IN-DEPTH SURVEY REPORT

CONTROL TECHNOLOGY FOR AUTOBODY REPAIR AND PAINTING SHOPS

AT

Cincinnati Collision Autobody Shop
Blue Ash, Ohio

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SUMMARY

At this autobody shop, National Institute for Occupational Safety and Health (NIOSH) researchers evaluated the ability of the following equipment to control or reduce worker exposure to air contaminants ventilated sanders, two vehicle preparation stations, a spray painting booth, and high-volume, low-pressure (HVLP), spray-painting guns Orbital and in-line sanders were evaluated while operating with their ventilation system connected and disconnected Three types of spray paint guns were used HVLP, gravity feed, and siphon cup Air sampling was conducted during sanding and spray painting operations Ventilation measurements were made to document ventilation system performance Video exposure monitoring (concurrently videotaping a worker's activities and instrumentally monitoring a worker's air contaminant exposure) was conducted during two sanding operations and four paint jobs in the spray painting booth

Sanders equipped for high-velocity, low-volume (HVLV) ventilation were evaluated In these sanders, air is exhausted through holes in the sandpaper and sanding pad In addition, samples were collected while nonventilated sanders were used Ventilated sanders are connected to one of eighteen outlets from a central vacuum system When ventilated sanders were used, total dust exposures were below 2 mg/m^3 An aerosol photometer was used to monitor a worker's dust exposure while he used an in-line and an orbital sander with and without ventilation These measurements showed that the sander's ventilation reduced relative dust concentrations by a factor of 20

Two semi-downdraft vehicle preparation stations were studied At the vehicle preparation station, the car to be repaired is placed under an air shower The air shower consists of an air distribution plenum and filters through which the air flows The air flows out of the air shower, over and around the car or object being painted, and toward a second set of filters located near the floor at the far end of the station Then, the air can be recycled back into the air distribution plenum for the air shower However, the workers usually did not use this "recycle mode" and the contaminated air is discharged through a duct to the outside of the building In this mode of operation, the air shower is not used Each station operated at about 12,000 cfm and air velocities were 100 fpm within 4 feet of the exhaust face When these stations were used for painting, overspray escaped into the surrounding areas, potentially exposing the painter and other workers in the area One air sample exceeded Oregon's permissible ceiling exposure limit for HDI polyisocyanates of 1 mg/m^3 The Occupational Safety and Health Administration (OSHA), NIOSH and American Conference of Governmental Industrial Hygienists (ACGIH) have not yet developed exposure limits for prepolymerized diisocyanates Neither the sum of individual personal solvent concentrations nor the total dust concentrations exceeded OSHA permissible exposure limits (PELs) or NIOSH recommended exposure limits (RELs)

In the downdraft spray painting booth, air enters the booth through a plenum extending the full length and width of the ceiling The air passes down over and around the vehicle and is exhausted from the booth through an opening in the floor that is the full length and width of an average vehicle The contaminated air is discharged through a duct to the outdoors The booth

operated at 12,000 cfm, near its designed flow rate of 14,000 cfm The air velocity around cars in the booth ranged between 45 to 130 fpm When the workers painted the side of the car, the ventilation tended to keep the overspray away from the worker When the workers painted the sides of cars in this booth, isocyanate and polyisocyanate concentrations did not exceed the Oregon's or the United Kingdom's standard exposure limits for polyisocyanates Neither the sum of the individual personal solvent concentrations nor the total dust concentrations exceeded OSHA PELs or NIOSH RELs

In the spray painting booth, the concentration data was evaluated to determine whether the type of spray painting gun affected total dust concentrations This analysis was done because the HVLP spray painting guns are reported to be more efficient than other types of spray painting guns The results of the study show that the HVLP spray painting guns were not associated with significantly lower total dust concentrations However, the fraction of the time that the different guns were used during the sampling periods was found to be an important covariate To some extent, the observed difference between the different types of spray painting guns is being affected by differences in the faction of time spent paint for the two different guns After adjusting for the effect of this covariate, there is about a factor of 2 difference in the total dust concentrations attributed to the type of spray painting gun However, this difference is not statistically significant (prob >|t| = 19) Thus, one can not make a conclusion as to whether spray painting gun affects exposure to paint overspray

Even though this booth controls much of the worker's exposure to paint overspray, respiratory protection is still needed because the booth does not completely control the worker's exposure to overspray Furthermore, air velocities caused by the spray guns appear to be much higher than the booth's air velocities, resulting in some risk of inadvertent overspray exposure The respirator program, as required by OSHA's respiratory protection standard (29CFR1910 134), is lacking at this body shop

INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) is the primary federal organization engaged in occupational safety and health research Located in the Department of Health and Human Services (DHHS), it was established by the Occupational Safety and Health Act of 1970 This legislation mandated NIOSH to conduct a number of research and education programs separate from the standard setting and enforcement functions conducted by the Occupational Safety and Health Administration (OSHA) in the Department of Labor An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards The Engineering Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering has been given the lead within NIOSH to study the engineering aspects of hazard control

