U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
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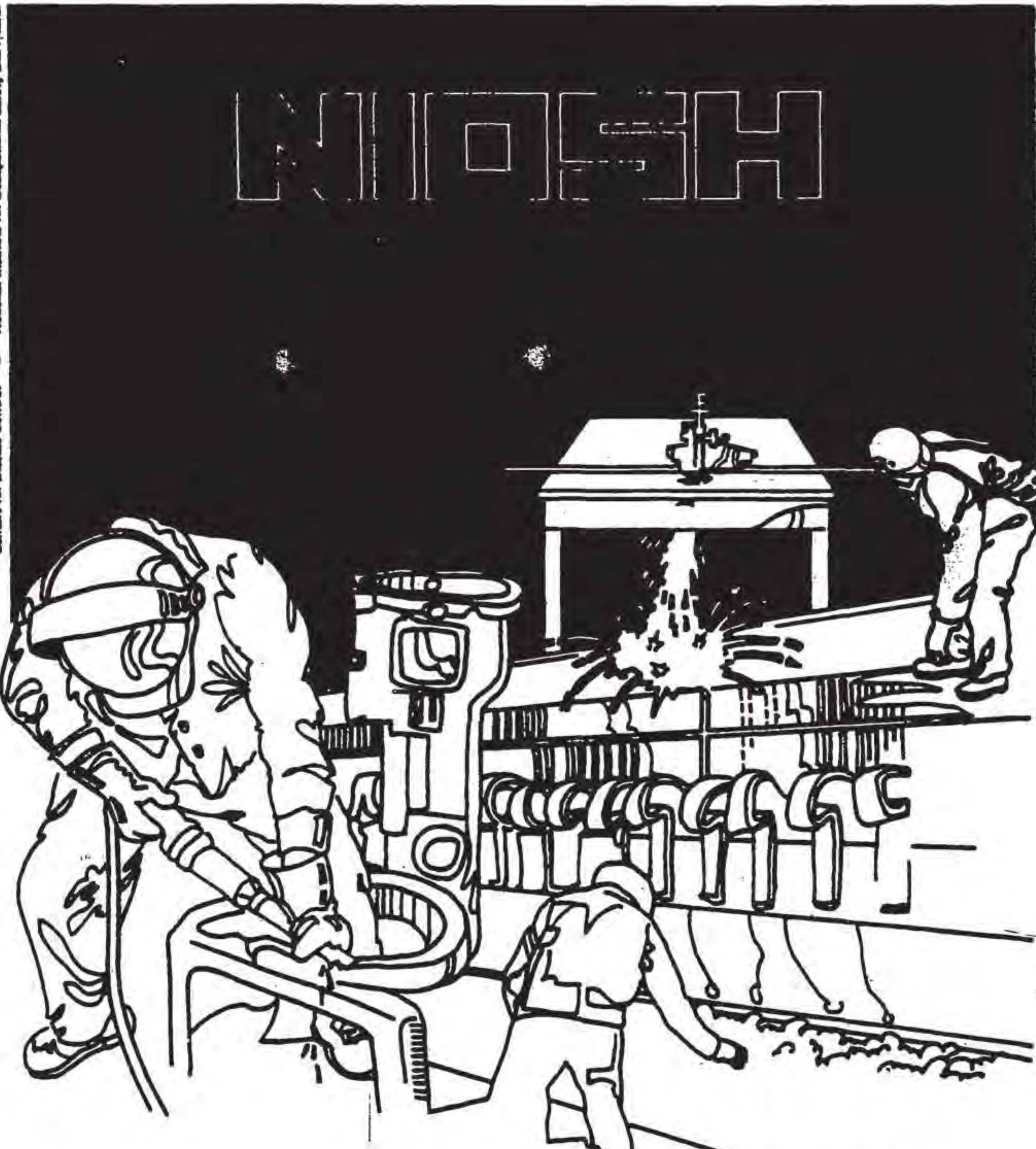

Health Hazard Evaluation Report

HETA 81-369-1591
HETA 81-466-1591
ELECTRIC MACHINERY - MCGRAW
EDISON COMPANY
MINNEAPOLIS, MINNESOTA

PREFACE

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

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

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ELECTRIC MACHINERY - McGRAW EDISON COMPANY
MINNEAPOLIS, MINNESOTA

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I. SUMMARY

In June 1981, the National Institute for Occupational Safety and Health (NIOSH) received a request to evaluate exposures to epoxy resin compounds and impregnated materials in the armature winding area and the vacuum, pressure, and impregnation room (VPI) of the Electric Machinery-McGraw Edison Company, Minneapolis, Minnesota. The request was prompted because of the reported hazardous work processes and poor working conditions and reported symptoms of dermatitis, eye irritation, headaches, nausea, and respiratory problems experienced by the employees.

On December 8-9, 1981, NIOSH conducted a medical questionnaire evaluation at the plant. The prevalence of dermatitis (skin rash and irritation) among the exposed workers ranged from 55% in the hand taping department to 78% among pole winders. Irritation of the eyes was reported by 56% (31 of 56) of those exposed to epoxy resins; nose irritation by 40% (22 of 56), and throat irritation by 28% (16 of 56). Of those workers not exposed to epoxy resins (57), eye irritation was reported by 12%, nose irritation by 7%, and throat irritation by 5%. Prevalence of carpal tunnel syndrome (CTS) was determined from 5 questions on the survey form which elicited information about symptoms and/or a history of surgical treatment for this condition. The areas with the highest prevalences were armature winding (70%) and hand taping (65%). The prevalence among the exposed group (56%) was significantly higher than that (7%) of the control group.

Personal breathing zone and stationary area air sampling was conducted on February 23-24, 1983, to assess employee exposure to total aliphatic amines, total aromatic amines, boron trifluoride monoethylamine, C_2-C_5 aliphatic aldehydes, epichlorohydrin, total volatile fluorides (via boron trifluoride), formaldehyde, lead, methyl tetrahydrophthalic anhydride, and n-butyl glycidyl ether. The work areas where the air samples were collected included the coil winding, hand taping, armature winding, pole winding, and VPI room. The only detectable concentrations of contaminants collected were those for formaldehyde, acetaldehyde, and lead. Two personal samples collected during soldering operations in the armature winding area revealed formaldehyde levels of 7.8 ug/m^3 (0.006 ppm) and 53.5 ug/m^3 (0.04 ppm) (evaluation criteria (EC): lowest feasible level). A trace of acetaldehyde (98.4 ug/m^3) was found in an area sample obtained during this same work process (EC-180 mg/m^3). The concentration of lead found in one personal sample (10.1 ug/m^3) collected in the coil winding department (soldering coil leads) was well within the NIOSH recommendation and OSHA standard of 50 ug/m^3.

An in-depth evaluation of the ergonomic job stresses was conducted on February 24, 1983, in the coil winding, hand taping, armature winding, pole winding and VPI areas of the plant. The work processes in these areas require many complex movements and postures, particularly hyperextension and hyperflexion of the wrist. Such wrist positions routinely occur during the assembly processes involving the manual application of many layers of insulating tape to the coils. In addition to carpal tunnel syndrome, a number of cases of cumulative trauma disorders such as lateral epicondylitis and ganglionic cysts were noted.

