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THOMBERT, INC.
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I. SUMMARY

On April 4, 1989, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from United Auto Workers (UAW) Local 997 in Newton, Iowa. The UAW was concerned with exposures to 1,5-naphthalene diisocyanate (NDI), 4,4'-diphenylmethane diisocyanate (MDI), volatile organic compounds (VOCs) including 2-methoxyethanol, dimethlyformamide (DMF), and with possible isocyanate-related respiratory problems and cumulative trauma disorders (CTDs). In response to these requests, site visits were conducted at the Thombert facilities in Newton and Malcom, Iowa on May 18-19, October 12, and November 13-17, 1989. On October 12, respiratory questionnaires were administered to the workers. During the November site visit, the NIOSH investigators performed pulmonary function tests and conducted an exposure assessment to determine the workers' exposures to MDI, NDI, VOCs and DMF. In addition, the NIOSH investigators reviewed employee medical records and the OSHA 200 Logs from 1985-1989, and conducted a telephone survey of selected workers.

Area air sampling for MDI and VOCs was conducted at the Newton facility. The average MDI concentration measured by this sampling was 3.9 micrograms per cubic meter of air (µg/m^3), with concentrations ranging from none detected (less than 1.1 µg/m^3) to 9.8 µg/m^3. These levels are well below the NIOSH recommended exposure limit (REL) for MDI of 50 µg/m^3. In addition, the average polyisocyanate concentration was 5.6 µg/m^3, and these levels ranged from 2.0 to 12.2 µg/m^3. Currently, no exposure standards exist for polyisocyanate. The following VOCs were identified in the qualitative samples: 1,1,1-trichloroethane, isooctane, 2-methoxy-1-propyl acetate, aliphatic hydrocarbons in the C_7 to C_8 range, ethanol, xylene, and isopropanol. The measured concentrations were well below the NIOSH RELs, OSHA permissible exposure limits (PELs), and the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs) for the above identified compounds, and were at levels that would not be expected to cause health effects in most workers. The personal breathing zone air sample obtained on the worker cleaning molds at the Dynasolve tank had a concentration of 24.3 milligrams of 2-methoxyethanol per cubic meter of air (mg/m^3). This exposure concentration was above the ACGIH TLV of 16 mg/m^3. NIOSH recommends that exposure to 2-methoxyethanol be reduced to the lowest feasible level based on its potential to cause adverse reproductive effects in both male and female workers.

The NIOSH investigators conducted area air sampling for NDI, VOCs, and DMF at the Malcom facility. Six of the seven samples for NDI had concentrations below the NIOSH REL for NDI of 40 µg/m^3, with three of these samples not having detectable amounts of NDI. Only one sample result (NDI concentration of 253.6 µg/m^3) was above the NIOSH REL; this sample was collected within a laboratory-type hood that was used as the mixing station. Smoke tube tests indicated that the hood effectively removed the contaminants from the workers weighing out NDI. The compounds identified by the qualitative analysis for VOCs were 1,1,1-trichloroethane, isooctane, 2-methoxy-1-propyl acetate, and a mixture of aliphatic hydrocarbons in the C_7 to C_8 range. The VOC concentrations were well below the OSHA, NIOSH, and ACGIH evaluation criteria. Due to analytical problems, the NIOSH investigators considered the air samples for DMF to be invalid. Considering that past industrial hygiene data did not measure any detectable levels of DMF, and that the solvent is used in a closed loop system, the NIOSH investigators concluded that workers were not likely overexposed to DMF.

Of the 18 Thombert workers previously evaluated for respiratory symptoms, medical records of 7 of these workers were suggestive of NDI-related asthma, and another indicative of NDI-related respiratory tract irritation. The attribution of symptoms to NDI is based on the temporal relationship between their onset and the use of NDI; MDI had been used previously, apparently

without a problem of similar magnitude. At the Newton facility, 14 of 22 production workers, and 3 of 18 administrative/clerical workers, who participated in the NIOSH survey, reported respiratory symptoms consistent with occupational asthma since beginning work at Thombert; 10 production workers and 1 administrative/clerical worker had current symptoms. Two of 9 workers who reported current symptoms and participated in the pulmonary function testing had across-shift decreases of more than 10% in one-second forced expiratory volume (FEV_1); both reported respiratory symptoms during the shift.

A review of the OSHA 200 Log revealed that between 1985 and 1988, the annual upper extremity CTD incidence rate was 15.8 per 100 full-time workers (compared to 0.35 total CTDs [upper and lower extremity] per 100 full-time workers for the industry as a whole in 1987 [SIC 3079; miscellaneous plastic products]). During this time, an average of 6.5 CTD-related surgical procedures were performed each year. In addition, between 1985 and 1989, an average of 5.2 back injuries and 8.8 eye injuries were reported annually on the OSHA 200 Log.

On the basis of the data collected during this investigation, NIOSH investigators conclude that a health hazard existed from exposure of the worker at the Dynasolve/mold cleaning tank to 2-methoxyethanol and that a potential health hazard existed from MDI exposure to workers filling the molds and from hot molds exiting the oven. The medical findings further indicate that an isocyanate-related occupational asthma hazard existed at the Newton facility between 1987 and 1988, and that some workers continue to be affected. There was also evidence for the existence of a serious upper extremity CTD hazard at the Newton facility since 1985.

Keywords: SIC 3089 (Plastic Products, Not Elsewhere Classified), isocyanate-related asthma, cumulative trauma disorder, CTD, carpal tunnel syndrome, thoracic outlet syndrome, 4,4'-diphenylmethane diisocyanate, MDI, 1,5-naphthalene diisocyanate, NDI, 2-methoxyethanol.

II. INTRODUCTION

On April 4, 1989, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from United Auto Workers (UAW) Local 997 in Newton, Iowa. The request stemmed from the union's concern about possible isocyanate-related respiratory problems among workers at Thombert, Inc. Representatives of the union also asked NIOSH to evaluate a possible cumulative trauma disorder (CTD) problem, and to assess exposures from cleaning molds with 2-methoxyethanol (2-ME). In response to these requests, site visits were conducted at the Thombert facilities in Newton and Malcom, Iowa on May 18-19, October 12, and November 13-17, 1989. On October 12, respiratory questionnaires were administered to the workers. During the November site visit, the NIOSH investigators performed pulmonary function tests and conducted an exposure assessment to determine the workers' exposure to MDI, NDI, VOCs and DMF. In addition, the NIOSH investigators reviewed the OSHA 200 Logs from 1985-1989, reviewed the employee medical records, and conducted a telephone survey of selected workers.

The medical data from these investigations were reported to Thombert and the UAW Local 997 in an interim letter dated March 30, 1991. In this letter, the NIOSH investigators offered recommendations pertaining to preplacement medical evaluations; medical evaluations of Thombert employees who were not working during the NIOSH site visits; further evaluation of workers with suspected work-related respiratory problems; establishment of a program to assess, monitor, and prevent CTDs and injuries; and the wearing of safety glasses to minimize the occurrence of work-related eye injuries. The workers participating in this study were notified of their individual medical results on December 13, 1989.

A report presenting the industrial hygiene data from the NIOSH studies was issued on May 9, 1991, to Thombert and the UAW Local 997. This document included as appendices the NIOSH Current Intelligence Bulletin 39: Glycol Ethers, the NIOSH recommended sampling and analytical method for 2-methoxyethanol (NIOSH Method 1403), and a local exhaust ventilation design recommendation for the Dynasolve mold cleaning tank. In addition to these appendices, the industrial hygiene report contained recommendations which were specific for the Newton and Malcom facilities of Thombert. These recommendations included methods for reducing workers' exposures to NDI, MDI, and 2-methoxyethanol; an active maintenance and preventive maintenance program for the engineering controls; and the prohibition of eating, drinking and smoking in all work areas.

III. BACKGROUND

A. Newton Facility

At the Thombert, Inc. facility in Newton, Iowa, 41 production workers and 24 administrative/clerical personnel were on the November 1989 payroll. Over the preceding 5 years, the average number of production workers ranged from 40-80. Employees are intermittently terminated and rehired, depending on production schedules. According to management representatives, only 5-10 employees had permanently left the company during the last five years. Since the early 1970's, tires and wheels for fork-lift trucks have been the primary products.

