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TRAILMOBILE, INC.  
CHARLESTON, ILLINOIS

NIOSH INVESTIGATORS:  
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## I. SUMMARY

On July 6, 1987, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request for a Health Hazard Evaluation from the Allied Industrial Workers of America, which represents the workers at Trailmobile, Inc. in Charleston, Illinois. The primary concern of the requestor was exposures to 4,4'-diphenylmethane diisocyanate (MDI), polymethylenepolyphenyl isocyanate (MDI prepolymer), and methylene chloride in the foaming areas, and exposure to the various chemicals used in the spray painting areas of this facility. Trailmobile, Inc. is a major manufacturer of tractor-trailers which are commonly used in the trucking industry.

Time-weighted average, personal breathing zone exposure monitoring was performed on workers in the foaming areas using OSHA Method 47 (MDI and MDI prepolymer) and NIOSH Method 1005 (methylene chloride). Area air sampling was also performed for MDI and MDI prepolymer using NIOSH Method 5521. Exposures to MDI were below the recommended exposure limits, with 5 of 17 samples not measuring detectable levels of MDI. The highest MDI exposure levels were measured in the foam helpers (4.6-9.1  $\mu\text{g}/\text{m}^3$ ), but these were still below the NIOSH recommended exposure limit (REL) of 50  $\mu\text{g}/\text{m}^3$ . Exposure to MDI prepolymer ranged from none detected to 0.6  $\mu\text{g}/\text{m}^3$ , with 12 of 17 samples not measuring detectable levels of MDI prepolymer. Area air sampling measured average MDI concentrations of 1.9  $\mu\text{g}/\text{m}^3$  for the hydraulic lifts used to foam the nose and roof, with non-detectable levels measured in all other areas. Conversely, MDI prepolymer was measured in all the area samples, with these levels ranging from 16.9 to 74.3  $\mu\text{g}/\text{m}^3$ . Again, the highest MDI prepolymer levels were found on the hydraulic lifts. Methylene chloride exposures in the foamers ranged from 1.3-5.1 parts per million (ppm), which are below the Occupational Safety and Health Administration's (OSHA) permissible exposure limit (PEL) and the ACGIH recommended standard. NIOSH considers methylene chloride to be a potential human carcinogen and recommends that exposures be reduced to the lowest feasible level.

The medical component of the initial investigation consisted of employee interviews, a review of medical records, and the analysis of a questionnaire that was distributed to 29 workers in the painting and foaming areas. Eighteen workers agreed to participate in a follow-up survey. Of these, seven workers (39%) reported experiencing at least two of the following symptoms in the workplace: wheezing, chest tightness, and shortness of breath. During the follow-up survey, workers voluntarily underwent pre- and post-shift pulmonary exams and pulmonary function tests (PFTs), a blood test to check for evidence of immunologic response to MDI, and a seven-day, self-administered evaluation of peak expiratory flow rates (PEFRs) using a portable meter. Results of the pre- and post-shift PFTs revealed that two of 18 (11%) employees had abnormal pre-shift (baseline) results. The results from the 15 individuals who performed at least one day of PEFR measurements were all normal. Five of the 18 (28%) employees had increased IgG-type antibodies to three types of isocyanates (HDI, MDI, and TDI). One individual had increased IgG-type antibodies to MDI and TDI. One person had increased IgG-type antibodies to TDI alone. None of the 18 employees had significantly increased IgE-type antibodies to MDI.

Two of the 18 (11%) employees may meet the criteria for occupational asthma. Both had an obstructive abnormality; however, reversibility and variability of the airway obstruction were not documented. Both individuals also had increases in their antibody response to at least one of the isocyanates. Both workers were foamers and had exposure to MDI and MDI prepolymer.

Personal breathing zone air sampling on the painters identified exposure to several hydrocarbons. Painting was performed in downdraft spray paint booths and the painters donned appropriate personal protective equipment. The exposures during the painting were at low levels, and were below the NIOSH and ACGIH recommended exposure levels, and the OSHA PELs for the identified hydrocarbons. Paint was observed on the face, arms, and hands of many of the painters. Two of the painters had skin conditions consistent with contact dermatitis.

The industrial hygiene data from this survey indicate that workers in the foaming areas are exposed to MDI and MDI prepolymer. Though the exposure to MDI was below the existing evaluation criteria, symptoms compatible with isocyanate-induced asthma and immunologic reactions to MDI were observed in some of the workers in these areas. On the basis of the data collected in this survey, and two previous studies which have documented isocyanate-induced asthma in workers exposed to levels of MDI below the existing standards, the NIOSH investigators conclude that a health hazard does exist from exposure to MDI and MDI prepolymer in the foaming areas of this facility. Recommendations are made in Section VIII of this report to protect workers from exposure to MDI and MDI prepolymer, to prevent all skin contact with the paint, and to eliminate eating, drinking, and smoking in all work areas.

**KEYWORDS:** SIC 3715 (Truck Trailers), 4,4'-diphenylmethane diisocyanate, MDI, polymethylenepolyphenyl isocyanate, isocyanate-induced asthma, polyurethane foaming operations, spray painting, respiratory protection, IgG antibodies, pulmonary function tests.

## II. INTRODUCTION

On July 9, 1987, NIOSH received a confidential request for a health hazard evaluation from the Allied Industrial Workers of America (AIW). Specifically, the AIW was concerned about exposures to workers in the painting and foaming areas at Trailmobile, Inc. in Charleston, Illinois.

