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DISTINCTIVE DESIGNS INTERNATIONAL, INC.
RUSSELLVILLE, ALABAMA

NIOSH INVESTIGATORS:
Elizabeth Jennison, MD, MPH
Corrado Ugolini, MD, MPH
Chris Piacitelli, IH

I. SUMMARY

In September 1991, the State of Alabama Department of Public Health requested technical assistance from the National Institute for Occupational Safety and Health (NIOSH) in investigating a possible health hazard at Distinctive Designs International, Inc., Russellville, Alabama. The request was prompted by the death of a former employee who initially became ill after working with diphenylmethane diisocyanate (MDI) at the plant. This individual had a respiratory illness which his physician felt was consistent with isocyanate-induced hypersensitivity pneumonitis. The facility produces artificial plant and tree arrangements and uses a MDI-based polyurethane foam to provide a rigid support for the arrangements.

NIOSH investigators conducted an initial site visit and walk-through inspection on October 7, 1991. Work on this project was delayed by the lack of an analytical method for measuring airborne MDI and by the departure of the initial medical project officer from NIOSH. On September 29, 1992, a second walk-through inspection was made by the new project team. An in-depth medical survey was conducted March 11-22, 1993, and an industrial hygiene survey was completed March 23-24, 1993.

Detectable concentrations of monomeric MDI were found in two of the five full-shift area air samples collected in impingers; however, these concentrations were below the limit of quantitation. The minimum detectable concentration was 0.6 ug/m^3, and the minimum quantifiable concentration was 1.6 ug/m^3 for the samples. The six impingers used for short-term personal sampling did not indicate detectable concentrations of monomeric MDI. The detection limit for these samples was about 20 ug/m^3.

Vapors/aerosols were observed rising into the faces of workers working with the foam. This observation and a chemical smoke tube test indicated that the ventilation systems in the foaming areas were not adequate for preventing worker exposure to MDI. Skin contact with the curing was also noted during the survey.

The medical portion of the survey consisted of a medical questionnaire, occupational and exposure histories, spirometry, and serial peak flow measurements. Of 93 current employees, 80 (86%) participated in some aspect of the survey. Individuals who reported high exposure to the polyurethane foaming process were more likely to report work-related nasal and eye irritation than were individuals in the other exposure categories. Self-reported exposure to the foaming process was not associated with any other symptoms, nor was it related to pulmonary function, as measured by spirometry and serial peak flow monitoring.

A total of 111 prior employees were contacted, asked to complete a brief questionnaire, and offered spirometry. Thirty-five individuals responded, four of whom had left work due to a lung or respiratory problem which they felt to be potentially work-related. Sixteen prior employees had spirometry testing and all had normal results, including two of the four who said they had left work because of a respiratory problem. Since the response rate was low (32%), this sample is unlikely to be a representative sample of former employees of Distinctive Designs International.

Based on the results of this investigation, the NIOSH investigators have concluded that, during the time of this evaluation, a potential health hazard existed at Distinctive Designs International, Inc. Workers exposed to the polyurethane foaming system reported nasal and ocular irritant symptoms suggesting that there is ongoing exposure to MDI. Although air sampling did not reveal MDI concentrations that exceeded exposure standards, observations made during the environmental survey suggested that the potential for overexposures did exist. Also, studies have suggested that exposures to MDI at levels below the exposure standards, and exposures to higher polymers of MDI (not sampled here, but present in the foam formulation) can impair respiratory function or cause sensitization. The recommendations made include informing workers of the potential hazards of MDI exposure, instituting a medical surveillance program to identify early respiratory effects associated with isocyanate exposure, improving the ventilation systems, and providing adequate personal protective equipment.

Keywords: SIC 3999 (Artificial flower arrangements-manufacturing), polyurethane foam, diphenylmethane diisocyanate (MDI), hypersensitivity pneumonitis.

II. INTRODUCTION

In September 1991, the State of Alabama, Department of Public Health requested technical assistance from the National Institute for Occupational Safety and Health (NIOSH) in investigating a possible health hazard at Distinctive Designs International which produces artificial plant and tree arrangements. The request was prompted by the death of a 41 year old employee who had initially become ill after working with diphenylmethane diisocyanate (MDI) at the plant.

On October 7, 1991, an industrial hygienist and a medical officer from NIOSH visited Distinctive Designs International. They conducted a walk-through evaluation of the plant, met with all the current workers who were involved with the polyurethane foaming process, and reviewed pertinent company records. They also met with the deceased worker's family and initiated the collection of his personal medical records.

A review of the available medical records revealed that the deceased worker's initial respiratory illness was consistent with isocyanate-induced disease. Further medical and environmental monitoring of workers at Distinctive Designs International was planned for the summer of 1992 but was delayed by lack of an adequate method for measuring airborne MDI and by the departure of the initial medical project officer from NIOSH.

On September 29, 1992, a second NIOSH walk-through was conducted to familiarize the two new medical officers with the facility and processes in use at Distinctive Designs International. The industrial hygienist who had been on the first walk-through also participated in this visit.

An in-depth medical survey was conducted March 11-22, 1993. An industrial hygiene survey was completed March 23-24, 1993.