Cast metal wheels are received and machined to specification with hand grinders and lathes in the metal-working area. Urethane and phenolic resin boards (used as spacers in some products) are also machined here. The metal wheels are then subjected to a "grey" metal process in which the metal is abraded via particle blasting, in preparation for the application of glue on the wheel's outer surface. As a final preparatory step, 1,1,1-trichloroethane is used to degrease the wheels. Gluing takes place on a semi-automated production line where glue is sprayed on the outer surface of the wheel.

Polyurethane molding takes place on two production lines where the metal rims are placed in molds and filled by dispensing a two-part urethane system by hand. The molds are then conveyed through an automated oven and heated to approximately 300°F, at the end of which the wheels are removed. The ovens are fitted with an exhaust ventilation system and are enclosed. In an adjacent hot plate operation, smaller specialty items are molded. The hot plates are equipped with local exhaust ventilation slots which extend the length of the plate. Once the polyurethane plastic is cured and has bonded to the metal rim/core, the wheels are subjected to a series of grinding and lathe operations to remove excess metal burrs and plastic flashing.

During the NIOSH survey, both Baytec MS-090 and Baytec MS-242 (manufactured by Mobay Corporation) were used; material safety data sheets provided by Thombert indicated that these products contain approximately 1-14% MDI. On the day of the NIOSH survey, approximately 1506 units were produced, consuming 2500-3000 pounds of MDI (5 to 6 drums of Baytec MS-090 and Baytec MS-242). Between the Summer of 1986 and December 1988, NDI was also used to manufacture the polyurethane plastic tires. During the approximately 18 months that NDI was used at the Newton facility, the manufacturing process was refined and local exhaust ventilation was added in an attempt to reduce NDI exposures. Representatives of the UAW Local 997 stated that during this period, several workers developed respiratory illnesses (including asthma) which they believed were a result of overexposure to NDI. In December of 1988, all production processes using NDI were moved to a Thombert/ITWC facility in Malcom, Iowa.

The molds are cleaned with Dynasolve MP500 (manufactured by Dynaloy, Inc.) which contains 2-methoxyethanol (also known as ethylene glycol monomethyl ether or Methyl Cellosolve). A worker lowers the molds into the Dynasolve using an electrical winch. After cleaning, the molds are removed from the tank, further cleaned with a handheld spray nozzle in an adjacent circular tank, and then allowed to dry. The tank containing the Dynasolve is fitted with local exhaust ventilation with a plenum containing two slots located on one of the long sides of the tank.

B. Malcom Facility

The Thombert facilities in Malcom, Iowa, are housed in two pole barns, with the main production facility being 40 feet in width, 65 feet in length, and 35 feet in height. Since December 1988, the main operation performed in these barns is the manufacture of polyurethane plastic wheels and tires using NDI.

The weighing and mixing of the NDI (Desmodur 15, manufactured by Bayer, Inc./Mobay Corp.) and polyester polyol (Vulkollon 2001K, manufactured by Bayer Inc./Mobay Corp.) is an operation that requires 30-40 minutes and is performed approximately three times per day. First, the polyol is weighed in a tared stainless steel container. Then, NDI flake solid is manually scooped from a drum and weighed in a tared kraft paper bag. All handling and weighing of NDI is performed in a cabinet equipped with local exhaust ventilation. The NDI flakes are then poured into the container which contains the polyol, and the container is covered and lowered into the reactor. The lid of the reactor is sealed, and the NDI-polyol blend is mixed and heated for approximately 30 minutes. The reactor unit contains two reactors and is equipped with local exhaust ventilation.

After mixing is completed, the NDI-polyol blend is placed into the SK-10 dispensing machine. This contains an adjustable dispensing boom that two workers use to pour the liquid NDI-polyol blend into the molds. The boom contains an exhaust plenum with a flexible duct. At the end of the workshift, the SK-10 dispensing machine is flushed for 15 minutes with DMF (manufactured by DuPont) using a closed-loop system.

Prior to filling the molds, the workers use compressed air to clean the molds. Bolts which are used in the interior of the molds are heated in an oven and coated with Thixon 409 (Whittaker-Dayton Chemical), which contains methyl ethyl ketone, toluene, a glycol ether acetate, and a lead chromate pigment. All spray application of Thixon 409 is performed in a ventilated spray booth.

The filling and curing of the molds is performed on two side-by-side hot plates which are 6 feet long and 3 feet wide. The assembled molds are arranged in rows on the hot plates and filled one at a time. The hot plates are equipped with slot-type exhaust ventilation, which is located 22" above the hot plates and runs the entire length of the hot plates.
On the day of the NIOSH industrial hygiene survey, this facility manufactured 486 bogie wheels to be used on combines. Each bogie wheel was approximately 2.75" in diameter and contained 40 grams of polyurethane plastic material.

IV. EVALUATION DESIGN AND METHODS

A. Industrial Hygiene Study

1. Newton Facility

The industrial hygiene study performed at the Newton Facility on November 15, 1989, consisted of area air sampling for MDI and VOCs. Area air sampling was used to estimate exposures to the workers working at specific work stations or in the general area of the sampling equipment. In addition, a personal exposure sample was collected from the breathing zone of the worker cleaning molds at the Dynasolve tank for VOCs (including 2-methoxyethanol).

a. MDI

Area air sampling was performed according to NIOSH Method 5521,[1] which utilizes a midget impinger containing 15 milliliters (ml) of a solution of 1-(2-methoxyphenyl) piperazine dissolved in toluene. Air was sampled at a nominal flowrate of 1.0 liter per minute (lpm) using a calibrated, battery-powered sampling pump. Upon completion of sampling, the impinger solutions are transferred to 20 ml glass vials, and shipped refrigerated to the analytical laboratory. The samples were prepared for analysis by adding 25 microliters (µl) of acetic anhydride to each sample, were evaporated to dryness in a nitrogen atmosphere, and were sonicated for

15 minutes in 5 ml of methanol. This leaves a sample residue which consists of the urea derivatives which are formed when 1-(2-methoxyphenyl)piperazine reacts with MDI. Aliquots of
25 µl were injected into the high performance liquid chromatograph (HPLC) with a mobile phase consisting of 40% acetonitrile and 60% buffer solution. The ureas were qualitated and quantitated and MDI prepolymer is 0.4 micrograms per sample (µg/sample); the limit of quantitation (LOQ) is
1.2 µg/sample. A bulk sample of the Baytec MS-090 was also analyzed and used to identify and quantitate peaks found in the samples.

b. VOCs

Area air sampling for VOCs was performed by drawing sample air through a SKC Lot 120 charcoal tube at a nominal flowrate of 200 ml/minute using calibrated, battery-powered sampling pumps. Air sampling was performed at three locations, with side-by-side charcoal tube samples collected at each location. One sample from each pair was used for qualitative VOC analysis, and the other for quantitative analysis based on the qualitative results. Also, a personal breathing zone air sample was obtained from the worker cleaning molds with Dynasolve/2-methoxyethanol. The qualitative charcoal tube samples were screened for VOCs according to NIOSH Method 1500.[1] The front and back sections of charcoal were desorbed for 30 minutes with 1 ml of carbon disulfide, and screened by gas chromatography with a flame ionization detector (GC-FID). Since all of the qualitative charcoal tube samples were identical, only one was selected for peak identification and confirmation using GC with mass spectroscopy. Using these results, the quantitative samples and field blanks were analyzed using the same method. The LODs and LOQs varied by VOC species detected in the samples.