Since 1976, ECTB has conducted several assessments of health hazard control technology based on industry, common industrial process, or specific control techniques The objective of each of these studies has been to document and evaluate effective techniques for the control of potential health hazards in the industry or process of interest, and to create a more general awareness of the need for, or availability of, effective hazard control measures

This study of autobody repair was undertaken by ECTB to provide information on control technology for preventing occupational disease in this industry This project is part of a NIOSH special initiative on small business and involves developing and evaluating control strategies and disseminating control technology information to a small business Several types of candidate small businesses with potential hazards were originally identified from letters from OSHA state consultation programs These letters, along with state consultation program contacts, discussions with the Division of Surveillance Hazard Evaluations and Field Studies (DSHEFS) and the Division of Respiratory Disease Studies (DRDS), and literature reviews identified a list of small businesses suitable for control technology studies From this list of small businesses, autobody repair and painting shops were one of several potential workplaces that were selected for study

The objective of this study of autobody repair and painting shops is to provide these shops with information about practical, commercially-available methods that control worker exposures to air contaminants (e g , isocyanates, refined petroleum solvents, spray paint mists, and airborne particles) To develop this information, commercially available control methods must be evaluated in actual shops Control measures to be studied include ventilated sanders and welders, vehicle preparation stations, and spray painting booths The results of individual field evaluations will be compiled with the available literature This control technology information will then be disseminated to autobody workers, owners, and operators of autobody repair and painting shops, and safety and health professionals

As part of this overall study, techniques for controlling air contaminants generated during painting operations are being studied At this particular body shop, ventilated sanders, two vehicle preparation stations, a downdraft spray paint booth, and two types of spray painting guns were studied

SHOP DESCRIPTION

There are five body repair technicians, three painters, and two general shop personnel (parts man, shop janitor, etc), and three office workers in this autobody shop As part of general maintenance, one man is assigned to continuously clean the autobody shop Also, every two months, the walls of the shop are cleaned using a pressure washer

The shop opened in 1990 and repairs and paints 25 to 30 vehicles per week Approximately 10 percent of the paint jobs involve the roof, 40 to 50 percent the hood and trunk sides, and practically all of the jobs involve the sides of a vehicle The layout of the shop is illustrated in Figure 1 In the surface body repair area, the vehicle's structural damage is repaired This involves sanding, grinding, and welding Sanding involves the removal of old paint or excess body filler compound to provide a smooth surface for the paint Both ventilated and nonventilated sanders are used After the vehicles are repaired, they are moved to the paint preparation area and readied for painting Some sanding with ventilated and nonventilated sanders can also take place in this area of the shop After the vehicle's surface has been prepared and masked as needed, it is painted in the downdraft spray paint booth

