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EMCO HIGH VOLTAGE COMPANY  
SUTTER CREEK, CALIFORNIA

NIOSH INVESTIGATORS:  
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## I. SUMMARY

On April 29, 1986 the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation at EMCO High Voltage Company, Sutter Creek, California. The requestor was concerned that he and another worker may be exposed to several chemical substances during the fabrication of power supply modules. Reported symptoms included lightheadedness and chest pain once or twice a week while working in the potting room.

On July 30-31, 1986 an initial environmental survey was conducted, and on August 18-19, 1986 a follow-up survey was conducted. Four environmental air samples were collected during the coating and developing operation to evaluate air concentrations of chlorobenzene, xylenes, and cyclohexanone. Chlorobenzene concentrations ranged from none detected to 1.5 ppm, and xylene concentrations ranged from 3.5 to 7.5 ppm. Both of these chemical air concentrations were well below the evaluation criteria. No cyclohexanone was detected. Also, four air samples were collected during the same process and analyzed for 2-methoxyethanol and 2-ethoxyethanol, but neither of these chemicals was detected.

Four environmental air samples were collected during the epoxy potting operation to evaluate air concentrations of butyl glycidyl ether (BGE) and epichlorohydrin. BGE air concentrations ranged from none detected to 0.99 ppm which is below the evaluation criteria, and no epichlorohydrin was detected.

Informal interviews were conducted with several workers. Employees working in the general work area reported no health complaints other than periodic complaints about a chemical odor during panel coating and developing. One worker reported intermittent nose and throat irritation during pot soldering.

Based on environmental air sampling results collected during the coating and developing operation, no overexposures to chlorobenzene or xylenes were measured, and no cyclohexanone, 2-methoxyethanol and 2-ethoxyethanol were detected. No overexposures to butyl glycidyl ether was measured, and epichlorohydrin was not detected. A potential exposure to the fluxing agent used during the pot soldering operation may exist based on observations and an interview with the operator. Recommendations are included in section VIII of this report to prevent unnecessary chemical exposures.

**KEYWORDS:** SIC 3679 (Electronic Components, Not Elsewhere Classified), manufacturing high voltage power supply modules, manufacturing printed circuit boards, epoxy potting, solder dipping operation.

## II. INTRODUCTION

On April 29, 1986 the the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation from an employee working at EMCO High Voltage Company, Sutter Creek, California. The employee was concerned that he and one other employee who work in the potting room may be exposed to several chemicals during the following processes: copper panel coating and developing, etching, solder dipping, and epoxy potting. The requestor reported lightheadedness and chest pain once or twice a week while working in the potting room.

On July 30-31, 1986 an initial environmental survey was conducted at EMCO High Voltage and on August 18-19, 1986 a follow-up survey was conducted.

## III. BACKGROUND

EMCO High Voltage Company is a manufacturer of power supply modules. The company has been in existence for about 11.5 years, and it has been in this facility for about two years. Thirteen employees currently work for the company. Employees generally work 8 hours a day, five days a week from 7:00 am to 3:30 pm. Employees are not required to take any pre-employment physical, and emergency medical services are available at a nearby hospital.

Several processes were observed during the manufacturing of high voltage power modules. The processes used to make the different modules do not differ, but the workload varies depending on the number of purchase orders received. None of the processes described below operate eight hours a day five days a week. The fabrication operator circulates from one task to another during the work day. In fact, several days may pass where an operation, e.g. epoxy potting, is not conducted at all.

Four processes were observed: coating and developing copper panels, etching copper panels, epoxy potting and solder dipping. All of these processes are located in the potting room (19' X 8') which has a general room exhaust fan. An attempt was made to measure the exhaust velocity of the fan, but this was not possible since there was no exhaust duct to calculate the surface area.

The panel coating and developing process is done in a wood/metal cabinet. The cabinet, which is on casters, is used outside during the warmer months and indoors during the cooler months. The cabinet has three small exhaust fans which remove the KODAK Photo Resist (KPR), Type 3 and KPR developer vapors while coating and drying and developing the panels. The cabinet fans exhaust the air through a common duct to the outside air.

Fiberglass panels (9" X 12") are pre-coated with a copper layer on one or two sides. These copper panels serve to make printed circuit boards for the power modular units.

1. Coating and Developing: Copper coated panels are coated with KPR using a lithopad. No more than six panels can be coated at one time due to the size of the drying cabinet which is ventilated outdoors. It takes about 4 to 5

minutes to coat six panels and about 20 to 30 minutes to dry. Once dry, a negative is taped to the panel and placed in an ultra-violet light exposure booth for 3.5 minutes. Afterwards, the negative is removed and the panel is placed into a series (3) of Kodak Photo Resist Developer (KPRD) baths for 3 minutes each, after which the panel is air dried in the developer booth, for 30 minutes, which is also ventilated outdoors. It should be noted that the developer is changed about every 2 to 3 weeks. Protective gloves were not worn by the operator at the time of the initial survey.