Questionnaire data revealed dermatitis (skin rash and irritation) to be a major problem among the exposed workers. Also a high prevalence of carpal tunnel was reported by workers. Sampling data indicated employee exposure to detectable formaldehyde levels. Based on NIOSH's recommendation that formaldehyde be considered a potential human carcinogen, attempts should be made to reduce the concentrations of formaldehyde to the lowest feasible level. Measures to improve working conditions and reduce potential exposures are recommended in Section VIII of this report.

KEYWORDS: SIC 3621 (Electrical Motors & Generators), epoxy resins, dermatitis, ergonomics, biomechanical stress, carpal tunnel syndrome

II. INTRODUCTION

On June 29, 1981, the National Institute for Occupational Safety and Health (NIOSH) received a request from the AFL-CIO, Local No. 1140, to evaluate exposures in the armature winding area and the vacuum, pressure, and impregnation room (VPI) of the Electric Machinery - McGraw Edison Company, Minneapolis, Minnesota, where epoxy resin compounds and impregnated materials are used. On September 21, 1981, NIOSH received an additional health hazard evaluation request from Local No. 1140, concerning employee exposures to epoxy resins in the pole winding area. In December 1981 the hazard evaluation was expanded to include the hand taping and the coil winding areas since epoxy impregnated materials are used in the hand taping area and reported biomechanical problems are experienced by employees in both areas. The requests were prompted because of the reported hazardous work processes and poor working conditions and reported symptoms of dermatitis, eye irritation, headaches, nausea, and respiratory problems experienced by the employees.

On August 28, 1981, an initial environmental survey was conducted at the plant. A follow-up environmental/medical survey was performed on December 8-9, 1981. Interim Report #1 was distributed in December 1981 and Interim Report No. 2 was issued in February 1982. On February 22-25, 1983, a comprehensive environmental/medical/ergonomic follow-up survey was conducted.

III. BACKGROUND

A. General

The Electric Machinery - McGraw Edison factory has been involved in manufacturing various sizes (5'-12' diameter) of electric generators/motors since 1926. The epoxy resin materials and processes which are used for electrical component encapsulation and insulation have been in operation since 1971. There are several different types of heat setting epoxy materials used. An average of 20 custom-built motors are produced each month. The total plant work force (550 employees), consists of 165 administrative and clerical staff, 350 production workers and 35 maintenance employees.

B. Process Description

1. Coil Winding and Hand Taping

The coil winding and hand taping areas, located on the second floor of the facility, each cover about 12,000 square feet. There are about 6 employees in the coil winding department and 30 employees in the hand taping area who work on a one shift, 5-day, 8-hour-per-day schedule. The hand taping area is temperature and humidity controlled and "person-cooling" fans are occasionally used to enhance or provide dilution ventilation.

The work processes in the coil winding area begins with the loop winding operation. In this procedure, copper wire (purchased outside: coated with fiberglass and varnish) is taped (mylar)® into a rectangular-shaped coil approximately 5' in length. The coils are then placed on one of three different sized compressed-air-powered coil forming machines. Coils are spread to appropriate lengths and widths and employees make adjustments using hand-held, steel-headed mallets and pinching/crimping tools. The hammering and crimping actions performed by the coil forming employees are a potential contributing factor to the biomechanical stresses experienced by the workers. Soldering the coil's copper leads is the last procedure done in the coil winding department.

From the coil winding floor the coils are sent to the hand taping area. The mylar tape which had been previously applied, is removed from the coil. Mica-paper is manually applied to the low voltage coils in 36" wide sheets and also to the high voltage coils in 3/4", 1", or 1 1/4" tape form. The number of layers of mica-paper or mica-tape applied to the coil varies with coil voltage specifications. Epoxy impregnated felts are inserted between the leads of the coil and mylar tape is wrapped around the leads. Dacron-fiberglass "outer-binder" tape is applied to all coils for protective purposes and a special dacron tape is occasionally applied to some high voltage coils for quality control testing.

In order to alleviate some of the ergonomic stresses associated with wrapping several layers of tape around the coils, several employees use a hand-held, non-powered winding spindle to apply the tapes. However, this tool is not used by all the hand taping employees.

Several of the employees use wrist length, perforated leather or vinyl protective gloves (with finger slots removed) to aid in preventing blisters and/or callouses caused by the repetitive wrapping motions incurred with application of the tapes. Water soluble protective skin creams are used by some employees to avert dermatitis.

The average high voltage coil process time through the hand taping department is 2 hours whereas the low voltage coil takes 25 minutes. Upon completion, the finished coils are sent to the armature winding floor or VPI room.

2. Armature Winding and VPI

The VPI room and armature winding area each cover about 4000 square feet. There are about 20 employees in the armature winding area and one employee in the VPI room per shift. During the NIOSH survey, the armature winding and VPI system employees worked on a two shift, 5-day, 8-hour-per-day schedule. Occasionally, however, the armature winding department operates on a 6-day work schedule.

The work processes in the armature winding area begins when the copper conductor coils, which were previously wrapped with epoxy inbedded mica tapes, are brought into the winding area and warmed to room temperature. The coils are manually inserted into the core of the generator and lashed in place with wire. The leads are soldered together using a rosin core solder and the coil is insulated with the epoxy resin inbedded felts, mica tapes, and other tape - binding materials. Other work processes on the winding floor using epoxy materials include the use of an epoxy glue to adhere temperature detectors onto the generator and an epoxy resin and an epoxy resin kit and mica tape for use in making minor repairs on new and old electric generators. From the winding floor, the coil/core assemblies are sent to the VPI room where the VPI operators apply the MRV-1000, a silicon release agent, manually by brush. After warming in the preheat oven (150°F for two hours) the coil/core assemblies are placed into the VPI tank which is 10' in diameter and has a capacity of about 5000 gallons. The sequence of processes in the VPI tank includes a dry vacuum cycle (1-1 1/2 hours), wet vacuum cycle (epoxy resin - 2 1/2 hours), and pressure cycle (90-110 lbs for 6-10 hours). When coil/core assembly is removed from the VPI tank, it is placed in the final cure gas-fired baking oven for about 2 hours at 150°F and 10 hours at 300°F. Some machines are recycled through the VPI system. If the generator passes electrical tests, then excess resin is cleaned off the generator using compressed air-powered sanders and buffers and non-powered file-scrapers. Following the cleaning, the motor is sent to the assembly floor area.

Due to their size, the largest generators/motors, B-stage coils, are slightly modified in regards to their processes of manufacture. The conductor coils, brought from the coil winding department, initially go through the VPI system separately, on racks, and are partially cured. On the winding floor the half cured coils are inserted into the generator cores, leads are soldered, and the insulating epoxy mica felts and tapes are put into place. Occasionally, liquid epoxy resin is painted on the completed generator manually by brush. The motor is final cured in large gas-fired ovens as a single unit.

Another VPI system, located in the VPI room, for the smaller generators, operates on a similar basic process. Unlike the large B-stage generators, the smaller generators are processed through a small VPI tank (5' diameter with 500 gallon capacity) wherein liquid epoxy resin impregnation occurs.

Welding (conventional shielded metal arc-consumable flux-coated electrode) is performed on the generator frames in the winding area for about 1/2 - 1 1/2 hours per shift by one employee.

3. Pole Winding

The pole winding department, located on the ground level between the armature winding area and VPI room, covers about 8000 square feet. A total of seven employees on first shift (07:00-16:00) and one employee on second shift (16:00-24:00) work in this area on a 5-day, 40-hour schedule.