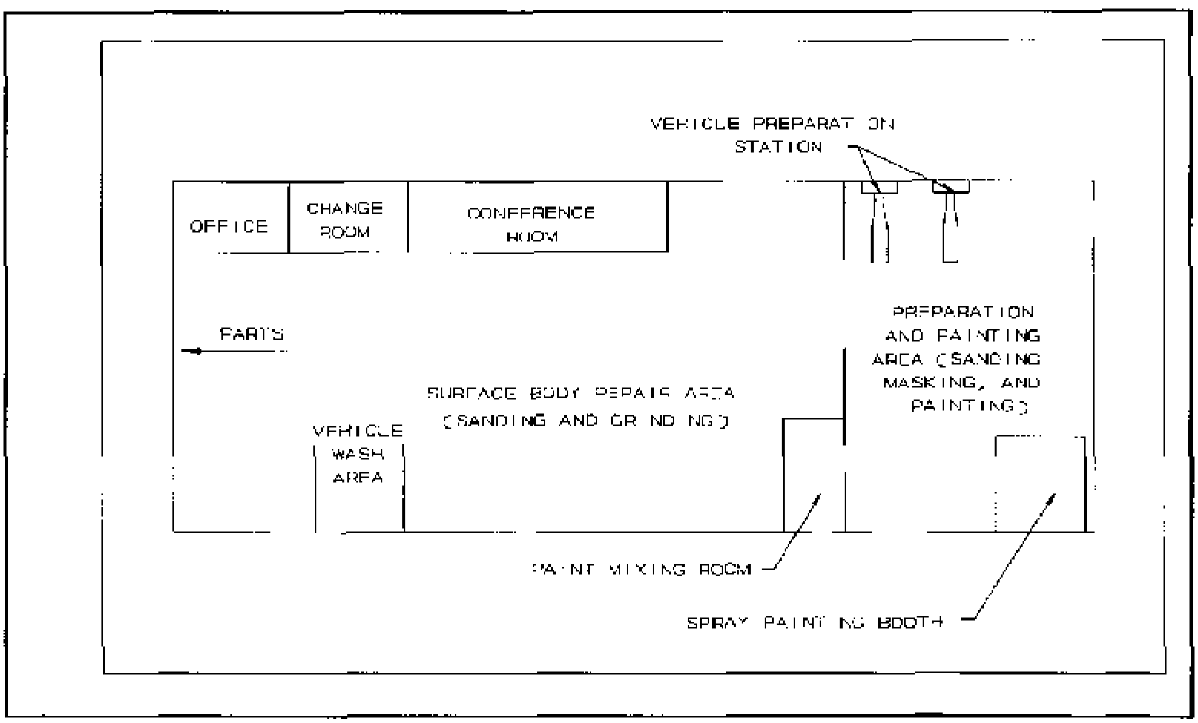

Figure 1 Sketch of the autobody shop and location of the paint booth

Both ventilated and nonventilated sanders were used in this shop The ventilated orbital sander (Industrial Pneumatic Speed Sander, Hutchins Manufacturing Company, Pasadena, CA) has a 6" diameter disk and six holes punched in the sandpaper The nonventilated orbital sander (DAQ, National Detroit Inc , Rockford, IL) also has a 6" diameter disk The ventilated in-line sander (Hustler, Pasadena, CA) is a single piston drive sander with a 3" by 16" sanding surface and 18 holes punched in the sandpaper The ventilated sanders are connected to a central vacuum system (EG&G Rotron, Model DR707089X) As part of the system, a cyclone separator is used to collect particulates before discharging the air outdoors The central vacuum system has nine hookups with a double outlet on each hookup These hookups extend the length of the Surface Body Area and into the Preparation Area The measured pressure at each hookup is about 6 inches of mercury

In 1990, two "Welbilt" F B (no model number) semi-downdraft vehicle preparation stations were installed Its dimensions are given in Figures 2 and 3 The vehicle and/or parts are positioned under the overhead arm and near the exhaust filters When painting is done at this station, the ventilation system is operated in the "exhaust mode", the air is exhausted through filters and a duct leading to the outside of the building After painting, the worker leaves the ventilation system running in the exhaust mode The station can also be operated in the "recycle mode " When the damper is closed, the exhausted airflow is redirected into the overhead arm plenum, through a second set of filters, down, over, and horizontally pass the object(s) being sanded or painted, and back through the exhaust filters at the floor level The painters normally do not use the recycle mode because solvent vapors would be recirculated

In 1990, an above ground, downdraft spray painting booth with ramp access was installed (See Figure 4) This spray painting booth is a "Welbilt" F B (Model 90) The inside dimensions of the spray painting booth areas follows 13 feet wide, 23 feet long, and 8 25 feet high There are two fans, each rated at 14,000 cfm The first fan draws air through filters at the intake and pushes air through duct work, an air distribution plenum on the roof of the booth, and filters in the ceiling of the booth In the booth, the air flows down, around the vehicle, and through a third set of filters located in the floor of the booth (see Figures 4 and 5) The second fan is downstream of the booth and pushes air through a duct which leads to the roof of the building The empty booth is designed to operate at a static pressure of +0 25 inches relative to the room

According to the shop manager, the air supply filters in the ceiling of the paint booth and preparation station are changed annually in autumn The exhaust filters and the filters for the heat exchanger are changed weekly At the start of the study, the exhaust and heat exchanger filters were 10 days old and were not changed during the study The painters observed more dust on painted surfaces when the filters are two or more weeks old

After the vehicle and/or parts to be painted are positioned in the spray painting booth, the doors are closed and the ventilation system is turned on Then, the painter fills his spray gun, enters the booth and connects the gun

