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Siemens Energy & Automation, Inc.
Distribution Products Division
Urbana, Ohio

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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.

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by J. Clinton Morley and Doug Trout, of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Analytical support was provided by Ardith Grote. Technical and field support was provided by Kevin Hanley. Desktop publishing was performed by Ellen E. Blythe (DSHEFS). Review and preparation for printing was performed by Penny Arthur.

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Health Hazard Evaluation Report 97–0154–2693
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Urbana, Ohio
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SUMMARY

In March 1997, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation (HHE) from the International Brotherhood of Electric Workers (IBEW) Local 1740. The request identified mouth sores, nose bleeds, blisters in the eyes, rashes, and throat irritation as potentially being associated with the manufacturing of circuit breaker cases in the plastics department at Siemens Energy and Automation plant in Urbana, Ohio. The material of concern was identified as a bulk molding compound containing styrene and vinyl toluene–based plastic resin. This request was followed by a similar management request in May 1997.

NIOSH investigators performed an initial site visit at the Siemens facility on August 20–22, 1997. During the initial site visit, employee interviews were conducted, a questionnaire was administered to plastics department employees, the manufacturing process and work practices were observed, company records were reviewed, and air samples were collected for vinyl toluene, styrene, metals, particle characterization, and volatile organic compounds. Subsequent head space analysis of heated raw process materials revealed the presence of formaldehyde. A follow–up site visit was performed on January 15–16, 1998, to collect air samples for formaldehyde vapor, formaldehyde on dust, and inhalable dust.

Employees reported upper respiratory irritant symptoms that appeared to be associated with the use of bulk molding compound #1412 at Press #37. Additionally, employees reported skin rashes that they felt were work–related. Employees are exposed to many contaminants which are known dermal, eye, and upper respiratory irritants. Individually, the air contaminant concentrations of the measured substances did not exceed established occupational exposure criteria; however, the combined effect of the exposures is not fully known and may be responsible for the reported symptoms. Recommendations are made in this report to minimize exposures including ventilation improvements, vacuum cleaning of parts in lieu of compressed air, and the prohibition of eating and drinking in the plastics department.

Keywords: Primary SIC: 3613 (Switchgear and Switchboard Apparatus), Secondary SIC: 3089 (Plastic Products, not elsewhere classified), Compression Molding, Plastics Manufacturing, Dermal Irritation, Eye Irritation, Upper Respiratory Irritation, Styrene, Vinyl toluene, Formaldehyde, Fiberglass, Circuit Breaker Cases, Bulk Molding Compounds

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INTRODUCTION

In March 1997, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation (HHE) from the International Brotherhood of Electric Workers (IBEW) Local 1740. The request identified mouth sores, nose bleeds, blisters in the eyes, rashes, and throat irritation as potentially being associated with the manufacturing of circuit breaker cases in the plastics department at Siemens Energy and Automation plant in Urbana, Ohio. The material of concern was identified as a bulk molding compound containing styrene and vinyl toluene–based plastic resin. In May 1997, NIOSH received a similar HHE request from management representatives at this facility. The management request identified nausea and dizziness associated with the manufacturing of circuit breaker cases in the plastics department.

NIOSH investigators performed an initial site visit of the Siemens facility on August 20–22, 1997. During the initial site visit, employee interviews were conducted, a questionnaire was administered to plastics department employees, the manufacturing process and work practices were observed, company records were reviewed, and air samples were collected for vinyl toluene, styrene, metals, particle characterization, and volatile organic compounds. Subsequent head space analysis of heated raw process materials revealed the presence of formaldehyde. A follow–up site visit was performed on January 15–16, 1998, to collect air samples for formaldehyde vapor, formaldehyde on dust, and inhalable dust.

BACKGROUND

Circuit breaker cases are manufactured in the plastics department at the Siemens Energy and Automation plant in Urbana, Ohio. The circuit breaker cases are formed by compression molding presses using styrene and vinyl toluene–based molding compounds. There are three types of molding compounds currently in use in the department: thick molding compound (TMC), sheet molding compound (SMC), and bulk molding compound (BMC). The molding compounds are either cut (TMC and SMC) or torn (BMC) to pre–determined weights (± 0.5 grams), depending upon the type of circuit breaker case to be manufactured. The TMC and SMC have the shape and appearance of taffy that is approximately 1–3 millimeter (mm) thick and one foot wide. This material is cut using a razor knife and weighed on a balance prior to being placed into the compression molding machine. The BMC has the shape and appearance of cotton candy, but much more dense and heavy. This material is torn by hand and weighed on a balance prior to being placed into the compression molding machine.

The machines operate at temperatures of approximately 350°F to compress and thermoset the molding compound into a rigid plastic circuit breaker case. Approximately 50 active presses produce over 300 different parts. There are currently 21 different raw materials used in the department, all either TMC, SMC, or BMC; they vary by color, fiberglass content, and/or slight differences in chemical composition or ingredient percentages.