III. BACKGROUND

Distinctive Designs International produces artificial plant and tree arrangements. The company has been at its present location since 1986; it occupied a rented building between 1981 and 1986. The plant currently has about 90 employees. Natural branches from birch, wax myrtle, and crepe myrtle trees are used to construct the trunks of the artificial trees. Natural moss is used for the "ground" of the artificial plants. Both the moss and the tree branches are fumigated with methyl bromide in a free-standing enclosed shack which is adjacent to the main building. Artificial foliage is attached to the trunks of the trees and is also used to construct the plant arrangements. The artificial foliage is not produced at the plant.

The containers for the artificial plants and trees are filled with a reacting polyurethane foam which polymerizes to a rigid form. This rigid foam serves as a durable physical support for the trees and plants. The polyurethane foam is also used in the shipping area to produce packaging material to protect large fragile items. The polyurethane foaming process has been used since 1983.

The polyurethane foam is produced from a two-part system of cylinders (component A and component B). Component A contains the diphenylmethane diisocyanate (MDI), which, in the pre-reacted mixture, is present in both monomeric and polymeric forms. Component B contains a mixture of the polyol blend, emulsifier, amine catalyst, and surfactant. The two cylinders are pressurized with nitrogen, and the contents of the two cylinders are brought together in a mixing chamber, where the polymerization reaction is initiated. The mixing chamber is heated to about 110-120^{o}F. The reaction is exothermic and the reacting components continue to generate heat as the foam is forming. The foam goes through a spontaneous curing process. The final product is a durable rigid foam. Two different densities of foam are used. The packaging area uses a foam with a density of .4 pound per cubic foot (lb/ft^{3}). The foam density for both the tree and the small arrangements areas is 1.5 lb/ft^{3}. The polyurethane foaming process has changed over the past few years. Since this system went from a chlorofluorocarbon (CFC) to a water-based (no CFC) formulation, some workers have noted an increased release of visible vapors/aerosols during the foaming processes. Empty tanks are returned to the supplier without being cleaned.

There are three operations which use the polyurethane foam. The first operation is in the small plant arrangement section. The foam is sprayed into small pots or vases that are arranged on a table mounted with wheels for portability. The expanding foam is sometimes compressed by hand to allow an even rise and to ensure all voids in the containers are filled. The filled containers go to another worker, who starts adding foliage. This worker shaves the expanded foam if the expansion is too great. This foaming process is conducted on a daily basis for a total of about two to three hours.

The second foaming operation is packaging, which takes place in the warehouse area of the building. This involves spraying large quantities of expanding polyurethane foam to form molds for shipping fragile plant/tree arrangements. Foam is sprayed into a box lined with plastic wrap. As the foam rises, a container similar to that which will be shipped is pushed into it to form the mold. When the foam attains rigidity, the container is removed. This process was not being done during either of the NIOSH walk-through visits. It was, however, used briefly during the period of the extended medical and industrial hygiene surveys. During the first NIOSH visit, some workers described a vapor/aerosol cloud migrating from this process toward the artificial trees area. The packaging process runs 2-3 times per week.

The third polyurethane foaming operation is in the artificial trees area, which is adjacent to the packaging area. The workers spend the major portion of each day arranging branches in

large containers in preparation for the introduction of foam to hold the arrangement in place. The foaming system is mounted on a wooden dolly which allows it to be moved along the rows of tree assemblies. The worker generally sits on a rolling chair while spraying foam into the containers. The rising foam is sometimes compressed by hand as it rises to ensure it fills all voids. Workers noted that when this is done, a small cloud of vapors/aerosols rises from the foam. The tree foaming process is done once a day and runs for about one hour. Often when the workers are not preparing tree arrangements, they fill large empty containers with foam in the same area.

The maintenance operation of the polyurethane systems includes cleaning the mixing chamber and running the system until the optimal component A to component B ratio is obtained and until the final polyurethane foam is of acceptable quality. The NIOSH investigators did not have the opportunity to observe this process.

In the fumigation process, methyl bromide is used to treat many of the natural products used in the arrangements, including tree trunks and branches and some of the moss. This process runs about once every 2 weeks. A single individual is responsible for the fumigation and has received special training and licensure in fumigation. The fumigation shack is a separate structure from the main building and is behind a padlocked gate. The fumigation process was not observed during the NIOSH visits.

A hot melt glue is used to attach artificial leaves to the tree trunks and in packaging and shipping. The hot glue contains ethylene vinyl acetate as an adhesive. Some of the containers and artificial foliage are painted on site. The painting process involves the use of enamel paint spray cans and dip tanks with water based paint. These processes were not evaluated.

IV. MATERIALS AND METHODS

A. Environmental

The industrial hygiene survey completed March 23-24, 1993, consisted of area and personal air sampling for MDI. In addition, chemical smoke tubes were used to visualize the movement of air in areas where the foam was used.