On December 1, 1987, a right-of-entry warrant was served on Trailmobile, Inc. management (hereinafter referred to as Trailmobile). An initial survey was performed on December 1 and 2, 1987; which included an industrial hygiene study to determine exposures in the painting and foaming areas, and the conduct of interviews and a questionnaire to screen workers for symptoms of occupationally-related respiratory complaints. The results from the initial site visit were forwarded to Trailmobile and the AIW via an interim letter dated September 21, 1988, which included the NIOSH Current Intelligence Bulletin #46, April 18, 1986, Methylene Chloride. On January 15, 1988, the NIOSH investigators subpoenaed the medical and personnel records of those employees participating in the medical survey on December 1-2, 1987. These records were received by the NIOSH investigators on January 26, 1988. The NIOSH investigators conducted a follow-up survey on February 22-23, 1989, which included an industrial hygiene study of exposures in the foaming areas, and a medical study of 18 painters and foamers for symptoms of occupationally related asthma. In a response letter dated May 18, 1989, the NIOSH investigators recommended that a dedicated, supplied-air respiratory protection system be installed for workers in the foaming areas, and that all efforts should be taken to prevent skin contact with the paint. The results from the medical study, along with interpretations and recommendations, were reported to all participating workers, the union, and Trailmobile management on October 16, 1989. Finally, the results from the personal breathing zone and area air sampling for MDI were reported on April 25, 1990, with a reiteration of the NIOSH recommendation of supplied-air respiratory protection for the workers in the foaming areas.

## III. BACKGROUND

Trailmobile, Inc. is a large scale manufacturer of tractor-trailers which are commonly used in the trucking industry. Several different types of trailers are manufactured at the Charleston, Illinois facility, including the standard tractor-trailer and refrigerated tractor-trailers (reefers). Assembly of the trailers is actually composed of many small operations, with each of these operations building on the previous to produce the trailer. This request and the evaluations dealt with exposures from two tasks performed at Trailmobile: foaming and painting.

In the foaming operations, a two-component polyurethane foam system is used to insulate the floors, walls, doors, and ceilings of the reefers. Component A of these rigid polyurethane foam systems typically contains 40-50% 4,4'-diphenylmethane diisocyanate (MDI) and 50-60% polymethylenepolyphenyl isocyanate (MDI prepolymer), and component B contains a mixture of polyether polyols, surfactants, catalysts, blowing agents, and various other additives. The two components mix in the nozzle of the spray gun, and are injected into a defined cavity, i.e., the space in the walls, ceilings, floors, or doors of the reefers. The components quickly react, forming an expanding foam that fills these defined cavities. After each application of the foam, the inside of the spray gun is cleaned by flushing the gun with methylene chloride. The waste solvent is deposited in a 55-gallon drum with local exhaust ventilation located at the opening in the top of the drum.

Painting of various parts is performed in spray paint booths with ventilation controls designed to remove paint overspray from the breathing zone of the workers. Typically, Trailmobile uses solvent-based enamel paints that contained VM&P naphtha, mineral spirits, aromatic

naphthas, alcohols, glycol ethers, other hydrocarbon-based solvents, and a metallic pigment. The painters are provided with coveralls, gloves, and half-face respirators with organic vapor cartridges. Trailmobile has a written respirator program, and a copy was provided to the NIOSH investigators. In addition to this, Trailmobile was installing a dedicated supplied-air respiratory protection system for the painters at this facility. It is important to note that the request included an evaluation of the bolster dip painting operation. During the NIOSH site visits, the bolster dip work station was dismantled and Trailmobile management stated they had no intention of reactivating this operation.

#### IV. EVALUATION DESIGN AND METHODS

##### A. Industrial Hygiene

The industrial hygiene surveys consisted of air sampling for MDI, MDI prepolymer, and methylene chloride in the foaming areas; hydrocarbons in the painting areas. The sampling and analytical methods are discussed below.

##### MDI and MDI Prepolymer

Personal breathing zone air sampling for MDI and MDI prepolymer was conducted according to OSHA Method 47.<sup>1</sup> Sample air was drawn through a glass fiber filter impregnated with 1-(2-pyridyl) piperazine at a nominal flowrate of 1.0 liter per minute (Lpm) using a calibrated, battery-powered sampling pump. The samples were desorbed in 4.0 milliliters of 10% dimethyl sulfoxide in acetonitrile, and analyzed by high performance liquid chromatography. The limit of detection (LOD) for this method was 0.05 micrograms of MDI and 0.02 micrograms of MDI prepolymer per sample (ug/sample); the limit of quantitation (LOQ) for MDI and MDI prepolymer is 0.15 and 0.06 ug/sample, respectively.

Area air sampling for MDI and MDI prepolymer was performed during the initial survey on December 1-2, 1987. Due to analytical problems, the data from this sampling were considered invalid by the NIOSH investigators, and the protocol was repeated during the follow-up survey on February 22-23, 1989. Performance of the area air sampling was according to NIOSH Method 5521,<sup>2</sup> which utilizes a midget impinger containing 15 milliliters (ml) of a solution of 1-(2-methoxyphenyl) piperazine dissolved in toluene. Air is sampled at a nominal flowrate of 1.0 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 impinger solutions were evaporated to dryness in a nitrogen atmosphere, leaving a sample residue which consists of the urea derivatives which are formed when 1-(2-methoxyphenyl)piperazine reacts with MDI. These residues were redissolved in 2 ml of 0.5% acetic anhydride in acetonitrile, and 50 microliter (ul) aliquots were injected into the high performance liquid chromatograph (HPLC). The ureas were qualified and quantitated by using the ratio of the outputs from an electrochemical and an ultraviolet detector. This method's LOD for MDI and MDI prepolymer is 0.5 micrograms per sample (ug/sample); the LOQ is 1.4 ug/sample.

