmental monitoring was done on October 7-8, 1987 to evaluate the exposure to nickel and total dust and on December 7-8, 1987 to evaluate exposure to methylene chloride and methyl chloroform. The medical survey was done in December 1987 and March 1988.

A. Environmental

The environmental evaluation used both personal breathing zone and area air samples to characterize worker exposures to chemicals in Building 34. The collection media, reference analytical procedures, and flow rate are presented in the following table. The flow rate is in liters per minute (lpm) or cubic centimeters per minute (cc/min.).

SUBSTANCE	COLLECTION DEVICE	FLOW RATE	ANALYSIS	REFERENCE
Total dust	Tared PVC filter	2 lpm	Total weight gravimetric	NIOSH Method 0500
Nickel	MCEF filter	1.8-2.5 lpm	Flame AA*	NIOSH Method 7300 S206
Methylene chloride	Charcoal tube	20 cc/min	G.C.-F.I.D.**	NIOSH Method 1003
1,1,1-trichloro ethane	Charcoal tube	20 cc/min	G.C.-F.I.D.	NIOSH Method 1005

* AA - atomic absorption
** G.C.-F.I.D. - gas chromotography with flame ionization detector

1. Plating - October 1987

Nickel

Three stationary, long-term area air samples were collected over three shifts: at the plating workbench, eye wash fountain, and the edge of the plating line. Seven personal breathing zone samples were also collected from the plating line operators over the same three shifts.

Total Dust

Total dust samples were taken as a method for evaluating possible exposure to synthetic graphite or other particulate matter. Three stationary area air samples were taken at the top of the chopper, in the packaging area, and in the weighing area. There the synthetic fibers were cut into one-inch pieces, weighed and packaged for shipment. One personal breathing zone sample was taken on one operator who was both feeding the machine and packaging the chopped dry blend.

2. Sizing Operation - December 1987

Methylene Chloride and 1,1,1-trichloroethane

The sizing operation was evaluated to determine employee exposure to methylene chloride and 1,1,1-trichloroethane. Ten personal breathing zone air samples were taken over the three-shift period. Ten stationary, long-term area air samples were taken at the dip tank and the oven exit. Methylene chloride and 1,1,1-trichloroethane are not used in the operation on a daily basis, but rather only when there is a special order which requires these materials. Latex sizing is used routinely.

B. Medical

The study population consisted of 2 groups: 1) all past and present employees who had ever been exposed to chemicals in the metal coated fibers department, (Group 1) and 2) an equal number of randomly selected employees who had never been occupationally exposed to chemicals in MCF (Group 2). Group 1 employees were identified through management and union work history records. All individuals in this group were asked to participate. Group 2 individuals were selected randomly, after stratifying for sex and age, from a seniority list of hourly workers supplied by the union. Any individual who was absent from work on the initial day of each study period was replaced by a randomly selected, age and sex-matched substitute. Half of the exposed and unexposed individuals participated in December 1987, and the remainder in March 1988. Informed consent was obtained from all participants, followed by completion of a questionnaire, and application of the skin patch test. A NIOSH dermatologist, who was unaware of an individual's exposure status, conducted physical exams of exposed skin and interrupted patch tests at 72 and 96 hours after initial application of the patches. Employees were notified of their individual results at the time of the final patch test reading. Medical records of all persons who ever worked in the MCF Department, and work history records of all persons asked to participate in the study, were obtained from the company.

Allergy to MCF chemicals was assessed by closed skin patch testing. Standard Finn chambers on Scanpor were used to apply the closed patch test.[1,2] All patch test allergens were prepared according to International Contact Dermatologist Research Group (ICDRG) standards[3] in NIOSH laboratories under the guidance of the NIOSH dermatologist. Uniformity of dispersion for the nickel in petrolatum was verified by dimethylglyoxime testing. Patch tests were applied to the lateral aspect of the upper arm in all cases but one individual, whose patch test was applied to the upper back. Patches were removed at 48 hours, and interpreted 72 and 96 hours after initial placement. To help differentiate an allergic from an irritant reaction, patch testing was done with both 2.5% and 5% nickel sulfate in petrolatum. To test for allergies to other MCF antigens, the following concentrations were also tested: bisphenyl-A epoxy resin, 1% in petrolatum; formaldehyde, 1% aqueous solution; and boric acid, 5% in petrolatum. Untreated polyacrylonitrile fibers, and

clean cotton flocked and unflocked work gloves provided by the manufacturer were also tested. Petrolatum and a blank Finn chamber were tested as controls. Methylene chloride, saccharin, and 1,1,1-trichloroethane were not tested because of the lack of evidence that they are sensitizers. A test was considered positive if, at 72 or 96 hours, there was red, raised skin with (a) a few pimple-like eruptions (a "+2" reaction), or (b) closely set vesicles, spreading beyond the margins of the patch (a "+3" reaction).