The pole body, made up of layers of flat copper, is brought to the pole winding area where the initial work procedure includes wrapping the pole body with insulation paper. Glastic (fiberglass) flanges are inserted into the corners of the poles to hold the copper wire in place. Six pole winding employees use electrically-powered machines to apply fiberglass and varnish coated copper wire to the poles which are temporarily bolted on the pole winding machines. The poles are mechanically rotated while the pole winders guide the wire onto the pole. Varnish coated copper wire is applied to some poles in a separate but similar process.

After each layer of wire is wrapped around the pole, a layer of viscous semi-liquid epoxy resin is manually applied, via paint brush, to the pole body. The number of layers of wire and epoxy resin applications varies according to the pole's specifications. Before use, the pasty epoxy resins are heated using 100 watt lamps. The pole's copper leads are insulated with epoxy impregnated felts and then soldered. Small amounts of mica-tape and dacron-fiberglass tape are placed on the poles for insulation purposes. Although winding time varies with the size of the pole; the average sized pole is wound in about 2 hours.

Wound poles are sent to the baking area where release paper is placed on the pole and the unit is baked at 300°F for 16-32 hours. After the poles are removed from the oven they are manually painted with an enamel-based insulating paint. In addition, a silicone rubber compound is applied to the poles for sealing purposes. The finished poles then go the the finish assembly area to be inserted into the cores.

Another work process performed in the pole winding area is the parallel ring wrapping operation. The parallel ring machine is used to wrap mica-tape around the circularly shaped steel ring used on the top and bottom of the generator coils (assembled on the armature winding floor). The frequency of use of this machine varies daily from 2-6 hours. Observations of this machine indicates that the operator may experience some ergonomic - biomechanical stresses involved with its use due to both the task requirements and the vibration of the machinery. Like in the hand taping area, the layers of mica-taped applied to the steel ring vary with the voltage requirements of the generator it is used with.

IV. EVALUATION DESIGN AND METHODS

A. Initial Survey

On August 21, 1981, an initial survey was conducted at the plant. Activities accomplished during the initial/environmental survey included a walk-through of the armature winding area and the VPI room to obtain process information and observe work practices and conditions of exposure. Additional tasks completed included brief non-directed employee interviews and collection of bulk samples.

B. Follow-Up Survey: Preliminary

1. Environmental

NIOSH received an additional health hazard evaluation request from Local No. 1140, on September 21, 1981, concerning employee exposures to epoxy resins in the pole winding area.

On December 8-9, 1981, a follow-up environmental/medical survey was conducted. The second walk-through covered the hand taping, coil winding and pole winding areas. Photographs were taken of several processes which appeared to contribute to the biomechanical stress of the worker and photos of several workers with dermatitis of potential epoxy resin origin were taken with the employee's permission. Material Safety Data Sheets available were collected to aid in identifying specific epoxy resin components and in development of future environmental sampling protocols and medical assessments.

2. Medical

A questionnaire designed to collect information on (a) the prevalence of various health effects (specifically dermatitis) previously shown in the literature to be associated with exposure to epoxy resin systems,[1,2,3] and (b) the prevalence of biomechanical problems, in particular, carpal tunnel syndrome (CTS), was administered to a sample of the labor force at McGraw Edison.

Participants were selected from four areas of the plant from which cases of dermatitis related to the use of epoxy resins had been reported. These areas included hand taping, VPI room, pole winding, and armature winding (total of 58 workers). A comparison group, matched for sex, age, and race, and was selected from the clerical staff, and the sheet metal and stacking department employees, a total of 63 workers not exposed to epoxy resins. A total of 121 questionnaires was distributed among these groups.

Arrangements were made by the NIOSH medical officer to meet with all members of both the exposed and non-exposed groups to explain the purpose of the questionnaire, assure confidentiality, solicit cooperation and answer any questions. All questionnaire forms were collected the following day, and a private interview was held at any individual worker's request.

A review of both individual employee health records and the latest available OSHA 102 (Injury and Illness) form (for 1979) was also conducted.

C. Follow-Up Survey: In-Depth

On February 22-25, 1983, a comprehensive environmental/medical follow-up survey was conducted that included evaluation of work processes and exposures in the following departments: coil winding, hand taping, armature winding, pole winding, and VPI room.

1. Environmental

Long-term personal and area environmental air sampling was performed on February 23-24, 1983, to characterize employee exposure to total aliphatic amines, total aromatic amines, boron trifluoride monoethylamine, C_2-C_5 aliphatic aldehydes, epichlorohydrin, total volatile fluorides (via boron trifluoride) formaldehyde, lead, methyl tetrahydrophthalic anhydride, and n-butyl glycidyl ether. The sampling and analytical methodology[4] for these substances, including collection device, flow rate, and referenced analytical procedures, are presented in Table I.

2. Medical

Employees from the same areas of the plant were interviewed by the medical investigator. Due to extensive lay-offs, the number of workers in these departments was reduced to twenty-four. Information was collected on the current prevalence of skin rash and mucous membrane irritation among the exposed group.

Copies of reports from both a local dermatologist and a regional environmental consultant hired by the company management in 1976 were reviewed by the medical officer.

(NIOSH was not aware of the existence of these documents during prior surveys.)

3. Ergonomic/Biomechanical Assessment & Carpal Tunnel Syndrome

During the initial plant survey in August 1981, the NIOSH investigator noted that the company had a number of cases of cumulative trauma disorders such as carpal tunnel syndrome, laterial epicondylitis and ganglionic cysts. The NIOSH medical officer did address these biomechanical stresses on the first follow-up survey (via questionnaires). However, since a more detailed assessment of the working environment was necessitated, an industrial engineer with NIOSH accompanied the NIOSH investigators on the comprehensive follow-up survey to evaluate the ergonomic stresses imposed by various jobs in the plant.

The biomechanical assessment included observation of working conditions and processes in the following areas: coil winding, hand taping, armature winding, VPI, and pole winding. These jobs require many complex movements and postures, particularly hyperextension and hyperflexion of the wrist. Videotapes of workers performing these jobs were made so that postures and movements could be analyzed later in the laboratory. In addition, the plants 1982 medical reports were reviewed.

V. EVALUATION CRITERIA

A. Environmental Standards

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 suseptibility, a pre-existing 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 are not usually 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 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. Often, the NIOSH recommendations and ACGIH TLV's® are lower than the 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 standards, 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 only 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 or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

The environmental evaluation criteria utilized in this study are presented in Table II. Listed for each substance are the evaluation criteria, source of the criterion, and the OSHA standard for those materials which personal and area air samples were collected and for which established exposure criteria has been promulgated.

B. Toxicological Effects

1. Formaldehyde[5,6]

Formaldehyde gas may cause severe irritation to the mucous membranes of the respiratory tract and eyes. Repeated exposure to formaldehyde may cause dermatitis either from irritation or allergy. Formaldehyde has induced a rare form of nasal cancer in two test animal species as reported in a study by the Chemical Industry Institute of Toxicology. Formaldehyde has also been shown to be a mutagen in several systems. NIOSH considers formaldehyde a potential occupational carcinogen and recommends that exposures be reduced to the lowest feasible level.