##### Methylene Chloride

Personal breathing zone air sampling for methylene chloride was performed in the foaming areas according to NIOSH Method 1005.<sup>2</sup> In this method, sample air is drawn through

two activated charcoal tubes (in series) at a nominal flowrate of 20 cubic centimeters per minute (cc/min), using calibrated, battery-powered sampling pumps. The samples were desorbed with 1.0 ml of carbon disulfide and analyzed by gas chromatography with a flame ionization detector. The LOD for this method is 0.01 milligrams per sample (mg/sample); the LOQ is 0.03 mg/sample.

### Hydrocarbons

Using material safety data sheets provided by Trailmobile and the AIW, the NIOSH investigators determined that hydrocarbons were the most toxic constituents in the paints. Consequently, personal breathing zone air sampling for hydrocarbons was performed on six painters in the painting areas. Sample air was drawn through activated charcoal tubes at a nominal flowrate of 20 cc/min, using calibrated, battery-powered sampling pumps. The samples were desorbed with 1.0 ml of carbon disulfide and qualitatively analyzed using gas chromatography/mass spectroscopy to determine the major hydrocarbons in the paint overspray. The remaining five breathing zone air samples were quantitatively analyzed for these hydrocarbons using gas chromatography with a flame ionization detector. The LOD for this analytical procedure is 5 ug/sample; the LOQ is 15 ug/sample, for each individual compound.

## B. Medical

During the initial survey, the NIOSH Medical Officer conducted interviews and distributed a questionnaire to workers in the painting and foaming areas. The questionnaire screened workers for symptoms of occupationally-related respiratory complaints, such as the symptoms associated with occupational asthma. Medical records of the participating workers were also reviewed by the NIOSH investigators.

Using the data collected in the initial survey, a study group was formed from those workers reporting at least two of the following symptoms: wheezing, chest tightness, or shortness of breath. Workers without symptoms were also asked to participate in the follow-up survey. During the follow-up survey, workers voluntarily underwent pre- and post-shift pulmonary exams and pulmonary function tests (PFTs), a blood test to check for evidence of immunologic response to MDI, and a seven-day, self-administered evaluation of peak expiratory flow rates using a portable meter.

### Pulmonary Function Tests (PFTs)

The PFTs measure the breathing capacity and air output of a person. The PFT machine provides specific results such as forced vital capacity (FVC - the air exhaled by a person after a deep inspiration), the forced expiratory volume (FEV1 - the air exhaled in one second after a deep inspiration), calculated ratios, and comparisons with predicted levels based upon the persons age, sex, and size.

### Peak Expiratory Flow

The workers in the study group were trained to use a portable breathing tube known as the mini-Wright peak flow meter. These individuals were asked to measure and record the output of air after a deep inspiration every three hours, while at home and at work, for seven full days. The goal of this test is to check for variability in measurements of serial peak expiratory flow rate (PEFR) over a period of several days, including periods on and off the job. At least a 20% variability over a 24 hour period would be considered abnormal.

### Immunologic Blood Tests

The production of antibodies in the blood plays a role in some cases of isocyanate-induced asthma. Detecting such antibodies supports, but does not establish, a diagnosis of occupational asthma. Conversely, since the antibodies are found in only a small proportion of the occupational asthma cases caused by MDI, failure to detect specific antibodies does not rule out the diagnosis.

Also, crossed immunologic reactivities between different isocyanates may be found; therefore, a person exposed to one type of isocyanate may also show an increased reaction to other isocyanates.

In this investigation, serum concentrations of immunoglobulin G (IgG) and immunoglobulin E (IgE) antibodies were measured using the radioallergosorbent test (RAST) and the enzyme-linked immunosorbent assay (ELISA). The definition of an increased reaction is a response greater than the mean plus two standard deviations of laboratory controls who had no known exposure to the isocyanates.

## V. EVALUATION CRITERIA

### A. Environmental 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 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, 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). Often, the NIOSH RELs and ACGIH TLVs are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLVs usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended standards, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required by the Occupational Safety and Health Act of 1970 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. Diisocyanates (MDI)

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, makes them ideal for polymer formation. Hence, they are widely used in surface coatings, polyurethane foams, adhesives, resins, and sealants. Diisocyanates are usually referred to by their specific acronym; e.g., TDI for toluene diisocyanate, HDI for hexamethylene diisocyanate, MDI for 4,4'-diphenylmethane diisocyanate, NDI for naphthalene diisocyanate, etc.<sup>3</sup>

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, 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.<sup>4</sup>

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.<sup>4,5</sup> 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 occupational exposure limit or standard, 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.<sup>6-9</sup> The only effective treatment for the sensitized worker is cessation of all diisocyanate exposure.<sup>10</sup>

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.<sup>4</sup> 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,<sup>11</sup> to 25% in polyurethane production plants<sup>7,11</sup> and 30% in polyurethane seatcover operations.<sup>12</sup> Recent evidence indicates that a specific immunological mechanism is involved, though this response is not fully understood. Diisocyanates, when inhaled, may act as sensitizing antigens, evoking the body to produce high serum concentrations of specific antibodies. Using RAST and ELISA, high levels of MDI-specific IgG and IgE antibodies have been detected in the serum of sensitized workers. It should be noted that these antibodies are not always detected in sensitized workers. Also, workers exposed to diisocyanates/MDI, even to levels below the occupational health limits and standards, may also have elevated serum concentrations of IgG and IgE antibodies.<sup>13-23</sup> Presently, elevated antibody levels are considered indicators of exposure, and require other diagnostic tools to determine and confirm cases of diisocyanate-induced sensitization (asthma).

