CENTERS FOR DISEASE CONTROL AND PREVENTION

NIOSH HEALTH HAZARD EVALUATION REPORT

HETA 95-0406-2609

Matrix Auto Body
Englewood, Colorado

Charles McCammon
Bambi Sorensen

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

TABLE OF CONTENTS

Preface
Acknowledgments and Availability of Report
Summary
Introduction
Background
Methods
- Isocyanates
- Total Dust
- Organics (solvents)
- Carbon Monoxide
- Noise

Evaluation Criteria
- Carbon Monoxide
- Organic Solvents
- Diisocyanates
- Diisocyanate-induced sensitization
- Prevention and treatment

Noise/Hearing Loss
Results
Discussion
Conclusions
Recommendations
References

PREFACE

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

The Hazard Evaluations and Technical Assistance Branch 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 the National Institute for Occupational Safety and Health.

ACKNOWLEDGEMENTS AND AVAILABILITY OF REPORT

This report was prepared by Charles McCammon, of the NIOSH Denver Field Office, Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Bambi L. Sorensen and Robb Menzies. Desktop publishing by Bambi Sorensen and Pat Lovell.

Copies of this report have been sent to employee and management representatives at Matrix and the OSHA Regional Office. This report is not copyrighted and may be freely reproduced. Single copies of this report will be available for a period of three years from the date of this report. To expedite your request, include a self-addressed mailing label along with your written request to:

NIOSH Publications Office
4676 Columbia Parkway
Cincinnati, Ohio 45226
800-356-4674

After this time, copies may be purchased from the National Technical Information Service (NTIS) at 5825 Port Royal Road, Springfield, Virginia 22161. Information regarding the NTIS stock number may be obtained from the NIOSH Publications Office at the Cincinnati address.

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

Health Hazard Evaluation Report 95-0406-2609

Matrix Auto Body
Englewood, Colorado
October 1996

Charles McCammon
Bambi Sorensen

SUMMARY

On June 24, 1995, the National Institute for Occupational Safety and Health (NIOSH) received a request from Matrix Auto Body in Englewood, Colorado, for assessment of worker exposure to isocyanates during spray painting of automobiles. Other concerns for worker exposure included solvents, total dusts, noise, carbon monoxide (CO), and metals. An initial survey was conducted in August 1995; an interim report was distributed in December 1995. A second survey was conducted on March 6, 1996, to assess the effects of seasonal variations. This report summarizes the exposures measured during both surveys.

Measurements made included personal breathing-zone (PBZ) and area airborne levels of hexamethylene-1,6-diisocyanate (HDI) monomer and oligomers, various solvents (including n-butyl acetate, toluene, xylene, and ethyl acetate), total dust (paint over-spray), metals (from welding), co, and noise.

All HDI monomer samples from August 1995 and March 1996 were below the analytical limit of detection (3-5 µg/sample), except one. This was an area sample, 40 micrograms per cubic meter of air (µg/m^3), collected in the paint booth for 4 hr. The 8-hr time-weighted average (TWA) exposure in the booth was below the NIOSH recommended exposure limit (REL) of 35 µg/m^3. The oligomer samples from August ranged from below the limit of detection (3 µg/sample) up to 261 µg/m<^{3}. PBZ oligomer samples collected in March were higher, often exceeding the industry recommendation of 500 µg/m^3, for short periods. However, when time-weighed over the full shift, all exposures were below 500 µg/m^3.

None of the air samples for solvents (n-butyl acetate, toluene, xylene, or ethyl acetate) exceeded their individual REL or permissible exposure limit (PEL). Furthermore, the mixture summation of all organics (the best indicator for total organic exposure), for all samples during both sampling times were not in excess of any evaluation criteria. Generally, the levels of organics measured in March were higher than those in August. Area total dust samples ranged from 3.5 to 26 milligrams per cubic meter of air (mg/m^3). Most of these samples were collected in the paint booth. PBZ total dust samples ranged from 4.1 to 35 mg/m^3 for short periods. PBZ TWAs for total dust ranged from 5.4 to 14.2 mg/m^3. Area CO concentrations averaged 54 parts per million (ppm) for the 8-hr sampling period. The peak CO concentration was 247 ppm and the highest 15-minute average was 121 ppm. The high peaks were associated with moving vehicles in and out of the shop. A personal noise monitor was placed on a body repair worker. The average noise level (using the OSHA criteria) was 94.4 dB(A), resulting in a 185% dose of the maximum allowable noise exposure. The maximum peak level measured was 135 dB(A). One welding sample was collected. Exposures to all metals were well below the respective evaluation criteria.

A potential health hazard existed from exposure to peak levels of carbon monoxide during the cold weather months. Levels of isocyanates, solvents, total dust, and noise were below respective evaluation criteria. The use of air-purifying respirators was deemed sufficient for the exposures documented. Recommendations are presented for control of exposures to CO, and to help reduce other exposures.

Keywords: SIC 7531(automotive body shops), isocyanates, solvents, total dust, carbon monoxide, noise, respirators

INTRODUCTION

On June 24, 1995, the National Institute for Occupational Safety and Health (NIOSH) received a request from Matrix Auto Body in Englewood, Colorado, for assessment of worker exposure to isocyanates during spray painting of automobiles. Other concerns for worker exposure included solvents, total dusts, noise, carbon monoxide (CO), and metals. An initial survey was conducted in August 1995; an interim report was distributed in December 1995. A second survey was conducted on March 6, 1996, to assess the effects of seasonal variations. This report summarizes the exposures measured during both surveys.

BACKGROUND

Matrix Auto Body is an autobody repair shop located in Englewood, Colorado. The repair work includes frame straightening, panel repair/replacement, body filling, painting and detailing. Repair is conducted in an open shop with body work performed in the north end, detail and cleaning in the center, and painting in a separate part of the building on the south end. Most top coat spraying is conducted in a paint spray booth located near the south end of the shop. Adjacent to the spray booth is the paint mixing area where

the paint components are stored and mixed. The general painting area, not including the paint booth, has a large exhaust fan located near the ceiling on the west wall. This fan can be used to help evacuate the air when painting is conducted outside the booth. The side-draft spray booth has a separate one-pass exhaust system. The booth also has the capacity to be heated to accelerate paint drying. On the northeast end of the building is a single bay prep station where primer coats are applied. Some primer spraying is also done in the open area of the main repair portion of the building (between the detail area and mechanical repair).