After the molding compound has been formed into a plastic circuit breaker case, the plastic part is removed from the press and allowed to cool. The press is then cleaned using compressed air and prepared for another part. After the formed part has cooled, excess plastic that is not part of the circuit breaker case, called flashing, is removed from the part with a hand file. The filing dust is cleaned off the part with compressed air. Once the flashing has been removed from the part, the part is either shot blasted using apricot seed shot and an anti–static agent that includes quaternary ammonium compounds, or stacked into a box. The shot blasting is done in a glove box to contain the shot. Once shot blasted, any dust remaining on the part is removed using compressed air. After the part is cleaned, it is stacked into a box. The boxes containing the circuit breaker cases are subsequently transported to another location for circuit breaker assembly.

At some presses, all the tasks are performed by one operator. At other presses, the tasks are performed by a team of two operators. The primary operator is responsible for weighing the raw molding compound, putting the pre–weighed material into the press, forming the part, and removing the part from the press. A secondary operator is then responsible for filing any flashing off the formed parts, shot blasting the parts, cleaning the parts, and stacking the parts into boxes for transportation.

Over the past five or six years, there has been heightened concern from management and employee representatives due to an increasing number of repetitive strain injuries (RSI) among the press operators. These RSI are believed to be related to ergonomic conditions of the work process. The repetitive and forceful use of a razor knife to cut the TMC and SMC was identified by Siemens' management as being a risk factor in this increase. This observation led to greater use of BMC at the plant. Employees can tear the BMC into its proper weight, thereby avoiding the repetitive use of a razor knife. Siemens' management has indicated plans to increase the use of BMC in the future. In October 1996, a new BMC #1412 was introduced into the shop. It was the use of this material at press #37 that led to the HHE requests.

METHODS

Industrial Hygiene

Based upon a review of applicable records, material safety data sheets (MSDSs), and conversations with union and management representatives, a sampling plan was established for the initial survey. Personal breathing zone (PBZ) and area air samples were collected for styrene, vinyl toluene, metals, formaldehyde, formaldehyde on dust, inhalable dust, volatile organic compounds (VOCs), and particle characterization. The survey focused on operations involving BMC, with a special emphasis placed on the use of BMC at press #37. Personal and area air samples were also collected around presses where TMC and SMC were being used. Bulk samples were collected of the TMC, SMC, and BMC for subsequent analysis.

PBZ air samples and area air samples for styrene and vinyl toluene were collected onto charcoal tubes at a flow rate of approximately 0.05 liters per minute (Lpm) using the protocol from NIOSH Method 1501, "Hydrocarbons, Aromatic."[1] The samples were analyzed by gas chromatography using a flame ionizing detector (GC–FID).

Area air samples for VOC analysis were collected onto thermal tubes at a flow rate of approximately 0.05 Lpm using the protocol from NIOSH method 2549, "Volatile Organic Compound (Screening)."[1] The samples were analyzed by gas chromatography–mass spectrometry (GC–MS). This method is a very sensitive analytical procedure that provides for the identification of VOCs present in minute quantities (generally the parts per billion range); however, it does not provide quantitative results.

BMC and SMC bulk samples were analyzed for organic compounds released when the materials were heated at 160°C (320°F). Approximately 3–6 milligrams (mg) of each raw material was placed into a glass tube which was then sealed at both ends with glass wool. The bulk samples were heated at 160°C for 10 minutes, and emissions were qualitatively evaluated using a GC–MS.

PBZ air samples and area air samples were collected for formaldehyde around press #37 using the protocol from NIOSH Method 2016, "Formaldehyde" (draft) and NIOSH Method 3500, "Formaldehyde by VIS."[1] NIOSH Method 2016 calls for the collection of samples at a flow rate of approximately 0.1 Lpm using silica gel cartridges coated with 2,4–dinitrophenylhydrazine (DNPH). Each sample was collected with two in–line silica gel cartridges to attempt to identify any breakthrough of formaldehyde from the front tube to the back tube. Samples were analyzed for 2,4–dinitrophenylhydrazone, a derivative of formaldehyde, using high performance liquid chromatography (HPLC) with ultraviolet (UV) detection. NIOSH Method 3500 calls for the collection of samples using impingers (an air through liquid bubbling device) with 20 milliliters (mL) of 1% sodium bisulfite solution at a flow rate of approximately 1 Lpm. Samples were analyzed using visible absorption spectrometry.

PBZ and area air samples were collected for inhalable dust and formaldehyde on dust around press #37 using NIOSH Method 5700, "Formaldehyde on Dust (Wood or Textile)."[1] Samples were collected onto 25–mm PVC filters (5–micrometer [µm] pore size) using Institute of Occupational Medicine (IOM) inhalable dust samplers. The filter samples were weighed before and after the sampling event to determine the inhalable dust concentrations. The filter samples were then extracted with DNPH and analyzed for 2,4–dinitrophenylhydrazone, using HPLC with UV detection.

