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HETA 99-0065-2780
General Motors Corporation
Allison Transmission Division
Indianapolis, Indiana

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PREFACE

The Hazard Evaluations and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health (OSHA) Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

HETAB also provides, upon request, technical and consultative assistance to Federal, State, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Kevin C. Roegner of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Analytical support was provided by Robert Streicher of the Analytical Research and Development Branch, Division of Physical Sciences and Engineering (DPSE). Desktop publishing was performed by Denise Ratliff. Review and preparation for printing was performed by Penny Arthur.

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Highlights of the NIOSH Health Hazard Evaluation

Isocyanate Exposures to Workers During Foam Packaging Operation at Allison Transmission

The National Institute for Occupational Safety and Health (NIOSH) was asked by an employee to look at exposures in the foaming area while parts were packaged in foam. Very low exposures were measured on the foamer and in adjacent work areas. NIOSH did make a few general recommendations to make the workplace safer.

What NIOSH Did

- # Measured chemicals (isocyanates) that are used in the foam packaging process.
- # Looked at how parts are packaged and what personal protective equipment was used by the foamer.
- # Reviewed GM policies about working with isocyanates.

What NIOSH Found

- # Very low levels of isocyanates were measured in the Foaming area.
- # Isocyanates were not detected in the Heavy Utilizing or Oiler work areas.
- # The foamer wore protective gloves and chemical splash goggles while packaging parts in the foam.
- # GM's medical department has issued recommendations for medical observation of employees working with isocyanates. These include recommendations for providing a pre-employment questionnaire and a breathing test.

What Allison Transmission Managers Can Do

- # Keep others out of the Foaming area while the foamer is packaging parts.
- # Follow GM's recommendations for pre-placement and annual medical observation of employees working with isocyanates.
- # Give the foamer a lightweight protective suit to wear while packaging parts.
- # Tell employees in the Foaming and nearby work areas about the hazards of isocyanates as part of the hazard communication program.

What Allison Transmission Employees Can Do

- # Encourage the foamer to wear a light coverall garment to lower the chance for skin exposure.
- # Persons who have not been medically cleared to work with isocyanates should not enter the Foaming area while parts are being packaged.



What To Do For More Information:
We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 1-513/841-4252 and ask for HETA Report # 99-0065-2780



Health Hazard Evaluation Report 99-0065-2780
General Motors Corporation
Allison Transmission Division
Indianapolis, Indiana
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Kevin C. Roegner

SUMMARY

On December 30, 1998, the National Institute for Occupational Safety and Health (NIOSH) received a request from employees of the General Motors Corporation, Allison Transmission Division, located in Indianapolis, Indiana, to conduct a health hazard evaluation (HHE). The request centered on isocyanate exposures arising from a polyurethane foam packaging operation. The packaging system used was an Instapak[®] foam-in-bag packaging system, marketed under the trade name of Speedy Packer[™].

Allison Transmission began packaging parts in polyurethane foam in 1988 using an Instapak[®] foam-in-place system. An employee using the foam-in-place packaging system had to be removed from the job after two days due to respiratory symptoms described by the affected employee as "constricting of the throat and wheezing." A different person began using the system and worked without incident. In February 1999, the foam-in-place system was replaced with the foam-in-bag system currently used in the warehouse.

In response to the request, NIOSH conducted a site visit in April 1999 to observe how the packaging system was used, learn about the occupational health programs in place for users of the packaging system, and obtain environmental measurements for 4,4'-diphenylmethane diisocyanate (MDI) and MDI oligomers. One person works directly with the foam-in-bag system and several employees work adjacent to the foaming area at distances of approximately 30 feet. Batches of parts are periodically delivered to the foaming area by a fork truck. The number of parts and the rate at which they are delivered vary considerably.

Area and personal breathing zone (PBZ) samples were collected for MDI and MDI oligomers. Six area samples were collected over the full shift, and two PBZ samples were collected over 15-minute periods to measure peak exposures while the foamer was using the foam-in-bag system. Wipe samples also were obtained for MDI on surfaces in the foaming area. MDI was detected in 4 of 8 air samples at concentrations below applicable exposure criteria. Oligomeric MDI was not detected in any sample. The greatest concentrations, 1.1 and 2.3 micrograms of MDI per cubic meter of air ($\mu\text{g}/\text{m}^3$), were measured in two short-term PBZ samples collected while the foamer used the foam-in-bag system. Other detectable MDI concentrations were measured near where the bags of foam are placed into boxes and in an area sample collected 10 feet from the foaming operation. The data from this survey indicate that MDI airborne exposures may occur in the foaming area during periodic peak episodes, and that the concentration decreases to non-detectable levels beyond the foaming area, at a distance greater than 10 feet from the source. Surface wipe tests, conducted immediately after the foam-in-bag system was used, did not identify measurable levels of MDI.