Presently, the OSHA PEL and the ACGIH TLV for MDI are 200 and 51  $\mu\text{g}/\text{m}^3$ , respectively.<sup>24,25</sup> 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  $\mu\text{g}/\text{m}^3$  for up to a 10-hour, time-weighted average exposure, and a ceiling limit of 200  $\mu\text{g}/\text{m}^3$ .<sup>26</sup> Evaluation criteria do not exist for exposure to MDI prepolymer.

## B. Methylene Chloride

Methylene chloride, or dichloromethane, is a chlorinated organic compound that is commonly used as a general solvent, paint remover, and degreaser. It may be absorbed into the body by inhalation of vapors and by absorption of liquid through the skin. If inhaled in high concentrations, methylene chloride may affect the nervous system, leading to symptoms such as mental confusion, light-headedness, nausea, vomiting, and headache. Continued exposure to very high concentrations may cause increased light-headedness, staggering, unconsciousness, and death.<sup>27</sup> High vapor concentrations may also cause irritation of the eyes and respiratory tract. There have also been reports of chronic (long-term) neurotoxic (nervous system) effects among workers who have been exposed to methylene chloride for several years. Symptoms reported from chronic exposure have included memory loss, insomnia, headaches, fatigue, and hallucinations.<sup>28</sup> Exposure to methylene chloride may aggravate the symptoms of angina pectoris (heart pain), which may be accompanied by feelings of suffocation and palpitations. If the liquid is held in contact with the skin, it may cause irritation or skin burns. Splashes of the liquid into the eyes may cause irritation. Rats and mice have developed tumors and cancers after exposure to methylene chloride under specific experimental conditions.<sup>29</sup> The current OSHA PEL for worker exposure to methylene chloride is 500 parts of methylene chloride vapor per million parts of air (ppm) averaged over an eight-hour work shift, with an acceptable ceiling level of 1000 ppm and a maximum peak concentration of 2000 ppm for five minutes in any two-hour period. Presently, these exposure limits are



being reconsidered by OSHA and are considered transitional limits, remaining in effect until December 30, 1992.<sup>24</sup> The ACGIH TLV for worker exposure to methylene chloride is 50 ppm averaged over an eight-hour workshift. Additionally, the ACGIH classifies methylene chloride as a suspected human carcinogen, and recommends that worker exposure be controlled to levels as low as reasonably achievable below the TLV.<sup>25</sup> In 1976, NIOSH recommended that the permissible exposure limit be reduced to 75 ppm averaged over a work shift of up to 10 hours per day, 40 hours per week, with a ceiling level of 500 ppm averaged over a 15-minute period. NIOSH further recommended that permissible levels of methylene chloride be reduced when carbon monoxide is also present at concentrations greater than 9 ppm, measured as an average exposure for the shift.<sup>28</sup> Since 1976, the carcinogenicity of methylene chloride has been documented in rats and mice, as shown by increased incidence of alveolar/bronchiolar neoplasms and of hepatocellular neoplasms.<sup>29,30</sup> Therefore, in 1986, NIOSH recommended that methylene chloride be regarded as a potential occupational carcinogen, and that exposure be controlled to the lowest feasible level.<sup>29</sup>

## VI. RESULTS

### A. Industrial Hygiene

Data from the personal breathing zone air sampling for MDI and MDI prepolymer are shown in Table 1. Exposures to MDI were well below the NIOSH REL and the ACGIH TLV, with 5 of the 17 samples not measuring detectable levels of MDI. The highest MDI exposure levels (9.1, 5.6, and 4.6  $\mu\text{g}/\text{m}^3$ ) were measured in the foam helpers, but these levels are still 5 to 10 times below the NIOSH REL.

Table 2 presents the area air sampling data taken in the quarter panel foaming area and the hydraulic lifts for foaming the nose and roof (Department 132), and in the reefer door foaming area (Department 71). The average MDI level was 1.9  $\mu\text{g}/\text{m}^3$  for the hydraulic lifts, with non-detectable levels in the quarter panels and reefer doors areas.

Conversely, MDI prepolymer was measured in all the samples taken in the above areas; prepolymer levels ranged from 16.9 to 74.3  $\mu\text{g}/\text{m}^3$ . The highest MDI prepolymer concentrations were measured on the hydraulic lifts, with an average concentration of 60.0  $\mu\text{g}/\text{m}^3$  versus 41.4 and 34.5  $\mu\text{g}/\text{m}^3$  for the quarter panels and reefer doors, respectively.