Area air samples were collected for particle characterization analysis using 37–mm cassettes with mixed cellulose ester membrane filters (0.8–µm pore size) at a flow rate of approximately 2 Lpm. These samples were analyzed using polarized light microscopy. One bulk sample of each molding compound, TMC, BMC, and SMC, was also analyzed for particle characterization using polarized light microscopy.

Area air samples were collected for metals screening using NIOSH Method 7300, "Elements by ICP."[1] Samples were collected using 37–mm cassettes with mixed cellulose ester membrane filters (0.8–µm pore size) at a flow rate of approximately 2 Lpm. A review of the MSDS indicated the presence of cadmium, chromium, lead, and mercury as pigments used in the raw molding compounds. The samples were analyzed for the following metals: arsenic, barium, cadmium, cobalt, chromium, lithium, manganese, nickel, lead, phosphorous, platinum, selenium, tellurium, thallium, titanium, yttrium, aluminum, beryllium, copper, magnesium, molybdenum, silver, vanadium, zinc, zirconium, calcium, iron, and sodium.

Medical

During the initial site visit, the NIOSH medical officer was available to interview all plastics department employees from the first shift who wished to be interviewed. Employees were informed of the voluntary medical interviews by union and management representatives during the week prior to the site visit. Company incident reports and the Occupational Safety and Health Administration (OSHA) Summary of Occupational Injuries and Illnesses (form 200) from 1996 through September 1997, were reviewed. Subsequent to the site visit, a one-page questionnaire was distributed to employees on all three shifts. The questionnaire concerned work and medical history. The primary purpose of the questionnaire was to receive information from second and third shift employees (those employees not at work at the time of the first shift interviews) concerning potential work-related health problems.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the 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 even though 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 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 Recommended Exposure Limits (RELs),[2] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[3] and (3) the U.S. Department of Labor, OSHA Permissible Exposure Limits (PELs).[4] In July 1992, the 11th Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard. OSHA is currently enforcing the 1971 standards which are listed as transitional values in the current Code of Federal Regulations; however, some states operating their own OSHA–approved job safety and health programs continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard and that the OSHA PELs included in this report reflect the 1971 values.[5]

A time–weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8–to–10–hour workday. Some substances have recommended short–term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short–term. A STEL generally refers to a TWA concentration over a 15–minute period, a ceiling refers to an airborne concentration that should not be exceeded during any part of the working exposure.

Styrene

Styrene monomer is a colorless to yellow, oily liquid with a reported odor threshold between 0.017 and 1.9 parts per million (ppm).[6] After a brief period of exposure to styrene, olfactory fatigue occurs and the characteristic odor may not be as pronounced. Styrene is primarily used in the manufacturing of polystyrene plastics, protective coatings, polyesters, copolymer resins with acrylonitrile and butadiene, and as a chemical intermediate.

The ACGIH recommends an 8–hour TLV–TWA for styrene of 20 ppm, and a 15–minute STEL of 40 ppm.[3] This recommendation is based upon a level of exposure that will minimize the potential for irritative health effects caused by occupational exposure to styrene.[7] The 20 ppm TLV–TWA is less than the threshold limit for eye irritation, central nervous system effects, and chromosomal changes.[7] NIOSH recommends an REL–TWA for styrene of 50 ppm, and a 15–minute REL–STEL of 100 ppm.[2] OSHA regulations mandate an 8–hour PEL–TWA for styrene of 100 ppm, a ceiling of 200 ppm, and a maximum 5–minute PEL of 600 ppm in any 3 hour period.[5]

Vinyl toluene

Vinyl toluene is a colorless, combustible liquid with a strong, disagreeable odor that can be detected at approximately 10 ppm.[6] Vinyl toluene is primarily used commercially in the plastics and surface coatings industry and it is also used as a component in insecticides. The toxicological properties of vinyl toluene appear to be similar to those of styrene.[8] The ACGIH recommends a TLV–TWA of 50 ppm and a 15–minute TLV–STEL of 100 ppm. These limits were established to minimize mucous membrane and ocular irritation. These levels of vinyl toluene should also minimize complaints of objectionable odor. OSHA has established a PEL–TWA for vinyl toluene of 100 ppm, with no STEL.[5] NIOSH has established a REL–TWA for vinyl toluene of 100 ppm, with no STEL or ceiling.[2]

Formaldehyde

Formaldehyde is a colorless, water soluble gas with a strong odor. Exposure can occur through inhalation and skin contact. The acute effects associated with formaldehyde are burning of the eyes, tearing, general irritation of the upper respiratory tract, and dermatitis. There is variation among individuals, in terms of their tolerance and susceptibility, to acute exposures to formaldehyde.[9]

Based upon animal experiments which show an association between cancer and exposure to formaldehyde, coupled with insufficient epidemiologic evidence identifying an increased risk of cancer in humans occupationally exposed to formaldehyde, formaldehyde has been designated a suspect human carcinogen by the ACGIH.[10] ACGIH recommends that worker exposure by all routes should be carefully controlled to levels "as low as possible." The ACGIH TLV–ceiling is 0.3 ppm.[3] This ceiling is based upon an exposure level that should minimize irritation; however, the ACGIH recognizes that the 0.3 ppm ceiling will not eliminate all worker complaints of sensory irritation.[10] NIOSH has also identified formaldehyde as a suspect human carcinogen and recommends that exposures be reduced to the lowest feasible concentration.[2] The OSHA action level for implementing a formaldehyde protection program is a TWA exposure of 0.5 ppm, the PEL–TWA is 0.75 ppm, and the 15–minute PEL–STEL is 2 ppm.[11]