2. Malcom Facility

On November 16, 1989, the NIOSH industrial hygienists performed an industrial hygiene study at the Malcom facility to determine workers' exposures to NDI, DMF, and VOCs. Area air sampling was performed for these chemical agents and used to estimate exposure to workers at specific locations or in the general area of the sampling equipment.

a. NDI

Performance of the area air sampling was according to the previously discussed NIOSH Method 5521.[1] The only differences between using this method to sample for MDI or NDI are the LOQs, LODs, and the analytical ranges. The analytical LOD is 0.2 µg/sample; the LOQ is 0.6 µg/sample. The analytical range for this method was reported to be 0.1 to 28.0 µg/sample.

b. DMF

Since the DMF is only used for approximately 10 minutes at the end of the workshift, air sampling was only performed during this period. Area air sampling equipment was positioned on the SK-10 dispensing machine and the drum of DMF to determine the worst case exposure level. These area air samples were collected using NIOSH Method 2004[1]. Sample air was drawn through a silica gel sorbent tube (150 milligrams [mg] front section, 75 mg back section) at a nominal flowrate of 200 ml/minute using a calibrated, battery-powered sampling pump. After sampling, the silica gel was desorbed by sonication for 60 minutes in 1 ml of methanol and analyzed by GC-FID. The LOD for this method was 0.05 milligrams per sample (mg/sample); the LOQ was 0.18 mg/sample.

c. VOCs

Area air sampling for VOCs was performed by drawing sample air through a SKC Lot 120 charcoal tube at a nominal flowrate of 200 ml/minute using calibrated, battery-powered sampling pumps. Air sampling was performed at three locations, with side-by-side charcoal tube samples collected at each location. One sample from each pair was used for qualitative VOC analysis, and the other for quantitative analysis based on the qualitative results. The qualitative charcoal tube samples were screened for VOCs according to NIOSH Method 1500.[1] The front and back sections of charcoal were desorbed for 30 minutes with 1 ml of carbon disulfide and screened by GC-FID. Since the chromatograms of the qualitative charcoal tube samples were identical, only one sample was selected for peak identification and confirmation using GC with mass spectroscopy. Using these results, the quantitative samples and field blanks were analyzed using the same method. For the VOCs detected in these air samples, the LODs ranged from 1 to 5 µg/sample, and the LOQs varied from 3 to 15 µg/sample.

B. Medical Study

On May 18, 1989, the NIOSH medical officer reviewed the medical records of employees who had been referred by Thombert, Inc. to an occupational medicine clinic for respiratory problems.

On October 12, 1989, medical questionnaires were administered to 27 production workers and 20 clerical/administrative personnel at the Newton facility. The purpose of the questionnaire was to identify individuals who may have developed occupational asthma from exposure to isocyanates. Employees who satisfied the following conditions were considered to be "possible" cases of occupational asthma:

1. Episodes of wheezing, shortness of breath, chest tightness, and/or coughing have occurred since working at Thombert, Inc., and

2. Episodes (a) occurred following certain activities at work, or
(b) occurred after exposure to specific materials at work, or
(c) decreased in frequency away from work.

Employees who did not satisfy conditions #1 and #2 were considered, for purposes of our investigation, not to have occupational asthma.

On November 13-15, 1989, pulmonary function tests (PFTs) were administered to 10 employees at the Newton facility, 9 of whom were possible current cases. Pulmonary function testing was conducted according to American Thoracic Society criteria.[2] Forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC) were measured and FEV_1/FVC was calculated. Predicted values for FEV_1 and FVC were derived using Knudson's equation.[3] In addition, the employees were given portable peak flow meters to monitor their breathing at home and at work for seven days. PFTs and peak flow meters were offered to all 10 production workers who were considered to be possible current cases of occupational asthma, based on questionnaire responses. Nine workers agreed to participate in the medical evaluation and 1 refused. Testing was not offered to the 1 administrative/clerical person who was a possible current case, as this individual had already had extensive testing for occupational asthma. On November 13-15, 1989, medical questionnaires, PFTs, and peak flow meters were also given to all 4 workers at the Malcom facility.

Employees who were possible cases of occupational asthma based on questionnaire responses and who had evidence on pulmonary function testing of reversible or variable airway obstruction (i.e., a decrease from baseline - temporally related to being at work - of either FEV_1 by more than 10% or peak flow by more than 20%) were considered to be "probable" cases of occupational asthma.[4]

In order to evaluate the risk of cumulative trauma disorders, the OSHA 200 Logs for 1985-1989 at the Newton facility were reviewed, and a telephone survey was conducted to verify the accuracy of a union-supplied list of employees who had surgery for CTDs.

V. EVALUATION CRITERIA

A. General Guidelines

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 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 the following: 1) NIOSH criteria documents and recommendations, including recommended exposure limits

(RELs), 2) the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs), and 3) the U.S. Department of Labor, OSHA permissible exposure limits (PELs). The OSHA standards 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 by the Occupational Safety and Health Act of 1970 to meet those limits specified by an OSHA standard.

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

B. Diisocyanates-MDI and NDI

The unique feature of all diisocyanate-based compounds is that they contain two -N=C=O functional groups, which readily react with compounds containing active hydrogen atoms to form urethanes. The chemical reactivity of diisocyanates and their unique ability to cross-link make them ideal for polymer formation. Hence, they are widely used in surface coatings, polyurethane foams, adhesives, resins, sealants, etc. Diisocyanates are usually referred to by their specific acronym; e.g. TDI for 2,4- and 2,6-toluene diisocyanate, HDI for 1,6-hexamethylene diisocyanate, MDI for 4,4'-diphenylmethane diisocyanate, NDI for 1,5-naphthalene diisocyanate, etc.[5]

In general, the potential respiratory hazards encountered during the use of diisocyanates in the workplace are related to the vapor pressures of the individual compounds. The lower molecular weight diisocyanates tend to volatilize at room temperature, creating a vapor inhalation hazard. Conversely, the higher molecular weight diisocyanates do not readily volatilize, but are still an inhalation hazard if aerosolized or heated in the work environment. In an attempt to reduce the vapor hazards associated with the lower molecular weight diisocyanates, prepolymer and oligomer forms of these monomers were developed and replaced the monomers in many product formulations. An example of this is biuret of HDI, which actually consists of three molecules of HDI monomer joined together to form a higher molecular weight molecule with similar characteristics to those found in HDI monomer. Also, many product formulations that contain MDI actually contain a combination of MDI monomer and MDI prepolymer (polymethylenepolyphenyl isocyanate). It should be noted that the higher molecular weight diisocyanates still may generate vapor concentrations sufficient to cause respiratory and mucous membrane irritation if they are handled in poorly ventilated areas.[6]

Actual experience has shown that diisocyanates cause irritation to the skin, mucous membranes, eyes, and respiratory tract. Worker exposure to high concentrations may result in chemical bronchitis, chest tightness, nocturnal dyspnea, pulmonary edema, and death.[6,7] One of the most important and most debilitating health effect from exposure to diisocyanates is respiratory and dermal sensitization. Exposure to MDI can lead to this sensitization, depending on the type of exposure, the exposure concentration, the route of exposure, and individual susceptibility. After sensitization, any exposure, even to levels below any current occupational exposure limit, will produce an allergic response which may be life threatening.