The results from the personal breathing zone sampling for methylene chloride in the foamers and hydrocarbons in the painters, are presented in Tables 3 and 4, respectively. The evaluation criteria for exposure to these compounds are in Table 5. All of the foam operators had exposures to methylene chloride below the OSHA PEL and the ACGIH TLV. The local exhaust ventilation around the waste methylene chloride drum was qualitatively evaluated using puffs of smoke from a smoke tube. Adequate capture velocity around the opening in the drum was observed by the NIOSH investigators.

Personal breathing zone air sampling on the painters identified exposure to the following hydrocarbons: 1,1,1-trichloroethane, n-butanol, 1-methoxy-2-propanol, MPK (2-pentanone), toluene, n-butyl acetate, xylenes, and VM&P naphtha/mineral spirits. In comparing the exposure data in Table 4 to the appropriate evaluation criteria in Table 5, the exposure concentrations were below the NIOSH and ACGIH recommended exposure levels, and the OSHA legally enforceable levels (PELs) for the above hydrocarbons.

## B. Medical

On December 1-2, 1987, a NIOSH medical officer conducted interviews and distributed questionnaires to 29 painters and foamers (100% of painters and foamers employed on two shifts). At that time, eight individuals (28%) described having at least two of the three following symptoms worse at the workplace: wheezing, chest tightness, and shortness of breath. Because of these medical complaints and the potential exposures to an asthmogenic chemical (MDI), a further investigation was undertaken.

On February 22-23, 1989, a study of 18 current employees from the painting and foaming areas was conducted for signs and symptoms of occupational asthma. This group included available workers who had noted symptoms compatible with occupational asthma on the original questionnaire, as well as a group of randomly selected asymptomatic painters and foamers. During the period of time between the two NIOSH site visits, three workers left their jobs in the above work areas for reasons other than health. The 18 employees voluntarily underwent pre-shift and post-shift pulmonary exams and PFTs, a blood test for evidence of an immunologic response to MDI, and a seven-day, self-administered evaluation of PEFs using a portable peak flow meter. All of these individuals had completed an occupational asthma questionnaire.

Analysis of this questionnaire revealed that seven of the employees in the study group (39%) complained of symptoms consistent with occupational asthma. The group, referred to as "symptomatic," complained of at least two of the following three symptoms worse in the work setting: wheezing, chest tightness, and shortness of breath.

Results of the pre- and post-shift PFTs administered by a NIOSH technician revealed that 2 of 18 employees had abnormal pre-shift (baseline) results. One was an ex-smoker and the other had never smoked. Both of these individuals were foamers, both were symptomatic, and both had evidence of obstruction to airflow. The obstruction to airflow may be consistent with an asthmatic condition or other chronic pulmonary disorder, most commonly smoking-related bronchitis and emphysema. One individual had PFTs which could not be interpreted. All others had PFTs that were within normal limits.

Nine individuals completed the seven days of using the mini-Wright peak flow meter as instructed. One individual completed six days, one completed five days, one completed four days, two completed two days, one completed one day, and three did not respond at all. The results from the 15 individuals who did at least one day of measurements were all normal.

Five of the 18 employees had increased IgG-type antibodies to three types of isocyanates (HDI, MDI, and TDI). Two of these were in the symptomatic group, and one also had PFT abnormalities. Another individual had increased IgG-type antibodies to MDI and TDI. This person was symptomatic and also had PFT abnormalities. One person had increased IgG-type antibodies to TDI alone and did not have any symptoms. None of the 18 employees had significantly increased IgE-type antibodies to MDI.

Of the six workers who had elevated MDI-specific IgG, five were foamers and one was a painter who had noted a past exposure to the foaming process. Of this group, three were symptomatic, and two of these three had an obstructive PFT pattern.

As a group, the foamers had elevations of MDI-specific IgG significantly higher than that of the painters (an optical density average of 0.99 for foamers, compared to 0.04 for painters).

The medical records supplied to NIOSH by the company were reviewed for 27 of the 29 employees who filled out the questionnaire in 1987. Twenty-four of these records contained at least one set of PFTs. There were no data in these records that helped establish any definite pulmonary diagnoses.

The medical records of one employee who sought private medical care were reviewed. Two documented PFTs conducted by the personal physician in February of 1989 noted a mild to moderate pulmonary obstructive defect that could be consistent with asthma.

Finally, paint was observed on the face, arms, and hands of many of the painters. In fact, two of the painters had skin conditions consistent with contact dermatitis.

## VII. DISCUSSION

The exposure concentrations measured by the air sampling protocol found exposures to methylene chloride in foamers, and hydrocarbons in painters, to be below the exposure criteria set forth by OSHA, and the recommended exposure criteria of ACGIH and NIOSH. These exposures were at levels that should not cause an adverse health effect in most healthy workers. The NIOSH investigators believe that the engineering controls in the painting and methylene chloride disposal areas (part of the foaming operation), have been effective in reducing the exposures in these workers.

The exposures to MDI in foam operators, foam helpers, and assemblers were below the recommended exposure criteria of NIOSH and ACGIH. Both personal breathing zone and area air monitoring documented exposures to MDI prepolymer; no exposure standards exist for MDI prepolymer. Data from this survey, along with data from other investigations, may eventually result in an appropriate exposure standard for MDI prepolymer. The NIOSH investigators do believe that the exposures measured during this investigation were consistent with exposures at other times with a similar level of foaming activity. The MDI and MDI prepolymer exposures should be directly proportional to the number of reefers constructed (i.e., the amount of foaming performed) during a given time period.