The nasal and upper respiratory effects of formaldehyde exposure have prompted concerns about exposures to particles containing formaldehyde based resins. This exposure is commonly seen in the wood product and wood paneling manufacturing industries. The literature was reviewed to identify any studies of formaldehyde adsorbed onto plastic particulate matter. No study was found evaluating the epidemiology of formaldehyde on plastic particulate; however, several studies involving wood products and formaldehyde have been conducted. Some epidemiologic studies have suggested an increased risk of nasopharyngeal and oropharyngeal cancer may exist for exposure to formaldehyde in combination with particulate matter; however, the studies are inconclusive at this point and research continues in this area.[12,13] Although an analytical method for the determination of formaldehyde on dust has been developed, no occupational exposure criteria have been established for the interpretation of this data.

Inhalable Dust

Inhalable particulate mass (inhalable dust) is defined by the ACGIH as material that is hazardous when deposited anywhere in the respiratory tract.[3] Criteria for the inhalable fraction of dust exposure have been established for particulate not otherwise classified (PNOC) based upon preventing overloading of the clearance mechanism of the lung.[14] This criteria requires that the particulate contain no asbestos and <1% crystalline silica. The criteria was established by the ACGIH in 1994 as a TWA–TLV of 10 milligrams/cubic meter (mg/m^3).

Continuous Filament Glass Fibers

Continuous filament glass fibers are produced by pulling molten glass continuously through bushings containing small orifices. Continuous filament glass fibers are used for reinforcement in plastics and building products and are the form of “fiberglass” identified on the MSDSs for the BMC, TMC, and SMC. Fiberglas™ is technically a trade name for glass wool manufactured by Owens Corning. Glass wool is produced by blowing or spinning molten glass through small holes to form glass fibers and is commonly used for thermal insulation.

Non–respirable exposure criteria have been established for continuous filament glass fibers to minimize the potential for mechanical irritation of the upper respiratory tract.[15] A non–respirable fiber is defined as a fiber which does not reach the lower gas–exchange regions of the respiratory tract. The vast majority of continuous filament glass fibers are 6 to 15 µm in diameter and are considered to be non–respirable. The ACGIH has indicated that “there is no epidemiological evidence of increased risk of pulmonary fibrosis or any other nonmalignant respiratory disease in workers exposed to continuous filament glass fibers."[15] From 1978–1997, the ACGIH TLV–TWA for fibrous glass dust was 10 milligrams per cubic meter (mg/m^3). In 1997, the ACGIH revised its TLV–TWA to differentiate several forms of synthetic vitreous fibers which have different toxicological properties. The newly revised TLV–TWA for non–respirable continuous filament glass fibers is 5 mg/m^3 when measured as inhalable dust. NIOSH considers fiberglass primarily to be a short–term exposure hazard as a dermal and upper respiratory irritant. The NIOSH REL–TWA for total fibrous glass is 5 mg/m^3. This criteria is intended to minimize eye, skin, and respiratory health effects.[2]

Metals

Cadmium, chromium, lead, and mercury were identified in the MSDSs as possible pigments used in the raw molding compounds. Cadmium is a severe pulmonary irritant, and a suspected human carcinogen.[2] One valence state of chromium, chromium VI, is a confirmed human carcinogen and a severe skin, eye, respiratory irritant.[2] Lead can cause kidney, blood, and nervous system health effects.[2] Metallic mercury can have central nervous system effects.[2]

RESULTS AND DISCUSSION

Styrene and Vinyl toluene

Thirteen PBZ air samples and 7 area air samples were collected for styrene and vinyl toluene analysis. The PBZ results for styrene and vinyl toluene are presented in Table 1. All sample concentrations were below the lowest applicable exposure criteria for both styrene and vinyl toluene. Because these two chemicals have similar health effects, the additive effect of these two chemical exposures was calculated. The additive exposures were less than 1, indicating that the TLV was not exceeded for the additive exposure of styrene and vinyl toluene. The TLV was used as a reference for this determination because the ACGIH exposure criteria for styrene and vinyl toluene are the most conservative.

The area air monitoring results for styrene and vinyl toluene are presented in Table 2. The air concentrations determined by the area monitoring are consistent with the air concentrations determined by the personal sampling. No air concentrations above applicable exposure criteria were identified.

Volatile Organic Compounds

Five area samples for VOCs were collected using thermal tubes. Two thermal tube samples were collected adjacent to Press #37, where BMC #1412 was being used (adjacent to the raw material and near the heated emissions). Similarly, two thermal tube samples were collected adjacent to Press # 12, where TMC was being used (adjacent to the raw material and near the heated emissions). The fifth sample was a background sample collected in the plastics department in an area away from direct exposure to the raw materials and molding emissions.