Area air samples were collected for full-shift duration in the work areas of workers using foam. Samples were collected with impingers that contained 15 milliliters of a solution of 1-(2-methoxyphenyl)-piperazine in toluene in accordance with NIOSH Method 5521.[1] Toluene evaporates during sampling, so the volume was frequently restored with toluene as the level of the impinger solutions dropped. Air was sampled at a flowrate of one liter per minute using calibrated battery-powered sampling pumps. The impingers and pumps were connected via a short length of teflon tubing. Samples were shipped refrigerated to the analytical laboratory where they were analyzed with high performance liquid chromatography (HPLC) for monomeric MDI.

Impingers were also used to evaluate personal exposures. To obtain personal breathing zone samples without exposing the workers to the toluene impinger solution, a short length of teflon tubing was attached to the workers' collars and to the air inlets of the impingers. These samples were collected on a few workers for periods of 10-15 minutes while using foam.

An MDA Scientific Model TLD-1 Toxic Gas Detector with a detection tape (paper tape) for diisocyanates was also used. This instrument provides average concentrations over 2-minute intervals. A short length of teflon tubing was connected between the workers' collars (adjacent to the tubing for the impingers) and the air inlet of this instrument to obtain personal breathing zone samples. This instrument was used in this survey to identify locations with potential for isocyanate exposure and to determine relative concentrations between different operations at the facility.

B. Medical

All current employees were invited to participate in the medical survey, which consisted of a health and symptoms questionnaire, occupational history, a questionnaire designed to assess exposure to the polyurethane foaming process, serial peak flow measurements, and spirometry. Cross-shift spirometry was performed on the first day of the work week and single session spirometry was performed on the last day of the work week.

Working with the foaming system was used as a indicator of potential isocyanate exposure. Exposure was classified as "never," "low," "intermediate," or "high" based on the following criteria. Individuals who reported performing the foaming process daily or several times a week were considered to have high exposure. Intermediate exposure status was assigned to individuals who reported using the foaming system on occasion, but not regularly. Individuals who have never used the foaming system but who reported handling foam while it was still warm were considered to have low exposure. Workers who reported never using the foaming system and had never handled foam or foam-containing containers while the foam was still warm were classified as never exposed.

The presence of respiratory symptoms and nasal, eye, and skin irritation was assessed by questionnaire. Chronic cough was defined as cough occurring on most days. Chronic phlegm was defined similarly. Grade I dyspnea was defined as shortness of breath when hurrying on level ground or walking up a slight hill. Grade II dyspnea was defined as shortness of breath while walking on level ground with people of one's own age, and Grade III was defined as having to stop for breath when walking at one's own pace on level ground. Individuals who currently smoked cigarettes were defined as current smokers. Individuals who had smoked five or more packs of cigarettes during their entire life, but did not currently use cigarettes, were classified as ex-smokers.

The company supplied a list of all employees who had terminated employment at Distinctive Designs International in the calendar years 1989-1992. Each of these prior employees received a letter describing the study and a two page questionnaire. The questionnaire asked the length of their employment at Distinctive Designs International, work area, involvement with the polyurethane foaming process, and whether the employee had left the company for health-related reasons. Respondents were also asked to indicate whether they were interested in having spirometry testing. Those who desired spirometry were contacted to set up appointments.

Spirometry

Spirometry was performed using a dry rolling-seal spirometer interfaced to a dedicated computer. At least five maximal expiratory maneuvers were recorded for each person. All values were corrected to BTPS (body temperature, ambient pressure, saturated with

water vapor). The largest forced vital capacity (FVC), and forced expiratory volume in one second (FEV_1) were the parameters selected for analysis, regardless of the curves on which they occurred. Testing procedures conformed to the American Thoracic Society's recommendations for spirometry.[2] Predicted values were calculated using the Knudson reference equations.[3] Predicted values for blacks were determined by multiplying the value predicted by the Knudson equation by 0.85.[4] Test results were compared to the 95th percentile lower limit of normal (LLN) values obtained from Knudson's reference equations to identify participants with abnormal spirometry patterns of obstruction and restriction.[3] Five percent of the population will have predicted values that fall below the normal range, or LLN, while 95% will have predicted values above the lower limit.

Using this comparison, obstructive and restrictive patterns are defined as:

Obstruction: Observed ratio of FEV_1/FVC% below the LLN.
Restriction: Observed FVC below the LLN; and
FEV_1/FVC% above the LLN.

The criteria for interpretation of the level of severity for obstruction and restriction, as assessed by spirometry, is based on the NIOSH classification scheme (available upon request from the Division of Respiratory Disease Studies). For those persons with values below the LLN, the criteria are:

	Obstruction (FEV_1/FVC x)	Restriction (% Predicted)
Mild	>60	>65
Moderate	$\geq$ 45 to $\leq$ 60	$\geq$ 51 to $\leq$ 65
Severe	<45	<51

Serial Peak Flow Measurements

All study participants were given log sheets and instructed in the use of the Mini-Wright Peak Flow Meter on the first day of the medical survey. Participants were asked to record flow results from three blows every 2 hours while awake for 8 consecutive days. They were also asked to record the presence of symptoms and the use of medication during the 2 hours prior to the measurement. For each recording day, information was collected about work hours (or whether it was a day off), and whether participants performed their "usual work" on that day.