The self-administered questionnaire was completed by each participant under the supervision of a NIOSH investigator. Questions were designed to obtain demographic information, work history, and job practices. A history of skin rashes and medical conditions that could produce effects similar to those of nickel exposure were also ascertained. In addition, a series of questions was asked to determine an individual's atopic status. Disease status was assessed by two separate methods. The questionnaire was used to define two categories of disease: 1) any employee who reported any skin rash since December 1983 on his/her face, neck, arms, hands, or fingers was considered a potential rash case; and 2) any employee so defined as a rash case whose rash improved on weekends/vacations or with job/work area changes was considered a work-related rash case. On the basis of examination of exposed skin, participants were classified as having: 1) no skin disorder; 2) a non-occupational skin disorder (such as fungal infections, acne, and scarring); 3) physical findings consistent with solvent dermatitis (defined as inflamed, chapped skin on the dorsum of the hands, with or without involvement of other areas); and 4) physical findings consistent with contact dermatitis (defined as papular inflamed lesions on the dorsum of the hands, with or without involvement of other areas).

Occupational exposure status for each worker was determined using company, NIOSH, and OSHA industrial hygiene data combined with individual work history and job practices obtained by the questionnaire. A worker was considered exposed to chemicals in the MCF if he/she had ever worked in the MCF and reported mixing solutions or working on either the plating or sizing line an average of 1 day a month or more. Subclassifications of exposure into nickel-exposed, sizing-exposed, and fiber-exposed were based on the predominant exposure for that job task, as determined by industrial hygiene data and dimethylglyoxime testing. A worker was considered exposed to nickel if he/she had been an employee in MCF, as determined by the above records, and reported mixing nickel solutions or working on the plating line an average of 1 day a month or more. A worker was considered exposed to sizing if he/she had been an employee in MCF, as determined by the above records, and reported mixing sizing solutions or working on the sizing line an average of 1 day a month or more. A worker was considered exposed to fibers if he/she had been an employee in MCF, as determined by the above records, and reported working on the plating or sizing lines an average of 1 day a month or more.

An individual was classified as atopic if he/she had ever had one of the following: 1) chest tightness, wheezing, shortness of breath, or prolonged coughing in association with exposure to inhalants (pollen, animal dander, dusts, or molds); 2) watery, itchy eyes; itchy, stuffy or runny nose; or frequent sneezing in association with exposure to inhalants (such as pollen or animal danger); or 3) a history of rash in the creases of his/her elbows or knees as an adult or child.

V. EVALUATION CRITERIA

Environmental

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 of workers may experience adverse health effects because of individual susceptibility, a pre-existing medical condition and/or by 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 are often 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 become available.

The primary sources of environmental evaluation criteria considered for this study were: 1) NIOSH criteria documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLVs), and 3) the U.S. Department of Labor (OSHA) federal occupational health standards. Often, the NIOSH recommendations and ACGIH TLVs are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLVs usually are based on more recent information that 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, 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 legally required 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 8-10 hour workday. Some substances have recommended short-term exposure limits or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures. The following table lists the criteria used in this evaluation.

STANDARDS AND ENVIRONMENTAL CRITERIA
(8-hour Time Weighted Average-TWA)

	ACGIH	OSHA	NIOSH
Inorganic nickel	Metal: 1.0 mg/m^3 Soluble compounds as Ni: 0.1 mg/m^3	Metal & soluble compounds: 1 mg/m^3	15 ug/m^3
Nuisance dust (total)	10 mg/m^3	15 mg/m^3	----------
Graphite (synthetic)	10 mg/m^3	----------	----------
Methylene chloride	175 mg/m^3(A2)*	525 mg/m^3	CA/LFL** (1986)
1,1,1-trichloro-ethane (methyl chloroform)	1,900 mg/m^3	1,910 mg/m^3	1,910 mg/m^3

* A2 = Suspected Human Carcinogen
** CA/LFL = Carcinogen; control to lowest feasible level

Toxicology

Methylene Chloride

Methylene chloride, or dichloromethane, is a chlorinated organic compound that is commonly used as a solvent, paint remover, and degreaser. It may be absorbed into the body by inhalation of vapors and by absorption of liquid through the skin. If inhaled in high concentrations, methylene chloride may affect the nervous system, leading to symptoms such as mental confusion, light-headedness, nausea, vomiting, and headache. Continued exposure to very high concentrations may cause increased light-headedness, staggering, unconsciousness, and death. High vapor concentrations may also cause irritation of the eyes and respiratory tract. There have been reports of chronic (long-term) neurotoxic (nervous system) effects among workers who have been exposed to methylene chloride for several years. Symptoms reported from chronic exposure have included forgetfulness, insomnia, headaches, fatigue, and hallucinations. Exposure to methylene chloride may aggravate the symptoms and angina pectoris (heart pain), which may be accompanied by feelings of suffocation and palpitations. If the liquid is held in contact with the skin, it may cause irritation or skin burns. Splashes of the liquid into the eyes may cause irritation. Rats and mice have developed tumors and cancers after exposure to methylene chloride under specific experimental conditions. Therefore, NIOSH recommends that methylene chloride be regarded as a "potential occupational carcinogen," and that exposure be controlled to the lowest feasible level.