The major compounds identified on all of the samples were styrene and vinyl toluene. Other compounds detected included formaldehyde, propane, methyl propene, acetone, isopropanol, tert–butyl alcohol, acetic acid, benzene, heptene, alkyl benzenes, aliphatic C_9–C_{12} hydrocarbons, benzaldehyde, methyl benzaldehyde isomers, acetophenone, benzoic acid, methyl methacrylate, toluene, ethylene glycol monobutyl ether, and xylene.

Formaldehyde, aliphatic C_9–C_{12} hydrocarbons, methyl benzaldehyde isomers, and acetic acid were only identified on the thermal tubes collected adjacent to Press # 37 where the BMC #1412 raw material was being used.

The analysis of heated emissions from two bulk samples identified the following major compounds: styrene, vinyl toluene, tert–butyl alcohol, acetone, dipropylene glycol, 2–ethyl–1–hexanol, benzaldehyde, benzoic acid, formaldehyde, and methyl benzaldehydes.

Formaldehyde

Formaldehyde Vapor

A total of six personal and area air samples were collected around press #37 for analysis using NIOSH Method 2016 "Formaldehyde," a draft analytical method. It is a convention to submit field blanks with each set of samples submitted for analysis. This is to identify potential problems with the analytical method, field contamination, or contamination of the media. The field blanks submitted with this set of samples identified 2.5 micrograms (µg) and 0.78 µg of formaldehyde. The reported analytical method limit of detection (LOD) is 0.04 µg per sample and the blanks should contain no more than 0.1 µg of formaldehyde from background levels in the media. Because of the high blank values, the analytical results can not be reported with confidence and will not be used in the hazard determination.

Four area air samples were collected for formaldehyde analysis using NIOSH Method 3500, "Formaldehyde by VIS."[1] Personal samples were not collected because this method calls for the use of glass impingers containing 20 mL of liquid sodium bisulfite solution. Two TWA area samples were collected for approximately 6 hours and two STEL samples were collected for 15 minutes.

One 6–hour TWA area sample was collected on the left hand side of Press #37. A second 6–hour TWA area sample was collected on the front right hand side of Press #37, near the control panel. Air concentrations of 0.025 ppm and 0.018 ppm were identified in these samples, respectively. Although formaldehyde was measured, it is ubiquitous in our environment at these very low concentrations. The concentrations identified here are similar to those found in many office buildings.

One STEL sample was collected from the molding compound staging area to the direct left and in front of Press #37. A second STEL sample was collected directly behind Press #37. Formaldehyde was not detected in either of these samples; the minimum detectable concentration (MDC) was approximately 0.03 ppm, based upon a sample volume of 14.76 liters.

Formaldehyde on Dust

Operations in the plastics department generate particulate which contains continuous filament glass fibers (10–20% of the raw material), aluminum trihydrate (40–50% of the raw material), calcium carbonate (10–20% of the raw material), and formed plastic particulate. The polymerized unsaturated polyester resins (10–11% of the raw material) or vapors generated in the forming of the circuit breakers could be adsorbed on the particles. This airborne particulate may be depositing in the upper respiratory tract of workers and then off–gassing vapors which can be irritative.

Two PBZ and two area air samples were collected for analysis of inhalable dust and formaldehyde on dust. PBZ samples were collected on the primary operator and secondary operator of press #37. Area samples were collected on the right and left sides of press #37. Samples were collected for 7–8 hours. The analytical results for inhalable dust and formaldehyde on dust are presented in Table 3. The concentrations of formaldehyde on dust ranged from below the MDC (<0.45 micrograms per cubic meter [$\mu g/m^3$]) to 2.6 $\mu g/m^3$. The concentrations of inhalable dust ranged from 0.29 to 1.07 mg/m^3.

Continuous Filament Glass Fibers

Six area air samples for particle characterization were collected during the initial site visit. The particles were all under 20 um in length and ranged from rounded to angular, some agglomerates of particles were larger. There were no extremely angular or sharp particles detected. Particle morphology analysis showed little difference between the fibers from the BMC, TMC, and SMC.

Bulk samples of BMC, TMC, and SMC were submitted for particle characterization. The BMC was found to contain pigments, resins, and large straight glass fibers. The fiber ends were angular, and the non–fibrous particles were mostly rounded. In general, the BMC looked like a combination of TMC and SMC.

Metals

One area air sample was collected for metals screening adjacent to the BMC staging shelf in front of press #37. This sample was collected for 338 minutes for a total volume of 776 liters of air. All metals screened with this sample were below the minimum detectable concentration or were present in trace quantities (below the minimum quantifiable concentration), with the exception of iron. The airborne concentration of iron was 0.004 mg/m^3.