No local exhaust ventilation was in place in the foaming area. The foamer wore shorts and a tee shirt throughout the shift. Chemical goggles and full-length Sol-Vex nitrile gloves (model 37-185) were worn while using the Speedy Packer[™]. Respiratory protection was not used. General Motors has a written medical surveillance program for employees who work with isocyanates. This program recommends and

provides guidelines for pre-placement and periodic medical evaluations of employees who work with isocyanates. Medical evaluations are to emphasize the respiratory system.

During periodic, short-term episodes, potential exposure to airborne MDI exists in the foaming area at concentrations below NIOSH's ceiling recommended exposure limit (REL-ceiling) of $200 \mu\text{g}/\text{m}^3$. NIOSH did not find an immediate health hazard for persons performing polyurethane foam packaging at the Allison Transmission facility. This finding assumes that Allison Transmission is adhering to General Motors' written medical surveillance programs for workers potentially exposed to isocyanates. Recommendations are made for the use of personal protective equipment (PPE) to prevent dermal exposures, and for the establishment of an isocyanate work zone in which only workers medically cleared to work with isocyanates should be permitted.

Keywords: SIC 3714 (Motor Vehicle Parts and Accessories); isocyanates; 4,4'-diphenylmethane diisocyanate; MDI; polyurethane foam; packaging; automobile parts

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INTRODUCTION

On December 30, 1998, the National Institute for Occupational Safety and Health (NIOSH) received a request from employees of the General Motors Corporation, Allison Transmission Division, located in Indianapolis, Indiana, to conduct a health hazard evaluation (HHE). The request centered on a polyurethane foam packaging, foam-in-bag, system used for packaging parts. Employees working with, and in the vicinity of the foam-in-bag system were concerned that unhealthy isocyanate exposures may be occurring.

In response to the request, NIOSH visited the Allison Transmission facility on April 7 and 8, 1999. Following an opening conference with management and employee representatives and a tour of the packaging area, NIOSH collected area and personal breathing zone (PBZ) samples for 4,4'-diphenylmethane diisocyanate (MDI) and MDI oligomers, observed the use of personal protective equipment (PPE), and reviewed relevant occupational health programs in use at the facility.

BACKGROUND

Allison Transmission is a designer and manufacturer of medium- and heavy-duty transmissions for trucks, busses, and off-highway equipment. Transmission parts are packaged and shipped from the warehouse in Indianapolis. Many of the parts are packaged in part-specific, prefabricated cardboard containers. To meet the specific requests of their customers, Allison Transmission packages some parts in polyurethane foam, using an Instapak[®] foam-in-bag system (Speedy Packer[™]). The polyurethane foam formulation used is Instapak[®]-W 40, a two-component system. Part A contains 45 percent (%) (by weight) MDI and 55% MDI-based polyisocyanate; part B is a polyurethane resin. Allison Transmission began packaging parts in polyurethane foam in 1988 using a foam-in-place system, a packaging system by which the A and B components are dispensed directly into a box around the part. In February 1999, the foam-in-place system was replaced with the foam-in-bag

system, a system by which the A and B components are dispensed into a vented bag which is placed into the box. Prior to the conversion to the foam-in-bag system, an employee assigned to the foaming operation had to be removed from the job after two days due to respiratory symptoms described by the affected employee as "constricting of the throat and wheezing."

One person works directly with the foam-in-bag system for up to 40 hours per week. Other employees work adjacent to the foaming area at distances of approximately 30 feet (ft.) for employees working in the "heavy unitizing" area and 25 ft. for the employee working at the oiler work station. The foam packaging work area is located along the east wall of a 166,000 square ft. warehouse. The foaming area measures approximately 20 ft by 25 ft. Within the foaming area, the Speedy Packer[™] system is laterally centered against a wall. Batches of parts, contained in a large wire mesh basket, are periodically brought to the foaming area by a fork truck. The number of parts and the rate at which they are delivered to the foaming area vary considerably. Cardboard shipping boxes of various sizes are also brought to the foaming area.