Nickel Metal and Soluble Nickel Compounds

Nickel metal and soluble nickel (nickel salts such as nickel nitrate, nickel sulfate, and many others) are used for nickel plating, nickel alloys, coins, batteries, magnets, stainless steel and as a chemical catalyst. Inhalation of dusts and mists can cause lung irritation, shortness of breath, coughing and wheezing. Skin contact can cause itching, burning and sores. This is referred to as "nickel itch." Contact with the eyes may cause irritation and damage to the cornea. Ingestion may cause giddiness and nausea. Long-term exposure may cause all the symptoms caused by short-term exposure, as well as impairment of the sense of smell, chest pain, destruction of nasal tissue, and asthmatic lung disease. Allergic sensitivity may also develop. Exposure to nickel has been associated with an increased risk of lung, throat, and nasal cancer.

1,1,1-Trichloroethane (Methyl Chloroform)

Methyl Chloroform is used in the cleaning of plastics, molds and cold type metal, and for dry cleaning and degreasing. Inhalation of levels above 900 parts per million (ppm) can cause dizziness, mental confusion, drowsiness, loss of coordination, and unconsciousness; death may result. Skin contact can cause irritation and rash. Skin absorption is moderate and may contribute significantly to the health hazard. Eye irritation occurs at levels of 450 ppm. Ingestion may cause symptoms similar to inhalation and, in addition, may cause mouth, throat and stomach irritation. Repeated or prolonged contact at levels above 450 ppm may result in irritation and dry, scaly fractured skin. Dizziness, mental confusion, slowed response time, and generally reversible liver and kidney damage may result from prolonged exposure.

Synthetic Graphite

Manufactured or synthetic graphite is used for electrodes, anodes, bricks, blocks, cylinders, engineering and chemical applications, jet engine throat lines, moderators in nuclear reactors, and as the "lead" in pencil.

There is no good evidence that exposure to synthetic graphite causes lung disease or other systemic illness; however, there have been several reports associating it with an irritant dermatitis. Synthetic graphite injected intra-peritoneally in mice produced a reaction characteristic of a biologically inert material. On the basis of the experimental evidence and lack of evidence of adverse systemic effects in humans, bare synthetic graphite is considered an "inert" or "nuisance" dust.[4]

VI. RESULTS

A. Environmental

Methylene Chloride

All air samples had quantifiable amounts of methylene chloride (Table 1). The six, 8-hour TWA personal breathing zone air concentrations ranged from 13.0 mg/m^3 to 74.4 mg/m^3. The area samples taken right at the chopper end, where the coated fibers come out of the oven and are exposed to the environment, had concentrations ranging from 0.8 to 33 mg/m^3. These results should be interpreted with the understanding that the 1988-1989 Threshold Limit Values as published by the American Conference of Governmental Industrial Hygienists list this compound as a suspect carcinogen. Also, the NIOSH Current Intelligence Bulletin (CIB) No. 46 published in 1986 stated that methylene chloride is a potential occupational carcinogen and exposure should be controlled to the lowest feasible level.

1,1,1,-Trichloroethane (Methyl Chloroform)

The personal breathing zone air concentrations of 1,1,1,-trichloroethane ranged from 6 to 36.6 mg/m^3 (Table 2). The area samples ranging from 7.7 to 48.1 mg/m^3. The highest level measured was less than 3% of the evaluation criterion.

Nickel

The environmental sampling data for nickel are presented in Table 3. The personal breathing zone air concentration ranged from 7.3 to 51.2 micrograms per cubic meter (ug/m^3). Two of the sample results exceeded the NIOSH recommended exposure limit (REL) of 15 ug/m^3. The three area samples had concentrations ranging from 2.9 to 44.6 ug/m^3. One (44.6 ug/m^3) exceeded the NIOSH REL for personal samples. The measured personal air concentrations are above the REL.

Total Dust and Synthetic Graphite

Four total dust samples were taken: three area and one personal breathing zone sample. The air concentrations ranged from non-detectable to 0.23 mg/m^3 (Table 4). Assuming that all the particulate collected was graphite, the highest level measured is only three percent of the evaluation criterion.

B. Medical

Fifty-six employees participated in the medical study. Twenty-two (81%) of 27 MCF employees participated (two employees refused, two were absent due to illness, and one was on vacation). Seven (50%) of 14 former MCF workers participated (seven employees had left the company and could not be located). Twenty-seven (75%) of the initially selected employees who had never worked in MCF participated (four refused, one was absent due to illness, two were on vacation, and two were not available because of their weekly work schedules; alternates were selected for these last two).

Review of personnel records and questionnaire information found that having ever worked in MCF did not necessarily mean a worker had been exposed to chemicals in the department. We determined that 3 workers currently employed in MCF and 1 worker who had been employed there previously had no contact with chemicals used in the department. These individuals, therefore, are considered for purposes of data analysis, to have never been exposed to MCF chemicals.