A second area air sample was collected for metals screening adjacent to the TMC staging shelf in front of press #37A. This sample was collected for 370 minutes for a total volume of 740 liters of air. All metals screened with this sample were below the minimum detectable concentration or were present in trace quantities, with the exception of sodium and calcium. The airborne concentration of sodium was 0.01 mg/m^3 and the airborne concentration of calcium was 0.01 mg/m^3.

The low levels of iron, calcium, and sodium measured in these two samples are common in industrial as well as non–industrial environments and are well below relevant occupational exposure criteria.

Ventilation Survey

The plastics department is provided make–up air through three supply air fans mounted in the ceiling. These fans are rated at 25,000 cubic feet per minute (cfm). These systems have the capacity for heating but not cooling. The air from these fans is not ducted equally throughout the department, but is supplied at the three locations. Exhaust air is removed from the department by eight fans mounted in the ceiling. These fans are rated at 24,000 cfm. Assuming all dilution ventilation fans are operating at their peak capacity, 75,000 cfm of fresh air is supplied to the department, and 192,000 cfm of air is exhausted from the department; this provides an imbalance of over 100,000 cfm. Furthermore, employees reported that the supply fans are not always operated.

Air pressure in the plastics department is negative to the surrounding areas of the plant and outdoors. Make–up air is provided to the department through two interior overhead doors and the windows and outside doors to the plastics department. The two overhead doors connect the plastics department to the rest of the facility and are generally left open. The windows in the department are opened during moderate weather. The outside doors to the department are frequently used by employees and air rushes into the department when they are opened. This effect is made worse during inclement weather, when the outside windows to the department are shut (the windows were shut on our follow–up survey in the winter). During the follow–up survey, the rush of air through the outside door was strong enough to blow a piece of paper approximately 20 yards into the plastics department.

Air mixing in the department is enhanced by an additional 12 ceiling–mounted area fans. These fans are operated intermittently for cooling. Employees also use personal space fans that are placed on the floor or on work tables to further provide cooling and air mixing.

Medical

Ten of the 35 plastics department employees from the first shift (29%) volunteered to be interviewed during the site visit. No information was collected concerning those not interviewed. Those interviewed had worked in the plastics department an average of 12 years. Seven employees reported symptoms of upper respiratory irritation (including hoarseness, loss of voice, and mucous membrane irritation) and headache; one reported headache only. Two employees reported no work–related symptoms. Seven of the eight employees reporting symptoms felt the symptoms were related specifically to using BMC #1412 as a raw material; one of the symptomatic employees related the symptoms to a black BMC, but not necessarily the BMC #1412. The symptoms were reported to last from several hours to several days after removal from exposure to the BMC. The interviewed employees reported no similar symptoms related to the use of other raw materials. One of the seven employees mentioned above, who was evaluated by a physician for loss of voice, sore throat, and blistering in the mouth, had a urinary mandelic acid level (drawn at the end of a work shift) of 95 milligrams per gram of creatinine (mg/g Cr).* One employee reported an episode of hives (urticaria) after being exposed to the dust from a machine–cleaning procedure using compressed air. Four employees reported itching skin and rash as a separate problem they felt was related to fibrous glass exposure (none of the employees had a rash at the time of the interview). Several of those employees reported that their 'fiberglass itch' was directly correlated with the percentage of fiberglass (fibrous glass) in the raw material being used.

Review of the plant incident reports revealed 20 reports among plastics department employees of rash, headache, or upper respiratory or mucous membrane irritation. Sixteen different employees, working either the first or third shift, were affected.

Fifteen of the 16 employees were reportedly using BMC #1412 at the time the symptoms occurred. The reports were made in November 1996 (1), January 1997 (4), February 1997 (9), March 1997 (5), and May 1997 (1). During the period of time these reports were being made, the machine which primarily used BMC #1412 as a raw material was relocated in the plant with the goal of improving the ventilation around the machine. One employee, who was symptomatic several times during that time period, performed a number of production 'tests' with various raw materials and differing work conditions. Irritative symptoms in that individual recurred under a variety of machine conditions and also with raw materials other than the BMC #1412. Review of the OSHA 200 log revealed entries for musculoskeletal and trauma–related injuries, but none for the symptoms mentioned above.

Thirty–eight questionnaires were completed, all from second or third shift employees (54% of the 70 employees on those two shifts). Twenty–two (58%) reported one or more symptoms (including nose/throat irritation, hoarseness, headache, difficulty breathing, nausea, or lightheadedness) that they felt were work–related. Of those 22, 17 identified black BMC (or the BMC #1412 material specifically) as being related to their symptom(s), 4 did not identify a specific work duty/material related to the symptom(s), and 1 identified a different work process. Fifteen (39%) of the 38 reported that they have had a skin rash that they felt was work–related. Ten (66%) of the 15 identified fiberglass as being related to the rash, three identified BMC as related to the rash, and two did not identify any particular substance as being related to the rash.