The symptoms for both respiratory and dermal sensitization may develop immediately or several hours after exposure, after the first few months of exposure, or may be delayed in onset until after several years of exposure.[8-11] The only effective treatment for the sensitized worker is cessation of all diisocyanate exposure.[12]

The dermal sensitization is similar to allergic dermatitis, including such symptoms as rash, itching, hives, and swelling of the extremities. In respiratory sensitization, the response is an asthmatic reaction characterized by difficulties in breathing; e.g. coughing, wheezing, shortness of breath, and tightness in the chest.[6] In fact, respiratory sensitization from exposure to diisocyanates has traditionally been referred to as "isocyanate asthma." Estimates of the prevalence of diisocyanate-induced asthma in exposed populations of workers vary considerably; from 5% in diisocyanate production facilities,[13] to 25% in polyurethane production plants[9,13] and 30% in polyurethane seatcover operations.[14]

Few reports pertaining to NDI-related respiratory sensitization exist in the scientific literature, especially when compared to the more common diisocyanates such as TDI and MDI. A possible explanation is that NDI is much less widely used in industry and that it is less volatile than the other isocyanates.[15] Reports in the English language literature, however, document NDI-related "sensitivity" in an English chemist (and two other unspecified workers),[16] NDI-related "chest illnesses" (including bronchitis) in English urethane manufacturers,[17] occupational asthma in English rubber manufacturers,[15] possible hypersensitivity pneumonitis in a Danish worker who ground NDI,[18] and "obstructive disease" in Swedish rubber tire manufacturers.[19]

The OSHA PEL and the ACGIH TLV for MDI are 200 and 51 $\mu g/m^3$, respectively.[20,21] The OSHA PEL is a ceiling limit while the ACGIH TLV is an 8-hour time-weighted average. The NIOSH recommended exposure limit is 50 $\mu g/m^3$ for up to a 10-hour, time-weighted average exposure, and a ceiling limit of 200 $\mu g/m^3$ based on any 10-minute sampling period.[6,22]

The NIOSH REL for NDI is 40 $\mu g/m^3$ for up to a 10-hour workshift, 40-hour workweek, and 170 $\mu g/m^3$ for any 10-minute sampling period during the workshift.[6,22] OSHA and ACGIH have not yet developed evaluation criteria for exposure to NDI.[20,21]

C. 2-Methoxyethanol

2-Methoxyethanol primarily effects the central nervous system (CNS) and the hematopoietic system of exposed workers. The CNS effects are sometimes referred to as toxic encephalopathy, and may include such symptoms as headache, lethargy, weakness, ataxia (impairment of coordinated movement), tremor, and somnolence (drowsiness).[23-25] These symptoms are usually reversible upon cessation of exposure. CNS symptoms tend to be the primary effect in workers with acute exposure to high concentrations. Workers exposed for prolonged periods of time may develop anemia.[23,24] There is also one report of CNS symptoms and a decrease in all types of blood cells in two workers exposed primarily through skin contact.[26]

In the NIOSH Current Intelligence Bulletin 39, Glycol Ethers, NIOSH summarized several studies that reported dose-related reproductive effects in animals exposed to 2-methoxyethanol.[27] Reproductive effects reported in these studies include embryonic deaths in rats and rabbits; testicular atrophy and abnormalities in rats, mice and rabbits; fetal abnormalities in mice; infertility in rats and mice; and abnormal spermhead morphology in mice. Based on the results of these animal studies, NIOSH recommends that 2-methoxyethanol be regarded in the workplace as having the potential to cause adverse reproductive effects in male and female workers. NIOSH also considers 2-methoxyethanol to be a workplace teratogen. Considering this, NIOSH recommends that exposures to 2-methoxyethanol be reduced to the lowest feasible level.[22,27] The OSHA PEL and ACGIH TLV for occupational exposure to 2-methoxyethanol are 80 milligrams per cubic meter of air (mg/m^3) and 16 mg/m^3, respectively. These are both based on a TWA exposure level for an 8-hour workshift. In addition, both the OSHA PEL and ACGIH TLV bear a "Skin" notation, indicating the potential for skin absorption of hazardous amounts of this chemical.[20,21]

VI. RESULTS AND DISCUSSION

A. Industrial Hygiene Study

1. Newton Facility

a. MDI

Analysis of the bulk sample of Baytec MS-090 found that it contained 10% MDI and 1% MDI-based polyisocyanate. The bulk sample was used to identify peaks in the air samples. The data from the area air sampling for MDI are presented in Table 1. Since NIOSH Method 5521 utilizes impingers containing a reagent dissolved in toluene, the air sampling devices were not attached to the worker, to avoid unnecessary toluene exposure. Thus, the concentrations measured by this area air sampling were used to estimate exposure to MDI. The average MDI concentration measured by this sampling was 3.9 µg/m^3, with concentrations ranging from none detected (less than 1.1 µg/m^3) to 9.8 µg/m^3. These levels are well below the NIOSH REL for MDI of 50 µg/m^3. In addition, the average polyisocyanate concentration was 5.6 µg/m^3, and these levels ranged from 2.0 to 12.2 µg/m^3. Currently in the U.S., no exposure standards exist for polyisocyanates.

The highest MDI concentrations were found in the area of the workers on Lines #1 and #3. On these lines, large molds are placed on conveyor belts and filled with the MDI-containing polyurethane system, then conveyed into the curing oven. The hot molds exit the oven at approximately the same location as where the filling is performed, and are removed from the line. MDI concentrations of 9.8 µg/m^3 and 6.3 µg/m^3 were measured in the mold filling area for Lines #3 and #1, respectively. Also, an MDI concentration of 6.1 µg/m^3 was measured at the exit opening for the Line #1 curing oven. Since exposure to low levels of MDI, even those below the NIOSH REL, can produce symptoms in workers already sensitized, engineering controls should be installed to reduce exposures to workers filling the molds and from hot molds exiting the curing oven.

b. VOCs

The data from the area air sampling for VOCs and personal breathing zone air sampling for VOCs on the worker cleaning molds in the Dynasol tank are shown in Table 2. The evaluation criteria for each identified VOC are listed below the data, in the column for each compound. The following VOCs were identified in the qualitative samples: 1,1,1-trichloroethane (methyl chloroform), isooctane, 2-methoxy-1-propyl acetate, aliphatic hydrocarbons in the C_7 to C_8 range, ethanol, xylene, and isopropanol. The measured concentrations were well below the NIOSH REL, OSHA PEL, and ACGIH TLV for the above identified compounds. These chemicals were at levels that would not be expected to cause health effects in most workers. Please note that OSHA, NIOSH, and ACGIH have not developed evaluation criteria for exposure to 2-methoxy-1-propyl acetate.

Trace levels of 2-methoxyethanol were measured in the area air samples. These levels were too low to accurately quantitate, and thus were not reported. Conversely, the personal breathing zone air sample obtained on the worker cleaning molds at the Dynasolve tank was 24.3 mg/m^3. This exposure concentration was above the ACGIH TLV of 16 mg/m^3. As previously mentioned, NIOSH recommends that exposure to 2-methoxyethanol be reduced to the lowest feasible level based on its potential to cause adverse reproductive effects in both male and female workers.

It should be noted that carbon disulfide was used to desorb the charcoal tube samples. NIOSH chemists found that when desorbing charcoal with carbon disulfide, the desorption efficiency for 2-methoxyethanol was only 53%. Considering this, the measured exposure concentration should be considered a minimum exposure level, and that the actual level may be much higher than the reported 24.3 mg/m^3. A more suitable desorbing solvent would be a methanol and methylene chloride solution.

2. Malcom Facility

a. NDI

The results from the area air sampling for NDI are presented in Table 3. In interpreting the data, it is important to consider why the sampling equipment was placed in the listed locations. Two samplers were used to estimate workers' exposures during pouring of the NDI-containing liquid into the molds. These were located on the front edge of the hot plates, and NDI was not detected in any of these samples (sampling and analytical

LOD of 0.6 µg/m^3). In addition, a sampler was located on the back side between the hot plates, just below the slot. A concentration of 5.0 µg/m^3 of NDI was measured in this sample, indicating that NDI is being drawn away from the workers by the slot-type exhaust ventilation system. This finding was visually confirmed during the survey using smoke tubes.

Samplers were also placed within the hood of the weighing station and between the two reactors. These samplers were only activated during the period of time that these operations were performed; thus, the measured concentrations should be considered task-specific. The highest measured concentration of NDI (253.6 µg/m^3) was found inside the hood where weighing of the NDI was performed. Also, an NDI concentration of 1.6 µg/m^3 was measured at the reactors. This concentration was between the LOD and LOQ of the analytical method, and should be considered to be a low to trace level of NDI. The NIOSH investigators used puffs of smoke from smoke tubes to visually assess the performance of the local exhaust ventilation systems at the weighing station and the mixing station/reactors. This assessment indicated that the ventilation systems effectively removed contaminants away from the workers weighing out NDI and mixing the NDI and polyol.