Matrix uses the BASF Corp. R-M™ and Diamont™ Solo™ isocyanate catalyzed paints. In general, the paints are composed of a base, a reducer, and a hardener. The percentage and make-up of each component varies depending on the type of paint coat, i.e., primer, base, color, or top (clear) coat. The paints contain hexamethylene-1,6-diisocyanate (HDI) polymer and very small amounts of the monomer (<0.006%). Some of the hardeners also contain isophorone diisocyanate (IPDI) polymer and monomer. All of the various components contain solvents, and the reducers are all solvents.

When painting, multiple thin layers of the different paint coats are applied. When base metal is exposed, these areas are first covered with a primer. Once the vehicle is ready for final painting, several base coats are applied, the paint is allowed to sit a short while (10-20 minutes), then the color paint is applied, again in several thin coats. Lastly, the clear top coat is sprayed on until a uniform gloss is achieved. The vehicle is then allowed to sit overnight or in a heated booth for 1-2 hours to allow the paint to dry.

New, high volume, low pressure (HVLP) spray guns were used to reduce the amount of paint over-spray. However, most of the painters still use the conventional spray gun to some degree, especially when applying the clear coats of paint. While most painting was done in the spray booth, sometimes, due to the number of cars being painted and the limitations on drying times, many of the various primer, base, and color coats were applied outside the spray booth. Most of the clear coats were applied in the spray booth to insure a dust-free finish coat. Matrix does use the space outside the booth as a large paint booth using the west wall exhaust fan to exhaust the paint over-spray. At the end of the day, multiple cars (3-10) are prepared in the general paint room and sprayed with clear coats. The vehicles are allowed to remain overnight for the clear coat to dry.

METHODS

Isocyanates

Air samples for isocyanates were collected in 20-mL of an absorbing solution in a midget impinger at a flow rate of 1.0 liter per minute using MSA Model G sampling pumps. The absorbing solution contained a reactive chemical dissolved in dimethyl sulfoxide. The samples were analyzed by high performance liquid chromatography (HPLC) according to NIOSH Analytical Method #5522. Since it is difficult to attach midget impingers in the breathing zone of workers, particularly since they had to bend over and move around, the impingers were attached to the sampling pumps on the worker's belt. Bulk samples of the various paint components were analyzed by HPLC to determine the amount of free isocyanate monomer present.

Total Dust

Air samples for total dust were collected on 35-millimeter pre-weighed glass fiber filters housed in plastic cassettes. Air was drawn through the filters at a flow rate of 2 liters per minute using battery operated Gilian model HFS 513A high flow pumps. The filters were analyzed gravimetrically according to NIOSH Analytical Method # 0500.[1]

Organics (solvents)

Air samples for organic chemicals (n-butyl acetate, xylene, toluene, and ethyl acetate) were collected on standard 150-milligram charcoal tubes at 200 milliliters per minute using battery operated Gilian model LFS 113D-C. The samples were analyzed by gas chromatography according to NIOSH Analytical Methods #1450 and 1501. One charcoal tube sample from each location was screened by gas chromatography/mass spectrometry (GC/MS) to determine what specific hydrocarbons were present in the air and approximate levels of each.

Carbon Monoxide

Carbon monoxide (CO) levels were measured with a Draeger Model 190 Datalogger. This instrument uses an electrochemical sensor for CO. It was calibrated on the day of use and zeroed in the field.

Noise

Personal noise measurements were taken with Quest Technologies Model M-27 Noise Logging Dosimeters. The unit stores and interprets data for a variety of different thresholds and exchange rates allowing comparison to different recommended evaluation criteria.

EVALUATION CRITERIA

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

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs)[8], (2) the U.S. Department of Labor, OSHA Permissible Exposure Limits (PELs)[9], and (3) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs™).[11] In July 1992, the 11th Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard. OSHA is currently enforcing the 1971 standards which are listed as transitional values in the current Code of Federal Regulations; however, some states operating their own OSHA approved job safety and health programs continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard and that the OSHA PELs included in this report reflect the 1971 values.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term. A brief discussion of the toxicity and evaluation criteria for the substances monitored follows:

Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials; e.g., natural gas. The initial symptoms of CO poisoning may include headache, dizziness, drowsiness, and nausea. These initial symptoms may advance to vomiting, loss of consciousness, and collapse if prolonged or high exposures are encountered. Coma or death may occur if high exposures continue.[2-7]

The NIOSH REL for CO is 35 ppm for an 8-hour TWA exposure, with a ceiling limit of 200 ppm which should not be exceeded.[8] The NIOSH REL of 35 ppm is designed to protect workers from health effects associated with carboxyhemoglobin (COHb) levels in excess of 5%.[2] The ACGIH recommends an 8-hour TWA TLV of 25 ppm.[10] The OSHA PEL for CO is 50 ppm for an 8-hour TWA exposure. In addition to these standards, the National Research Council has developed a CO exposure standard of 15 ppm, based on a 24 hours per day, 90-day TWA exposure.[11]

Organic Solvents

Exposure to organic solvents can occur through inhalation of the vapors, skin contact with the liquid, or ingestion. As many organic solvents have relatively high vapor pressures and readily evaporate, inhalation of vapors is considered a primary route of exposure. Overexposure to many organic solvents can result in mucosal irritation, central nervous system depression, headache, nausea, and possible effects on the liver, kidney, or other organs.[12-14] Many industrial solvents are primary irritants, and can cause defatting of the

skin and dermatitis. Solvents are among the leading causes of occupational skin disease.[14] Biological effects of exposure can range from practically non-toxic (e.g., some freons) to highly toxic (e.g., carbon tetrachloride) or carcinogenic (e.g., benzene).[3] The ability to detect the presence of a solvent by the sense of smell will vary widely depending on the specific substance, and individual sensitivity. Substances are considered to have good warning properties if an average person with normal sensory perception can detect the presence of the chemical at a level below the recommended exposure limit. The following table summarizes the principle health effects associated with these solvents and the NIOSH RELs and odor detection thresholds for these compounds.