CONCLUSIONS

The union request for health hazard evaluation identified health effects of mouth sores, nose bleeds, eye blisters, rashes, and throat irritation. The management request for health hazard evaluation identified health effects of nausea and dizziness. The medical survey indicates that a number of Siemens' employees reported symptoms of upper respiratory

* The ACGIH biological exposure index (BEI) for mandelic acid in urine to monitor occupational exposure to styrene is 800 mg/g Cr (end of shift) and 300 mg/g Cr (at the start of a shift).

irritation which appear to be related to working with BMC, particularly the BMC #1412 at press #37. Based upon a review of MSDSs, there appear to be no substantial ingredient differences between the BMC and other bulk raw materials; however, the percentages of the identified components may vary.

The industrial hygiene air sampling indicates that personal exposures to vinyltoluene and styrene are below applicable occupational exposure criteria. Area samples indicate that air concentrations of formaldehyde are comparable to those in most office environments. Other chemicals identified in the plastics department were not quantified, including the following known eye, skin, and mucous membrane irritants: fibrous glass, acetic acid, methyl benzaldehyde isomers, benzoic acid, ethylene glycol monobutyl ether, tert–butyl alcohol, methyl methacrylate, and xylene. Additionally, formaldehyde, acetic acid, and methyl benzaldehyde isomers were identified in qualitative VOC samples collected adjacent to the BMC, but not the TMC. The combined effect of these chemical exposures in the plastics department is not known and may be responsible for the symptoms reported by individuals. Additionally, some individuals may be more sensitive to a particular chemical and develop an irritative reaction to that chemical at concentrations below its established occupational exposure criteria.

Personal exposures to inhalable dust at press #37 were 0.29 mg/m^3 and 1.07 mg/m^3. These concentrations would not be sufficient to overwhelm the clearance mechanism of the upper respiratory tract. However, irritating substances may be adsorbed on the particulate. Release of these volatile substances or direct contact with mucous membranes of the upper respiratory tract could cause or contribute to the symptoms of upper respiratory tract irritation (i.e., mouth sores, nose bleeds, and throat irritation). As previously mentioned, there are currently no occupational exposure criteria to evaluate such exposures.

The ventilation system is not properly balanced in the plastics department. The department should be maintained under sufficient negative pressure to assure that odors do not migrate into the rest of the facility; however, there is over a 100,000 cfm difference between the volume of supply air and the volume of exhaust air in the plastics department. This large difference is made up with air drawn from the main facility into the plastics department through two open overhead doors, and air drawn from the outside through open windows and doors.

The use of ceiling–mounted and portable space fans to cool employees results in the prolonged suspension of irritative particles in the air. The use of compressed air to clean the presses, to clean flashing filings off the parts, to clean dust off employee clothing and skin, and to clean the parts following shot blasting also contributes to this prolonged suspension of particulates. A plenum duct connected to the three supply air fans in the department would properly distribute make–up air, reduce turbulence, improve dilution ventilation, and minimize temperature fluctuations throughout the department.

Four (40%) of the ten interviewed employees, and 13 (34%) of the 38 employees responding to the questionnaire reported skin rashes thought to be related to fibrous glass or BMC. These skin complaints are likely related, at least in part, to airborne exposure to fibrous glass particulate resulting from the work practices mentioned above, and to the handling of raw BMC without gloves.

RECOMMENDATIONS

Although the industrial hygiene monitoring was unable to conclusively identify an individual cause for the reported symptoms, workplace conditions and exposures could be contributing to the employees' health problems. The following recommendations are provided to reduce exposures in the plastics department.

(1) Local exhaust ventilation should be provided to Press # 37 where parts are manufactured using BMC #1412 as a raw material. This particular operation appears to be associated with more symptoms than any other operation in the plastics department. Local ventilation should be designed to remove air from the employee breathing zone both where the BMC is handled and where emissions from the press are released.

(2) The use of compressed air in the department should be replaced with the use of a vacuum system. The turbulence created by the use of compressed air causes potentially irritative particulate material to become airborne. A vacuum system would minimize exposure to small particles, thereby decreasing potential employee exposures to skin and mucous membrane irritants.

(3) The supply ventilation system should be improved. A plenum to properly distribute air from the supply fans should be installed. Additional supply fans should be installed and attached to the plenum to more adequately distribute the air in the plastics department.

(4) Employees working with raw BMC should wear gloves for material handling. Gloves that will provide barrier resistance to the irritative chemicals found in the BMC and the environment (benzaldehyde, formaldehyde, styrene, methyl methacrylate, xylene, etc.) should be selected (e.g., PE/EVAL gloves).[16] Cotton gloves can be worn over the chemically resistant gloves as desired.

(5) Eating and drinking in the manufacturing area should not be allowed. Employees should be provided with an enclosed lunch room that is independently ventilated, with access to a sink for hand washing to minimize the potential for hand–to–mouth contamination. Employees should wash their hands prior to eating, drinking, or smoking.