2. Acetaldehyde[7]

Acetaldehyde is an irritant of the eyes and mucous membranes. The irritant effects of the vapor at lower concentrations, such as cough and a burning sensation in the nose, throat, and eyes, usually prevent exposure sufficient to cause central nervous system depression.

3. Epoxy Resins

To be termed an epoxy, the basic chemical requirement is the presence of a three-membered epoxide ring; consisting of an oxygen atom bridging two adjacently-joined carbon atoms. This ring is highly reactive and can be opened by almost all nucleophilic (electron-donating) substances, such as amines, anhydrides, amides, and alcohols (free hydroxyl groups).[2]

Epoxy resins are usually prepared by the condensation reaction of epichlorohydrin with another molecule (usually an alcohol, phenol or fatty acid) to form an ether or ester linkage. The majority (about 90 percent) of commercial epoxy resins are prepared by reacting epichlorohydrin with 4,4-isopropylidenediphenol (bisphenol A) to obtain a molecule of desired chain length and molecular weight. All resins formed in this fashion have a glycidyl ether linkage at both ends of the molecule; they are referred to as epoxy resins of the bisphenol A type by manufacturers, regardless of molecular weight. The resin of smallest molecular weight (340) is the diglycidyl ether of bisphenol A.[2]

An epoxy resin system is composed of two or more reactive components: the resins, which contain a terminal unreacted alpha epoxy group; the curing polymerizing agent, which is also referred to as the hardener, catalyst, accelerator, activator, or setting agent; and sometimes a reactive diluent and modifier for changing the physical characteristics of the final plastic.[8]

The stability and strength of epoxy resin systems is achieved through the hardening or curing of the resin. The hardeners are usually from one or more of three chemical classes: polyamines, polyamides, or anhydrides.[2] A list[9] of some compounds available for use as curing agents is as follows:

Chemical Classes	Compounds
1. Amines	
Primary aliphatic	Ethylene diamine Diethylenetriamine
Triethylene tetramine	
	Dimethylamino propylamine Diethylamino propylamine
Secondary aliphatic	Triethylamine
Primary aromatic	Metaphenylene diamine
2. Organic Acids	Oxalic acid
3. Organic Acid Anhydrides	Phthalic anhydride Maleic anhydride Hexadhydrophthalic anhydride
4. Polyamides	Condensation products of dibasic acids and diamines

Other typical commercial curing agents include a boron trifluoride-amine complex, amino formaldehyde, urea formaldehyde, and melanamine formaldehyde. Any one of the above mentioned curing agents or other variants may be used depending upon the characteristics and application techniques required.[10,11]

Reactive diluents are low molecule weight epoxy compounds which are added in small quantities to the principal, higher molecular weight epoxy resin as a plasticizer or viscosity control agent. Unlike the major resins, which are diglycidyl ethers, reactive diluents are usually monoglycidyl ethers and contain only one reactive epoxy group.[2] The major ones are phenyl-, allyl-, and butyly glycidyl ether, styrene oxide, and styrene.[12]

Nonreactive solvents are used in some resin formulations, principally in those intended for surface-coating applications. These include methyl isobutyl ketone, methyl ethyl ketone, butanols, cellosolve acetate, acetonitrile, xylene, and toluene.[11]

Depending on the application various fillers may be added to the resin system, either to the epoxy resin component or to the uncured mixture. A few of the more common fillers include glass fibers, powdered mica, and silicates.[11]

There are other materials that may be added to the epoxy resin system such as pigments, catalysts, and stabilizers which are not discussed in this report.

Epoxy compounds may produce a range of toxic effects. Some epoxy resins are primary skin irritants, sensitizers, or both. Those effects seen with greatest frequency are dermatitis (either irritative or secondary to induction of sensitization), eye irritation, and pulmonary irritation.[13,14]

Dermatitis from epoxy resin systems may be caused by irritation or allergic sensitization due to epoxy resin itself, the hardener, or the additive.[2] Acute and chronic dermatitis is common among workers and may affect the hands and face as well as the genitalia. All degrees of dermatitis are encountered from the transient to the severe.[1,15,16]

The diglycidyl ether of bisphenol A (MW 340) is a potent skin sensitizer in both animals and humans. As the chain length and MW of the resin increase, the ability to sensitize the skin decreases dramatically. The decreasing capacity of larger molecular weight resins to sensitize the skin is thought to be due to a decreased ability of the larger molecules to penetrate the skin. Unfortunately, some commercial resins of large molecular weight may contain small amounts of 340 MW oligomer, either by accident or design, and still produce allergic contact dermatitis.[2]

The irritating effects of epoxies are even more pronounced in the presence of high moisture and temperature. Dernehl found that 60% of the factory workers working with epoxy resins reported dermatitis in the hot months. He noted that both the irritative allergic phenomena are also prevalent in warm environments.[12]

Sensitization reactions in man caused by repeated exposures to epoxy compounds may be manifested by skin reactions or by asthma-like reactions of the respiratory tract.[14] There is an important difference in the amount of material needed to produce dermatitis on a sensitization basis. Only a very small amount of the allergenic material is required to produce a dermatitis once an individual has been sensitized - whereas in irritant dermatitis there is a time-concentration factor.[1] Previously sensitized persons have developed face dermatitis after passing through workshops where unhardened epoxy compounds were present even though they never touched them.[3] Hardened or "cured" epoxy resins usually contain little free epoxy resin oligomer and are much less likely to sensitize. Extremely allergic individuals, already sensitized, may still react on occasion to the hardened resin.[2] Because this condition is difficult to treat, sensitized individuals may require transfer to other working areas.[14]

One of the major problems in handling epoxy resin systems occurs from the curing agents.[7] Exposures to vapors of the volatile amines can produce lung irritation with respiratory distress and cough, irritation of the mucous membranes of the nose and throat, eye irritation with lacrimation conjunctivitis, primary skin irritation and dermatitis, and sometimes sensitization.[12,8] Polyamide curing agents are distinctly less hazardous to handle than the amines. They can be moderately irritating to the skin but extremely irritating to the eyes. They are less likely to cause skin sensitization than the amines.[12] The acid anhydrides are very irritating to the skin and may also cause allergic sensitization.[15]

Some solvents used in epoxy resin formulations such as methyl isobutyl ketone and xylene are primary skin irritants because of their ability to dehydrate and remove natural oils from the skin. Although sensitization is not associated directly with solvents, they render the skin more vulnerable to attack by the more potent dermatitis producing components of epoxy resin formulations. In this manner they may enhance the sensitizing potentialities of the other materials.[7]

C. Cumulative Trauma Disorders (CTD's)

There is evidence in the literature that cumulative trauma disorders (CTD's) are associated with repetitive and forceful movements of the joints and muscles [17-20]. Examples include tendonitis, tenosynovitis, carpal tunnel syndrome, ganglionic cysts, epicondylitis, myositis, and bursitis. These disorders affect the nerves, tendons, and tendon sheathes of the upper extremity. The reported causal factors of these ailments, particularly those found in the workplace, are the force of an exertion, the posture of the hand/arm during the exertion, and the frequency of the movement. The postures most often associated with upper extremity cumulative trauma disorders are wrist extension and flexion, ulnar and radial deviation of the wrist, open-hand pinching, twisting movements of the wrist and elbow, and shoulder abduction. CTD's are considered in many cases to be work-related because these types of postures and movements are required in many manufacturing and assembly jobs in industry. Occupations for which high incidence of CTD's is known to exist include electronic components assembly, textile manufacture, small appliance manufacturing and assembling, meat processing and packing, fish filleting, and buffing and filing. What is common to all of these jobs is repetitive, stereotyped movement of the hand, arm, and wrist coupled with varying degrees of muscular exertion. The incidence of CTD's among these and other industries has not yet been established, but incidences as high as 44 cases per 200,000 work hours are known to exist[21].