Peak flow logs from each worker were reviewed for completeness. A record from a 24-hour survey day was considered valid if it contained peak flow results from at least three recording times that spanned at least 8 hours that day. A worker's record was included in the analysis if valid records from a minimum of 4 of the 8 survey days were present, including at least 1 day off work. Logs which failed to meet these minimal criteria were excluded from analysis.

The highest of the three recorded values from each peak flow measure-ment time was used for calculations and subsequent interpretation. For each worker, an overall mean peak flow was calculated from these values. In addition, a daily mean was calculated for each survey day with valid results. Diurnal variation in peak flow was calculated as the difference between the daily maximum and minimum best values for the survey day divided by the daily mean. Overall variation in peak flow was calculated as the difference between the maximum and minimum best values for the entire survey, divided by the overall mean. Overall variation of $\geq$ 20% is suggestive of increased airway responsiveness.[5] If peak flow level is lower on work days compared to days away from work, or variation $\geq$ 20% is seen on work days and absent on days off work, a relationship between airflow changes and workplace exposures is suggested.

V. EVALUATION CRITERIA AND TOXICOLOGY

A. Criteria

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Criteria Documents and recommendations, (2) the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs), and (3) the U.S. Department of Labor (OSHA) occupational health standards. Often, the NIOSH recommendations and ACGIH TLVs are lower than the corresponding OSHA standards. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet those levels specified by an OSHA standard.

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

B. Toxicology

Isocyanates

Within industries where isocyanates are used, the prevalence of isocyanate-related symptoms may reach 10%. A recent study reported a 10.3% prevalence of MDI asthma in a foundry with 78 employees.[6] Among workers with respiratory symptoms, the predominant clinical diagnosis is bronchial asthma. Rhinitis (runny nose), conjunctivitis (inflamed eyes), chronic obstructive lung disease, and skin lesions are also observed.[7]

Isocyanates can induce immediate, late, and dual (combined intermediate and late) asthmatic responses; the late asthmatic reaction predominates on inhalation challenge testing.[8] In a study of 29 workers referred for specific inhalation challenges with isocyanates, seven had an immediate response, fifteen had an early late or late response, and seven had dual reactions. Late asthmatic reactions were seen with exposure to MDI as well as to toluene diisocyanate (TDI) and hexamethylene diisocyanate (HDI).[9] Delayed asthmatic reactions may be missed by cross-shift spirometry, but should be detected by serial measurements of peak expiratory flow rates. In one study, workers currently exposed to MDI had cross-shift changes in FEV_1 that were not significantly different from zero. However, the comparison population of workers with no history of MDI exposure had a mean cross-shift increase in FEV_1, so there was a significant difference between the two groups.[10]

The role of immunologic testing in diagnosing cases of isocyanate-induced asthma is still under investigation. Estimates of the percentage of symptomatic individuals with isocyanate-induced asthma who have immunoglobulin-E (IgE) antibodies directed against isocyanates conjugated to human serum albumin have ranged from 14%[6] to 80%.[11] Isocyanates, including MDI[12], can also cause hypersensitivity pneumonitis, characterized by shortness of breath and fever for several hours after exposure and the presence of isocyanate-specific immunoglobulin-G (IgG) antibodies. In a study of 29 individuals with positive inhalation challenges to isocyanates, 10 of whom had positive challenge tests to MDI, none had isocyanate-specific IgE alone.

Twenty of these subjects had isocyanate-specific IgG only, while nine had both IgE and IgG.[9] Recent evidence suggests that a hypersensitivity pneumonitis-type of reaction may be a more frequent consequence of MDI exposure than previously recognized, approaching 5%.[13]

Studies of the natural history of occupational asthma[14] indicate that, although improvement is often noted after exposure to the precipitating agent is terminated, symptoms and bronchial hyperreactivity may persist for many years or indefinitely. Persistence of chronic asthma appears to be related to the duration of an individual's exposure following onset of the disease and may also be related to the severity of the asthmatic reaction. In a follow-up study of 50 workers with isocyanate-induced asthma, 16 of whom were sensitized to MDI, 82% continued to have respiratory symptoms, and approximately half of these required inhaled or oral medications for asthma at least once per week. All of these individuals had avoided isocyanate exposure for at least 4 years.[15] Death has been reported in an isocyanate-sensitized worker who continued to work with polyurethane paint containing toluene diisocyanate.[16]

Both the ACGIH TLV and NIOSH REL for MDI are a TWA of 5 parts MDI per billion parts air (ppb) [equivalent to 50 micrograms per cubic meter of air (ug/m^3)] for an 8-hour workday (ACGIH) or up to a 10-hour workday (NIOSH).[17-19] NIOSH also recommends a 10-minute TWA ceiling of 20 ppb (200 ug/m^3). The OSHA PEL for MDI is a 20 ppb ceiling level that should not be exceeded during any part of the workday.[20]

Some studies have suggested that exposure to MDI levels below the exposure criteria may produce isocyanate-induced respiratory sensitization in some workers.[21,22]