An area sample was also collected using a sampler located on the drum designated for disposal of waste liquid NDI and polyol. A NDI concentration of 5.1 µg/m^3 was measured in this sample. Though this is a low level when compared to the NIOSH REL, it does suggest a need for engineering controls to minimize exposures associated with waste NDI. Finally, air sampling was performed during the trimming of finished wheels using a lathe. No NDI was detected in this sample, which was expected since the plastic was fully cured and solid before being trimmed. The data collected and the observations made during the NIOSH survey indicate that the NDI exposures were low, and the engineering controls effectively removed NDI from the work areas. Since worker protection from NDI relies on these controls (e.g. the various exhaust ventilation systems), active maintenance and preventative maintenance programs should be in place to insure that these engineering controls continue to operate effectively.

b. DMF

Due to analytical problems encountered during the analysis of the DMF air samples, the NIOSH investigators considered the sampling data to be invalid. The SK-10 dispensing machine is flushed using a closed system, and flushing only occurs 1-2 times per day for short periods of time. In addition, air sampling by Mobay Corporation on August 4, 1987, did not measure any detectable levels of DMF. Considering this, the NIOSH investigators believe that overexposure is probably not occurring to workers using the DMF, and that further exposure monitoring by NIOSH was not warranted.

c. VOCs

The major peaks identified by the qualitative analysis were 1,1,1-trichloroethane, isooctane, 2-methoxy-1-propyl acetate, and a mixture of aliphatic hydrocarbons in the C_7 to C_8 range. Using this data, these VOCs were quantitated in the remaining charcoal tube samples. The data from this analysis are presented in Table 4. These data indicate that the VOC concentrations measured during the NIOSH survey were well below the OSHA, NIOSH, and ACGIH evaluation criteria (given in the bottom section of Table 2) and would not be expected to cause adverse health effects in most workers.

B. Medical Study

1. Review of Records

Between June 1987 and December 1988, at least 18 employees from the Newton facility with respiratory problems were sent by Thombert, Inc. to an occupational medicine clinic. Eight of the workers were believed to have NDI-related illnesses, including 7 with occupational asthma and one with acute respiratory tract irritation. Three of these employees are currently on long-term disability. The etiology of the respiratory problems in the other workers was not determined. It is important to note that the criteria used to diagnose occupational asthma varied among physicians.

2. Questionnaires

At the Newton facility 26 of 41 production workers completed questionnaires. Eight workers refused to participate, 6 did not show up for their questionnaire appointments, and 1 was on medical leave. Among administrative/clerical personnel, 20 of 24 employees completed questionnaires (4 employees were out of the office on the day the questionnaire was administered). At the Malcom facility, all 4 employees completed the survey.

At the Newton facility (see Table 5), among production workers, 14 reported respiratory problems consistent with possible occupational asthma, 6 reported no respiratory problems, and 6 reported non-asthmatic breathing problems. Of the 14 workers who fit the case definition for possible occupational asthma, 4 related having problems only in the past and 10 reported that they were currently having problems. The 4 who had problems in the past and 1 who currently had a problem cited NDI as the cause of their respiratory disorders, based on having had their symptoms start or markedly worsen when they were exposed to NDI.

Among administrative/clerical personnel (see Table 5), 3 reported respiratory problems consistent with possible occupational asthma, 14 people reported no respiratory problems, and 3 reported non-asthmatic breathing problems. Of the 3 people who fit the case definition for possible occupational asthma, 2 related having problems only in the past and 1 reported a current problem. All 3 employees attributed their respiratory disorders to NDI, because their symptoms began upon exposure to NDI.

At the Malcom facility, employees also reported respiratory complaints. Due to the small number of workers at this facility, the nature and frequency of these complaints will not be discussed to protect confidentiality.

3. Pulmonary Function Testing

At the Newton facility, pulmonary function testing was conducted on 10 production workers, 9 of whom were possible current cases of occupational asthma and 1 who did not have a respiratory problem. At the Malcom facility, pulmonary function testing was done on all 4 employees. None of these employees were among the group already diagnosed as having NDI-related occupational asthma by company consultants.

a. Cross-Shift Spirometry

One employee at the Newton facility had a 12.5% drop in FEV_1 over the course of one workday. This employee also reported having respiratory symptoms during the shift. A second worker in Newton had a drop in FEV_1 of 15.5% and similarly reported having respiratory symptoms during the shift. This employee was a heavy smoker and had recently had a respiratory illness. A third Newton employee, who only had a pre-shift test, showed evidence of an obstructive pattern on pulmonary function testing. This worker was a former smoker who had not had a cigarette for many years. One participant became dizzy at the start of the first breathing test and could not complete it. The 10 remaining participants (at Newton and Malcom) completed the testing and did not show abnormal patterns.

b. Peak Flow Monitoring

Eleven employees (at Newton and Malcom) completed peak flow monitoring. One worker (the same person who had shown a 15.5% drop in FEV_1 on pulmonary function testing) had a greater than 20% drop in peak flow over the course of his/her shift. This drop was noted on 4 out of 5 workdays.

4. Review of OSHA 200 Logs

The review of the OSHA 200 Log revealed that there were 10 upper extremity problems noted in 1985, 7 in 1986, 15 in 1987, 13 in 1988, and 4 in 1989 (up to November), for an average of 10 cases/year. More than half of these problems resulted in lost workdays (Table 6). An average of 9.5 of the upper extremity problems were attributed to CTDs each year (i.e. noted in column 7F on the OSHA 200 Log), from 1985-1988 (Table 7). There were 3 back problems noted in 1985, 10 in 1986, 3 in 1987, 8 in 1988, and 2 in 1989 (up to November), for an average of 5.2/year. More than half of these problems resulted in lost workdays (Table 6). There were 12 eye injuries noted in 1985, 7 in 1986, 10 in 1987, 12 in 1988, and 3 in 1989 (up to November), for an average of 8.8/year. Foreign bodies in the eye accounted for most injuries (Table 6).

5. Interviews of Employees Who Had CTD-Related Surgery

Union representatives provided NIOSH investigators with a list of 16 current and former employees who had CTD-related surgical procedures between 1983 and 1989. Telephone interviews were conducted with 15 of these individuals (Table 8). The interviews and list revealed that 16 employees had a total of 35 operations between 1983 and 1989. Four operations were performed in 1983, 3 in 1984, 4 in 1985, 10 in 1986, 4 in 1987, 8 in 1988, and 2 in 1989.

Nineteen operations were for carpal tunnel syndrome, 8 were for thoracic outlet syndrome, 6 were for elbow problems (including "tennis elbow" and "nerve problems"), 1 was for a rotator cuff tear, and 1 was for removal of a ganglion cyst. One additional employee at the Newton facility told NIOSH investigators that he/she was scheduled for carpal tunnel and ganglion cyst surgery later this year.

6. Discussion of Data Pertaining to Occupational Asthma

At least 7 employees (as noted in medical records) and possibly as many as 14 (including 7 who reported problems on questionnaires), may have had NDI-related occupational asthma in 1987 and 1988. Thombert, Inc. supplied NIOSH with reports from industrial hygiene surveys performed during this time period. These reports indicate that the NIOSH REL for NDI of 5 parts per billion (ppb) was exceeded on several occasions, and employees reported that NDI was used under poorly controlled conditions. Several employees continued to have ongoing breathing problems, in spite of their no longer being exposed to isocyanates.

MDI was also used at Thombert, Inc. during the 1987-1988 period (and prior to it). While it is not possible to absolutely determine which chemical, NDI or MDI, may have been responsible for the initiation of occupational asthma, MDI appears to be a less likely cause for the following reasons: 1) it was apparently used under more tightly controlled conditions (as the company had greater experience with it); 2) air monitoring for it (in 1987 and 1988) did not reveal levels above the NIOSH REL for MDI of 5 ppb; and 3) employees began complaining of serious respiratory problems only after NDI was introduced.