While occupational factors are considered to be major in the development of these disorders, there are many reported non-occupational components of CTD's. Outside activities such as woodworking, tennis, weight lifting, knitting, and sewing impose the same type of physical demands on the musculo-tendinous system as manual work. The carpal tunnel syndrome, and entrapment disorder affecting the median nerve, is associated with other common conditions such as pregnancy, menopause, diabetes, use of oral contraceptives, gynecological surgery, rheumatoid arthritis, acromegaly, and gout[22]. The nature of many of these conditions explains in part why carpal tunnel syndrome occurs from 3 to 10 times more often in women than in men.

An ergonomic evaluation of jobs or work tasks suspected to be associated with cumulative trauma disorders consists primarily of a documentation of the aforementioned hazardous with their respective frequency of occurrence. Videotapes and 35mm still pictures are often taken to aid in this job analysis. The amount of muscular force exerted while performing a particular activity can be measured through the use of surface electromyography[23] of the muscle group of interest, but since there are no definitive studies linking a degree of risk with a certain muscular force level, this measurement is often excluded in a worksite evaluation. Force levels can often be assessed by weighing tools used and objects handled, or by subjectively judging the amount of effort required to perform a certain activity.

There are studies which indicate a level of risk associated with certain frequencies of movements.[23-30] Reported number of movements for which an incidence of CTD's has occurred range from 5000 to 50,000 per day. The variety of activities described, however, e.g., cutting poultry, keystroking, hand sanding/filing, and packing tea, etc., make it difficult to quantitatively assess this variable. Any inferences drawn from these studies about the contribution of frequency of movement as a causative factor to the development of CTD's involves a degree of professional judgement. Consequently, the strategy for reducing the risk of CTD's for a certain task through ergonomic analysis, is to minimize exposure to causative work factors. This is achieved through redesign of work stations, tools used, or work methods that the job analysis indicates are associated with the risk factors.

VI. RESULTS

Initial Survey

On the initial environmental survey a standard non-directed medical questionnaire was administered to 25 employees (8 first shift and 17 second shift) from the armature winding and VPI areas. Review of the questionnaires revealed that dermatitis (9), eye irritation (7), and headaches (6) were the most prevalent symptoms reported.

During the initial survey, deficiencies in work practices and process controls were recognized. General housecleaning procedures in the armature winding area were poor. This was especially evident when the epoxy resins were applied by brush onto the generators. Also, there were no functional wash facilities in the armature winding area nor the VPI room.

A. Follow-Up Survey: Preliminary

1. Environmental

Following the second walk-through which was conducted on the preliminary follow-up survey and covered the hand taping, VPI room, and the coil, armature, and pole winding areas, it was verified that there are numerous epoxy resin systems in use in these areas at the plant. This variety of epoxy resin systems were comprised of several different and unique liquid epoxy resins, epoxy impregnated felts and tapes, and other materials which contained epoxy resin components. Furthermore, many companies manufacture and supply these epoxy materials used at McGraw Edison and hold the contents of their products as proprietary.

Although numerous delays occurred in obtaining the specific composition of the epoxy resin products used, this information was vital to the development of an environmental sampling protocol for the follow-up (in-depth) survey and in making sound recommendations such as substitution of certain epoxy resin liquids/tapes and felts, containing agents known to be highly toxic with substances of lesser toxicity.

2. Medical

A total of 121 questionnaires were distributed during the initial survey; 58 to exposed workers from the four areas mentioned in the HHE request, and 63 to non-exposed workers. The return rate of completed usable questionnaires was 93%. (97% in the exposed and 90% in the comparison group).

Information collected through questionnaire response revealed dermatitis (skin rash and irritation) to be a major problem among the exposed workers, ranging from 55% in the hand taping department to 78% among pole winders.

In addition, irritation of the eyes (56%), nose (40%), and throat (28%) were also significant health complaints among those exposed to epoxy resins at the workplace (Table III).

A high percentage of workers (ranging from 83% - 97%) indirectly related their somatic complaints to workplace exposure by affirming that the reported condition improved when they were away from the job site either on weekends or vacation.

Prevalence of carpal tunnel syndrome (CTS) was determined from 5 questions on the survey form which elicited information about symptoms and/or a history of surgical treatment for this condition. Areas reporting the highest prevalence were armature winding and hand taping (70% and 65% respectively) (Table IV a). The prevalence among the exposed group (56%) was significantly higher than that (7%) of the control group (Table IV b). Women had a higher prevalence of CTS [11 (79%) of 14 workers] than men [19 (48%) of 40 workers], although the difference was not statistically significant (x^2 = 2.89, $0.10 > p > 0.05$).

The OSHA 102 Form showed that in 1979 "occupational skin diseases and disorders" accounted for 23 days away from work and 218 days of restricted work activity. Likewise, "disorders associated with repeated trauma" resulted in 281 days away from work and 29 days of restricted work activity.

B. Follow-Up Survey: In-Depth

1. Environmental

Personal breathing zone and stationary area air sampling was conducted on February 23-24, 1983, to assess employee exposure to total aliphatic amines, total aromatic amines, boron trifluoride monoethylamine, C_2-C_5 aliphatic aldehydes, epichlorohydrin, total volatile fluorides (via boron trifluoride), formaldehyde, lead, methyl tetrahydrophthalic anhydride, and n-butyl glycidyl ether. All sample results were calculated as time-weighted averages for the time period sampled. The areas sampled included the coil winding, hand taping, armature winding, pole winding, and VPI room.

Aldehydes

During soldering operations (soldering leads/connections using rosin core solder) in the armature winding area, two long-term personal and two area air samples were collected for measurement of employee exposure to formaldehyde, acetaldehyde, propionaldehyde, butyraldehyde, and valeraldehyde. The air olumes (in liters) which equaled the total time sampled (in minutes) for these four samples were as follows: 305 (area) and 390 (personal) collected on February 23, 1983, and; 416 (area) and 402 (personal) collected on February 24, 1983. The formaldehyde concentrations for the personal samples were 7.8 ug/m^3 and 53.5 ug/m^3 and the area samples were 53.7 ug/m^3 and 68.5 ug/m^3 (laboratory analytical limit of detection (LOD) in micrograms (ug) per milliliter (ml) was 0.3, and; using a mean field reagent impinger volume of 8.4 ml and mean field sample air volume of 378 liters, the LOD was 6.7 ug/m^3.

These four formaldehyde values are well below the ACGIH[31] 1984-85 criterion of 1500 ug/m^3 (1 ppm) and the OSHA[32] standard of 3700 ug/m^3 (3 ppm). NIOSH, however, considers formaldehyde as a potential occupational carcinogen and as such concludes that an absolute safe concentration cannot be established. Moreover, NIOSH recommends that occupational exposures to formaldehyde be reduced to the lowest feasible level.[6]

One of four of these same samples collected for acetaldehyde revealed trace concentrations (98.4 ug/m^3) in an area sample taken on February 23, 1983 (LOD assuming an impinger volume of 12.5 ml was 0.02 milligrams (mg) per sample, and; LOD using field mean impinger volume and air volume of 8.4 ml and 378 liters, respectively, was 0.44 mg/m^3). This concentration is far below the OSHA[32] standard (360 mg/m^3) and ACGIH[31] criteria (180 mg/m^3) for acetaldehyde.