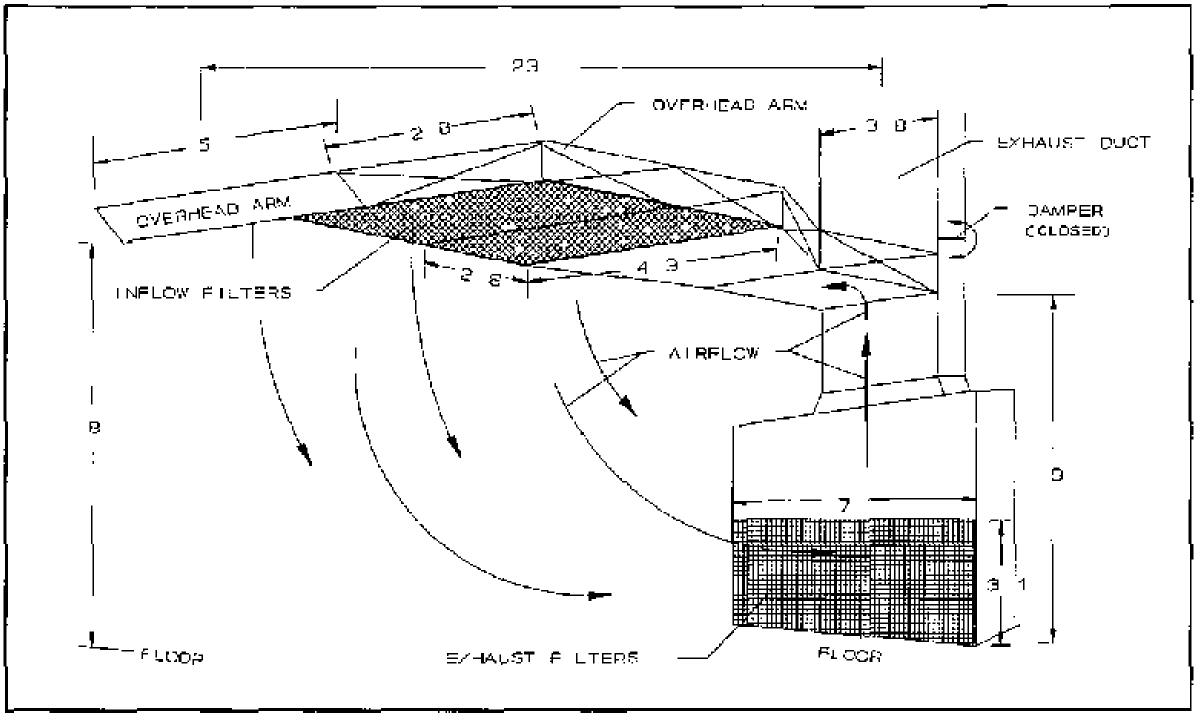

Figure 2 Vehicle preparation station and its airflow patterns while operating in the "recycle mode "