Chemical	NIOSH REL	Odor Threshold & Description[16]	Principle Health Effects[5,15-17]
ethyl acetate	400 ppm	1 ppm sweet/fruity	central nervous system depression, dizziness, eye irritation
methyl-ethyl ketone (2-butanone)	200 TWA 300 ppm STEL	17 ppm sweet, sharp	Headache, dizziness, numbness of extremities. Dermal and eye irritation.
toulene	100 TWA 150 ppm STEL	1.6 ppm sour, burnt	eye/respiratory irritation, fatigue, headache, narcotic effects
xylene	100 TWA 150 ppm STEL	20 ppm sweet	eye/respiratory irritation, narcosis, headache, dermal effects
acetone	250 ppm TWA	62 ppm sweet, fruity	eye irritation, nausea, headache, central nervous system depression
N-butyl acetate	150 ppm TWA 200 ppm STEL	7 ppm sweet, fruity	eye/respiratory irritation, narcosis

Note:

TWA = time-weighted average concentration for up to 10 hours/day
C = ceiling limit not to be exceeded
STEL = short-term exposure limit - 15 minute average

Note that many solvents have similar toxic effects. When there are exposures to two or more substances that act upon the same

organ system, their combined effect is evaluated. Unless there is scientific evidence to the contrary, the effects are considered to be additive (as opposed to potentiating, synergistic, or antagonistic), and are calculated as follows:

$$\text{Combined REL} = \frac{C_1}{REL_1} + \frac{C_2}{REL_2} + \ldots \frac{C_n}{REL_n}$$

Where:

C = measured atmospheric concentration
REL = corresponding recommended exposure limit

If the sum of the above fractions exceed 1.0, the combined REL is considered to be exceeded.

Diisocyanates

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 specify 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. Commercial-grade TDI is an 80:20 mixture of the 2,4- and 2,6- isomers of TDI, respectively.

In general, the type 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. An example is biuret of HDI, which actually consists of three molecules of HDI monomer joined together to form a higher molecular weight oligomer 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 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 wakening, pulmonary edema, and death. [18,21] 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.[19-21]

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 such symptoms as rash, itching, hives, and swelling of the extremities.[18,21]

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,[22,23] to 25% in polyurethane production plants[22,24] and 30% in polyurethane seatcover operations.[25]

A worker suspected of having diisocyanate-induced sensitization will present with symptoms of traditional acute airway obstruction; e.g., coughing, wheezing, shortness of breath, tightness in the chest, nocturnal awakening, etc.[18,20] Upon first exposure to diisocyanates, the worker may develop an asthmatic reaction immediately or several hours after exposure, after the first months of exposure, or after several years of exposure.[18,20,23,26,27] Some evidence exists which suggests that the onset of sensitization occurs after a mean exposure interval of 2 years.[28] After sensitization, any exposure, even to levels below any occupational exposure limit or standard, can produce an asthmatic response which may be life threatening. This asthmatic reaction may occur minutes after exposure (immediate), several hours after exposure (late), or a combination of both immediate and late components after exposure (dual).[20,26] The late asthmatic reaction is the most common, occurring in approximately 40% of diisocyanate-sensitized workers.[29] Recurrent nocturnal asthma has been described in workers sensitized to TDI and MDI.[30,31] An improvement in symptoms may be observed during periods away from the work environment (weekends, vacations).[18,20,26]

The percentage of sensitized workers with persistent symptoms of asthma after years of no exposure may be 50% or higher. Studies have shown that workers with persistent asthma have a significantly longer duration of symptoms prior to diagnosis, larger decrements in pulmonary function, and a severe degree of nonspecific bronchial hyperactivity at diagnosis.[26] These data suggest that prognosis is improved with early diagnosis of diisocyanate-induced respiratory sensitization and early removal from diisocyanate exposure. This emphasizes the need to minimize workplace exposure concentrations, and for active medical surveillance of all workers potentially exposed to diisocyanates.

Prevention and treatment

Whenever there is a potential for a hazardous exposure to diisocyanates, traditional industrial hygiene practice dictates that the following hierarchy of controls, in decreasing order of desirability and effectiveness, be implemented to protect worker health:

1. Elimination of the toxic substance from the workplace.
2. Substitution of the toxic substance with a less toxic substance.
3. Installation of engineering controls designed to reduce exposure.
4. Use of administrative controls to reduce exposure.
5. Use of personal protective equipment to reduce exposure.

In many instances, it is not possible to eliminate or substitute a diisocyanate from a production process without altering the integrity of the desired product. Thus, most strategies for reducing diisocyanate exposure center on the use of engineering controls and personal protective equipment. Local exhaust ventilation and/or process isolation are commonly used controls for diisocyanate exposure reduction. Personal protective equipment should only be used when engineering controls are not feasible, in the interim when engineering controls are being installed or repaired, or when engineering controls have not suffciently reduced exposures. NIOSH recommends that whenever there is a potential for exposure to diisocyanates, including concentrations below the NIOSH recommended exposure level, that the employer provide the worker with supplied-air respiratory protection.[18] Air-purifying respirators are not approved for diisocyanates owing primarily to the fact that diisocyanates have poor odor warning properties. However, several studies have demonstrated that air-purifying respirators with combined dust/mist and organic cartridges effectively trap TDI, HDI, and MDI.[32-34] Personal protective equipment should also be used to prevent skin and eye contact with diisocyanates.