The NIOSH recommended levels apply to diisocyanate monomers only, and not to the higher polymers of these compounds. Little is known about the toxicological effects of polymeric isocyanates. However, it is thought that the inhalation of any species having multiple unreacted isocyanate groups may impair respiratory function or give rise to sensitization.[23,24] In 1983, the United Kingdom Health and Safety Commission set a "common control limit" for workplace exposure to all isocyanates. This new control limit is 20 ug/m^3 of isocyanate group (NCO) expressed as an 8-hour TWA, and 70 ug/m^3 NCO as a 10-minute TWA. This new control limit requires that the analytical methods be applicable to "total isocyanate," that is, the sum of all isocyanate species, including monomers and prepolymers.[25]

VI. RESULTS AND DISCUSSION

A. Environmental

Detectable concentrations of monomeric MDI were found in two of the five full-shift area air samples collected with impingers; however, these concentrations were below the limit of quantitation. These two samples were collected in the arrangements and artificial trees areas of the facility. The limit of detection was 0.6 ug/m^3, and the limit of quantitation was 1.6 ug/m^3 for the samples.

The six impingers used for short-term personal sampling did not indicate detectable concentrations of monomeric MDI. The detection limit for these samples was about 20 ug/m^3.

While sampling one foaming operation in the arrangements area, concentrations indicated on the paper-tape monitor ranged from 0 to 5 ppb MDI during the machine's 2-minute reporting intervals. The maximum 10-minute TWA was 2 ppb. Five operations were sampled with this machine in the artificial trees area. The 2-minute readings ranged from 0 to 8 ppb, and the maximum 10-minute TWA concentrations during these operations ranged from 1 to 6 ppb. Similar sampling was attempted during the packaging process, but the worker became ill and did not return to finish filling the boxes. When MDI is heated, the vapor pressure increases and MDI vapor evolves. This vapor readily condenses to aerosol as it cools to the ambient temperature[26,27] Aerosols may not always register on paper-tape monitors.[28,29] Although no conclusions will be drawn from the paper-tape monitor data about the actual concentrations in these areas, the monitor was useful in determining whether airborne MDI was released in some of the foaming operations and determining relative concentrations between different operations.

The paper-tape monitor was also used in an attempt to determine if vapors/aerosols continued to rise from curing foam. With the inlet held directly above the foam immediately after it had been poured, it took 10 minutes for the concentration to drop from 13 ppb to 0 ppb.

In the arrangements area a small exhaust fan was located in a nearby wall. The rolling table holding the containers was positioned so the containers were from 3 to 8 feet from the fan. When a chemical smoke tube was used to visualize air movement in the area, it was noted that the tube had to be within 2 feet of the fan before the smoke was captured by the fan. The position of the table also required the worker to stand between the containers and the fan while foaming. Had the fan been capable of drawing contaminants from the operations at this table, they would enter the breathing zone of the operator as they travelled toward the fan. A counter below the fan would not allow the table to be positioned directly below and adjacent to the fan. The fan exhausted into the warehouse in which the packaging and tree foaming operations were conducted.

Near the artificial trees area, two exhaust fans were located in an adjacent outside wall which was 20 feet from the closest tree foaming operations and 40 feet from the most distant. The distance to the exhaust fans is much greater from the operations of filling large containers (without trees) and packaging. A chemical smoke tube revealed that with a nearby large overhead door closed, only smoke released near trees closest to the wall was quickly captured by the fans. Smoke released near the other trees very slowly migrated toward the fans but predominantly lingered within the area. Smoke emitted near the large containers and packaging remained in the area of release for a long period and eventually migrated to the tree area. With the large overhead door open, as is usual according to the plant manager, incoming outside air mixed the smoke but it still remained in the area of release for a substantial time. With the door open, the capture distance of the fans also decreased. These findings are consistent with workers' reports that often a large cloud of vapors/ aerosols remains in the area when large numbers of containers are filled with foam, especially when large quantities of packaging foam are produced. It should be noted that, even if these fans were effective in exhausting releases from the foaming processes, in many circumstances it would require them to pass through workers' breathing zones prior to reaching the fans. Also releases from the plant arrangements would be introduced into the packaging and artificial trees areas since its fan was not exhausted outside the facility.

Vapors/aerosols were observed rising from the surface of the foam as it was sprayed and while the foam was rising. To obtain a better view of their work, workers often sprayed foam with their faces positioned within inches of the containers directly in the rising vapors/aerosols. These emissions were especially noticeable when workers manipulated the foam. Examples of this manipulation of the foam included pushing on the rising foam to fill voids of containers, forcing of containers into packaging foam, and cutting of foam. When containers were pushed into the packaging foam, very large amounts of emissions were discharged directly into the face of the worker.

Workers in the foaming operations were observed wearing either rubber or cotton gloves. The cotton gloves were covered with foam, and patches of foam were noted on the exposed arms of a worker who wore a short-sleeved shirt. Workers also wore

aprons and protective eye goggles. No respiratory protection devices were worn by workers involved in the foaming operations.

A functioning eyewash fountain was observed in the plant arrangements area. Installation of a fountain in the artificial trees and packaging areas had never been completed.