No detectable propionaldehyde, butyraldehyde, or valeraldehyde were found on these 4 air samples collected during the soldering operations in the armature winding area (LOD 0.02 mg/sample).

Lead

The last procedure performed in the coil winding department (a one-person job) is soldering of the coil copper leads. On February 24, 1983 a full shift (362 minute) personal sample was collected during this process to assess employee exposure to airborne lead (sample volume: 724 liters). The concentration of lead found, 10.1 ug/m^3 (limit of quantitation (LOQ) in ug Pb/sample was less than 1.0), is within the NIOSH and OSHA[32] standards of 50 ug/m^3 and the ACGIH[31] TLV® of 150 ug/m^3.

Boron Trifluoride

Sixteen full-shift air samples were collected for total volatile fluoride analysis to determine if boron trifuoride was present in the air in the armature winding (B-stage process), VPI room, pole winding, and hand taping areas. Eight personal samples and 8 area air samples were collected, 2 each per area and 1 each per day per area on February 23-24, 1984. There was no fluoride detected in any of the samples (LOD of 4 ug fluoride/sample).

MTHPA

Long-term air samples were collected on February 23-24, 1983 to characterize employee exposures to methyl tetrahydrophthalic anhydride (MTHPA) in the armature winding, pole winding, and VPI room. None of the 12 air samples, 6 personal and 6 area (one area sample and one personal sample each per area per day) had any detectable quantities of MTHPA (LOD of 10 ug/sample).

Amines

Seven bulk air area samples (36-43 liters) were collected for qualitative and quantitative aromatic amine analysis: each per area per day in the armature winding, pole winding and hand taping areas and one sample in the VPI room on February 24, 1983. No measurable levels of aromatic amines were found on these high volume area samples (LOD of 1.0 ug/sample) and thus the six long-term personal air samples for specific aromatic amines collected in the armature winding, pole winding and hand taping areas (one each per day for two days) were not analyzed.

To characterize employee exposures to aliphatic amines in the armature winding, pole winding, hand taping, and VPI room, 7 full-shift bulk air area samples (36-44 liters) were collected and analyzed qualitatively and quantitatively: one sample per day in each area for two consecutive days except in the VPI room where one sample was collected on February 23, 1983. Since no detectable quantities of aliphatic amines were found (LOD of 0.1 mg/sample), the six long-term personal samples collected for boron trifluoride monoethylamine in the armature winding, pole winding, and hand taping areas, over two days, (1 per day per area) were not analyzed.

Epichlorohydrin & N-Butyl Glycidyl Ether

Results of air sampling conducted (12 long-term full-shift air samples: 4 personal and 8 area) for epichlorohydrin and n-butyl glycidyl ether revealed no measureable levels (LOD of 0.01 mg/sample) of these compounds in the armature winding (2 personal samples and 2 area samples), pole winding (2 area samples), hand taping (2 personal samples and 2 area samples), and the VPI room (2 area samples).

2. Medical

Rash continued to be reported by 29% (7 of 24) of workers exposed to epoxy resins, and 75% (9 of 12) of workers in the armature winding reported mucous membrane irritation (Table V). The latter was attributed by all affected workers to exposures resulting from running the "B" stage.

A report issued by a company-hired dermatologist in 1976 concluded the fact that skin problems in the hand taping area were related to direct exposure to mica tapes. At that time the dermatologist patch tested 29 employees, 28% of whom were found to be allergic to some component of the mica tapes, but the specific allergen could not be identified.

3. Ergonomic/Biomechanical Assessment & Carpal Tunnel

An ergonomic job analysis was made in the following areas: coil winding, hand taping, armature winding, VPI, and pole winding. In order to discuss the biomechanical stresses associated with these jobs a brief description of the work processes in each of these areas is included.

Coil Winding

At the time of the February 1983 survey, 3 men were working in this area. Production rate was about 100 armature coils per day. In performing this operation, layers of coil are wrapped around a rotating armature. Most of the work is done by the machine, but the operator must align successive layers of coil by hand as the coil is being made. This requires forceful pinch grips. After the winding is completed, the layers are secured with a tape. While doing so, the layers of coil are manually realigned and the tape is applied forcefully, with many pinch grips and extensions and flexions of the wrist required.

Coil Forming

During this operation, the coil wound in the above job is formed by a machine into a piece resembling a figure 8. The compressed air machine does not completely form the coil, so the operator must make adjustments using a mallet. Due to the height and location of the coil when it is in the machine, the mallet is swung with the elbow extended and shoulder flexed 90 degrees in front of the body. The lateral movements made place stress mainly on the elbow and shoulder but also on the wrist. The operator uses clamps to align the layers of wire, but they appear to impose no unusual stresses to the hand/wrist system.

Hand Taping

After the coil is formed, layers of tape (about 7 or 8) are wound around the coil in the hand taping area. At the time of the February 1983 evaluation, there were about 6 women working in this department. Each one completes about 3 coils per day.

Hand taping requires many movements of the hands and wrists, mostly wrist flexion and wrist extension. Considerable force is required because the tape is pulled tightly as it is wound. Taping straight areas of the coil is facilitated by a tool with a handle on it that holds the tape in a dispenser. Curved areas must be done by hand. One problem with this tool, however, is that the coils are mounted on fixtures to provide clearance for the tool as it is wound around the coil. This fixture height requires that the operators work at shoulder height most of the time while taping. Positive aspects of this tool are that it relieves the worker from constantly holding a large roll of tape in the left hand and it minimizes wrist deviations while winding.

Spring-loaded clamps are used to hold layers of tape in place. These require much pinch force to open and seem oversuited for their intended purpose. Some workers use clothes-pin type clamps made of scrap coil instead of the pinch clamps. These require no force to apply and hold the tape in place adequately.

Armature Winding

There were 12 men working in this area at the time of the February 1983 evaluation. The first part of this operation is to insert coils into the core of the generator. Hammers are used to secure them into place. There is some bending over and in other cases reaching above the shoulders while inserting these coils. The main biomechanical stresses are to the elbow while hammering. Reaching above the shoulders is minimized by rotating the generator core as the insertion of coils progresses.

Tape is wound around the coils after they are inserted. This requires many finger manipulations and deviations of the wrist. The pace of this work, however, is moderate, and the variety of activities performed, e.g., hammering, applying resins and glue, winding tape, distributes the stresses to several areas of the musculoskeletal system rather than localizing it to one.

Following this operation, the core is moved to another area in armature winding and placed on its side. Leads are bent to shape and soldered together, and additional insulating tapes are applied. This is very "tight" work requiring many hand and finger manipulations to wind the tape around the closely positioned coils. Hooks are used in some cases to pull the tape through hard to reach places. The pace of this work is also moderate, but considerable muscular force is exerted while wrapping the layers of tape around the coils.