OSHA currently has standards for only two of the diisocyanates, TDI and MDI. OSHA recommends a ceiling limit of 0.02 parts per million (ppm) [140 micrograms per cubic meter, µg/m^3] for both TDI and MDI. For MDI, NIOSH recommends a TWA of 0.005 ppm (35 µg/m^3) and a 10-minute ceiling of 0.02 ppm [200 µg/m^3]. NIOSH considers TDI a carcinogen and recommends exposure be limited to the lowest feasible concentration.

For HDI, NIOSH recommends a TWA of 0.005 ppm [35 µg/m^3] and a 10-minute ceiling limit of 0.02 ppm [140 µg/m^3]. For isophorone diisocyanate (IPDI), NIOSH recommends a TWA of 0.005 ppm [45 µg/m^3] and a ceiling limit of 0.02 ppm [180 µg/m^3] with a skin designation. This means that skin absorption is considered as a primary route of exposure and skin contact should be avoided.

Neither NIOSH nor OSHA have exposure limits for the polymeric isocyanate groups (oligomers). The United Kingdom Health and Safety Commission set a standard in 1982 for total isocyanate group per cubic meter of air. This standard is 20 µg of isocyanate group/m^3 for a TWA and 70 µg/m^3 for a 10-minute ceiling.[35] Miles Laboratories recommends in their MSDS for the Glasurit HDI-based paints that a limit of 500 µg/m^3 be followed for the polymeric isocyanates.

Noise / Hearing Loss

Noise-induced loss of hearing is an irreversible, sensorineural condition that progresses with exposure. although hearing ability declines with age (presbycusis) in all populations, exposure to noise produces hearing loss greater than that resulting from the natural aging process. This noise induced loss is caused by damage to nerve cells of the inner ear (cochlea) and, unlike some conductive hearing disorders, cannot be treated medically.[36] While loss of hearing may result from a single exposure to a very brief impulse noise or explosion, such traumatic losses are rare. In most cases, noise-induced hearing loss is insidious. Typically, it begins to develop at 4000 or 6000 Hz (the hearing range is 20 Hz to 20000 Hz) and spreads to lower and higher frequencies. Often, material impairment has occurred before the condition is clearly recognized. Such impairment is usually severe enough to permanently affect a person's ability to hear and understand speech under everyday conditions. although the primary frequencies of human speech range from 200 Hz to 2000 Hz, research has shown that the consonant sounds, which enable people to distinguish words such as "fish" from "fist" have still higher frequency components.[37]

The A-weighted decibel [dB(A)] is the preferred unit for measuring sound levels to assess worker noise exposures. The decibel unit is dimensionless, and represents the logarithmic relationship of the measured sound pressure level to an arbitrary reference sound pressure (20 micropascals, the normal threshold of human hearing at a frequency of 1000 Hz). Decibel units are used because of the very large range of sound pressure levels which are audible to the human ear. The dB(A) scale is weighted to approximate the sensory response of the human ear to sound frequencies. Because the dB(A) scale is logarithmic, increases of 3 dB(A),10 dB(A), and 20 dB(A) represent a doubling, tenfold increase, and 100-old increase of sound energy, respectively. It should be noted that noise exposures expressed in decibels cannot be averaged by taking the simple arithmetic mean.

The OSHA standard for occupational exposure to noise (29 CFR 1910.95)[38] specifies a maximum PEL of 90 dB(A)-slow response for a duration of eight hours per day. The regulation, in calculating the PEL, uses a 5 dB time/intensity trading relationship, or exchange rate. This means for a person to be exposed to noise levels of 95 dB(A), the amount of time allowed at this exposure level must be cut in half in order to be within OSHA's PEL. Conversely, a person exposed to 85 dB(A) is allowed twice as much time at this level (16 hours) and is within his daily PEL. NIOSH, in its Criteria for a Recommended Standard,[39] proposes an exposure limit of 85 dB(A) for 8 hours, 5 dB less than the OSHA standard. In 1995, NIOSH recommended a 3 dB exchange rate. In 1994, the ACGIH changed its TLV to a more protective 85 dB(A) for an 8-hour exposure, with the stipulation that a 3 dB exchange rate be used to calculate time-varying noise exposures. Thus, a worker can be exposed to 85 dB(A) for 8 hours, but to only 88 dB(A) for 4 hours or 91 dB(A) for 2 hours.

Time-weighted average (TWA) noise limits as a function of exposure duration are shown as follows:

Duration of	Sound Level dB(A)

Exposure (hrs/day)	ACGIH	NIOSH	OSHA
16	82	82	85
8	85	85	90
4	88	88	95
2	91	91	100
1	94	94	105
1/2	97	97	110
1/4	100	100	115*
1/8	103	103	---
	***		**

* No exposure to continuous or intermittent noise in excess of 115 dB(A).
** Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.
*** No exposure to continuous, intermittent, or impact noise in excess of a peak C-weighted level of 140 dB.

The duration and sound level intensities can be combined in order to calculate a worker's daily noise dose according to the formula:

$$\text{Dose} = 100 \times (C_1/T_1 + C_2/T_2 + \ldots + C_n/T_n),$$

where C_n indicates the total time of exposure at a specific noise level and T_n indicates the reference duration for that level as given in the above table. During any 24-hour period, a worker is allowed up to 100% of his daily noise dose. Doses greater than 100% are in excess of the OSHA PEL.

The OSHA regulation has an additional action level (AL) of 85 dB(A) which stipulates that an employer shall administer a continuing, effective hearing conservation program when the TWA value exceeds the AL. The program must include monitoring, employee notification, observation, an audiometric testing program, hearing protectors, training programs, and recordkeeping requirements. All of these stipulations are included in 29 CFR 1910.95, paragraphs (c) through (o).

The OSHA noise standard also states that when workers are exposed to noise levels in excess of the OSHA PEL of 90 dB(A), feasible engineering or administrative controls shall be implemented to reduce the workers' exposure levels. Also, a continuing, effective hearing conservation program shall be implemented.