The fumigation process was not evaluated, but it was noted that the fumigation vent stack was in close proximity to the main building. Of concern was the potential for introduction of methyl bromide into the building through a large overhead door which is reportedly often open or through exhaust fan openings for the artificial trees area if these fans were not running.

B. Medical

Evaluation of Prior Employees

A total of 111 letters were sent to employees identified by the company as having terminated employment in the calendar years 1989-1992. Eighteen letters were returned for an incorrect address, and no response was received from 56 others. Two individuals who had terminated employment during this period were working at Distinctive Designs International again during this medical survey, and were evaluated with the current employees. A total of 35 individuals responded, either by returning the questionnaire or via telephone. Of these, 28 individuals requested spirometry, while seven declined. Spirometry appointments were made for all but three of those desiring testing. Of those not scheduled, one individual was away at college, one could not come on either of the two testing days, and the third could not be reached. Sixteen (64%) of those who scheduled spirometry times kept their appointments. The results of the spirometry testing were within normal limits for all 16 prior employees tested.

Prior employees who completed the questionnaire had worked a mean of 20 months. Those requesting spirometry reported a mean of 21 months since last employment at Distinctive Designs International. Of 33 individuals who answered the question asking whether they had left employment at Distinctive Designs International for health reasons, eight (24%) answered "Yes." Insufficient information was available to make any further determinations regarding reasons for leaving work. Four individuals indicated that they had left work because of lung or respiratory disease, but insufficient information was available to determine whether these conditions were work-related. All four individuals had worked in the main production area. Two had used the foaming system on a regular basis and two had used it intermittently. Two of these individuals had spirometry testing, and both had normal results. Although 4 of the 35 (11%) prior employees who responded to the letter reported leaving work because of respiratory disease, respondents represent only 32% of former employees. Those having pulmonary function testing comprised only 15% of known prior employees and may not be a representative sample of former employees of Distinctive Designs International.

Evaluation of Current Employees

The symptoms questionnaire was completed by 72 workers, the exposure assessment questionnaire was completed by 79 workers, and occupational history information was collected from 77 workers. Spirometry was performed on 71 workers, while 64 workers provided peak flow measurements for at least part of the study period. Female workers comprised 82% of the work force. Workers ranged from 16 to 66 years of age, with a median age of 36 years. The prevalence of current cigarette smoking was 25%. Current smokers had smoked a median of 18 years, and 72% of them reported smoking one or more packs of cigarettes per day. Eighteen percent of workers reported that they were former smokers. These individuals had smoked a median of 10 years, and 62% reported smoking one or more packs per day. The remaining 57% of workers reported that they had never smoked.

The median employment tenure at Distinctive Designs International was 3 years. Of those surveyed, 67% worked in the main production area, 18% worked in the warehouse, and 15% worked in the office or retail shop. Ninety percent of respondents had worked in the warehouse or main production area at some time. Using self-reported work history as an indicator of potential isocyanate exposure, 9% of workers were considered to have high exposure, 27% had intermediate exposure, 30% had low exposure, and 34% fell into the never exposed category. Occupational histories revealed that seven (9%) of the participants had been exposed to isocyanates other than at Distinctive Designs International. Three workers had worked with other known asthmagens, and 11 had worked with respiratory irritants.

Nasal and eye irritation were the two most frequently reported symptoms, regardless of foam exposure category. Individuals with high exposure were more likely to report these symptoms than those in any other exposure category. Individuals in the high exposure category were also more likely to report that their nasal or eye irritation improved when they were away from work than were individuals in other exposure categories. For the remainder of symptoms, including skin irritation, chronic cough, chronic phlegm, chronic shortness of breath, chest tightness, wheezing/ whistling in the chest, and attacks of shortness of breath with wheezing, there was no clear pattern of symptom prevalence across exposure categories. (Table 1)

Seven participants had pulmonary function test results that fell outside the normal range, including six individuals who exhibited a mild obstructive pattern, and one who had a moderate obstructive pattern. One individual was in each of the high, intermediate and low exposure categories, three were in the never exposed group, and exposure information was not available on the seventh individual. The mean percent predicted FVC, FEV_1, and the FEV_1/FVC ratio did not vary substantially over foam exposure level. (Table 2) Baseline spirometry was related to a history of cigarette smoking. Current smokers had a lower mean percent predicted FEV_1 and a lower mean FEV_1/FVC ratio than did former or never smokers. (Table 3) Three (16%) of the current smokers had obstructive patterns on pulmonary function testing, compared to no former smokers and three (7%) of the never smokers. Only one individual had a cross-shift decline in FEV_1 that was greater than 10%. This individual did not provide peak flow measurements and had been classified as "low exposure" to MDI. This individual reported Grade I dyspnea and a history of chest tightness, but had never experienced wheezing or attacks of shortness of breath with wheezing.

Interpretable peak flow data were available for 53 (83%) of the 64 participants who took a meter. The most common cause of uninterpretable results was an insufficient number of days of recording. Thirteen workers had peak flow tracings that had a $\geq$20% variation over the recording period. This was unrelated to foam exposure category (Table 4). One worker had a pattern of peak flow variability that suggested work-relatedness. This individual had worked at Distinctive Designs International for 12 years, was in the low exposure category, and had never smoked. This worker had Grade II dyspnea, reported chest tightness and wheezing, and had work-related nasal and eye irritation. Fourteen percent of current smokers, 44% of former smokers, and 22% of never smokers had excessive peak flow variability.