The mean age of participants was 38 years. Forty-three (77%) participants were male and 45 (80%) were white. The exposure groups were comparable with respect to gender and race (Table 5).
Non-participants had an average age of 36 and were 85% male and 100% white. Review of medical records for those employed in MCF indicated that 5 of the 7 former employees who could not be located had had a rash while working in MCF.

Table 6 presents data on estimated exposure, reported as average number of days/month. Of those participating in the study, 31 had no workplace exposure to nickel solutions, sizing solutions, or fibers; 19 were currently exposed; and 6 had previous but not current exposure. Of the past and currently exposed employees, all were exposed to nickel and fibers, and 21 of 25 (84%) were also exposed to sizing solutions. The mean number of days per month worked on the nickel plating line was twice that of the sizing line. Exposures to nickel and fibers were significantly correlated, and neither was significantly correlated to sizing exposure (Table 7).

Table 8 shows the association between history of exposure in MCF and dermatitis. Thirteen employees (23%) met the case definition for rash. Self-reported history of rash was not statistically different among the different exposure categories (Chi-Square$_{2df}$ = 3.0; p = .22). Seven employees met the criteria of having a work-related rash. Six of the seven work-related rash cases had been working in MCF at the onset of their rash. A comparison of the prevalence of work-related rash among workers with either current or past exposure to chemicals in MCF and those never exposed results in a relative risk of 7.4 (95% CI: 1.4, 40.7). However, there was no significant difference between persons with work-related rashes and those without, with respect to the number of days per month worked with nickel, sizing, or fibers. (Analyses using work-related rash used only non-rash cases as a comparison group, excluding non-work-related rashes).

Table 9 reports the findings based on physical examination. Thirty-six percent (20 of 56) of participants had positive findings on physical examination: 12 had findings consistent with solvent use, and 8 had findings consistent with mild contact dermatitis. All 8 employees with findings consistent with contact dermatitis were examined in December 1987. Only 1 of the 12 cases (8%) of solvent dermatitis was examined in December 1987; the remaining 11 were examined in March 1988. The greater prevalence of solvent dermatitis among non-MCF workers (29%) than among current and former MCF workers (12%) was not statistically significant (RR = 2.4, 95% CI = 0.7, 8.0).
Twenty-three percent of participants reported a history of atopic traits (Table 10). Although the proportion of those reporting atopic traits was highest among the currently exposed workers (37%), there were no significant differences in prevalence between exposure categories of atopic individuals (X^2 = 3.0, p < 0.22).

MCF employees had a prevalence of work-related dermatitis 7 times that of non-MCF employees (RR = 7.04, 95% CI: 1.29, 38.6) (Table 11). Stratification by atopic history showed a comparable but statistically non-significant risk for non-atopics. Among exposed workers, the prevalence of work-related rash was 50% (4 of 8) for atopics and 13% (2 of 15) for non-atopics (RR = 3.75; 95% CI: 0.87, 16.2). Questionnaire responses indicated that use of gloves, barrier creams, and hand washing was universal, and almost universally began on the first day of employment in MCF. Therefore, these exposure modification variables were not further analyzed.

Exposures to nickel, fibers, and sizing were analyzed individually for association with work-related rash. There was no significant difference in work-related rash prevalance with respect to exposure to nickel (RR = 1.98, CI: 0.75, 5.23) or fibers (RR = 1.98, CI: 0.75, 5.23). It should be noted that, since all individuals who ever worked in MCF reported to have worked with both nickel and fibers, the relative risks calculated for both these exposures is the same as that calculated for the more crude estimate of exposure, ever vs. never exposed in MCF (see Table 9). For the same reason, the relationship between work-related rashes and ever being exposed in MCF (RR = 7.04) was the same as that seen with exposure to either nickel or fibers.

The overall relative risk of work-related rash and exposure to sizing was 9.8 (95% CI: 1.96, 49.0) (Table 12). The relative risk was less among non-atopics (RR = 3.4; 95% CI: 0.38, 30.7). However, among atopics, 4

of 5 persons exposed to sizing compounds had a history of work-related rash, whereas none of the non-exposed persons had such a rash (relative risk undefined; p = 0.01, Fisher's exact test, 1-tailed).

Two employees, both female, had positive patch tests to nickel (2.5% and 5%). One women had a history of exposure to MCF chemicals and a work-related rash, and the other had no occupational exposure to MCF chemicals or reported rash. There were no positive reactions to other tested substances.

VII. DISCUSSION

This evaluation found air nickel concentrations in excess of the NIOSH recommended exposure level on the plating line, despite the presence of ventilation. In this area, respirator use was optional. This situation therefore requires an improvement in the ventilation. The measured methylene chloride levels are not actual exposures as workers were required to wear air-supplied respirators when accessing the mixing booth and sizing tank containing methylene chloride. The results do indicate the potential for exposure, however, the need for continued use of the prescribed personal protective equipment and operation of the engineering controls.