RESULTS

A summary of the hexamethylene diisocyanate results (HDI) from August 1995 are presented in Table 1. The less than value (<) in the table represent the lowest detectable concentration for that sample based on the sample volume and the detection limit (3 µg/sample). Sample #IMA-23 was an area sample collected inside the paint booth in the middle of the day. This sample was 40 µg/m^3 which is above the NIOSH REL of 35 µg/m^3 for an 8-hr TWA but below the 140 µg/m^3 ceiling REL. If this sample is averaged over 8 hours it is 19.4 µg/m^3, which is below the NIOSH REL. Three oligomer samples were above the limit of detection, the highest being 261 µg/m^3.

The sample results for HDI from March 1996 are summarized in Table 1a. All the monomer exposures are below the analytical limit of detection (5 µg/sarnple) but most of the oligomer samples had detectable results. These ranged from 514 to 1530,µg/m^3. These concentrations are consistently above the industry recommended concentration of 500 µg/m^3 but only for short periods. The TWA oligomer concentration were all below 500 µg/m^3.

Air samples for organics are summarized in Table2 (August 1995) and Table 2a (March 1996). None of the individual chemical levels (n-butyl acetate, toluene, xylene, or ethyl acetate) exceeded their individual REL or PELs. Furthermore, the mixture summation of all organics (the best indicator for total organic exposure), for all samples during both sampling times were not in excess of any evaluation criteria. Generally, the levels of organics measured in March were higher than those in August.

Sample results for total dust are summarized in Table 3 (August) and Table 3a (March). In both cases, area samples in the booth exceeded the PEL. Two personal samples were above the PEL of 15 mg/m^3, but only for short periods. The individual TWAs are below 15 mg/m^3. Generally, the results from March were higher than those collected in August.

One welding sample was collected and is summarized in Table 4. Exposures to all metals were well below the respective evaluation criteria.

The one datalogger monitor output for CO is shown in Figure 1 from March 1996. The CO concentrations in the body repair area averaged 54 ppm for the 8-hr sampling period. The peak CO level was 247 ppm and the highest 15-minute average was 131 ppm. The high peaks were associated with moving vehicles in and out of the shop.

A personal noise monitor was placed on a body repair worker for 8 hours in March 1996. The average noise level (using the OSHA criteria) was 94.4 dB(A), resulting in a 185% dose of the maximum allowable noise exposure. The maximum peak levels measured was 135 dB(A).

DISCUSSION

The HDI results generally demonstrate low exposures to monomer. For both sampling periods, only one sample was in excess of the NIOSH REL of 35 µg/m^3 yet it was below the more applicable ceiling REL of 140 µg/m^3. This sample was collected in the warm weather months. The oligomer samples were higher during the winter months and were above what is recommended by the paint manufacturer (500 µg/m^3). The HDI samples indicate the potential for some exposure exists, but not at levels in excess of existing evaluation criteria.

Exposures to solvents were generally higher in the winter than in the summer. The highest exposures were around 75% (75 and 76%) of the allowable exposure for solvent mixtures. The highest exposures were consistently to n-butyl acetate and toluene. Use of protective gloves to reduce skin exposure (and absorption) of solvents was inconsistent. Gloves were mostly used when mixing paint and spray painting but were not always used during spray gun cleaning.

Total dust levels due to paint over-spray (measured as area samples) were consistently in excess of OSHA PEL inside the spray booth. Personal exposures to total dust exceeded the OSHA PEL of 15 mg/m^3 on 3 samples that were of short duration. The head painter's TWA in the summer averaged 14.2 mg/m^3. His average in the winter was 5.4 mg/m^3. The area samples collected inside the spray booth appear to be about the same during the winter and summer months even though the head painter's TWA exposure was higher in the summer.

CO levels exceeded the NIOSH ceiling limit of 200 ppm. The average exposure for the nearly 8-hr sample (54 ppm) exceeded the OSHA PEL, ACGIH TLV, and once the NIOSH REL. The levels were high enough, consistently enough, that some remediation is necessary to control exposure. Since cars moved into and out of the shop were the source of the CO and since it is very difficult to control these moving sources, the best solution is to increase general building dilution ventilation. This increase in ventilation would also help reduce other exposures such as solvents, isocyanates (when sprayed outside the booth) and total dust.

Noise exposures were above both the OSHA and NIOSH exposure limits. Body work that produces the highest noise levels is an inconsistent work practice, therefore, more measurements representing a wider variety of body work is recommended to increase the baseline monitoring database. The major noise sources were in the body shop area.

This is also true for welding and grinding operations where metal exposure is the issue. The one sample collected during this evaluation may not be representative of the exposure potential.

CONCLUSIONS

HDI monomer exposures were below the various evaluation criteria. Oligomer air samples were above the industry guidelines of 500 µg/m^3 in the winter months for short periods of time. An occasional monomer sample approached the NIOSH REL indicating a need for protective measures. NIOSH recommends air-supplied respirators whenever there is the potential for exposure to isocyanates. There are no NIOSH approved air-purifying respirators for isocyanates because isocyanates have no odor warning properties to indicate breakthrough of the cartridge. However, studies have shown that combination dust/mist and organic cartridges effectively stop isocyanates and that the various solvents, particularly n-butyl acetate, will break through the cartridge long before the isocyanates.[32-

[34] Therefore, the combination dust/mist/organic air-purifying respirators should provide adequate protection against the small amounts of isocyanate present and the n-butyl acetate odor can be used to indicate breakthrough of the cartridges. Eye and skin protection also needs to be provided with isocyanate monomers.

Both solvent and total dust exposures approached, but did not exceed, the OSHA evaluation criteria. Use of the combination air-purifying respirators during painting would also provide sufficient protection for solvents and total dust. Use of gloves and eye protection will provide the needed skin and eye protection for the solvents. Eye protections in the entire shop should be a general requirement due to the potential for flying objects from body work (grinding and welding), detailing, painting, polishing, etc.