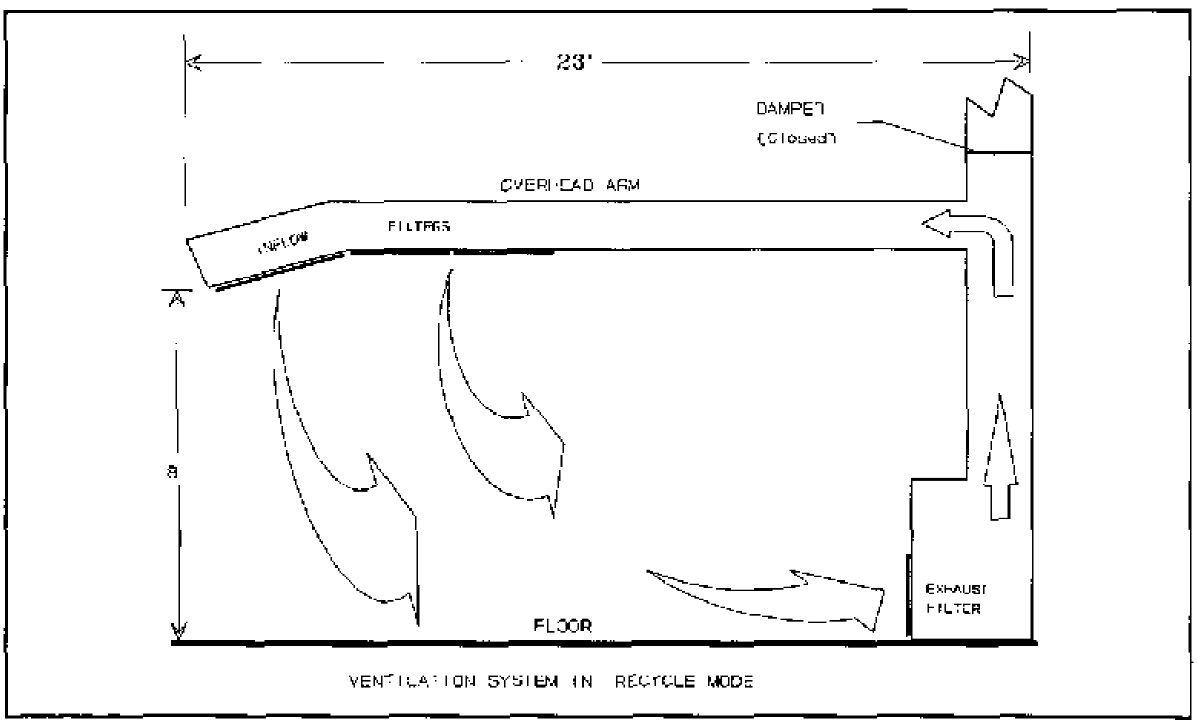

Figure 3 Side view of vehicle preparation station

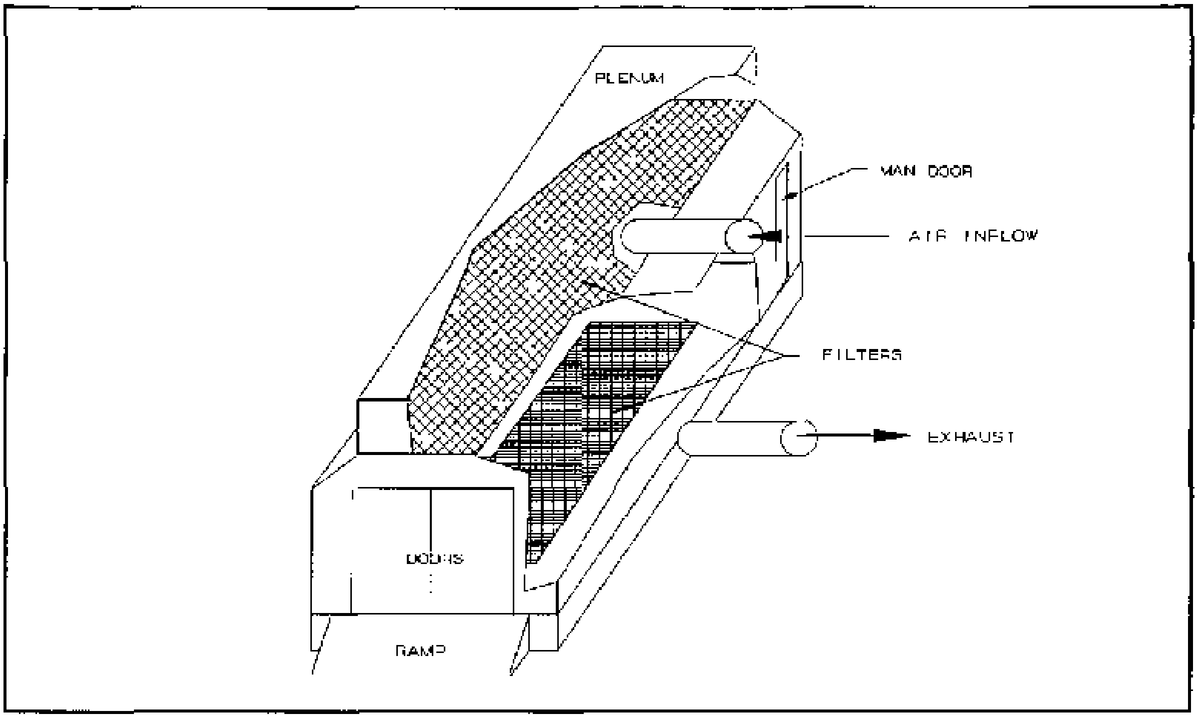

Figure 4   Downdraft spray paint booth

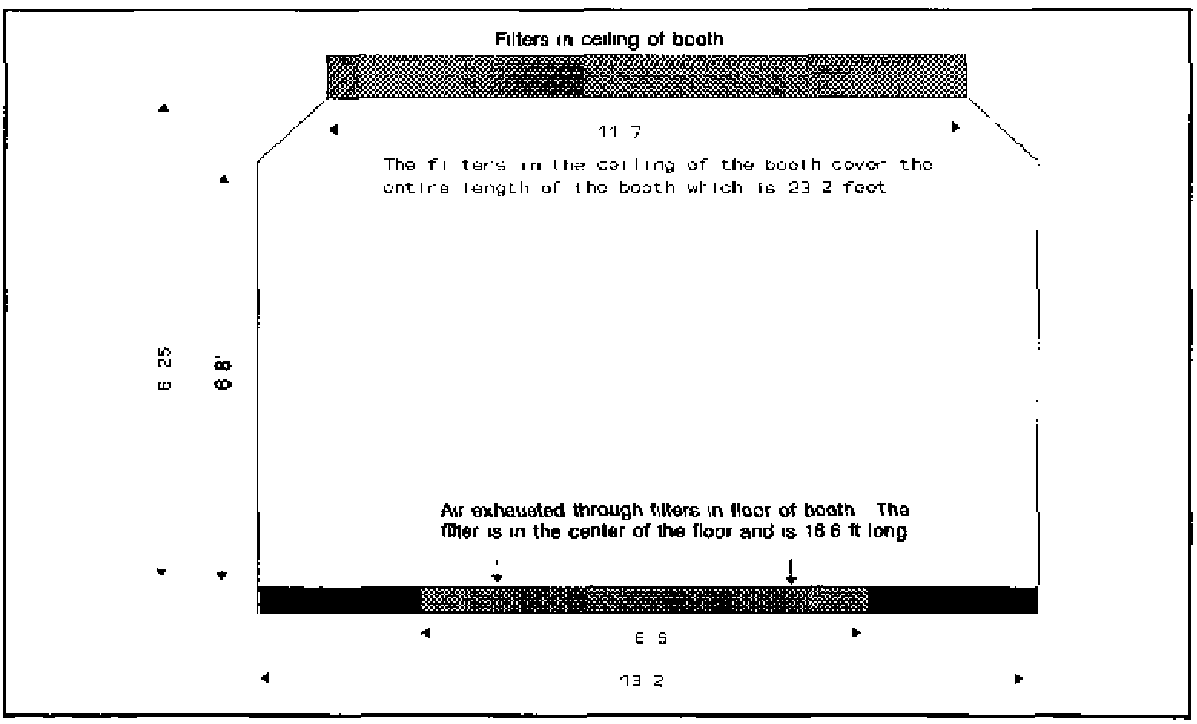

Figure 5   Inside dimensions of the downdraft spray painting booth

to an air line After the vehicle or part(s) have been painted, the worker leaves the painting chamber and switches the booth to the curing cycle to cure the paint at temperatures of 120° to 140°F During the curing cycle, airflow is reduced with about 90 percent of the exhaust air being recycled

To apply the primer, paint, and clear coat, the painters used a variety of spray painting guns The HVLP, spray-painting gun is a Mattson Atom-Miser™ (Model LP-DC), the gravity-feed, spray-painting gun is a DeVilbiss (Model GFG 503), and the siphon-cup, spray-painting guns are a DeVilbiss (Model JGA 502) and a Binks (Model 7 and Model 62)