Medical Discussion

Single session spirometry is an insensitive means of screening workers for occupational asthma. Since late asthmatic responses may occur away from work,[8] even cross-shift spirometry may be an insensitive screening modality. A brief screening questionnaire could be used to identify individuals with symptoms suggestive of occupational asthma,

and these individuals could subsequently be referred for more in-depth testing. Serial measurement of peak expiratory flow rates seems to be the most sensitive means of assessing late asthmatic responses, but it is not practical for screening.

With the exception of a high prevalence of work-related nasal and ocular irritation among individuals with high isocyanate exposure, there were no clear differences in symptoms, pulmonary function, and peak flow variability across the various categories of foam exposure. This may reflect the inaccuracy of using working with the foaming process as an indicator of potential isocyanate exposure. The two individuals who had what may be work-related changes in pulmonary function were both in the low exposure category. The exposure category of these individuals may have been misclassified, or, they may have been sensitized by single high dose exposures and now be reacting to minute quantities of MDI in the workplace atmosphere.

All prior employees who were tested had normal pulmonary function. Only 15% (16/109) of identified prior employees were tested, so this may not be a representative sample of former employees of Distinctive Designs International. It is somewhat surprising that no former employees had abnormal pulmonary function tests, since it is a common belief among occupational health investigators that individuals who perceive themselves as ill are more likely to volunteer for such testing.

VII. CONCLUSIONS

There was no evidence of impaired pulmonary function among former Distinctive Designs International employees who participated in this study. There was no apparent relationship between chronic pulmonary impairment, as assessed by spirometry, or reactive airway disease, as measured by peak flow variability, and working with the foaming system. Current workers who work directly with the polyurethane foaming system were found to have a substantial prevalence of work-related nasal and ocular irritation, suggesting that there is ongoing exposure to an irritant.

The air sampling did not indicate concentrations of MDI above the exposure standards, but the sampling assessed only the monomeric form of MDI. However, as noted earlier, there is suggestion that exposures to MDI concentrations below the current exposure standards and exposure to the polymeric forms of MDI also contribute to impairment of respiratory function. Without reliable means to measure the total isocyanate exposure, it should be assumed that there is exposure, and the most protective measures for preventing exposure to the isocyanates should be taken. NIOSH is currently attempting to develop a method for the measurement of total reactive isocyanate groups.

VIII. RECOMMENDATIONS

1. If the exhaust fans, as they are currently situated, were effective in capturing process emissions, the isocyanate vapor/aerosols would have to pass through the breathing zones of workers. Positioning the processes closer to the fans and arranging the area so that the worker is never between the fan and the work would probably provide marginal improvement in the ventilation. However, these fan arrangements are not the recommended method of ventilation to prevent exposure to contaminants. The preferred method is local exhaust ventilation, which captures the contaminant directly at the source and prevents migration through any working area. This type of system would only be effective if the contaminated air is not exhausted into another working area. Because all the processes are basically stationary, a local exhaust system should be a feasible solution. A ventilation engineer should be consulted for the design of an effective system.

2. To avoid breathing rising vapors/aerosols workers should be instructed to avoid positioning their faces directly above containers as they fill them and when they manipulate foam.

3. In accordance with the requirements of OSHA Standard 29 CFR 1910.1200, a comprehensive hazard communication program should be instituted so that workers will understand the potential hazards of the chemicals in their workplaces. At the beginning of employment, all employees with potential exposure to the polyurethane

foaming process should be informed of the potential hazards of exposure to diisocyanates. Employees should be instructed to follow work practices and sanitation procedures to help protect their health and safety and that of their fellow employees. Emergency handling procedures for MDI should be included in the training. In addition, employees should be warned that the improper home use of polyurethane products, such as foam kits and varnishes that contain diisocyanates, may increase their risk of developing isocyanate-related health problems.

4. Skin contact with MDI should be avoided. Workers should be provided with rubber or polyvinyl chloride gloves and long-sleeved coveralls, and they should be required to wear them. The provision and use of protective eye goggles should be continued.

5. Installation of the eyewash fountain near the artificial trees area should be completed so that workers have immediate access should MDI come in contact with their eyes. All eyewash fountains should be tested regularly to assure they are in working order.

6. When methyl bromide is being exhausted from the fumigation shack, the adjacent overhead door should remain closed and the artificial trees area exhaust fans should be running to prevent introduction of the fumigant into the main building.

7. A medical history should be obtained from all new employees and should include questions regarding pre-existing respiratory symptoms and disease, including asthma. An occupational history should also be obtained to seek evidence of previous exposure to isocyanates. Under the Americans with Disabilities Act (Public Law 1-1-336 [S. 993]; July 26, 1990), unless these examinations reveal a disabling condition which would prevent the applicant from performing the essential functions of the job, even if "reasonable accommodations" were made, the applicant may not be refused employment.[30] Thus, a history of pre-existing asthma would not be grounds for refusing an individual employment or assignment to a job involving isocyanate exposure.