The CO levels measured during the winter months, when the shop was fairly airtight, rose to levels in excess of the NIOSH/OSHA ceiling limit and the PEL/REL. Since vehicles need to be moved around and in and out of the shop to keep the repair process going, the only real control option is to provide general building ventilation for the shop. The only exhaust in the building occurs through leakage and from open doors. Outside air needs to be brought into the building, tempered and partially exhausted. The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) recommends certain levels of outside air in their guideline Ventilation for Acceptable Indoor Air Quality, standard ASHRAE 62-1989.[40] This guideline recommends 1.5 cubic feet per minute of outside per square feet of shop for auto repair shops and enclosed parking garages to control CO.

RECOMMENDATIONS

1. NIOSH recommends air-supplied respirators when there is the potential for exposure to isocyanates. However, if air-purifying respirators are used, there are a few items which should be noted. First, there are no NIOSH approved air-purifying respirators for isocyanates primarily because isocyanates have no odor warning properties. Studies have shown that combination dust/mist and organic cartridges effectively stop isocyanates and that the various solvents will break through long before any isocyanate.[32-34] Therefore, the odor property of n-butyl acetate could be used to determine when respirators need to be replaced. Eye and skin protection should be provided during spray painting. At a minimum, air-purifying respirators are indicated by the organic chemical and total dust exposures.

2. General ventilation for the entire shop is needed to control CO levels in the winter. This ventilation should meet the guidelines recommended by ASHRAE 62-1989.

3. A complete respiratory protection program needs to be implemented as per 29 CFR 1910.134. Many of the elements of the 10-point respirator plan are in effect, but all elements must be in place including medical testing of workers for the ability to wear respirators, respirator training, fit testing of respirators, and respirator maintenance.

4. Paint spraying should be conducted in the paint booth as much as possible. The levels of total dust and organics can be substantial, so the best way to control these exposures is to limit spraying to the booth. When any spraying is done outside the booth, all employees in the area should be wearing their respirators.

5. All employees in the shop area should wear appropriate eye protection. No eating, drinking, or smoking should be allowed in the shop area.

6. Gloves should be worn when mixing paint, cleaning paint guns, or at any time when bulk paint and/or solvents may come into contact with the skin. Testing for isocyanate monomers with SWYPE™ samples demonstrated monomer content in used solvent, therefore demonstrating the need to avoid skin contact with this solvent.

7. The still for the used solvent had a substantial leak. The still should be repaired.

8. Noise levels should be remeasured during a variety of different body shop operations for several different days. If average noise levels exceed 85 dB(A) as a TWA, then a comprehensive hearing conservation program needs to be implemented.

9. Additional monitoring for metal exposures should be conducted during grinding and welding jobs to establish a better metal exposure database.

REFERENCES

1. NIOSH [1994]. National Institute for Occupational Safety and Health. NIOSH Manual of Analytical Methods. 4th ed. Cincinnati, Ohio.
2. NIOSH [1972]. Criteria for a recommended standard: occupational exposure to carbon monoxide. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Health Services and Mental Health Administration, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 73-11000.
3. NIOSH [1972]. Criteria for a recommended standard: occupational exposure to carbon monoxide. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Health Services and Mental Health Administration, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 73-11000.
4. NIOSH [1977]. Occupational diseases: a guide to their recognition. Revised ed. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 77-181.
5. NIOSH [1979]. A guide to work-relatedness of disease. Revised ed. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 79-116.
6. Proctor NH, Hughes JP, Fischman ML [1988]. Chemical hazards of the workplace. Philadelphia, PA: J.B.Lippincott Company.
7. ACGIH [1994]. Documentation of threshold limit values and biological exposure indices (with 1995 supplements). 7th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.
8. NIOSH [1990]. Pocket guide to chemical hazards. Cincinnati, OH: U.S. Departmentof Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 90-117.

9. NIOSH [1992]. NIOSH recommendations for occupational safety and health; Compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control; National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-100.
10. Code of Federal Regulations [1989]. 29 CFR 1910.1000. Washington, DC: U.S. Government Printing Office, Federal Register.
11. ACGIH [1995]. Threshold limit values and biological exposure indices for 1995-1996. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.
12. NRC [1985]. Emergency and continuous exposure guidance levels for selected contaminants. Washington, DC: National Research Council. Nat'l Academy Press.
13. Axelson O. Hogstedt C [1988]. On the health effects of solvents. In: Zenz C, ed. Occupational medicine, principles and practical applications. 2nd ed. Chicago, IL: Year Book Medical Publishers, Inc., p 775.
14. Cone JE [1986]. Health hazards of solvents. Occupational Medicine: State of the Art Reviews 1(1):69-87.
15. Doull J. Klaassen C, Amdur MO, eds [1980]. Casarett and Doull's toxicology: the basic science of poisons. 2nd ed. New York, NY: Macmillan Publishing Company, Inc.
16. ILO [1983]. Stewart RD, Trichloroethanes. In: Encyclopedia of Occupational Health and Safety. Vol II/I-z. Geneva: International Labour Office. p 2214.
17. AIHA [1989]. Odor thresholds for chemicals with established occupational health standards. American Industrial Hygiene Association.
18. NIOSH [1981]. NIOSH/OSHA occupational health guidelines for chemical hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 81-123.
19. NIOSH [1978]. Criteria for a recommended standard: occupational exposure to diisocyanates. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 78-215.
20. NIOSH [1994]. Pocket guide to chemical hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94-116.
21. NIOSH [1986]. Occupational respiratory diseases. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 86-102.
22. Levy BS, Wegman DH (editors) [1988]. *Occupational Health: Recognizing and Preventing Work-Related Diseases.* Second Edition. Boston/Toronto: Little, Brown and Company.
23. Weill H [1979]. Epidemiologic and medical-legal aspects of occupational asthma. *The Journal of Allergy and Clinical Immunology 64*:662-664.
24. Porter CV, Higgins RL, Scheel LD [1975]. A retrospective study of clinical, physiologic, and immunologic changes in workers exposed to toluene diisocyanate. *American Industrial Hygiene Association Journal 36*:159-168.
25. Adams WGF [1975]. Long-term effects on the health of men engaged in the manufacture of tolylene diisocyanate. *British Journal of Industrial Medicine 32:*72-78.
26. White WG, Sugden E, Morris MJ, Zapata E [1980]. Isocyanate-induced asthma in a car factory. *Lancet i:*756-760.
27. Chan Yeung M, Lam S [1986]. Occupational asthma. *American Review of Respiratory Disease 133*:686-703.