Pole Winding

This area is part of armature winding. The only job evaluated was the parallel ring wrapping operation. This machine is used to apply a mica tape around a circular ring which is positioned around the generator core. The parallel ring machine works automatically; the operator only has to move the ring as tape is being applied. However, this machine is hard to control and often breaks the tape. When it reaches operating speed, it causes the table to vibrate, and the operator must exert considerable force to hold onto the ring and move it smoothly in a circular fashion. There appears to be quite a bit of vibration imparted to the hand, arm, and wrist while using the parallel ring machine.

VPI

Following the armature winding operations, the core is sent to the VPI room where a silicon agent is applied manually with a brush, and the core is baked. After various vacuum and pressure cycles are completed, excess material must be chiseled off the edges of the core. This requires manual activity with at times, considerable muscular force. There is chiseling work done above shoulder height which can be minimized if the core is rotated as a particular quadrant of the piece is completed.

Review of the plant's 1982 medical reports revealed 38 cases (31 men, 7 women) which affected the musculoskeletal system. Thirteen cases accounted for 306 lost days, for an average of 23.5 days per lost time incident. The other 25 cases resulted in no lost time.

The distribution of these medical cases per area of the plant was as follows:

Armature Winging: 21
Tapers: 6
Assemblers, Stackers: 2
Machine Shop: 4
Welders: 2
Test Floor, Maintenance Department: 3

Reported disorders on these medical records included:

Carpal tunnel syndrome: 6, bilateral: 3, decompressions: 4
Ganglionic cysts: 1
Dequervain's: 1
Trigger finger: 1
Back, shoulder pain: 10
Elbow, arm pain: 7
Finger pain: 3
Wrist pain: 7
Knee pain: 2

Of the 6 carpal tunnel syndrome cases, 2 were women hand tapers, 3 were male armature winders, and the last was a female armature winder.

VII. DISCUSSION

A. Environmental

The only detectable levels of airborne contaminants found was that of lead, acetaldehyde, and formaldehyde. Employee exposure to traces of formaldehyde was indicated by the results of personal and area air samples.

B. Dermatitis

At McGraw Edison, the different epoxy resin systems and their component parts (hardeners or curing agents, diluents, modifiers, fillers, etc.) have some chemical ingredients common to all of them. The majority of the resin systems used at the plant contain dermatitis causing agents and many have known sensitizers or allergens. However, as was the finding at McGraw Edison, in most cases it is not known whether the high incidence of dermatitis (and potential for sensitization) is due to the uncured epoxy resin, the resin modifier, the curing agent, or the cured resin.[33]

Both mucous membrane irritation and dermatitis were common among workers exposed to epoxy resins; the prevalence of dermatitis decreased slightly between the two medical surveys.

C. Ergonomic/Biomechanical Assessment & Carpal Tunnel Syndrome

Effects consistent with repeated biomechanical trauma, specifically carpal tunnel syndrome, were also commonly reported, especially among workers in the armature winding and hand (coil) taping areas. While the literature has debated whether gender[34,35] is a contributing factor, since the majority of reported CTS cases are female, it appears from this survey that job task rather than gender may be the major contributing factor. Notably high proportions of both men and women performing repetetive taxing tasks reported either having symptoms or surgery for this disorder than did workers not performing these tasks.

Due to the nature of the work performed at McGraw Edison, the elimination of manual activity from jobs is virtually impossible. Forming wire into coils, wrapping coils with insulating tape, and inserting coils into generator cores is best done by hand. There are operations, particular in the armature winding area, where space limitations preclude the use of automatic tools. The goal of the company should be to design tools, workplaces, and fixtures and implement work practices which minimize the manual activity required to perform the various operations needed to manufacture electric generators/motors.

VIII. RECOMMENDATIONS

In view of the findings of the environmental, medical, and ergonomic investigations; the following recommendations are made to ameliorate existing or potential hazards and to provide a better work environment.

A number of the following recommendations were also made in the Interim Reports.

Dermatitis & Epoxy Related Recommendations:

1. Employees should be encouraged to report every case of dermatitis, no matter how minor, so that prompt medical attention may be received and potential occupational causes can be identified and controlled.

2. Scrupulous attention to proper work practices and good personal hygiene should be stressed, with the goal of preventing or minimizing contact with the epoxy resin materials. More frequent hand washing by workers using epoxy resins, especially preceeding eating, drinking, smoking, breaks, the use of lavatories, and before leaving the plant. Neutral or acid soaps should be used instead of alkaline, powdered or abrasive cleansing agents. If solvents (such as isopropanol) are used for removing epoxy materials from skin surfaces, they should be used with great care, limited to the removal of small areas of hardened resin from the skin, and followed by washing with soap and water. A subsequent application of an acid mantle cream will also help to neutralize alkaline residuals.

3. Personal protective equipment including long sleeved shirts, coveralls or aprons, and gloves should be provided for and used by those employees exposed to epoxy resins. The gloves used should be tear-resistant, disposable, impervious to the epoxy resin materials, and of sufficient length.

4. Barrier creams (which will not interfere with the insulating process) should continue to be provided and used. If necessary, the company should employ a local dermatologist to advise affected workers about their problems.

5. Establish and practice good housekeeping standards to facilitate keeping the work areas as clean as possible.

Education

6. Plant management should obtain current Material Safety Data Sheets and all available information regarding epoxy resin materials used (their content and health effects) and make this information available to all personnel.

7. Worker Education: Classes concerning the potential health problems associated with epoxy resin exposure and methods of protection should be offered on a regular basis (at least once a month). This could be a joint responsibility of the medical personnel at the plant and the occupational safety and health committee.

General Monitoring

8. A monitoring system should be instituted and maintained by the plant nurse to keep concise updated records on the type and number of health complaints reported by workers. In addition, updating of OSHA 200 Forms for 1979 through the present is advised.

Ergonomic Recommendations

9. In the coil winding area, use a hand held tape dispenser which would apply a loop of tape around the coil cross-section in one motion. Tools of this nature are used in supermarkets to put pricing labels on food products.

10. Install an adjustable or at least raised surface to stand on in the coil forming area. During much of the cycle time (loading machine, hammering, securing clamps, unloading machine), the worker is in a posture with the hands at elbow height and above. Angling the machine towards the worker (if this were possible) is an additional way to minimize reach distances and undesirable postures during the forming process.

    A mallet with a slightly bent handle would reduce the amount of wrist deviations required while forming the coil. This tool could be custom made or use a mallet with a Bennett handle (19° handle deviation) which is commercially available.

11. In the hand taping area, angle the fixtures toward the worker so that hand heights can be reduced from the current shoulder level. One reason the fixtures are as high as they are is to provide clearance for the hand taping tool. If the fixtures were moved to the edge of the table, there would be no difficulties with clearance regardless of the height of the fixture.

    The hand taping tool is well-designed in its present form. A consideration, however, is to provide a better handle. Hand forces while using the tool could be minimized if the handle was about 1.5 inches in diameter, long enough to span the thenar and hyperthenar eminences of the hand (fatty parts below the thumb and little finger), and made of a firm, but yielding material.

12. Discontinue the use of the spring-type clamps in the hand taping area. These clamps are very difficult to open, requiring a pinch-type grip, and are much too strong for their intended purpose. The clothes-pin type clamp made of used coil or any other similar type secures the tape as well, but requires no forceful pinch grips to open.

13. Redesign or discontinue using the parallel ring machine in the pole winding area of armature winding. This machine imparts trauma to the hand/arm/wrist and is not very efficient. Unless the excessive vibration can be reduced, hand taping of the large circular coils is recommended.