It is important to recognize that there are several limitations to the testing and monitoring that was done. Firstly, employees whose respiratory function had been adversely affected by isocyanates may not have had symptoms and may therefore not have been tested. (With the exception of 3 people, only currently symptomatic workers were studied.) Secondly, there is no general agreement on the "best" way to diagnose occupational asthma. Pre- and postshift pulmonary function testing is easy to do and is reproducible. However, there are several potential problems with it: (1) true diurnal variation in airflow may obscure the effect of a workplace exposure, (2) a representative exposure may not occur on the day of testing, (3) many employees with occupational asthma have a relatively fixed impairment of airway function (from repeated work exposures) and may not experience an acute ventilatory decrement over the course of a shift, and (4) such testing lacks sensitivity in employees with the "late" pattern of asthmatic response, in whom acute reactions may occur after the postshift testing session. Peak flow monitoring can be effective in identifying employees with occupational asthma, but some employees may have difficulty doing it properly. (In this investigation, 3 employees did not complete the peak flow monitoring.) Many clinicians and researchers utilize bronchial provocation tests, such as the methacholine challenge, to aid in the diagnosis of occupational asthma. These tests must be done under careful medical supervision, and typically have not been performed during health hazard evaluation surveys.

Considering the limitations and problems discussed above, it is difficult to definitively exclude NDI-related or MDI-related occupational asthma in the 8 currently symptomatic employees who had normal pulmonary function testing or the 2 currently symptomatic employees who had abnormal (but not definitive) testing, without performing methacholine challenge tests or other diagnostic tests.

7. Discussion of Data Pertaining to Cumulative Trauma Disorders

The OSHA 200 Logs review revealed that between 1985 and 1988, the annual upper extremity CTD incidence rate was 15.8 per 100 full-time production employees. (This figure was calculated from data showing an average of 9.5 CTDs/year between 1985 and 1988, when the company had an average of 60 production workers.) The rate for all CTDs (including upper extremity, lower extremity, back, and chest wall) in the industry as a whole (SIC Code 3079; miscellaneous plastic products) in 1987 (the last reported year) was 0.35 per 100 full-time workers.[28] The industry's incidence rate for upper extremity CTDs is not known.

Several biases can influence the difference in CTD incidence rates between factories. These include ascertainment bias (differences in access to the plant physician for symptomatic employees), misclassification bias (differences in CTD diagnostic criteria), and recording bias (differences in interpreting criteria for work-related illnesses being "recordable" in the OSHA 200 Logs). These biases could account for part of the 47-fold increase in the CTD incidence rate seen at Thombert, Inc. when compared to the rest of the industry. Even so, these limitations are unlikely to account for all the discrepancies. This is especially true when considering that the rates at Thombert, Inc. are only for upper extremity CTDs, while the rate cited for the industry as a whole is for all CTDs.

During the 1985-1988 period, there was an average of 6.5 CTD-related surgical procedures performed each year. It is beyond the scope of this investigation to determine if these were necessitated by the high CTD incidence rate at Thombert, Inc. or were a reflection of overly aggressive medical management (i.e., not reassigning symptomatic workers to less ergonomically stressful jobs, operating too early, etc.).

VII. CONCLUSIONS

Based on the data collected during this evaluation, the NIOSH investigators conclude the following:

A. Considering the NIOSH policy regarding occupational exposure to 2-methoxyethanol, and the personal breathing zone exposure concentration above the ACGIH TLV for this compound, a health hazard exists from exposure of the worker at the Dynasolve tank to 2-methoxyethanol. The data indicate that the local exhaust ventilation system for the Dynasolve tank does not adequately protect the worker from 2-methoxyethanol.

B. Since exposure to low levels of MDI can produce sensitization in some workers, a potential health hazard exists from MDI exposure to workers filling the molds and from hot molds exiting the oven.

C. No health hazard exists from exposure to NDI, DMF, and VOCs (excluding the 2-methoxyethanol used at the Newton facility).

D. From the data collected during the NIOSH medical investigation, isocyanate-related occupational asthma exists among workers at the Newton facility of Thombert, and that the problem began in 1987 and 1988, when NDI was used at this facility.

E. Since at least 1985, a health hazard has existed at the Newton facility from cumulative trauma disorders.

VIII. RECOMMENDATIONS

The following recommendations are made per the data collected during the NIOSH site visits.

A. Newton Facility-Thombert

1. Local exhaust ventilation should be installed to capture MDI vapors that are emitted when molds are filled with the polyurethane system, and when the hot molds exit the curing oven.

2. Thombert, Inc. should consider substituting the Dynasolve with a less hazardous material. This recommendation is based on the highly toxic nature of 2-methoxyethanol, and the overexposure documented during the NIOSH study. Extreme care must be taken when selecting a suitable alternative. The alternate should not only accomplish the goal of properly cleaning the molds, but also pose a reduced health risk to potentially exposed workers. If the alternate is considered to have toxic properties, then engineering controls and personal protective equipment should be used to reduce worker exposure. A recommended work station and exhaust ventilation design is discussed below in recommendations 3a and 3b.

3. If Thombert, Inc. continues to use Dynasolve (or any other solvent containing 2-methoxyethanol), then the following steps should be taken to reduce worker exposure:

    a. The local exhaust ventilation system for the Dynasolve tank should be upgraded to reduce worker exposure to

2-methoxyethanol to the lowest feasible level. A recommended design specification of such a system is shown in the attached Appendix. The exhaust hoods and ductwork should be constructed of fire-resistant materials, and the ventilation system should be equipped with alarms, flowmeters, and/or other devices to indicate malfunction or blockage of the system. These systems should be inspected at the beginning of each workshift where molds are to be cleaned. The efficacy of newly installed engineering controls should be tested by performing personal breathing zone exposure monitoring on the worker cleaning the molds. This exposure monitoring for 2-methoxyethanol should be performed using NIOSH Method 1403[1], which uses a solution of 5% methanol in methylene chloride to desorb the charcoal tube samples.

b. A dedicated drying station should be constructed where all solvent-soaked molds will be placed until they are dry. This station should be equipped with a local exhaust ventilation system designed to capture the solvent vapors evaporating from the molds. The recommended design specification given in the Appendix details construction of a drainboard station next to the tank. While a cleaned mold is drying in the drainboard area, a dirty mold can be submerged in the solvent tank. This design will require the installation of a second overhead winch in this area.

c. The worker cleaning molds in the Dynasolve area should be provided with appropriate respiratory protection until the ventilation system upgrade and drying station are installed and tested. Only after a reduction in exposure of the worker to 2-methoxyethanol is documented by industrial hygiene monitoring, should the worker be allowed to work without respiratory protection. When respirators are used, a complete respiratory protection program should be provided; minimum standards for such a program are set forth in the OSHA General Industry Standards, 29 CFR 1910.134.

d. All efforts should be taken to prevent the worker's skin from coming in contact with 2-methoxyethanol. Any worker who cleans the molds with solvents containing 2-methoxyethanol should be provided with, and required to wear, personal protective equipment which is impervious to 2-methoxyethanol. This should include a work suit (which should either be disposable or cleaned daily to remove 2-methoxyethanol), gloves with the open end taped to the sleeves of the work uniform, splash-proof safety goggles, and a face shield (minimum length of 8 inches). The worker should be provided with a fresh, clean suit prior to the beginning of the workshift. After use and/or at the end of the workshift, the work suit should be placed in a closed container until it is discarded or laundered.

e. If a worker's skin comes in contact with 2-methoxyethanol, the worker should immediately wash or shower to remove the chemical. Employees who work with 2-methoxyethanol should wash their hands thoroughly before eating or smoking.

B. Malcom Facility-Thombert/ITWC

1. A local exhaust ventilation system should be installed for the waste NDI drum to control NDI emissions.

2. Any workers spray painting bolts with Thixon 409 should wear gloves impermeable to the chemicals in this product. These gloves should also be worn whenever handling recently coated/wet bolts.

3. An active maintenance and preventive maintenance program should be in place for the process ventilation systems. These systems should be inspected prior to the beginning of the workshift to insure that they are operating properly. The systems should be equipped with alarms, flowmeters, and/or other devices to warn workers when the systems are malfunctioning or not operating at full capacity.