28. NIOSH[1981]. Technical report: respiratory and immunologic evaluation of isocyanate exposure in a new manufacturing plant. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National hlstitute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 81-125.
29. Burge P [1989]. Diagnosis of occupational asthma. *Clinical and Experimental Allergy* 19:649-652.
30. McKay RT, Brooks SM [1981]. Toluene diisocyanate (TDI): biochemical and physiologic studies. *American Review of Respiratory Disease 123*:132.
31. Zammit-Tabona M, Sherkin M, Kijek K, Chan H. Chan-Yeung M [1983]. Asthma caused by diphenylmethane diisocyanate in foundry workers. *American Review of Respiratory Disease 128*:226-230.
32. Siracusa A, Curradi F. Abritti G [1978]. Recurrent nocturnal asthma due to tolylene diisocyanate: a case report. Clinical Allergy 8:195201.
33. Rosenberg C, Tumomi T [1984]. Airborne Isocyanates In Polyurethane Spray Painting: Determination and Respiratory Efficiency. *Amer. Ind.Hyg.Assoc. Jr 45*:117-121.
34. Vasta JF [1985]. Respirator Cartridge Evaluation for Isocyanate Containing Imron and Centari Enamals. *Amer. Ind. Hyg Assoc. Jr. 46*:39-44.
35. Dharmarajan V, Lingg RD, Hackathorn DR [1986]. Evaluation of Air-Purifying Respirators for Protection Against Toluene Diisocyanate Vapors. *Amer. Ind. Hyg Assoc. Jr. 47:*393-398.
36. European Chemical News [1982], 39: issue 1057, p.24.
37. Ward WD [1986]. Anatomy & physiology of the ear: normal and damaged hearing. Chapter 5. In: Berger EH, Ward WD, Morrill JC, Royster LH, eds. Noise & hearing conservation manual. 4th ed. Akron, OH: American Industrial Hygiene Association, pp. 177-195.
38. Ward WD, Fleer RE, Glorig A [1961]. Characteristics of hearing loss produced by gunfire and by steady noise. Journal of Auditory Research 1:325-356.
39. Code of Federal Regulations [1992]. OSHA. 29 CFR 1910.95. Washington, DC: U.S. Government Printing Office, Federal Register.
40. NIOSH [1972]. Criteria for a recommended standard: occupational exposure to noise. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Health Services and Mental Health Administration, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 73-11001.
41. ASHRAE [1989]. Ventilation for Acceptable Indoor Air Quality, ASHRAE 62-1989. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. Atlanta, Georgia.

Table 1

Summary of Air Sample Results for Hexamethylene Diisocyanates

Matrix Auto Body

Englewood, Colorado

HETA 95-0406

August 30,1995

Sample	Sample Description	On	Off	Sample Time (min)	Volume at 1 Lpm (m^3)	Concentration (µg/m^3)	
						Monomer	Oligomer
IMA-20	Personal-Dave-Vehicle#1	11:00	12:40	100	0.100	<30	<30
IMA-21	Personal-Dave-Outside Booth	12:40	2:16	96	0.096	<31	<31
IMA-22	Area-Mixing Table outside Booth #1	10:55	2:53	238	0.238	<13	<13
IMA-23	Area-Inside Paint Booth	12:21	4:18	234	0.234	40.0	<13
IMA-24	Personal-Dave-In/Out Paint Booth	3:29	4:15	46	0.046	<65	261
IMA-25	Personal-Paul	3:20	4:00	40	0.040	<75	(50)
IMA-26	Area-Mixing Table Outside Booth#2	2:54	4:20	46	0.086	<35	(47)
Analytical Limit Of Detection (µg/sample)						3	3

NIOSH Recommended Exposure Limit: HDI 35 µg/m^3 for TWA, 140 µg/$m^3$for 10-min Ceiling
OSHA Permissible Exposure Limit: none

Table 1a

Summary of Air Sample Results for

Hexamethylene Diisocyanates

Matrix Auto Body

Englewood, Colorado

HETA 95-0406

March 6, 1996

Sample	Sample Description	On	Off	Sample Time (min)	Volume at 1 Lpm (m^3)	Concentration (µg/m^3)	
						Monomer	Oligomer
IMX-41	Personal-Dave-Paint Booth	1:30	3:17	107	0.107	<47	514.0
IMX-42	Personal-Nick-Clear coat	3:57	4:36	39	0.039	<128	564
IMX-43	Personal-Pat	4:07	4:58	51	0.051	<98	1529.4
IMX-44	Personal-Dave-Clear coat	4:22	5:23	61	0.061	<82	<82
IMX-40	Area-In Paint Area	4:24	5:23	59	0.059	<85	898
Analytical Limit of Detection (µg/sample)						5	5

NIOSH Recommended Exposure Limit: HDI 35 µg/m^3 for TWA, 140 µg/m^3 for 10-min Ceiling
OSHA Permissible Exposure Limit: none

Table 2

Summary of Air Sample Results for Organics

Matrix Auto Body

Englewood, Colorado

HETA 95-0406

August 30, 1995

Sample	Sample Description	On	Off	Sample Time	Volume at .2 Lpm	Concentration (mg/m^3)				Mixture REL/PEL
						n-Butyl	Toluene	Xylene	Ethyl	