In the HVLP, spray-painting gun, controlled air pressure is supplied to meter the flow of paint into the orifice where atomization occurs The air pressure at this point is less than 10 psi Reportedly, HVLP spray guns are much more efficient at transferring the paint from the gun to the car than for the siphon cup or gravity feed spray painting guns HVLP guns are believed to have a transfer efficiency of at least 65 percent Some air pollution control districts require the use of spray painting equipment with a transfer efficiency of at least 65 percent [1]

In a siphon cup gun, the acceleration of the airflow through an orifice causes a reduction in static pressure The reduced static pressure causes the paint to flow from the cup into the orifice where the paint is atomized Air pressure at the atomization orifice is typically 65 psi

Gravity feed guns were infrequently used in this shop In a gravity feed gun, the paint reservoir is in a cup on top of the spray gun and gravity assists the flow of paint to the orifice where atomization takes place The air pressure at the orifice of these guns is typically 40 to 50 psi Some manufacturers believe that gravity feed guns produce less overspray than conventional siphon cup guns

In this shop, most painting jobs involve the application of a primer (1 coat), base coat (3 coats), and clear coat (3 coats) Typically, the base coat contains colored pigments and carrier solvents For the paint jobs observed during this study, the material safety data sheets for the base coats used listed the following metals chromium, nickel, antimony, and titanium A clear coat is applied over the base coat Clear coat is composed of the following two components a clear and a hardener The clear is based upon polyurethane or polyol and acrylic resins The hardener contains polyisocyanates which are trimers of hexamethylene diisocyanate

RESPIRATOR USAGE

In this shop, respirators are supplied and inspected by local representatives of Zee Medical (Irvine, CA) Zee Medical supplies half-face piece respirators which are manufactured by Glendale (NIOSH approval number 21TC23-88) Respirators not being used are stored in a metal cabinet which has a space for each worker's respirators Zee Medical used qualitative fit tests to select respirators for each individual in this autobody shop However, two painters had partial beards which would interfere with the seal between the respirator and his face These workers would receive inadequate protection from their respirators [2] Zee Medical does not fit test workers with beards which interfere with respirator fit This autobody shop did not have a written respirator program According to advertisements, Zee Medical can provide a fill-in-the-blanks, generic, written respirator program for their customers

Each worker is responsible for keeping his respirator clean and the filters changed Cleaning ranges from wiping with a dry or wet rag, to using water, soapy water, or a glass cleaner The frequency of filter changes varied from twice a week to once every two weeks Most of the workers were clean shaven The workers were given some instructions on how to properly wear and clean their respirators However, the company's respirator program, as compared to that described by OSHA standards,[3] appears to be incomplete

POTENTIAL HAZARDS

The International Agency for Research on Cancer (IARC) has reviewed the health effects associated with painting operations [4] In the IARC publication, the term "painters" included workers who apply paint to surfaces during construction, furniture manufacturing, automobile manufacturing, metal products manufacturing, and autobody refinishing After reviewing a wide range of publications, they concluded that "There is sufficient evidence for the carcinogenicity of occupational exposure as a painter " In addition, they noted that painters suffer from allergic and nonallergic contact dermatitis, chronic bronchitis, asthma, and adverse central nervous system effects

Workers involved in autobody repair at this shop are potentially exposed to a multitude of air contaminants During structural repair of a vehicle, activities such as sanding, grinding, and welding generate aerosols which are released into the worker's breathing zone If the surface of the vehicle contains toxic metals such as lead, cadmium, or chromium, exposure to these metals is possible Workers who paint cars are potentially exposed to organic solvents, hardeners which may contain isocyanate resins, and pigments Health effects attributed to the exposures to specific chemicals are discussed in Appendix A

EXPOSURE EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff use exposure limits as evaluation criteria for assessment of a number of chemical and physical agents These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week, for a working lifetime without experiencing adverse health effects Table 1 summarizes exposure limits for air contaminants which may be present in this autobody shop It is 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 preexisting medical condition, and/or a hypersensitivity (allergy)

Table 1   Occupational Exposure Limits

Substance	NIOSH Recommended Exposure Limit (REL)[5]	*OSHA Permissible Exposure Limit (PEL)[6]		ACGIH Threshold Limit Value (TLV)[7]	
	TWA[a]	TWA[b]	STEL[c]	TWA[b]	STEL[c]
Antimony	0 5 mg/m^3	0 5 mg/m^3		0 5 mg/m^3	
n-Butyl Acetate	150 ppm	150 ppm	200 ppm	150 ppm	200 ppm
Chromium (VI), hexavalent	0 001 mg/m^3	0 1 mg/m^3		0 05 mg/m^3	
Chromium (II) compounds	0 5 mg/m^3	0 5 mg/m^3		0 5 mg/m^3	
Chromium (III)	0 5 mg/m^3	0 5 mg/m^3		0 5 mg/m^3	
Ethyl Acetate	400 ppm	400 ppm		400 ppm	
Hexamethylene diisocyanate (HDI monomer)	0 035 mg/m^3 0 14 mg/m^3 (Ceiling)			5 ppb	
Soluble Nickel Compounds (of Ni metal)	0 015 mg/m^3	0 1 mg/m^3		0 1 mg/m^3	
Total Dust (not otherwise regulated) Total Respirable		 15 mg/m^3 5 mg/m^3		 10 mg/m^3 5 mg/m^3	
Toluene	100 ppm 150 ppm (Short Term Exposure Limit)	100 ppm	150 ppm	50 ppm	
Xylene	100 ppm 150 ppm (Short Term Exposure Limit)	100 ppm	150 ppm	100 ppm	150 ppm