14. Encourage workers in the armature winding area to follow established work practices such as to rotate the large generator cores as insertion of coils progresses. This practice minimizes working above elbow and shoulder height. Tools with bent handles as recommended in #10 above with dimensions as recommended in #11 above should be considered to minimize hand forces while using the various types of hand tools which are found in this area.

15. In the VPI room, if feasible, consider masking the outer edges of the generator core so that the excess material does not have to be chiseled off after the impregnation process is complete. A high temperature material would have to be used, but a significant amount of manual activity could be avoided if a suitable material could be found.

    As in armature winding, established practices such as rotating the core as material is removed, should be followed. Tools used in this area should also be designed with handle configurations as recommended above.

16. Consider a job rotation program within similar areas so that biomechanical stresses are not concentrated in one area of the upper extremity.

17. Conduct education and training programs in the plant so that workers are aware of the different types of hand/wrist/arm postures that are associated with cumulative trauma disorders of the upper extremity. Many of the jobs evaluated were very unstructured, providing much flexibility in the motion patterns required to complete the work. If workers know which postures are most stressful, some could be avoided with no loss of production rate or quality. A booklet which could be used as a model for such a program is Industrial Ergonomics.[36]

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XI. DISTRIBUTION AND AVAILABILITY OF REPORT

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

1. Electric Machinery Power Systems Group McGraw Edison Company
2. AFL-CIO Local 1140
3. NIOSH, Region V
4. OSHA, Region V

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 I
Air Sampling and Analysis Methodology
Electric Machinery-McGraw Edison Company
Minneapolis, Minnesota
HETA 81-369 & 81-466

Substance	Collection Device	Flow Rate (liters per minute)	Analysis	References[4]
Aliphatic Amines	Silica Gel Tube	0.1	Gas Chromatography	NIOSH P&CAM 276 with modifications*
Aromatic Amines	Silica Gel Tube	0.05 - 0.1	Gas Chromatography	NIOSH P&CAM 168 with modifications*
Total Volatile Fluorides (Boron Trifluoride)	Millipore© Backup Pad treated with 300 uL sodium carbonate (glycerol)	1.5	Ion Chromatography	----
n-Butyl Glycidyl Ether	Charcoal Tube	0.05 & 0.1	Gas Chromatography	NIOSH P&CAM 127 with modifications*
Epichlorohydrin	Charcoal Tube	0.05 & 0.1	Gas Chromatography	NIOSH P&CAM 127 with modifications*
Formaldehyde	Midget Impinger with 15ml. Sodium Bisulfite	1.0	Colorimetric	NIOSH P&CAM 125
Acetaldehyde Propionaldehyde n-Butyraldehyde n-Valeraldehyde	Midget Impinger with 15 ml sodium bisulfite	1.0	Gas Chromatography	NIOSH P&CAM 127 with modifications*

* The modifications included sample preparation, instrument condition settings, and/or column selection
** The only available media at the time of the environmental survey

Table I (cont'd)
Air Sampling and Analysis Methodology
Electric Machinery-McGraw Edison Company
Minneapolis, Minnesota
HETA 81-369 & 81-466

Substance	Collection Device	Flow Rate (liters per minute)	Analysis	References[4]
Lead	Millipore©** Backup Pad Treated with 300 ul Sodium	2.0	Inductively Coupled Plasma Atomic Emission Spectroscopy	NIOSH P&CAM 351 with modifications*
Methyl Tetrahydrophthalic Anhydride	FVC Filter	1.5 & 2.0	Gas Chromatography	NIOSH P&CAM 322 with modification*

* The modifications included sample preparation, instrument condition settings, and/or column selection
** The only available media at the time of the environmental survey

Table II
Environmental Evaluation Criteria
Electric Machinery-McGraw Edison Company
Minneapolis, Minnesota
HETA 81-369 & 81-466

Substance	Evaluation Criteria (mg/m^3)2	Source	OSHA Standard (mg/m^3)2
Boron Trifluoride	3 (1ppm) ceiling limit	ACGIH	3 (1ppm) ceiling limit
n-Butyl Glycidyl Ether	30 (5.6 ppm) 15 minute ceiling limit	NIOSH	270 (50 ppm)
Epichlorohydrin	NIOSH recommends that epichlorohydrin be handled as if it were a human carcinogen. Exposures should be minimized with engineering and work practice controls. practice controls.	NIOSH	19 (5 ppm) Studies of carcinogenicity were not available when this standard was developed.
Lead	0.05	OSHA	0.05
Acetaldehyde	180	ACGIH	360
Formaldehyde	NIOSH recommends that formaldehyde be handled as a potential occupational carcinogen. Engineering controls and work practices should be employed to reduce occupational exposure to the lowest feasible limit.	NIOSH	3.7 (3 ppm)3
n-Valeraldehyde	175	ACGIH	----

1. All concentrations are time-weighted averages (TWA) exposures for a normal workday unless designated as a ceiling value.

2. mg/m^3: milligrams of substance per cubic meter of air.

3. ppm: parts of material per million parts of air.

Table III
Percent of Workers Reporting Symptoms on Initial Survey
Electric Machinery-McGraw Edison Company
Minneapolis, Minnesota
HETA 81-369 & 81-466

Symptom	Exposed Workers*	Non-Exposed Workers**	Condition Improves Days off/Vacation
Red, itchy skin (no bumps)	39%	7%	95%
Red, itchy skin (with bumps)	21%	2%	83%
Dry skin	33%	14%	84%
Eye irritation	56%	12%	97%
Nose irratation	40%	7%	83%
Throat irritation	28%	5%	94%

*Total = 56
**Total = 57

Table IVa
Percent of Exposed Workers, by Department, Reporting Symptoms or Surgical History For Carpal Tunnel Syndrome
Electric Machinery-McGraw Edison Company
Minneapolis, Minnesota
HETA 81-369 & 81-466

Department	Percent Reporting CTS Symptoms/Surgery
VPI	0%
Pole Winding	11%
Hand (Coil) Taping	65%
Armature Winding	70%

Table IVb
Percent of Exposed Workers, by Department, Reporting Symptoms or Surgical History For Carpal Tunnel Syndrome
Electric Machinery-McGraw Edison Company
Minneapolis, Minnesota
HETA 81-369 & 81-466

Group	Number	Percentage*	P-Value
Exposed	30	56%	<.001 (highly significant)
Non-Exposed	4	7%	

*Denominators used for both groups are the number of persons answering the questions pertaining to CTS.

Table V
Somatic Complaints Reported By Exposed Group During Follow-Up Survey
Electric Machinery-McGraw Edison Company
Minneapolis, Minnesota
HETA 81-369 & 81-466

Dept.	No. Exposed	Current Rash	(%)	History of Rash Past 3 Months	Current Mucous Membrane Irritation	(%)
VPI	2	1	(50%)	0 (0%)	1	(50%)
Pole Wind.	4	1	(25%)	1 (25%)	0	(0%)
Arm. Wind.	12	3	(25%)	3 (25%)	9	(75%)
Hand Taping	6	2	(33%)	1 (17%)	0	(0%)
Total	24	7	(29%)	5 (21%)	10	(42%)

DEPARTMENT OF HEALTH AND HUMAN SERVICES
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