General Motors has a written medical surveillance program for employees who work with isocyanates. This program, authored by General Motors' Corporate Medical Director, recommends and provides guidelines for pre-placement and periodic medical evaluations. The program suggests that periodic evaluations be conducted before initial placement, and at one month, three months, and annually thereafter for employees who work with isocyanates. These evaluations are to focus on the respiratory system.

METHODS

Surface Wipe Sampling

Wipe samples were obtained from surfaces in the foaming area using Aromatic Isocyanate Surface Swipe[™] Pads, produced by Omega Specialty Instrument Company (Chelmsford, MA). Due to the short environmental half-life of MDI, wipe samples were collected immediately after a part

was packaged. The limit of detection for a Swipes pad is 3-5 micrograms (μg) of isocyanate per pad.¹

Air Sampling

Personal breathing zone (PBZ) sampling was conducted to measure the foamer's MDI exposure while parts were being packaged, while area samples were collected to map out MDI concentrations in the nearby work area. Area samples were collected over the full shift, and PBZ samples were collected over 15-minute periods to measure peak exposures while the foamer was using the foam-in-bag system. Area samples were collected by drawing air through an impinger containing a solution of 1-(9-anthracenylmethyl) piperazine (MAP) in butyl benzoate followed in series by a 37-millimeter (mm) diameter quartz fiber filter (QFF) impregnated with MAP. Battery operated sampling pumps calibrated to a nominal flow rate of one liter per minute (Lpm) were connected to the collection media with Tygon® tubing. Due to the limitations of using impingers for personal exposure sampling, PBZ samples were collected using only the MAP treated QFF. Filters were removed from the cassette immediately after sampling and placed in a jar containing 5 milliliters (mL) of a solution of MAP in acetonitrile. Impinger samples were transferred into glass vials. All samples were shipped and stored in a cool environment prior to analysis.

Filter samples were analyzed by pH-gradient high pressure liquid chromatography (HPLC) with ultraviolet (UV) and fluorescence (FL) detection for MDI monomer and MDI oligomer. Impinger samples were subjected to solid-phase extraction, followed by the same analysis used for the filter samples. Upon receipt, 10 microliters (μL) acetic anhydride was added to each filter sample. The acetic anhydride was allowed to react with the excess MAP overnight. The filter-sample solutions were filtered and concentrated to 1 mL. Impinger solutions were subjected to solid-phase extraction to exchange the butyl benzoate for a more HPLC-compatible solvent. The HPLC analysis used a 150 x 4.6 mm C_8 Inertsil column containing 5-micrometer (μm) particles. The mobile phase flow rate was 1.5 mL per minute (min). The mobile phase consisted of 65% acetonitrile/35% buffer. The gradient involved

beginning the analysis at pH 6.0, holding there for 4 min, changing the buffer gradually to pH 1.6 over the next 13 min, and holding at pH 1.6 for 13 min. Thirty microliters of each sample were injected. Analysis of MAP-derivatized monomer standards in the appropriate concentration range were interspersed with the sample analyses. The impinger samples were quantified using standards that passed through the solid-phase extraction procedure. Monomers were quantified based on comparison of their FL peak heights to those of monomer standards. If detected, oligomers are quantified based on comparison of their UV peak areas to those of monomer standards.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increases the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),² (2) the American Conference of Governmental Industrial

Hygienists' (ACGIH[®]) Threshold Limit Values (TLVs[®]),³ and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).⁴ Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 95-596, sec. 5.(a)(1)]. Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short-term exposure limits (STELs). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

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 STEL or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

MDI

The unique feature common to all diisocyanates is that they consist of two $-N=C=O$ (isocyanate) functional groups attached to an aromatic or aliphatic parent compound. Because of the highly unsaturated nature of the isocyanate functional group, the diisocyanates readily react with compounds containing active hydrogen atoms (nucleophiles). Thus, the diisocyanates readily react with water (humidity), alcohols, amines, etc.; the diisocyanates also react with themselves to form either dimers or trimers. When a diisocyanate species reacts with a primary, secondary, or tertiary alcohol, a carbamate ($-NHCOO-$) group is formed which is commonly referred to as a urethane. Reactions involving a diisocyanate species and a polyol result in the formation of cross-linked polymers; *i.e.*, polyurethanes. Hence, they are widely used in surface coatings, polyurethane foams, adhesives, resins, elastomers, binders, sealants, etc.