*Note In July 1992, the 11th Circuit Court of Appeals vacated revisions to the OSHA PELS listed in 29CFR1910 1000 The OSHA PELs listed in Table 1 were the PELs which were enforced at the time of the study

[a]TWA - Time Weighted Average based upon a 10 hour day, 40 hour work week for a NIOSH Recommended Exposure Limit
[b]TWA - 8-hour Time Weighted Average
[c]STEL - Short-Term Exposure Limit

The primary sources of environmental evaluation criteria in the United States that are used for the workplace are 1) NIOSH Recommended Exposure Limits (RELs), 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs), and 3) the U S Department of Labor (OSHA) Permissible Exposure Limits (PELs) The OSHA PELs are required to consider the feasibility of controlling exposures in various industries where the agents are used, the NIOSH RELs, by contrast, are based primarily on concerns relating to the prevention of occupational disease ACGIH Threshold Limit Values (TLVs) refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects ACGIH states that the TLVs are guidelines It should be noted that ACGIH is a private, professional society, and that industry is legally required to meet only those levels specified by OSHA PELs

At the time of this study, OSHA was enforcing the exposure limits listed in Table 1 Most of these exposure limits were revised in a 1989 revision to the Air Contaminants Standard (29 CFR 1910 1000) In July 1992, the 11th Circuit Court of Appeals vacated this standard OSHA is currently enforcing the version of the Air Contaminants Standard which was in effect before 1989, however, some states operating their own OSHA-approved job safety and health programs will continue to enforce the 1989 limits OSHA continues to encourage employers to follow the 1989 revisions

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 criteria 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

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 that are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures

Generally, spray painters are exposed to multiple solvents To evaluate whether the total solvent exposure is excessive, a combined exposure, C_E, is computed

$$C_E = \frac{C_1}{L_1} + \frac{C_2}{L_2} + \quad + \frac{C_n}{L_n} \qquad (1)$$

Where C_n = Exposure to an individual contaminant, and
L_n = The lowest exposure limit for a specific component listed in Table 1

If the value of C_E is less than 1, the combined exposure is believed to be acceptable

OTHER ENVIRONMENTAL EVALUATION CRITERIA

Although health effects are attributed to prepolymerized diisocyanates, OSHA, NIOSH and ACGIH have not yet developed exposure limit values for these substances [8] The Oregon Occupational Safety and Health Administration has adopted an exposure limit of 1 mg/m^3 as a ceiling and an 8-hour time weighted average of 0 5 mg/m^3 for exposure to HDI polyisocyanates [9] These polyisocyanates are the biuret trimer of HDI (HDI-BT) and the isocyanurate of HDI These exposure limits were set to protect workers from pulmonary irritation and are the same exposure limits published in the manufacturer's material safety data sheet [10] In contrast, Sweden has a 5 minute short-term exposure limit of 0 2 mg/m^3 for occupational exposure to hexamethylene diisocyanate biuret [11]

The United Kingdom's Health and Safety Executive (HSE) has specified a control limit for occupational exposure to diisocyanates and oligomers of these diisocyanates [12] In reviewing the health effects associated with isocyanate exposure, the HSE assumed that the health consequences of inhaling aerosols containing -N=C=O (NCO) functional groups are not different from inhaling diisocyanate monomers As a result, the HSE has specified the following control limits for NCO functional groups in the air

1 An 8-hour Time Weighted Average of 20 $\mu g/m^3$, and
2 A 10-minute ceiling limit of 70 $\mu g/m^3$

During spray painting operations, occupational exposure to isocyanates frequently exceed these control limits [12]

EVALUATION PROCEDURES

The objectives of this site visit was to evaluate the ability of the following equipment to control or minimize worker air contaminant exposure ventilated sanders, semi downdraft vehicle preparation stations, a downdraft spray painting booth, and HVLP spray painting guns This was accomplished by conducting air contaminant exposure monitoring and video exposure monitoring Also, ventilation measurements were made to document airflow volumes through the sanders, within the preparation station work area, and in the spray painting booth

AIR CONTAMINANT EXPOSURE MONITORING

NIOSH Method 0500 was used to measure the worker's total dust exposure [13] A known volume of air is drawn through a preweighed PVC filter For painting operations, a flow rate of 5 0 liters per minute was obtained by using a personal sampling pump (Aircheck Sampler, Model 224 -- PCXR7, SKC Inc, Eighty Four, PA) For sanding operations, a flow rate of 13 liters per minute was obtained by using a critical flow orifice and a vacuum pump which maintained a vacuum of 20 to 25 inches of mercury downstream of the critical flow orifice