This study showed a positive relationship between occupational dermatitis and work in the MCF. This was observed, however, only for irritant contact dermititis, not for allergic contact dermatitis. Furthermore, the relationship was statistically significant for workers with a prior history of atopic traits and appeared to be due to exposures on the sizing line.

Exposures in MCF are complex, and it is difficult to identify a single, specific etiology for the rash reported by workers in this department. Several explanations for the occurrence of rash among workers in this department are plausible.

The primary hypothesis at the onset of the investigation was that the rash might be allergic contact dermatitis from sensitization to nickel. This hypothesis was based on several observations: 1) rash among nickel-platers historically has been an allergic rather than an irritant contact dermatitis; 2) exposure to nickel solutions occurs during work in the MCF due to the design of the process and lapses in industrial hygiene practices; 3) predisposing factors such as heat and occlusion of the chemicals against the skin are present in the MCF Department; and 4) pre-existing contact dermatitis is possible from exposure to other irritating chemicals and fibers in the department. Although this study did not support nickel allergic contact dermatitis as a significant etiology of the rash reported by the workers in MCF, it is possible that the relationship was missed due to an inability to test half of the workers who had left MCF. It is likely that only those with the most severe rashes were seen in the medical clinic, and these would be the ones subsequently medically disqualified from working in the department. Such persons would, therefore, not be included as cases in the study sample if they had left the company. Due to the nature of allergic contact dermatitis (ACD), it is also possible that workers experiencing the most severe rashes were those whose rash was a result of nickel sensitivity rather than irritation.
It is important to note that if exposure continues, allergy to nickel may play a significant role in producing dermatitis in these workers in the future, even if it is not currently a significant etiological factor. Current engineering and industrial hygiene practices allow for appreciable exposures to nickel, and the presence of another rash in these workers many predispose them to developing nickel hypersensitivity. In addition, the gloves that must be worn as protection from the solutions increase sweating and occlusion, thereby increasing the probability of sensitization.

Another possible etiology for the dermatitis reported in the MCF Department is the fiber used on the sizing line. The fiber tow used on the sizing line consists of synthetic graphite, which has already been nickel-plated. These nickel-plated fibers tend to fragment into splinters, which can imbed in unprotected skin. This action alone can produce an irritant dermatitis. The imbedding of the splintered fibers under the skin may also increase the probability of sensitization to nickel.

It is likely that most of the work-related rashes reported among MCF employees are irritant in nature, since only two individuals, one exposed and one unexposed, had a positive skin patch test to nickel. In addition, there were no positive tests to the sizing solution components tested (formaldehyde and epoxy resin), making allergy to these

substances an unlikely explanation for the rashes. It is possible, however, that the methylene chloride, formaldehyde, epoxy, or 1,1,1-trichloroethane components of the sizing solution are responsible for the dermatitis, if it is irritant in nature.

There are two work practices that, although unlikely to be primary etiologies for the rash reported in MCF workers, may be contributing factors. Occasionally, workers will remove their gloves to increase their manual dexterity while working on the plating and sizing lines. Usually, they will use a barrier cream to protect their ungloved skin. However, often they do not remove the cream before re-donning their gloves. The use of the creams with the gloves is inappropriate and could contribute to an irritant dermatitis. In addition, some workers use a "medicated" powder in the gloves to help absorb perspiration. This powder contains additives such as eucalyptus which, by themselves, can be irritating to the skin.

Previous studies have tried to determine whether atopy is a personal risk factor predisposing to allergic or irritant contact dermatitis. This study showed an association between irritant, but not allergic, contact dermatitis and a history of atopic traits. However, it is difficult to document the rule of atopy, primarily because it is difficult to determine accurately atopic status.
It is possible that factors involved in the selection of the study population may have served to underestimate the risk of developing allergic and irritant dermatitis for MCF workers. As indicated earlier, review of company medical records indicated that 5 of 7 employees who could not be located had reported a skin rash while working in the MCF Department. Therefore, the number of rash cases among the workers ever employed in MCF was most likely underestimated.

Physical examination was primarily conducted to determine what workers were defining as a rash; therefore, analyses using physical examination data were limited. This was primarily because of the inappropriateness of using a measure of current disease to estimate the occurrence of both current and past disease. Approximately half of the study was conducted in December, and the other half in March, with an equal number of MCF and non-MCF workers tested at each time. Eleven of the 12 persons diagnosed by physical examination as having solvent dermatitis were examined in March. Winter eczema and dry skin are risk factors in developing solvent dermatitis, and may not appear any different. It is reasonable, therefore, that "solvent" dermatitis would have a higher prevalence in March, at the end of winter, than in December. In addition, a higher rate of solvent dermatitis was observed among the non-MCF employees. This may be attributable to the use of solvents in other non-MCF departments, combined with less frequent use of gloves for protection. Although non-MCF employees were not systematically observed at work or asked about glove use, it is likely that glove use was less frequent in non-MCF workers since the primary reason for glove use in the MCF Department is to limit exposure to nickel, not solvents.