C. Thombert and ITWC (Both the Newton and Malcom Facilities)

1. Employees should have preplacement medical examinations (including comprehensive medical and work histories, physical examinations, pulmonary function tests, and when appropriate, chest x-rays) and periodic (at least annual) medical examinations (including medical and work histories, and pulmonary function tests). During examinations, applicants or employees found to have medical conditions that could be directly or indirectly aggravated by exposure to isocyanates should be counseled on their increased risk from working with these substances, and be offered employment in diisocyanate exposure-free areas of the plant.

2. Employees who were not working at the time of the NIOSH survey (because they were temporarily laid off) should have (1) a respiratory history taken, (2) pre- and postshift pulmonary function testing, and (3) peak flow monitoring for seven days.

3. Symptomatic employees with normal pulmonary function testing and peak flow monitoring and employees with breathing patterns that may be consistent with a work-related breathing disorder should be further evaluated by an occupational, pulmonary, and other appropriate physician for further evaluation. Further diagnostic testing, such as methacholine or isocyanate challenge testing, may be appropriate.

4. Thombert, Inc. should have a thorough ergonomic and safety assessment of its facilities, establish a CTD and injury prevention program, create a surveillance plan to monitor the incidence of CTD's and injuries, and develop a protocol for the medical management of symptomatic workers.

5. Employees should be provided with, and required to wear, safety glasses when working in areas where there is potential for foreign body-induced eye injuries.

6. Eating, drinking, and smoking should be prohibited in all work areas; eating and drinking should be restricted to designated break areas or rooms. If smoking is permitted, it should be restricted to dedicated rooms that have no other common purpose, and have air exhausted directly outdoors. Workers who smoke should be counseled on how smoking may exacerbate the adverse effects of respiratory hazards (e.g. exposure to diisocyanates [MDI/NDI]).

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1. President, UAW Local 997
2. President, Thombert, Inc.
3. Iowa Methodist Occupational Medicine Clinic
4. The University of Iowa Occupational Health Service
5. Administrator, Iowa OSHA
6. Epidemiologist, Iowa Department of Health
7. NIOSH Denver Region
8. OSHA Region VII

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Table 1
Results from Area Air Sampling for MDI and Polyisocyanate

Thombert, Inc.
Newton, Iowa
HETA 98-198
November 15, 1989

Sample Location	Sample Time	Sample Volume[1]	Concentration of MDI[2]	Concentration of Poly[2]
Top of Line #4, Center of Slot Hood	0715-1326	371	(1.6)[3]	3.8
Line #1 Where Molds Exit the Oven	0719-1520	361	6.1	12.2
Line #1 Work Table, 2 ft. from Workers Breathing Zone, 3 ft. from Oven	0718-1520	458	6.3	6.3
Line #3 Control Panel	0707-1533	506	(1.4)[3]	4.3
Line #5 Above Ventilation Slot	0707-1326	379	ND	6.6
Line #3 Mold Filling Area	0706-1514	488	9.8	(2.0)[3]
Top of Drum of MDI-Prepolymer/Baytec MS-090 for Line #3	0746-1520	386	(1.3)[3]	5.4
Top of Drum of MDI-Prepolymer/Baytec MS-090 for Line #1	0745-1520	453	3.8	3.8
Average Concentration in Molding Areas			3.9	5.6
NIOSH REL			50.0	NSA
ACGIH TLV			51.0	NSA

[1] Sample volumes expressed in liters of air.
[2] Concentrations expressed in micrograms per cubic meter of air ($\mu g/m^3$).
ND-none detected, below the limit of detection of 1.1 $\mu g/m^3$.
NSA-no standard available.
Poly-polyisocyanate.
[3] Values in parenthesis fall between the LOD and LOQ of the analytical method and should be considered semi-quantitative.

Table 2
Results from Personal Breathing Zone and Area Air Sampling for VOCs

Thombert, Inc.
Newton, Iowa
HETA 89-198
November 15, 1989

Sample Location	Sample Time	Sample Volume[1]	Concentrations[2] TCE	ISO	MPA	THC	ETH	XYL	ISP	MEC
Line #1, Top of Work Table, 3 ft. from Fill Line	0805-1520	87	0.4	14.7	(0.1)	7.4	ND	ND	ND	-
Line #3, 4 ft. from Oven	0807-1515	86	0.2	6.9	0.3	25.0	ND	(0.02)	ND	-
On Work Table for Line #5	0809-1326	63	0.4	23.8	0.3	6.9	ND	ND	(0.05)	-
Worker Cleaning Molds at the Dynasol Cleaning Tank	0820-1430	74	0.9	57.2	2.3	16.4	0.8	0.1	0.3	24.3
OSHA PEL			1900	NSA	NSA	NSA	1900	435	980	80
NIOSH REL			1900	350	NSA	350	1900	435	980	LFL
ACGIH TLV			1910	NSA	NSA	NSA	1880	434	983	16

[1] Sample volumes expressed in liters of air.
[2] Concentrations expressed in milligrams per cubic meter of air (mg/m^3).
TCE - 1,1,1-trichloroethane.
ISO - isooctane.
MPA - 2-methoxy-1-propyl acetate.
THC - total hydrocarbons, aliphatic hydrocarbons in the C_7 to C_8 range.
ETH - ethanol.
ISP - isopropanol.
XYL - xylene.
MEC - methyl cellosolve.
ND - none detected, below the limit of detection.
NSA - no standard available.
LFL - NIOSH considers to be a potential human carcinogen and recommends that exposures be reduced to the lowest feasible level.

Table 3
Results from Area Air Sampling for NDI

Thombert, Inc.
Malcom, Iowa
HETA 89-198
November 16, 1989

Sample Location	Sample Time	Sample Volume[1]	Concentration of NDI[2]
Front Portion of Left Hot Plate	1001-1601	360	ND
Front Portion of Right Hot Plate	1001-1601	360	ND
Back Portion Between Hot Plates	1001-1601	360	5.0
Mixing Station Between Reactors	0903-1439[4]	129	(1.6)[3]
Weigh-out Station Within Hood	0846-1427[4]	56	253.6
Waste NDI Drum	1045-1601	254	5.1
One Foot from Lathe Trimming Wheels	1318-1348	30	ND
NIOSH REL			40.0

[1] Sample volumes expressed in liters of air.
[2] Concentrations expressed in micrograms of NDI per cubic meter of air (µg/m^3).
ND-none detected, below the limit of detection of 0.9 µg/m^3.
[3] Values in parentheses fall between the LOD and LOQ of the analytical method and should be considered semi-quantitative.
[4] Three discrete weighings and mixings were performed during the workshift. Samples were only collected during these procedures. The total time for weighing during the workshift was 56 minutes; the total time for mixing was 129 minutes.

Table 4
Results from Area Air Sampling for VOCs

Thombert, Inc.
Malcom, Iowa
HETA 89-198
November 16, 1989

Sample Location	Sample Time	Sample Volume[1]	Concentrations[2] TCE	ISO	MPA	THC
Boom of SK-10 Dispensing Machine	0903-1615	432	0.03	2.4	0.04	1.2
Ledge above Hot Plates	0902-1602	420	0.02	1.5	0.04	1.0
X-B Hardener Heating Tank	0859-1613	434	ND	0.7	0.05	1.1
OSHA PEL			1900	NSA	NSA	NSA
NIOSH REL			1900	350	NSA	350
ACGIH TLV			1910	NSA	NSA	NSA

[1] Sample volumes expressed in liters of air.
[2] Concentrations expressed in milligrams per cubic meter of air (mg/m^3).
TCE - 1,1,1-trichloroethane
ISO - isooctane
MPA - 2-methoxy-1-propyl acetate
THC - total hydrocarbons, aliphatic hydrocarbons in the C_7 to C_8 range
ND - none detected, below the limit of detection
NSA - no standard available

Table 5
Questionnaire Results for Workers in Newton, Iowa

Thombert, Inc.
HETA 89-198

A. PRODUCTION WORKERS

No. of Participants Current	Past	Possible Occupational Asthma*	No. Respiratory Problems	Non-Asthmatic Respiratory Problems
22	4	14	6	6

B. ADMINISTRATIVE/CLERICAL PERSONNEL

No. of Participants Current	Past	Possible Occupational Asthma	No. Respiratory Problems	Non-Asthmatic Respiratory Problems
18	2	3	14	3

* - See text for definition.