Diisocyanates are usually referred to by their specific acronym; *e.g.*, TDI for 2,4- and 2,6-toluene diisocyanate, HDI for 1,6-hexamethylene diisocyanate, MDI for 4,4'-diphenylmethane diisocyanate, NDI for 1,5-naphthalene diisocyanate, etc.

In general, the types of exposures encountered during the use of diisocyanates in the workplace are related to the vapor pressures of the individual compounds. The lower molecular weight diisocyanates tend to volatilize at room temperature, creating a vapor inhalation hazard. Conversely, the higher molecular weight diisocyanates do not readily volatilize at ambient temperatures, but are still an inhalation hazard if aerosolized or heated in the work environment. The latter is very important since most reactions involving diisocyanates are exothermic in nature, thus providing the heat for volatilization. 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 have replaced the monomers in many product formulations. This is the case with the MDI used at Allison Transmission, which actually contains a combination of MDI monomer and MDI oligomer (polymethylene polyphenyl isocyanate). Experience with both the monomeric and oligomeric forms of diisocyanates has shown that the occurrence of health effects is dependent on exposure, not molecular weight.

Exposure to the diisocyanates produces irritation to the skin, mucous membranes, eyes, and respiratory tract. High concentrations may result in chemical bronchitis, chest tightness, nocturnal dyspnea, pulmonary edema, and death.^{5,6} The most common adverse health outcome associated with diisocyanate exposure is increased airway obstruction (asthma), and to a lesser extent dermal sensitization and hypersensitivity pneumonitis.^{6,7,8}

NIOSH and OSHA have established a ceiling concentration of 200 micrograms of contaminant per cubic meter of air ($\mu\text{g}/\text{m}^3$) as a concentration not to be exceeded. NIOSH has also established a REL of $50 \mu\text{g}/\text{m}^3$ as a time-weighted exposure not to be exceeded as an average during any work period of up to 10 hours. The ACGIH has established a TLV of $51 \mu\text{g}/\text{m}^3$ as a time-weighted

exposure not to be exceeded as an average during any 8-hour work period. These occupational exposure limits for MDI were established to protect healthy workers from the onset of allergy, bronchial asthma, and chronic bronchitis; individuals who have developed a hypersensitivity to isocyanates will not be protected at these concentrations.

Diisocyanate-induced sensitization

Probably the most debilitating health effects from workplace exposure to diisocyanates are respiratory and dermal sensitization. Exposures can lead to sensitization depending on the type of exposure, the exposure concentration, the route of exposure, and individual susceptibility. Dermal sensitization can result in symptoms such as rash, itching, hives, and swelling of the extremities.^{5,8} Respiratory sensitization from exposure to diisocyanates results in the typical symptoms of asthma. Estimates of the prevalence of diisocyanate-induced asthma in exposed worker populations vary considerably; from 5% to 10% in diisocyanate production facilities,^{9,10} to 25% in polyurethane production plants,^{9,11} and 30% in polyurethane seatcover operations.¹²

In addition, the scientific literature contains a limited amount of animal data suggesting that dermal exposure to diisocyanates may produce respiratory sensitization. In three studies, male and female guinea pigs were sensitized following dermal applications of the animals to varying concentrations of TDI or MDI in solution.^{13,14,15} This finding has yet to be confirmed in dermally-exposed workers.

Diisocyanate-induced hypersensitivity pneumonitis

Hypersensitivity pneumonitis (HP) has been described in workers exposed to diisocyanates.^{16,17,18,19,20,21} Currently, the prevalence of diisocyanate-induced HP in the worker population is unknown, and is considered to be a rare event when compared to the prevalence rates for diisocyanate-induced asthma.⁸ Whereas asthma is an obstructive respiratory disease usually affecting the bronchi, HP is a restrictive

respiratory disease affecting the lung parenchyma (bronchioles and alveoli).