Classification of disease status was based on self-report. It is possible that recall bias was present for MCF workers, all of whom were aware of the reason for the investigation, and therefore may have been more likely to recall a rash. It is unlikely that MCF employees underreported rash, and considering the number of MCF workers who had been seen in the medical clinic with a complaint of rash, it is unlikely that overreporting was severe. Unfortunately, it is not possible to validate reported rash cases using company medical reports because of underreporting to the medical clinic. The desirability of working in the MCF Department, and the known history of medical disqualifications from this department, increases the likelihood that only the more severe cases of dermatitis are seen in the medical clinic.

VIII. RECOMMENDATIONS

This investigation found an association between occupational dermatitis and working in the MCF Department. Although this association was seen predominately among those workers with a history of atopic traits and was related to working on the sizing line, all workers would benefit from adhering to the following practices in addition to those currently used in this department:

1) Gloves should be worn at all times and not be removed while handling solutions, wet fiber, or sized fiber. The work gloves provided should allow for sufficient dexterity to perform the necessary job tasks of repairing tow lines and packaging cut fibers.

2) Barrier creams should be used whenever gloves have to be removed. Barrier creams are designed to be a substitute for gloves, but do not afford the same degree of protection. Therefore, barrier creams should only be substituted for gloves when absolutely necessary and should always be completely removed before re-donning gloves. Use of the creams under gloves may increase sweating and irritation and predispose employees to dermatitis.

3) Talc or corn starch should be substituted for the "medicated" powders currently used as an absorbative agent inside gloves. The medicated powders contain additives that can irritate the skin.

4) Uniforms provided to the workers should be in good repair and should be changed immediately if they become heavily contaminated with solutions.

5) There should be regular monitoring of all employees in the department by the medical clinic (for instance, every 2 months), to obtain each worker's history of rash in the preceding 2 months, with referral to the company physician if a rash is present.

6) The use of engineering controls should be investigated in order to reduce further the possibility of off-gassing of solvents and other chemicals as the dry blend comes from the ovens in the sizing operation.

7) Improved ventilation on the nickel plating line should be instituted.

8) Respiratory protection at the nickel plating line should be mandatory rather than optional until improvements in the ventilation are accomplished.

Currently, there is no medical test available to screen reliably for susceptibility to contact dermatitis. Employment disqualification based upon medical screening procedures that do not have a high predictive value may be unfair discrimination.[4] Since it is not possible to identify persons at high risk with accuracy, all workers should be well trained in specific job assignments and monitored for the development of skin rash.

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XI. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are temporarily available upon request from NIOSH, Hazard Evaluations and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Information Service (NTIS), 5885 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. American Cyanamid, Wallingford, Connecticut
2. International Chemical Workers Union
3. OSHA Region I

For the purpose of informing 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.

TABLE 1

Methylene Chloride Exposures
American Cyanamid
Wallingford, Connecticut
December 7-8, 1987

JOB*	SAMPLE NUMBER	TIME MIN.	VOLUME LITERS	METHYLENE CHLORIDE mg/m^3**	METHYLENE CHLORIDE TWA mg/m^3	8-HR TWA mg/m^3
A-Dip Tank	12721 A	240	6.8	67.01		
At Opening	B	215	6.13	61.97	64.6	61.3
P-MCF Oper	12722 A	240	6.75	34.06		
	B	215	6.11	22.9	28.8	27.3
P-MCF Oper	12723 A	240	7.01	28.5		
	B	220	6.48	131.16	77.6	74.4
A-Chopper	12724 A	245	6.71	34.27		
End	B	215	5.96	31.85	33.1	31.7
P-MCF Oper	12731 A	221	6.52	18.41		
	B	214	6.09	16.41	17.43	15.8
P-MCF Oper	12732 A	226	6.51	32.25		
	B	205	5.99	11.68	22.51	22.2
A-Dip Tank	12733 A	208	4.16	47.52		
	B	220	6.82	27.8	37.4	33.3
A-Chopper	12734 A	210	5.90	30.5		
End	B	217	6.14	4.88	17.48	15.5
P-MCF Oper	12811	418	12.05	20.75	18.07	18.07
P-MCF Oper	12812	415	11.83	16.06	18.39	13.89
A-Dip Tank	12813	428	12.95	5.40		4.82
Chopper End Of Line	12814	430	11.91	0.84		0.75

*-A = Area
P = Personal
** mg/m^3 = milligram per cubic meter
Limit of Detection = 0.01 mg/sample
Limit of Quantitation = 0.03 mg/sample

TABLE 2
Methyl Chloroform Exposures
American Cyanamid
Wallingford, Connecticut
December 7-8, 1987