Table 6
Review of Annual OSHA 200 Log
Injuries And Illnesses: Upper Extremity, Back, and Eye

Thombert, Inc.
HETA 89-198

INJURY OR ILLNESS	1985	1986	1987	1988	1989	TOTAL
Shoulder						
Surgical[1]	3	-	-	-	-	3
Other-With Days Off[2]	1	2	1	1	1	6
Other-No Days Off[2]	-	1	4	-	-	5
Elbow						
Surgical[3]	1	-	-	-	-	1
Other-With Days Off[4]	-	-	1	2	-	3
Other-No Days Off[4]	-	-	1	2	1	4
Wrist						
Surgical[5]	3	1	1	-	-	5
Other-With Days Off[6]	1	1	3	2	-	7
Other-No Days Off[6]	-	2	4	1	2	9
Hand						
Surgical	-	-	-	-	-	0
Other-With Days Off[7]	-	-	-	1	-	1
Other-No Days Off[7]	1	-	-	4	-	5
Total Upper Extremity	10	7	15	13	4	49
Back						
Surgical[8]	1	-	-	-	-	1
Other-With Days Off[9]	2	8	2	1	-	13
Other-No Days Off[9]	-	2	1	7	2	12
Eye[10]	12	7	10	12	3	44

1: thoracic outlet syndrome
2: pain, overuse, pulled muscle, muscle spasm and/or bursitis
3: not specified
4: pain and/or tendinitis
5: carpal tunnel syndrome
6: pain, tingling, mass, tendinitis, and/or carpal tunnel syndrome
7: pain
8: herniated disc
9: strained back, twisted back, pulled muscle and/or not specified
10: mainly foreign body in eye

Table 7
Review of Annual OSHA 200 Log
Injuries and Illnesses: Upper Extremity and Back

Thombert, Inc.
HETA 89-198

INJURY OR ILLNESS	1985	1986	1987	1988	TOTAL
Shoulder					
CTDs*	4	2	0	0	6
Injuries	0	1	5	1	7
Elbow					
CTDs*	1	0	2	4	7
Injuries	0	0	0	0	0
Wrist					
CTDs*	4	4	8	3	19
Injuries	0	0	0	0	0
Hand					
CTDs*	1	0	0	5	6
Injuries	0	0	0	0	0
Total Upper Extremity					
CTDs*	10	6	10	12	38
Injuries	0	1	5	1	7
Back					
CTDs*	0	0	0	0	0
Injuries	3	10	2	8	23

* cumulative trauma disorders, from column 7f

Table 8
Cumulative Trauma Disorder Surgical Procedures
1983-1989

Thombert, Inc.
HETA 89-198

SITE OF SURGERY	1983	1984	1985	1986	1987	1988	1989	Total
Carpal Tunnel	4	3	3	3	3	3	1*	20*
Thoracic Outlet	0	0	0	7	0	0	1	8
Elbow	0	0	1	0	1	4	0	6
Rotator Cuff	0	0	0	0	0	0	1	1
Ganglion Cyst	0	0	0	0	0	1	1*	2*
Total	4	3	4	10	4	8	4**	37**

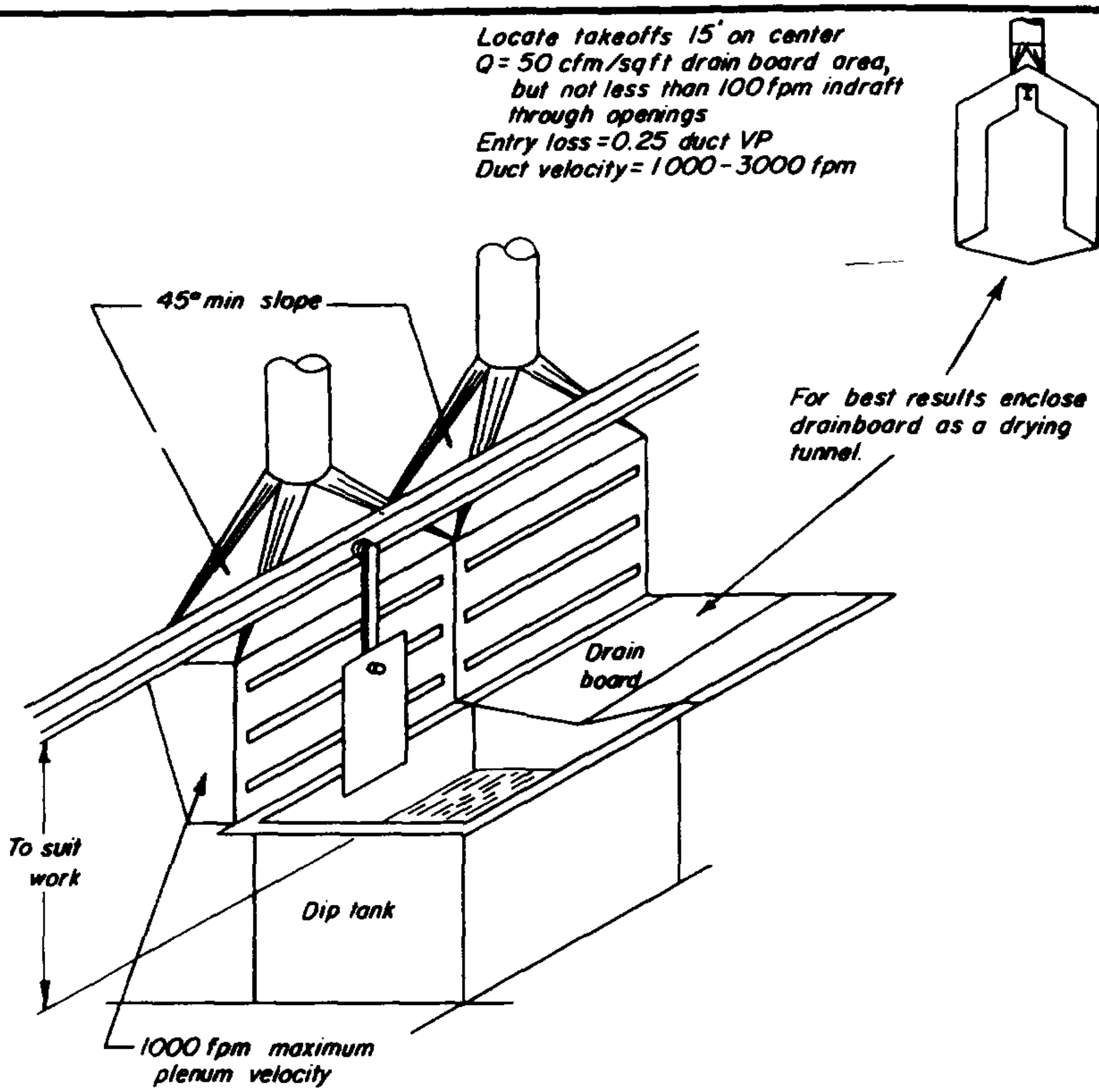
* includes one operation scheduled for 1989
** includes two operations scheduled for 1989

Appendix

Recommended Exhaust Ventilation System for Mold Cleaning Tank

From: Industrial Ventilation, A Manual of Recommended Practice, 19th Edition. Published by the American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio. 1986.

Locate takeoffs 15' on center
Q = 50 cfm/sq ft drain board area, but not less than 100 fpm indraft through openings
Entry loss = 0.25 duct VP
Duct velocity = 1000 - 3000 fpm



Q = 125 cfm/sq ft of tank and drainboard area
Slot velocity = 2000 fpm
Entry loss = 1.78 slot VP + 0.25 duct VP
Duct velocity = 1 000 - 3000 fpm
NOTE: For details on drying oven, See VS-602

For air drying in a room or enclosure, see Section 2 for dilution ventilation required.

For construction and safety, consult NFPA.[113]

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

DIP TANK

DATE 1-78 | VS-502