The symptoms associated with diisocyanate-induced HP are flu-like; including shortness of breath, non-productive cough, fever, chills, sweats, malaise, and nausea.^{7,8} An examination may reveal rapid breathing, basilar rales (upon inspiration), a proportional reduction in forced expiratory volume in one second (FEV₁) and forced vital capacity (FVC), and an increase in the alveolar-arterial oxygen difference. In general, the flu-like symptoms and pulmonary decrements tend to reverse within a few weeks of exposure avoidance. Tobacco smoking and other chemical exposures are risk factors in the induction, progression, and severity of HP.⁷

OBSERVATIONS AND RESULTS

All foam packaging occurred during two separate 18-minute periods. The first period being between 7:38 a.m. and 7:56 a.m., and the second between 11:39 a.m. and 11:57 a.m. A variety of different parts were packaged in polyurethane foam. The foamer followed a series of steps to package each part in polyurethane foam. The foamer: 1) prepared all of the boxes needed for the batch of parts to be packaged, 2) brought the parts to the foaming area, 3) placed each of the parts in a bag designed to prevent rust, 4) programmed the Speedy Packer™ to generate the appropriate size of foam-filled bag to fill the area of box under the part, 5) while the Speedy Packer™ filled the bags one at a time, placed the bags of reacting foam in the bottom of the boxes, placing the part on top of the bag as the foam sets up, 6) programmed the Speedy Packer™ to generate the appropriate size of foam-filled bag to fill the box above the part, 7) while the Speedy Packer™ filled the bags one at a time, placed the bags of reacting foam in on top of the part and closed the box, and 8) taped each box closed.

No local exhaust ventilation was in place in the foaming area. The foamer wore shorts and a tee shirt throughout the shift. Chemical goggles and full-length Sol-Vex nitrile gloves (model 37-185)

were worn while handling the bags of reacting foam. Respiratory protection was not used.

PBZ and area sampling results for MDI and MDI-based polyisocyanate are presented in Table 1. MDI was detected in 4 of 8 samples. No MDI was measured at concentrations exceeding applicable exposure criteria. Oligomeric MDI was not detected in any sample. The greatest concentrations, 1.1 and 2.3 $\mu\text{g}/\text{m}^3$, were measured in two short-term PBZ samples while the foamer used the foam-in-bag system. Trace concentrations of MDI were measured near where the bags of foam are placed into boxes, and at a distance of 10 feet from the foaming operation. Surface wipe testing conducted immediately after the foam-in-bag system was used in the foaming area didn't identify measurable levels of MDI.

DISCUSSION AND CONCLUSIONS

This is the first time NIOSH investigators evaluated MDI exposures using a foam-in-bag packaging system. In two previous HHEs, NIOSH has evaluated MDI exposure while foam-in-place systems, similar to the one formerly used at Allison Transmission, were used. One HHE revealed short-term exposures that exceeded the NIOSH REL ceiling limit of 200 $\mu\text{g}/\text{m}^3$ while the foam-in-place system was used without engineering controls. The second evaluation measured MDI and oligomeric MDI at concentrations below the REL where a local exhaust ventilation system was used to control exposures.^{22,23} In light of previous findings, one could hypothesize that MDI exposures at Allison Transmission were greater when the foam-in-place system was in use than they are with the foam-in-bag system.

In addition to being measured in short-term personal air samples, a low concentration of MDI was measured at the location where bags of foam and parts are placed into boxes, and 10 feet from the Speedy Packer™ (12 feet from where the parts are placed into boxes). MDI was not detected in an area sample collected at the Speedy Packer™, or in samples collected at a distance greater than 10 feet from either point source. These data

suggest that with a foam-in-bag system, MDI emissions emanate from the bag at the point where it is placed into the box, rather than from the system dispensing the foam. These data also support the establishment of an isocyanate work zone. Work zones have been recommended for similar isocyanate exposure scenarios.²⁴ The data from this survey indicate that MDI exists in the foaming area in periodic peak episodes at concentrations below current occupational exposure criteria. The MDI concentration decreases to non-detectable levels beyond the foaming area. During routine packaging operations, NIOSH did not find a health hazard for persons performing polyurethane foam packaging at Allison Transmission. It is important that workers who may be exposed to MDI, even at concentrations below the REL be enrolled in the General Motors isocyanates medical surveillance program. This program will aid in identifying employees who may be more susceptible to the effects of MDI. Workers who have not had the isocyanate medical evaluations should avoid the foaming area while the Speedy Packer™ system is being used.

RECOMMENDATIONS

NIOSH offers the following recommendations to Allison Transmission based on the findings of this survey, previous NIOSH HHE's, and the current scientific literature. These recommendations are intended to provide for a safer work environment at Allison Transmission.