2. Etching: Sodium persulfate is used to etch the copper panels. The etching solution consists of eight gallons of sodium persulfate diluted in 4 gallons of deionized water. The operator turns on the bench top etcher to pre-heat the sodium persulfate solution (about 80-85° F). When the etcher tank is ready, the developed copper panel is placed inside the etch tank, the lid is closed and the sprayer is turned on. The etching process can take from 5 to 15 minutes depending on the age of the etching solution, dirtiness of the KPRD, etc. Once etching is completed, the panel is removed, rinsed in water, cleaned, and inspected. The panel is cut into the individual cards, drilled and sized to specifications, and used on the assembly line. No protective equipment was worn by the operator while inserting or removing the panels from the etching tank.

3. Epoxy Potting: Once the power module units have been assembled and inspected, they are bottom potted. A two part resin (Eponç Resin 815 and Versamidç 140) is poured into a cup, in equal parts, and mixed together. A black dye is then added to the resin and mixed about 3 to 4 minutes. The resin is poured into an aluminum foil tray and slightly warmed to make the resin less viscous so it can be easily poured into the units. The units are bottom potted, i.e. about 90 percent of the resin is poured into the units after which the epoxy is dried overnight and the units are tested. After testing the equipment, the units are top potted with the epoxy resin. No protective equipment was worn by the operator during this operation.

4. Solder Dipping: The solder dipping table is positioned in front of the general room exhaust fan. A large and small solder pot containing a 60%-40% lead tin solder is heated to about 500°F. The cards are dipped into a flux (3 % hydrochloric acid) and then dipped into the soldering pot. The operator wears safety glasses and a lab coat whenever performing this operation.

On May 19, 1986 a California Occupational Safety and Health Administration (CAL-OSHA) investigator conducted a follow-up investigation at EMCO High Voltage during which time an area air lead sample was collected while the solder dip pots were being heated. No airborne lead was measured, i.e. the concentration was below the analytical limit of detection 16 micrograms/sample.

#### IV. DESIGN AND METHODS

Several workers were informally interviewed to determine if there were any health complaints regarding any of the processes evaluated.

1. Environmental air samples were collected on a charcoal tube during the coating and developing process. The tube

was analyzed for chlorobenzene, cyclohexanone, and xylenes. The A and B sections of the charcoal tube were separated and analyzed by gas chromatography (G-C) according to NIOSH Methods 1500 and 1501 with modifications. The limit of detection was 0.01 milligram/sample for chlorobenzene and xylenes, and 0.02 milligram/sample for cyclohexanone.(1) Also, environmental air samples were collected on charcoal tubes and analyzed for 2-methoxyethanol and 2-ethoxyethanol. The A and B sections of the charcoal tube were separated and analyzed by G-C according to NIOSH Method 1403 with modifications. The limit of detection was 0.01 milligram/sample for all analytes.

2. Environmental air samples were collected during the epoxy potting operation on charcoal tubes. The tube was analyzed for butyl glycidyl ether(BGE) and epichlorohydrin. The A and B sections of the charcoal tube were separated and analyzed by G-C according to NIOSH Method 1010 and S-81 with modifications. The analytical limit of detection was 0.01 milligram/sample for both analytes.

## V. EVALUATION CRITERIA

### A. 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 may experience adverse health effects because of individual susceptibility, 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 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 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 (OSHA) occupational health standards. Often, the NIOSH recommendations and ACGIH TLV's are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLV's usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended exposure limits, 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- 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. Substances with their environmental criteria for this evaluation are shown below.

TABLE A

Recommended Exposure Limit  
8-Hour Time-Weighted

<u>SUBSTANCE</u>	<u>Exposure Basis ppm (1)</u>	<u>Source</u>
Butyl Glycidyl Ether(BGE)	4.4	NIOSH
	25	CAL-OSHA, ACGIH
Epichlorohydrin	0.5	NIOSH
	2	CAL-OSHA, ACGIH
Chlorobenzene	75	CAL-OSHA, ACGIH
Cyclohexanone	25	CAL-OSHA, ACGIH
Xylene	100	NIOSH, CAL-OSHA, ACGIH
2-Ethoxy Ethanol	5	ACGIH
	50	CAL-OSHA
2-Methoxy Ethanol	5	ACGIH
	50	CAL-OSHA