In comparing the air sampling data from Table 1 and Table 2, there is some discrepancy in the MDI and MDI prepolymer levels measured by the two methods. The personal breathing zone air sampling measured concentrations of MDI from non-detectable to 9.1  $\mu\text{g}/\text{m}^3$ , and low to non-detectable concentrations of MDI prepolymer. Conversely, the area air sampling measured concentrations of MDI prepolymer between 16.9 and 74.3  $\mu\text{g}/\text{m}^3$ , and low to non-detectable levels of MDI. This discrepancy in MDI and MDI prepolymer levels was possibly due to three factors:

- a. Location of the sampling devices. NIOSH Method 5521 was used to collect area air samples and OSHA Method 47 was used to collect personal breathing zone air samples. Since the workers donned the sampling equipment used to collect the OSHA Method 47 samples, and the area samples were located at stationary locations near the work process, the levels of MDI and MDI prepolymer may have been different in the vicinity of these two types of sampling devices.
- b. Differences in the sampling techniques. OSHA Method 47 uses a reagent-coated glass fiber filter to collect diisocyanates, whereas NIOSH Method 5521 uses a reagent-filled midget impinger.
- c. Differences in the analytical methods. NIOSH Method 5521 is a better technique for measuring MDI prepolymer. OSHA Method 47 is designed to determine airborne

concentrations of MDI, and is not an effective means for determining concentrations of higher molecular weight species of MDI (i.e. MDI prepolymer).

The fact that five foamers, and one painter with documented past exposure to the foaming operations, had significant increases in IgG-type antibodies to MDI, does indicate a past exposure of foamers to MDI.

Diagnosis of occupational asthma is based on a number of criteria. These include:

- a. symptoms suggestive of asthma, such as wheezing, shortness of breath, cough, or chest tightness, which are variable or intermittent; and
- b. documentation of significant reversible or variable airway obstruction; and
- c. evidence of an association between the pattern of airways obstruction and some workplace exposure; and
- d. documentation of a workplace exposure to an asthmogenic agent.

Two of the 18 employees may meet these criteria. Both had an obstructive abnormality; however, reversibility and variability of the airway obstruction were not documented. Both individuals also had increases in their antibody response to at least one of the isocyanates. Both workers were foamers and had exposure to MDI and MDI prepolymer.

Five of the employees had symptoms compatible with occupational asthma but without documentation of airway obstruction. In this survey, airway obstruction may not have been identified because of the following reasons: a) an exposure may not have occurred on the day of testing that would result in airway obstruction; b) these workers may have a pattern of asthmatic response where airway obstruction would arise 6-8 hours after exposure and therefore would not have this obstruction at the time tested; or, c) these workers do not have occupational asthma. Therefore, it is not possible for the NIOSH investigators to determine if these workers had occupational asthma.

Finally, a question exists as to whether exposures to MDI below the NIOSH REL and the ACGIH TLV could induce respiratory sensitization (occupational asthma) in exposed workers. A cursory literature search revealed two articles associating low level MDI exposure to a documented health effect. A NIOSH health hazard evaluation at a foundry<sup>31</sup> found MDI exposure levels in coremakers and molders between 8.9 and 28.4 ug/m<sup>3</sup>, with exposure to polymeric forms of MDI also measured. Concurrent medical studies found symptoms compatible with isocyanate-induced asthma in 27% (n=26) of the workers, and increased levels of MDI-specific IgG antibodies in 19% (n=26) of the workers. Also, Baur, Dewair, and Rommelt described the case of worker who occasionally sprayed an MDI-based polyurethane foam and was diagnosed as having isocyanate-induced asthma and hypersensitivity pneumonitis.<sup>32</sup> Inhalation challenge testing with MDI in this worker resulted in decreases in pulmonary function (both FEV1 and FVC), and an elevation in serum IgG antibody levels specific for MDI. According to a company report cited in the article, the average MDI air concentrations during the application of the foam system were 20.5-30.7 ug/m<sup>3</sup>, and the MDI-based foam system was applied for a total of approximately 10 weeks per year. These data suggest that exposure to levels of MDI below the evaluation criteria may produce isocyanate-induced asthma/sensitization in some workers.

## VIII. RECOMMENDATIONS

The following recommendations are offered per the data collected and observations made during the NIOSH investigation:

1. Since MDI and MDI prepolymer are sensitizers, even exposures to low concentrations may produce the asthmatic reaction/sensitization. Because of this, NIOSH recommends that supplied-air respirators be donned whenever there is a potential for exposure to these compounds. Trailmobile should investigate the possibility of expanding the dedicated supplied-air respiratory protection system (presently being installed for the painters) to accommodate all workers in the foaming areas.
2. Although no definite case of occupational asthma was found in this investigation, at least two workers may have occupational asthma. Both individuals have been advised to seek the recommendations of their physicians for further diagnostic testing.
3. The following medical procedures should be made available to each employee who is exposed to MDI. This should be done prior to assignment in an MDI-exposed area and should be repeated on at least an annual basis:
  - a. A complete work and medical history and physical examination: The purpose is to detect pre-existing conditions that might place the exposed employee at increased risk, and to establish a baseline for future health monitoring. Persons with a history of asthma, allergies, or known sensitization to any diisocyanate (including MDI and/or MDI prepolymer) would be expected to be at increased risk from exposure. Examination of the eyes and respiratory tract should be stressed.
  - b. Pulmonary function testing to include FVC and FEV1: MDI and MDI prepolymer are respiratory irritants and sensitizers. Persons with impaired pulmonary function may be at increased risk from exposure.
4. If employees complain of symptoms of shortness of breath, wheezing, or chest tightness that are associated with the workplace, they should be advised to seek medical care. If employees are diagnosed as having occupational asthma they should be reassigned to areas where exposure to asthmogenic chemicals would not occur.
5. All efforts should be taken to prevent painters from having skin contact with the paint.
6. Eating, drinking, and smoking should be prohibited in all work areas. These activities should only be allowed in designated break areas which are separate from the work areas. Employees who choose to smoke should be counseled on how smoking may exacerbate the adverse effects of other respiratory hazards.