- 1) The Allison Transmission medical department should provide pre-placement and periodic medical surveillance for all workers potentially exposed to diisocyanates.⁵ The pre-placement examinations should consist of detailed medical and work histories with emphasis on pre-existing respiratory and/or allergic conditions, a physical examination that centers on the respiratory tract, a baseline pulmonary function test that measures FEV₁ and FVC, and a judgement on the worker's ability to wear a supplied-air respirator if exposure monitoring results indicate that respiratory protection is necessary to protect workers. Workers should be provided with annual examinations which measure the worker's FEV₁ and FVC, and which update their medical and

work histories. The recommendations offered by the General Motors Corporate Medical Department for medical surveillance of workers potentially exposed to isocyanates are consistent with NIOSH recommendations.

2) Areas containing isocyanates should be restricted to essential workers. Accordingly, only persons who are necessary to the completion of the polyurethane foam packaging operation, and who have been medically cleared to work with isocyanates should be permitted in the foaming area while the Speedy Packer™ system is in use. A sign should be posted in the foaming area indicating that only employees who have been medically approved to work with isocyanates should be in the foaming area while the Speedy Packer™ system is being used. Also, employees in adjacent areas should be informed of the new policy.

3) MDI exposure monitoring should be conducted subsequent to any process change or annually to assure that exposures remain below exposure criteria. Sampling should be conducted in a manner which captures full-shift (averaged over 8-hours) and peak (averaged over 15-minutes) exposures.

4) The occupational health community has not fully determined the role of dermal exposures in overall exposure and immunologically mediated asthma. Until this relationship is better understood, employees should be protected against dermal exposure to isocyanates. Workers should wear a lightweight protective suit to limit skin exposure to airborne MDI while using the Speedy Packer™ system. An appropriate protective suit is one through which MDI will not permeate during a typical 8-hour work shift. Examples include Saranex and polyethylene coated Tyvek®. Uncoated Tyvek® provides less than 15 minutes of protection. A complete listing of protective suits that provide 8-hours of protection may be obtained through the Alliance for the Polyurethane Industry (202) 974-5200; publication AX-178 *PMDI User Guidelines for Chemical Protective Clothing Selection*. This publication describes resistance of various gloves and other protective clothing to polyurethane MDI. It provides additional information on these

protective clothing items such as thickness, availability, and approximate costs.

5) Workers employed in the foaming and adjacent work areas should be informed and trained in the hazards of MDI consistent with paragraph (h) of OSHA's *Hazard Communication Standard* [Code of Federal Regulations 1910.1200]. This training should be provided at the time of initial assignment to the area where MDI is used.

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Table 1 Personal Breathing Zone and Area Sampling Results for 4,4'-Diphenylmethane Diisocyanate (MDI) Monomer and Oligomer During Polyurethane Foam Packaging Operation, April 8, 1999. Allison Transmission, Indianapolis, Indiana. HETA 99-0065-2780.

Sample Location	Sample Time ¹	Sample Volume ²	MDI ³		MDI Oligomers
			Short-term	Full-shift	
Foamer PBZ sample	0738-0753	22.5	1.1	-	ND
Foamer PBZ sample	1139-1155	24.0	2.3	-	ND
At Speedy Packer™ system near control pad	0614-1408	474	-	ND	ND
Area where part is placed in box	0612-1406	465	-	(0.05) ⁴	ND
Oiler Work Station - 23 feet from Speedy Packer™	0611-1406	475	-	ND	ND
Heavy Utilizing work area- 26 feet downwind of Speedy Packer™	0614-1406	463	-	ND	ND
10 feet downwind of Speedy Packer™	0628-1406	458	-	(0.04)	ND
20 feet downwind of Speedy Packer™	0628-1406	458	-	ND	ND
NIOSH REL			200	50	none est.
ACGIH TLV			none est.	51	none est.
Minimum Detectable Concentration (MDC)				0.04	0.03

¹ This is the start and stop time (in military time) for the sampling device.

² Sample volumes are expressed in liters of air.

³ Concentrations are expressed in micrograms of analyte per cubic meters of air ($\mu\text{g}/\text{m}^3$). An “ND” (none detected) in this column means that none of the analyte was detected in the sample, and the airborne concentration was below the minimum detectable concentration (MDC) for the sampling and analytical method.

⁴ Concentrations in parenthesis denote semiquantitative trace levels.

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