JOB*	SAMPLE NUMBER	TIME MIN.	VOLUME LITERS	METHYL CHLOROFORM mg/m^3**	METHYL CHLOROFORM TWA mg/m^3	8-HR TWA mg/m^3
A-Dip Tank	12721 A	240	6.8	15.50		
At Opening	B	215	6.13	9.13	12.49	11.8
P-MCF Oper	12722 A	240	6.75	8.50		
	B	215	6.11	3.91	6.33	6.0
P-MCF Oper	12723 A	240	7.01	8.50		
	B	220	6.48	9.57	9.01	8.72
A-Chopper	12724 A	245	6.71	10.50		
End	B	215	5.96	5.22	8.03	7.7
P-MCF Oper	12731 A	221	6.52	15.00		
	B	214	6.09	4.29	9.73	8.82
P-MCF Oper	12732 A	226	6.51	22.50		
	B	205	5.99	2.86	13.16	11.8
A-Dip Tank	12733 A	208	4.16	40.00		
	B	220	6.82	12.86	26.05	23.2
A-Chopper	12734 A	210	5.90	25.00		
End	B	217	6.14	1.43	13.02	11.6
P-MCF Oper	12811	418	12.05	42.00		36.58
P-MCF Oper	12812	415	11.83	28.67		24.78
A-Dip Tank	12813	428	12.95	54.00		48.15
Chopper End Of Line	12814	430	11.91	14.67		13.14

*-A = Area
P = Personal
**mg/m^3 = milligram per cubic meter
Limit of Detection = 0.01 mg/sample
Limit of Quantitation = 0.03 mg/sample

TABLE 3

Inorganic Nickel Exposures
American Cyanamid
Wallingford, Connecticut
October 7-8, 1987

JOB*	SAMPLE NUMBER	TIME MIN.	VOLUME LITERS	NICKEL ug/m^3**	8-HR TWA ug/m^3
P-MCF Oper	1	450	810	Lost in Analysis	
P-MCF Oper	2	446	892	54.9	51.2
P-MCF Oper	3	449	898	7.8	7.3
Area Plating	4	444	1110	3.1	2.9
P-MCF Oper	5	450	810	10.4	9.8
Area Plating	6	436	872	49.3	44.6
P-MCF Oper	8	360	756	14.6	11.0
P-MCF Oper	9	213	426	61	27
P-MCF Oper	10	362	724	11.4	8.6
A-Eye Wash	11	361	650	2.6	2.0

*-A = Area
P = Personal
** ug/m^3 = micrograms per cubic meter
Limit of Detection = 0.5 mg/nickel
Limit of Quantitation = 1.6 mg/nickel

TABLE 4

Total Dust Exposures
American Cyanamid
Wallingford, Connecticut
October 7-8, 1987

JOB*	SAMPLE NUMBER	TIME MIN.	VOLUME LITERS	TOTAL DUST mg/m^3**	8-HR TWA mg/m^3
A-Chopper	9885	95	190	0.53	0.01
A	9884	96	192	ND***	ND
P-MCF Oper	9875	433	862	0.26	0.23
A-Chopper	9886	322	644	0.0003	0.0002

*-A = Area
P = Personal
** mg/m^3 = milligram per cubic meter
*** ND = Not Field Blank Corrected

TABLE 5

Demographic Characteristics of Study Participants
Classified by Exposure to Chemicals in the
Metal Coated Fiber Department*

	Never Exposed	Currently Exposed	Exposed In Past	Total
# OF EMPLOYEES	31	19	6	56
AGE [mean(s.d.)]	38 (11.6)	35 (11.8)	45 (12.0)	38 (11.9)
GENDER (% male)	81	68	83	77
RACE (% white)	77	79	100	80

* Never Exposed = never worked with chemicals in MCF; Currently Exposed = currently working with chemicals in MCF; Exposed in Past = currently working elsewhere, but at one time worked with chemicals in MCF.

TABLE 6

Exposure to Nickel, Sizing, and Fibers*
by Exposure Status**

	Currently Exposed	Exposed In Past
NUMBER	19	6
NICKEL***		
#Days/Month (s.d.)	17 (5.6)	11 (5.5)
Range	6,26	2,18
SIZING***		
#Days/Month (s.d.)	9 (4.7)	8 (3.3)
Range	1,20	2,11
FIBERS***		
#Days/Month (s.d.)	17 (6.2)	18 (9.0)
Range	6,26	4,30

* Exposures are classified by predominant exposure
** Currently Exposed = currently working with chemicals in MCF; Exposed in Past = currently working elsewhere, but at one time worked with chemicals in MCF.
*** Nickel = worked on plating line with nickel and fiber or mixed nickel solutions; Sizing = worked on sizing line with sizing and fiber or mixed sizing solutions; Fibers = worked on sizing or plating lines with fiber, sizing and nickel.

Table 7

Correlation Matrix of Exposure Variables (Pearson)

	Nickel Days*	Sizing Days**	Fiber Days***
Nickel Days	1.0	0.10	0.58#
Sizing Days	1.0	0.14	
Fiber Days		1.0	

* Nickel Days = number of days/month working on the nickel plating line or mixing solutions for the nickel tanks.
** Sizing Days = number of days/month working on the sizing line or mixing solutions for the sizing tanks.
*** Fiber Days = number of days/month working on the sizing or plating lines (less than one day per month handling fiber only).