				(min)	(m^3)	Acetate			Acetate	
CMA-20	Area-Mixing Table	10:55	11:31	36	0.0072	67	82	13	6.4	0.35
CMA-21	Personal-Dave Out Booth	12:40	2:17	97	0.0194	13	1.3	4.6	ND	0.03
CMA-22	Area-In Booth	12:21	2:59	158	0.0316	21	1.6	6.6	ND	0.05
CMA-23	Personal-Dave Vehicle #1	11:00	12:41	101	0.0202	35	15	10	7.9	0.12
CMA-24	Area-Mixing Table	11:32	2:53	201	0.0402	77	32	17	3.2	0.24
CMA-25	Personal-Dave In/Out Booth	3:29	4:15	46	0.0092	109	88	41	72	0.53
CMA-26	Area-Mixing Table	2:54	4:20	86	0.0172	157	145	47	49	0.75
CMA-27	Personal-Paul	3:20	4:00	40	0.0080	125	19	31	41	0.33
CMA-28	Area-Inside Paint Booth	3:00	4:18	78	0.0156	26	20	9.6	18	0.12
NIOSH Recommended Exposure Limit-8 hour TWA-mg/m^3 (ppm)						710 (150)	375 (100)	435 (100)	1400 (400)	1.0
OSHA Permissible Exposure Limit-8 hour TWA-mg/m^3 (ppm)						710 (150)	375 (100)	435 100	1400 (400)	1.0

Table 2a

Summary of Air Sample Results for Organics

Matrix Auto Body
Englewood, Colorado

HETA 95 0406

March 6, 1996

Sample	Sample Description	On	Off	Sample Time (min)	Volume at .2 Lpm (m^3)	Concentration (mg/m^3)				Mixture REL/PEL
						n-Butyl Acetate	Toluene	Xylene	Ethyl Acetate	
CMX-20	Personal-Pat- Booth #1	2:15	3:50	95	0.0190	42	6	10	1.3	0.10
CMX-21	Personal-Dave- Clear coat	4:22	5:23	61	0.0122	139	131.1	55.7	123	0.76
CMX-22	Personal-Nick- Clear coat	3:57	5:03	66	0.0132	106	49	31	52.3	0.39
CMX-23	Personal-Dave- Paint Booth	1:30	3:20	110	0.0220	268	50	36	11.4	0.60
CMX-24	Area-Paint Booth	9:21	2:01	280	0.0560	36	21	14	5.4	0.14
CMX-25	Area-Next to Paint Scale	1:33	4:10	157	0.0314	169	15	23	6	0.34
CMX-26	Personal-Pat- Booth #2	2:02	5:23	201	0.0402	184	60	37	42	0.53
CMX-27	Personal-Pat	4:07	4:28	51	0.0102	27	8	22	4	0.11
CMX-28	Area-In Paint Area	4:24	5:23	59	0.0118	119	110	45.8	102	0.64
NIOSH Recommended Exposure Limit-8 hour TWA-mg/m^3 (ppm)						710 (150)	375 (100)	435 (100)	1400 (400)	1.0
OSHA Permissible Exposure Limit-8 hour TWA-mg/m^3 (ppm)						710 (150)	375 (100)	435 (100)	1400 (400)	1.0

Table 3

Summary of Air Sample Results for Total Dust

Matrix Auto Body

Englewood, Colorado

HETA 95-0406

August 30, 1995

Sample	Sample Description	On	Off	Sample time (min)	Volume at 2 Lpm (m^3)	Concentration (mg/m^3)
95-2276	Area-Mixing Table Outside Booth #1	10:55	2:53	238	0.476	3.9
95-2031	Personal-Dave-Vehicle#1	11:00	12:40	100	0.200	9.1
95-2267	Area-Inside Paint Booth	12:21	4:18	237	0.474	3.5
95-2269	Personal-Dave-Outside Booth	12:40	2:16	96	0.192	12
95-2274	Area-Mixing Table Outside Booth #2	2:54	4:20	86	0.172	20
95-2266	Personal-Paul	3:20	4:00	40	0.080	12
95-2268	Personal-Dave-In/Out Paint Booth	3:29	4:15	46	0.092	30

OSHA Permissible Exposure Limit = 15 mg/m^3 for Total Dust as an 8-hr TWA

Table3a

Summary of Air Sample Results for Total Dust

Matrix Auto Body

Englewood, Colorado

HETA 95~406

March 6, 1996

Sample	Sample Description	On	Off	Sample Time (min)	Volume at 2 Lpm (m^3)	Concentration (mg/m^3)
95-3227	Personal-Casey	9:30	11:16	106	0.212	4.1
95-3205	Personal-Dave-In Paint Area	1:30	3:20	110	0.220	7
95-3211	Area-Next to Paint	1:33	4:10	157	0.314	3.2
95-3213	Personal-Pat-Paint Booth	2:15	3:50	95	0.190	12
95-3197	Personal-Nick-Clear Coat	3:57	5:03	66	0.132	8.6
95-3223	Personal-Pat	4:07	4:58	51	0.102	35
95-3222	Personal-Dave-Clear coat	4:22	5:23	61	0.122	30
95-3230	Area-In Paint Area	4:24	5:23	59	0.118	26

OSHA Permissible Exposure Limit = 15 mg/m^3 for Total Dust as an 8-hr TWA

Table4

Summary of Air Sample Results for Metals

Matrix Auto Body

Englewood, Colorado

HETA 95-406

March 6, 1996

Sample	Sample Description	Sample Time (min)	Volume at 2 Lpm (m^3)	Concentration (mg/m^3)						
				Aluminum	Barium	Calcium	Iron	Magnesium	Maganese	Zinc
AMX-50	Personal-Casey-Welding	104	0.2080	0.023	0.023	0.067	0.063	0.030	0.007	0.023
AMX-51	Personal-Casey-Welding	90	0.1800	0.026	0.089	0.061	0.467	0.036	0.010	0.067
NIOSH Recommended Exposure Limit-8 hour TWA-mg/m^3				10	0.5	2	5	--	1	5
OSHA Permissible Exposure Limit-8 hour TWA-mg/m^3				15	0.5	5	10	15	C5	5

(Figure 1 will be available soon)

Figure 1: Carbon Monoxide Levels in Center of Shop, Matrix Auto Body 3/6/96