1. ppm-Parts of a vapor or gas per million parts of contaminated air by volume

B. Toxicology

1. Solvents: xylene, chlorobenzene, cyclohexanone, 2-ethoxyethanol, and 2-methoxyethanol are solvents. They are primarily absorbed by inhalation or through the skin in workplace exposures. Excessive exposure to solvents may result

in neurologic effects and dermatologic effects, including: eye and upper respiratory tract irritation, sleepiness, fatigue, headache, memory disturbance, difficulty in concentrating, nausea, vomiting, abdominal cramps, loss of appetite, weight loss, flushed skin, skin defatting and irritation, and folliculitis (inflammation of hair follicles). The intoxicating effects of alcohol are frequently increased when alcohol is consumed after exposure to solvents.(2,3,4,5)

Extreme exposures may result in tremor, loss of coordination, mental confusion, loss of consciousness, coma and death. In addition, excessive or prolonged exposure to some of these solvents may result in chronic or delayed-onset effects including visual disturbances, loss of the sense of smell, impaired coordination and sense of touch, decreased nerve conduction velocity, neurobehavioral changes, and kidney and liver damage.

2. Butyl Glycidyl Ethers: This is a colorless liquid which is used as reactive diluent in epoxy resins. BGE causes central nervous system depression and is a skin and eye irritant in animals; it is expected that severe exposure will produce similar effects in humans. No chronic skin effects have been reported in humans.(3) However, sensitization dermatitis may occur with repeated skin contact.(3,6)

3. Epichlorohydrin: This solvent is used in the manufacture of epoxy resins. Locally, exposure to epichlorohydrin results in irritation to the eye, respiratory tract, skin, and systemic toxicity from absorption of the liquid through the skin.(8) Cancers in mice were caused, under certain conditions, by skin application and subcutaneous injection.(9) Mutagenic effects were observed in microbial systems and the fruit fly exposed to epichlorohydrin.(7)

## VI. RESULTS AND DISCUSSION

On August 18 and 19, 1986 NIOSH conducted environmental air monitoring of two operations to determine whether employees are being overexposed to any chemicals. All chemical exposures are compared to the NIOSH evaluation criteria or the CAL-OSHA standard listed in Table A, page 6. Since the work load varies, an attempt was made to characterize a worst case workload for the purpose of this study.

At the conclusion of the initial survey, a closing conference was held with the company owners. The NIOSH investigator recommended that specific personal protective equipment (see section VIII) be used during certain operations. Also, the investigator indicated that there may be a long term potential fire hazard from the solvents in the KPR and KPRD which may be absorbed by the wooden cabinet. Given the potential fire risk, the owners decided, subsequent to the initial survey to move the operation outside where it was previously done. Additionally, the owners decided to phase out the coating and developing process by the end of September because this process was too slow to keep up with the workload. The company will purchase the printed circuit boards from another manufacturer, and a silk screening process will be used to make prototype boards only. The NIOSH investigator was unaware of these changes until the follow-up survey was to be conducted. Thus, the KPR and KPRD operation was not surveyed as it existed during the initial survey, but it was monitored outdoors.

Four environmental air samples were collected outdoors during the coating and developing of 11 cards to evaluate air

concentrations of chlorobenzene, xylenes, and cyclohexanone (Table I). Chlorobenzene concentrations ranged from none detected to 1.5 ppm, xylene concentrations ranged from 3.5 to 7.5 ppm, and no cyclohexanone was detected. Both of the chemical air concentrations measured were well below the evaluation criteria listed in Table A. In addition, four air samples were collected during the same process and analyzed for 2-methoxyethanol and 2-ethoxyethanol, but neither of these chemical were detected. It should be noted that the ambient air temperature was measured to be about 97°F with no breeze which is considerably warmer than the temperature inside the potting room.

Four environmental air samples were collected during the epoxy potting operation to evaluate air concentrations of butyl glycidyl ether and epichlorohydrin. A total of 48 cups were potted at one time which was described to be a heavy work load. BGE air concentrations ranged from none detected to 0.99 ppm which is below the evaluation criteria, and no epichlorohydrin was detected.

No air samples were collected during the etching operation because the bench top etcher is enclosed, and the solution is only slightly heated which would not give rise to the production of vapors based on the operation observed. The worker did not use protective gloves when removing the panels from the bench top etcher.

No air samples were collected during the solder dipping operation because no airborne lead was measured during the CAL-OSHA investigation. During the NIOSH follow-up study, the solder dipping operation was observed for the first time, and it appeared that there may be a potential exposure to the fluxing fumes as the part is being dipped into the soldering pot. The general room exhaust fan which is positioned within two feet of the pots does not appear to collect all the flux fumes. The operator was observed blowing the fumes away from his face so not to inhale the irritating fumes.