# $p < 0.01$

Table 8

Prevalence of Rash
Reported for History of Any Rash* and History of Work-Related Rash**
Classified by Exposure Status***

	Never Exposed	Currently Exposed	Exposed In Past	Total
NUMBER	31	19	6	56
HISTORY OF ANY RASH number (%)	5 (16)	7 (37)	1 (17)	13 (23)
HISTORY OF WORK-RELATED RASH number (%)	1 (3)#	5 (26)	1 (17)	7 (13)

* History of Any Rash = self-report of rash on face, neck, arms, hands or fingers since December 1983.
** History of Work-Related Rash = self-report of rash, as defined above, which improved away from exposure.
*** Never Exposed = never worked with chemicals in MCF; Currently Exposed = currently working with chemicals in MCF; Exposed in Past = currently working elsewhere, but at one time worked with chemicals in MCF.
\# Comparison of Ever Exposed (current and past) and Never Exposed for work-related rash. RR = 7.4 (95% CI: 1.4, 40.7; p=0.04)

Table 9

Physical Diagnosis of Any Rash, Classified by Exposure Status*

	Never Exposed	Currently Exposed	Exposed In Past	Total
NUMBER	31	19	6	56
PHYSICAL EXAM (n=55)**				
No Rash number(%)	19 (61)	12 (67)	4 (67)	35 (64)
Contact Dermatitis number(%)	3 (10)	4 (22)	1 (17)	8 (14)
Solvent Dermatitis number(%)	9 (29)	2 (11)	1 (17)	12 (22)

* Never Exposed = never worked with chemicals in MCF; Currently Exposed = currently working with chemicals in MCF; Exposed in Past = currently working elsewhere, but at one time worked with chemicals in MCF.

** One participant refused patch testing and the physical exam. See text for classification criteria for solvent dermatitis and contact dermatitis.

TABLE 10

History of Atopic Traits*, Classified by Exposure Status**

	Never Exposed	Currently Exposed	Exposed In Past	Total
NUMBER	31	19	6	56
# ATOPIC (%)	5 (16%)	7 (37%)	1 (17%)	13 (23%)

* Positive atopic history is defined as a history of respiratory or rhinoconjunctival symptoms in relation to inhalants, or a history of childhood eczema. See text for details.

** Never Exposed = never worked with chemicals in MCF; Currently Exposed = currently working with chemicals in MCF; Exposed in Past = currently working elsewhere, but at one time worked with chemicals in MCF.

TABLE 11

History of Work-Related Rash*, Classified by General Exposure Status**
Stratified by Atopic Status***

		History of Work-Related Rash Yes	No	Total
Ever exposed in MCF	Yes	6	17	23
	No	1	26	27
				50

RR+ = 7.04 (95% CI:++ 1.29, 38.6)

		HISTORY OF ATOPIC TRAITS				NO HISTORY OF ATOPIC TRAITS		
		History of Work-Related Rash				History of Work-Related Rash		
		Yes	No	Total		Yes	No	Total
Ever exposed in MCF	Yes	4	4	8	Yes	2	13	15
	No	0	4	4	No	1	21	22
				12				37

RR = undefined, p = 014# RR = 2.9 (95% CI: 0.32, 27.1)

* History of Work-Related Rash = self-report of rash on face, neck, arms, hands or fingers since December 1983, which improves away from exposure.
** Never Exposed = never worked with chemicals in MCF; Ever Exposed = currently working with chemicals in MCF or currently working elsewhere, but at one time worked with chemicals in MCF.
*** Positive atopic history is defined as a history of respiratory or rhinoconjunctival symptoms in relation to inhalants, or a history of childhood eczema. See text for details.
\+ RR = Relative Risk
++ 95% CI: = 95% Confidence Interval
\# Fisher's exact test, 1-tailed

TABLE 12

History of Work-Related Rash*, Classified by Sizing Exposure Status**
Stratified by History of Atopic Traits***

		History of Work-Related Rash		
		Yes	No	Total
Worked with Sizing	Yes	6	13	19
	No	1	30	31
				50

RR = 9.79 (95% CI: 1.96, 49.0)

		HISTORY OF ATOPIC TRAITS				NO HISTORY OF ATOPIC TRAITS		
		History of Work-Related Rash				History of Work-Related Rash		
		Yes	No	Total		Yes	No	Total
Worked with Sizing	Yes	4	1	5	Yes	2	12	14
	No	0	7	7	No	1	23	24
				12				38

RR = undefined, p = 0.01[#] RR = 3.4 (95% CI: 0.38, 30.7)

* History of Work-Related Rash = self-report of rash on face, neck, arms, hands or fingers since December 1983, which improves away from exposure.
** Exposure to Sizing = worked on sizing line with sizing and fiber or mixed sizing solutions (workers not exclusively exposed to sizing, see text for details).
*** Positive atopic history is defined as a history of respiratory or rhinoconjunctival symptoms in relation to inhalants, or a history of childhood eczema. See text for details.
\+ RR = Relative Risk
++ 95% CI: = 95% Confidence Interval
\# Fisher's exact test, 1-tailed