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X. DISTRIBUTION AND AVAILABILITY OF REPORT

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

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3. Vice President of Employee Relations, Trailmobile
4. Employee Relations Manager, Trailmobile
5. Labor Relations and Safety Supervisor, Trailmobile
6. Health and Safety Director, AIW
7. President, AIW Local 591
8. Safety and Health Officer, AIW Local 591
9. NIOSH Cincinnati Region
10. OSHA Region 5

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 of Personal Breathing Zone Air Sampling for MDI  
OSHA Method 47Trailmobile, Inc.  
HETA 87-350

February 22 and 23, 1989

| Job Title               | Sample Time | Sample Volume <sup>1</sup> | Concentrations <sup>2</sup> |            |
|-------------------------|-------------|----------------------------|-----------------------------|------------|
|                         |             |                            | MDI                         | Prepolymer |
| Sampling Date: 02/22/89 |             |                            |                             |            |
| Foam Operator           | 0712-1618   | 546                        | 1.0                         | (0.1)      |
| Foam Operator           | 0718-1615   | 537                        | 1.2                         | ND         |
| Foam Operator           | 0725-1634   | 426                        | ND                          | ND         |
| Foam Helper             | 0734-1615   | 525                        | 9.1                         | 0.6        |
| Foam Helper             | 0737-1617   | 527                        | 1.8                         | (0.1)      |
| Foam Operator           | 0739-1618   | 525                        | 0.6                         | ND         |
| Assembler               | 0743-1622   | 490                        | ND                          | ND         |
| Assembler               | 0751-1543   | 475                        | (0.1)                       | ND         |
| Sampling Date: 02/23/89 |             |                            |                             |            |
| Foam Operator           | 0707-1603   | 536                        | 0.5                         | ND         |
| Assembler               | 0727-1610   | 523                        | (0.1)                       | ND         |
| Foam Helper             | 0752-1619   | 507                        | ND                          | ND         |
| Foam Helper             | 0711-1601   | 530                        | 5.6                         | 0.4        |
| Assembler               | 0720-1607   | 527                        | 0.2                         | ND         |
| Foam Operator           | 0708-1600   | 532                        | (0.3)                       | ND         |
| Foam Helper             | 0734-1558   | 564                        | 4.6                         | 0.2        |
| Foam Operator           | 0727-1607   | 520                        | ND                          | ND         |
| Foam Operator           | 0750-1616   | 506                        | ND                          | ND         |
| NIOSH REL               |             |                            | 50                          | NSA        |
| ACGIH TLV               |             |                            | 51                          | NSA        |

<sup>1</sup> Sample volumes are expressed in liters of air.<sup>2</sup> Units expressed in micrograms of analyte per cubic meter of air. Values in parenthesis fall between the LOD and LOQ for the sampling and analytical method and should be considered semi-quantitative.

ND-none detected

NSA-no standard available

Table 2

Results of Area Air Sampling for MDI and MDI Prepolymer  
NIOSH Method 5521Trailmobile, Inc.  
HETA 87-350

February 22 and 23, 1989

| Foam Area/Dept. No.     | Sample Time | Sample Volume <sup>1</sup> | Concentrations <sup>2</sup> |            |
|-------------------------|-------------|----------------------------|-----------------------------|------------|
|                         |             |                            | MDI                         | Prepolymer |
| Sampling Date: 02/22/89 |             |                            |                             |            |
| Reefer Doors/71         | 0946-1634   | 408                        | ND                          | 27.0       |
| Hydraulic Lift/132      | 1016-1650   | 394                        | (3.0)                       | 38.1       |
| Reefer Doors/71         | 0946-1634   | 408                        | ND                          | 56.4       |
| Hydraulic Lift/132      | 1016-1650   | 394                        | (2.5)                       | 68.5       |
| Quarter Panels/132      | 1039-1658   | 379                        | ND                          | 31.7       |
| Quarter Panels/132      | 1039-1658   | 379                        | ND                          | 16.9       |
| Sampling Date: 02/23/89 |             |                            |                             |            |
| Hydraulic Lift/132      | 0859-1634   | 455                        | (2.0)                       | 52.7       |
| Hydraulic Lift/132      | 0859-1634   | 455                        | ND                          | 72.5       |
| Quarter Panels/132      | 0905-1629   | 444                        | ND                          | 42.8       |
| Reefer Doors/71         | 0917-1618   | 421                        | ND                          | 26.1       |
| Quarter Panels/132      | 0905-1629   | 444                        | ND                          | 74.3       |
| Reefer Doors/71         | 0917-1618   | 421                        | ND                          | 28.5       |
| NIOSH REL               |             |                            | 50                          | NSA        |
| ACGIH TLV               |             |                            | 51                          | NSA        |

<sup>1</sup> Sample volumes are expressed in liters of air.<sup>2</sup> Units expressed in micrograms of analyte per cubic meter of air. Values in parenthesis fall between the LOD and LOQ for the sampling and analytical method and should be considered semi-quantitative.