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Table 1
Full–shift Worker Exposures to Styrene and Vinyl toluene
Siemens Energy and Automation
Urbana, Ohio
HETA 97–0154

Sampling Date	*Job Title*	*Sampling Time (t_i) (minutes)*	*Styrene Concentration (ppm)*		*Vinyl toluene Concentration (ppm)*		*Additive Effect †*
			Conc(c_i)	*TWA‡*	*Conc (c_i)*	*TWA‡*	
8/21/97	Primary Operator at Press #35 using BMC	275	0.28	0.37	0.54	(0.51)	0.03
		179	0.52		(0.46)		
8/21/97	Primary Operator at Press #8 using BMC	223	4.0	4.0	1.6	1.6	0.23
8/21/97	Primary Operator at Press #3 using BMC #1412	267	3.1	2.3	ND (<0.09)	ND (<0.11)	
		184	1.2		ND (<0.13)		
8/21/97	Primary Operator at Press #37 using BMC #1412	267	2.8	2.6	1.2	1.0	0.15
		187	2.3		0.77		
8/21/97	Secondary Operator at Press #37 using BMC #1412	268	0.59	1.7	(0.15)	(0.66)	0.01
		187	3.3		1.4		
8/21/97	Primary Operator at Press #37A using SMC	240	7.3	8.1	(0.23)	(0.18)	0.41
		190	9.1		(0.14)		
8/21/97	Primary Operator at Press #15 using TMC	262	4.0	4.0	ND (<0.09)	ND (<0.11)	
		188	4.0		ND (<0.13)		

Evaluation Criteria for full–shift PBZ exposure:	*Styrene (ppm)*	*Vinyl toluene (ppm)*
NIOSH REL	50	100
OSHA PEL	100	100
ACGIH TLV	20	50

Notes:
‡ = Time–weighted averages were computed using the "actual" sampling times with the following formula:
$TWA = \sum (conc_i \times time_i) + ... + (conc_n \times time_n) / \text{total time}$.
† = Additive effect was calculated using the TWA concentration for styrene and vinyl toluene divided by the ACGIH TLV–TWA:
† $C_1/TLV_1 + C_2/TLV_2 = x$ ... If x>1, then TLV is exceeded for the combined exposure.
( ) = Sample result was between the analytical Limit of Detection (LOD) and the Limit of Quantitation (LOQ). Hence, the airborne concentration is between the Minimum Detectable Concentration (MDC) and Minimum Quantifiable Concentrations as shown in brackets. The MDC is calculated by dividing the analytical LOD by the air sample volume.
ND = not detected
ppm = parts per million

Table 2
Area Air Monitoring for Styrene and Vinyl toluene
Siemens Energy and Automation
Urbana, Ohio
HETA 97–0154

Sampling Date	*Location*	*Sampling Time (t_i) (minutes)*	*Styrene Concentration (ppm)*		*Vinyl toluene Concentration (ppm)*	
			Conc(c_i)	*TWA‡*	*Conc (c_i)*	*TWA‡*
8/21/97	Press #37 using BMC #1412	114	5.8	2.8	3.1	3.1
		139	0.26		ND (<0.09)	
		22	<0.45		ND (<0.59)	
		22	<0.45		ND (<0.59)	
8/21/97	Press #35 using BMC	134	(0.18)	0.34	2.5	1.7
		146	0.49		1.0	
8/21/97	Press #15 using TMC	147	10.8	6.6	ND (<0.08)	ND (<0.85)
		131	1.8		ND (<0.09)	

Evaluation Criteria for full–shift PBZ exposure:	*Styrene (ppm)*	*Vinyl toluene (ppm)*
NIOSH REL	50	100
OSHA PEL	100	100
ACGIH TLV	20	50

Notes:
‡ = Time–weighted averages were computed using the "actual" sampling times with the following formula:
$TWA = \sum (conc_i \times time_i) + ... + (conc_n \times time_n) / \text{total time}$.
( ) = Sample result was between the analytical Limit of Detection (LOD) and the Limit of Quantitation (LOQ). Hence, the airborne concentration is between the Minimum Detectable Concentration (MDC) and Minimum Quantifiable Concentrations as shown in brackets. The MDC is calculated by dividing the analytical LOD by the air sample volume.
ND = not detected
ppm = parts per million

Table 3
Full–shift Worker Exposures and Area Air Monitoring
for Inhalable Dust & Formaldehyde on Dust
Siemens Energy and Automation
Urbana, Ohio
HETA 97–0154

Sampling Date	*Job Title / Location*	*Sampling Time (t_i) (minutes)*	*Inhalable Dust Concentration (mg/m³)*	*Formaldehyde on Dust Concentration (µg/m³)*
8/21/97	Primary Operator at Press #37 using BMC #1412	446	0.29	ND (<0.45)
8/21/97	Secondary Operator at Press #37 using BMC #1412	464	1.07	2.0
8/21/97	Right side of Press #37 using BMC #1412	456	0.32	17
8/21/97	Left side of Press #37 using BMC #1412	446	0.29	2.6

Notes:
ND = Not Detected
BMC = Bulk Molding Compound
TMC = Thick Molding Compound
SMC = Sheet Molding Compound
µg/m³ = micrograms per cubic meter
mg/m³ = milligrams per cubic meter

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