8. All new employees potentially at risk for isocyanate exposure should receive baseline pulmonary function testing performed in accordance with American Thoracic Society criteria.

9. Employees should receive written reports of all medical surveillance tests performed by the company, regardless of the results of such tests.

10. Follow-up medical examinations should be conducted at least annually and should include a brief respiratory symptoms questionnaire in addition to pulmonary function testing. Workers with either abnormal spirometry or symptoms such as persistent cough, cough at night, wheezing, shortness of breath, or difficulty breathing should receive a more thorough medical evaluation. Workers who develop any symptoms suggestive of occupational asthma in the period between the annual exams should also receive a medical evaluation.

11. Individuals who become sensitized to MDI should be advised of the health risks of continued exposure to isocyanates and given the opportunity to transfer to an area of the facility where they will have no exposure to MDI. Workers would have less incentive to conceal work-related health problems or to continue working in areas of potential MDI exposure if, after job transfer, they retained all wages and benefits associated with their previous job.

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X. AUTHORSHIP AND ACKNOWLEDGEMENTS

Report Prepared by: Elizabeth Jennison, MD, MPH
Medical Officer

Chris Piacitelli
Industrial Hygienist

Evaluation Conducted by: Elizabeth Jennison, MD, MPH
Medical Officer

Corrado Ugolini, MD, MPH
Medical Officer

Brad Husberg, RN, MSPH
Medical Investigator

Chris Piacitelli
Industrial Hygienist

Joseph Burkhart, CIH
Industrial Hygienist

Originating Office: Respiratory Disease Hazard Evaluations and Technical Assistance Program
Clinical Investigations Branch
Division of Respiratory Disease Studies
National Institute for Occupational Safety and Health
Morgantown, West Virginia 26505

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1. Alabama Department of Public Health
2. Distinctive Designs International
3. U.S. Department of Labor/OSHA Region IV

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

PREVALENCE OF RESPIRATORY SYMPTOMS, NASAL, EYE, AND SKIN IRRITATION
BY FOAM EXPOSURE LEVEL (71 RESPONDENTS):
Distinctive Designs International
Russellville, Alabama
HETA 91-0386

	FOAM EXPOSURE LEVEL			
	High N=6	Intermediate N=17	Low N=24	Never N=24
	Yes %	Yes %	Yes %	Yes %
Chronic Cough	1 17	1 6	2 8	1 4
Chronic Phlegm	2 33	3 18	1 4	2 8
Dyspnea				
Grade I	0 0	3 18	6 25	9 38
Grade II	1 17	2 12	3 12	0 0
Grade III	1 17	1 6	0 0	2 8
Chest Tightness	2 33	5 29	5 21	2 8
Wheezing/Whistling in Chest	2 33	7 41	3 12	1 4
Attacks of Shortness of Breath w/ Wheeze	2 33	2 12	1 4	1 4
Nasal Irritation	5 83	11 65	13 54	16 67
work related	3 50	2 12	2 8	2 8
Eye Irritation	3 50	8 47	10 42	10 42
work related	3 50	2 12	3 13	1 4
Skin Irritation	1 17	4 24	3 13	2 8

TABLE 2

SPIROMETRY VERSUS FOAM EXPOSURE LEVEL
(70 PARTICIPANTS):
Distinctive Designs International
Russellville, Alabama
HETA 91-0386

	FOAM EXPOSURE LEVEL							
	High N=6		Intermediate N=17		Low N=23		Never N=24	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Percent Predicted FVC	108.3	8.8	101.3	11.5	102.3	9.5	104.0	12.0
Percent Predicted FEV_1	99.2	8.7	97.4	14.1	100.1	9.5	98.7	11.1
FEV_1/FVC (%)	77.3	3.2	80.9	4.7	82.3	6.3	79.7	6.4

TABLE 3

SPIROMETRY VERSUS SMOKING HISTORY (71 PARTICIPANTS)*:
Distinctive Designs International
Russellville, Alabama
HETA 91-0386

	CIGARETTE SMOKING HISTORY					
	Current N=16		Former N=12		Never N=41	
	Mean	SD	Mean	SD	Mean	SD
Percent Predicted FVC	103.2	10.3	105.4	15.9	102.4	9.1
Percent Predicted FEV_1	94.3	10.2	103.7	16.0	98.7	9.5
FEV_1/FVC Ratio	77.2	7.6	82.7	6.1	80.9	6.1

*Information on cigarette smoking history was not available for two individuals.

TABLE 4

PEAK FLOW VARIABILITY VERSUS FOAM EXPOSURE LEVEL (53 PARTICIPANTS):
Distinctive Designs International
Russellville, Alabama
HETA 91-0386

% Peak Flow Variability	FOAM EXPOSURE LEVEL			
	High N=5 n (%)	Intermediate N=12 n (%)	Low N=18 n (%)	Never N=18 n (%)
< 20 %	4 (80%)	8 (67%)	13 (72%)	15 (83%)
> = 20%	1 (20%)	4 (33%)	5 (28%)	3 (17%)