On September 15, 1986 a follow-up telephone call was made to the CAL-OSHA inspector to discuss the solder dipping operation. It was learned that the lead area air sample was collected to determine whether the heated soldering pot released any lead fumes. No soldering was done during the day of the inspection, thus the inspector did not have the opportunity to observe solder dipping of fluxed parts.

Based on interviews with the fabrication operator, it appears that he may have intermittent exposures to fluxing fumes if he stands close to the soldering pot. The general room exhaust fan does not immediately exhaust all the flux fumes away from the operator's breathing zone. It is unlikely that any lead fumes would be generated during solder dipping since the temperature of the soldering pot is kept at 500°F, and lead fume production is usually insufficient at temperatures below 1000°F.(10) Interviews with several of the employees who work inside the potting room and in the general work area revealed that there were no specific health complaints other than periodic complaints about the KPR odors. The fabrication operator noted that the KPR could still be smelled on his fingers after washing.

## VII. CONCLUSIONS

Based on the environmental air sampling results collected during this investigation, no overexposures to chemicals were measured during the developing and coating and epoxy potting operation. Airborne exposures to the sodium persulfate

during the etching operation are unlikely to occur based on the operation observed. A potential exposure to fluxing fumes may occur during the pot soldering operation. The operator's periodic complaints of throat and nose irritation indicates that the general room exhaust fan is not properly exhausting the flux fumes away from the worker's breathing zone.

#### VIII. RECOMMENDATIONS

1. The fabrication operator should wear a protective glove during the coating and developing of the copper boards with KPR and KPR developer to prevent dermal exposure.
2. A protective glove and goggles should be worn when weighing-out the sodium persulfate to prevent unnecessary exposure.
3. A protective glove should be worn whenever removing panels from the bench top etcher.
4. A protective glove should be worn whenever mixing and pouring the epoxy resins.
5. If the coating and developing process is not phased out as planned, air monitoring should be conducted if the coating and developing process is returned indoors.
6. It is recommended that local exhaust ventilation with a movable duct be used during the pot soldering operation to collect fluxing fumes.

IX. REFERENCES

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1. Emco High Voltage Company
2. California-Occupational Safety and Health Administration
3. NIOSH, Region IX
4. U.S. Department of Labor, Region IX

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  
 SUMMARY OF ENVIRONMENTAL AIR  
 SAMPLES COLLECTED FOR SOLVENTS  
 DURING COATING AND DEVELOPING

EMCO High Voltage Company  
 Sutter Creek, California  
 August 18, 1986

<u>Sample Number</u>	<u>Type Sample</u>	<u>Description/Location</u>	<u>Exposure Period</u>	<u>Volume (Liters)</u>	<u>Solvent Concentration (ppm<sup>1</sup>)</u>	
					<u>Xylene</u>	<u>Chlorobenzene</u>
1	P <sup>2</sup>	Developing process	0947-1618	9.2	3.5	0.24
3	A <sup>3</sup>	On the cabinet counter	0947-1123	10.1	7.5	1.5
5	A	On the cabinet counter	1124-1450	21.5	4.9	ND <sup>4</sup>
7	A	On the cabinet counter	1451-1618	8.9	4.6	1.2
Limit of Detection per sample (mg <sup>5</sup> )					0.01	0.01
Limit of Quantitation per sample (mg)					0.01	0.01

1. ppm-Parts of a vapor or gas per million parts of contaminated air by volume.
2. P-Personal air samples.
3. A-Area air samples.
4. ND-None Detected.
5. mg-Milligrams of a substance

TABLE II  
 SUMMARY OF ENVIRONMENTAL  
 AIR SAMPLES COLLECTED DURING  
 THE EPOXY POTTING OPERATION  
 EMCO High Voltage Company  
 Sutter Creek, California  
 August 19, 1986

<u>Sample Number</u>	<u>Type Sample</u>	<u>Description/Location</u>	<u>Exposure Period</u>	<u>Volume (Liters)</u>	<u>Butyl Glycidyl Ether (ppm<sup>1</sup>)</u>
11	P <sup>2</sup>	Potting room, mixing and pouring epoxy	1323-1534	2.8	0.67
12	A <sup>3</sup>	Potting room, mixing and pouring epoxy	1323-1534	17.1	0.99
13	A	Assembly line, just outside potting room	1323-1534	10.8	ND <sup>4</sup>
14	A	Assembly line, just outside potting room	1323-1534	14.9	ND
Limit of Detection per sample (mg <sup>5</sup> )					0.01
Limit of Quantitation per sample (mg)					0.01

1. ppm-Parts of a vapor or gas per million parts of contaminated air by volume.
2. P-Personal air samples.
3. A-Area air samples.
4. ND-None Detected.
5. mg-Milligrams of a substance