ND-none detected

NSA-no standard available

Table 3

Results of Personal Sampling for Methylene Chloride

Trailmobile, Inc.  
HETA 87-350  
December 2, 1987

| Job Title     | Sample Time | Sample Volume <sup>1</sup> | Concentration <sup>2</sup> |
|---------------|-------------|----------------------------|----------------------------|
| Foam Operator | 0705-1515   | 9.2                        | 1.3                        |
| Foam Operator | 0722-1527   | 8.7                        | 5.0                        |
| Foam Operator | 0721-1524   | 9.3                        | 3.1                        |
| Foam Operator | 0714-1525   | 8.5                        | 5.1                        |
| Foam Operator | 0721-1525   | 8.3                        | 4.5                        |

<sup>1</sup> Sample volumes are expressed in liters of air.

<sup>2</sup> Units expressed in parts per million (ppm) of methylene chloride.

Table 4

## Results of Personal Sampling for Organic Compounds

Trailmobile, Inc.  
HETA 87-350

December 2, 1987

| Job Title       | Sample Time | Sample Volume <sup>1</sup> | 1,1,1-Trichloroethane <sup>2</sup> | n-Butanol <sup>2</sup> | 1-Methoxy-2-propanol <sup>2</sup> | MPK <sup>2</sup>   | Toluene <sup>2</sup> | n-Butyl <sup>2</sup> Acetate | Xylenes <sup>2</sup> | VM&P Naptha/Mineral Spirits <sup>2,3</sup> |
|-----------------|-------------|----------------------------|------------------------------------|------------------------|-----------------------------------|--------------------|----------------------|------------------------------|----------------------|--|
| General Painter | 0810-1512   | 8.8                        | (0.9) <sup>4</sup>                 | ND                     | ND                                | 3.1                | 2.1                  | 1.9                          | 36.0                 | 74.4                                       |
| General Painter | 0809-1513   | 8.8                        | (0.9) <sup>4</sup>                 | ND                     | ND                                | (0.9) <sup>4</sup> | 2.1                  | 4.9                          | 29.6                 | 125.9                                      |
| Parts Painter   | 0757-1509   | 8.4                        | (1.0) <sup>4</sup>                 | ND                     | 2.3                               | ND                 | 5.9                  | 7.1                          | 35.8                 | 172.1                                      |
| Finish Painter  | 0744-1506   | 11.0                       | ND                                 | ND                     | 4.8                               | ND                 | (0.5) <sup>4</sup>   | ND                           | 9.8                  | 73.6                                       |
| Painter         | 0739-1528   | 9.2                        | ND                                 | 11.8                   | 57.6                              | ND                 | 2.2                  | ND                           | 58.9                 | 178.2                                      |

LOD: 5 ug/sample for individual compounds, 50 ug/sample for total other hydrocarbons.

LOQ: 15 ug/sample for individual compounds, 100 ug/sample for total other hydrocarbons.

ND: Chemical not detected in this sample.

<sup>1</sup> Units expressed in liters of air.<sup>2</sup> Units expressed in milligrams of compound(s) per cubic meter of air.<sup>3</sup> "VM&P Naptha/mineral spirits" includes various aliphatic and aromatic hydrocarbons found in the naphtha portion of the chromatogram.<sup>4</sup> Values in parentheses are between the LOD and LOQ for the method.

Table 5

## Evaluation Criteria

Trailmobile, Inc.  
HETA 87-350

December 2, 1987

| Compound                     | NIOSH  | OSHA                   | ACGIH                     |
|------------------------------|--|------------------------|---------------------------|
| Methylene Chloride           | LFL  | 500 ppm                | 50 ppm                    |
| 1,1,1-Trichloroethane        | 1910 mg/m <sup>3</sup> -CL<br>1091 mg/m <sup>3</sup> -AL | 1900 mg/m <sup>3</sup> | 1900 mg/m <sup>3</sup>    |
| n-Butanol                    | NA   | 300 mg/m <sup>3</sup>  | 150 mg/m <sup>3</sup> -CL |
| 1-methoxy-2-propanol         | NA   | NA                     | 360 mg/m <sup>3</sup>     |
| MPK (2-Pentanone)            | 530 mg/m <sup>3</sup>                                    | 700 mg/m <sup>3</sup>  | 700 mg/m <sup>3</sup>     |
| Toluene                      | 375 mg/m <sup>3</sup>                                    | 750 mg/m <sup>3</sup>  | 375 mg/m <sup>3</sup>     |
| n-Butyl Acetate              | NA   | 710 mg/m <sup>3</sup>  | NA                        |
| Xylenes                      | 434 mg/m <sup>3</sup>                                    | 435 mg/m <sup>3</sup>  | 435 mg/m <sup>3</sup>     |
| VM&P Naphtha/Mineral Spirits | 350 mg/m <sup>3</sup><br>1800 mg/m <sup>3</sup> -CL      | NA                     | 1350 mg/m <sup>3</sup>    |

Abbreviations: LFL - lowest feasible level

ppm - parts per million

mg/m<sup>3</sup> - milligrams per cubic meter of air

CL - ceiling limit

AL - action level

NA - none available