The weight gain of the filter is used to compute the milligrams of dust per cubic meter of air After weighing, the filters were analyzed for lead, antimony, chromium, nickel, and titanium The metals on each filter were analyzed using a modification of NIOSH Method 7300 [14] Modifications to NIOSH Methods 0500 and 7300 are presented in Appendices B1 and B2

Material safety data sheets were reviewed to identify organic solvents which may be present during spray painting Exposure measurements were made for the following solvents butyl acetate, ethyl acetate, toluene, and xylene The samples were collected by placing charcoal tubes (SKC lot 120) in a charcoal tube holder and mounting the charcoal tube holder on the worker Tubing connected the charcoal tube holder to a personal sampler pump (Model 200, Dupont Inc) operating at 200 cm^3/min NIOSH Methods 1450 and 1501 were used to determine the mass of organic solvents absorbed onto the charcoal [15] Modifications to this method are presented in Appendix B3

During spray painting operations involving the use of isocyanate hardeners, the concentration of hexamethylene diisocyanate and its trimer were monitored by using NIOSH method 5521 [16] Although this method specifies a flow rate of 1 liters per minute, air samples were collected at a sampling rate of 2 liters per minute in order to increase the sample volume The impinger contains a solution of 1-(2-methoxyphenyl)piperazine, which reacts with the isocyanate to form ureas, in toluene The concentration is 43 mg/L The ureas are quantitated by high pressure liquid chromatography by NIOSH method 5521

Because analytical standards are not available for trimers of diisocyanate monomers, the NIOSH method extrapolates the calibration curve for the hexamethylene diisocyanate monomer to the prepolymers According to the paint manufacturer, the hardener is manufactured by diluting Desmodur N 3300 (Mobay, Pittsburgh PA) or Tolonate HDT 90 (Rhone Poulenc, Princeton, NJ) with organic solvents According to the material safety data sheets, Desmodur N 3300 is nearly 100 percent by mass, respectively, the isocyanurate trimer of HDI (CAS NO 28182-81-2) and Tolonate HDT 90 is 90 percent by mass the trimer of HDI (CAS NO 3779-63-3) [10 17] The HDI monomer is less than 0 2 percent of the total weight of these products The results of NIOSH method 5521 are reported in terms of mass of isocyanate per sample Since monomer standards are used to quantitate the peak areas for the prepolymers, a limit of detection (LOD), for HDI prepolymers could not be calculated directly Modifications to NIOSH Method 5521 are presented in Appendix B4

The ultra violet (UV) response obtained during the NIOSH 5521 analysis method was used to obtain the mass of the isocyanate trimmers in the air sample Analytical standards were made by diluting the Desmodur N3300 and Tolonate HDT 90 into the NIOSH Method 5521 impinger solution After sitting for three days these standards were prepared the same as the samples Samples were quantitated by UV detection These results are reported in terms of mass of Desmodur N3300 or Tolonate HDT 90 per sample

For spray painting operations, air samples were collected at three of the following sampling locations

1. On the upper part of the worker's chest, outside of any respiratory protection that the worker might be wearing,

2. On the side of the spray painting booth, and

3. Near the exhaust filters In a downdraft booth, this sampling location was under the object being painted In a crossdraft or semi-downdraft booth, this location was in front of the filters on the back of the booth

Sample volumes were based upon the sampling time for the worker The pumps on the painter were started shortly before he entered the booth The pumps for the area samples were started before the worker's pump The worker's time was used as the sampling time because there could be no air contaminant generation before the worker started painting

VIDEO EXPOSURE MONITORING

Video exposure monitoring was used to study in greater detail how specific tasks affect the worker's exposure to the air contaminants [18 19] Worker exposures were monitored with direct reading instruments and their analog output were recorded with a data logger Workplace activities were simultaneously recorded on videotape The analog output of the real-time instruments was connected to a data logger (Rustrak Ranger, Gulton, Inc , East Greenwich, RI) When the data collection was completed, the data logger was downloaded to a portable computer (Compaq Portable III, Compaq Computer Corporation, Houston, TX) for analysis

During sanding operations, the Hand-held Aerosol Monitor (HAM, PPM Inc , Knoxville, KY) was used to measure relative dust concentrations The aerosol scatters the light emitted from a light-emitting diode The scattered light is detected by a photomultiplier tube The analog output of the HAM is proportional to the quantity of the scattered light detected by a photomultiplier tube Because the calibration of the HAM varies with aerosol properties such as refractive index and particle size, the analog output of the HAM is reported as a relative dust concentration A personal sampling pump (Aircheck, SKC Inc , Eighty Four, PA) was used to draw air through the HAM's sensing chamber at a rate of 3 5 lpm

During spray painting, a Photovac TIP II (PHOTOVAC Inc, Thornhill, Ontario) was used to monitor worker solvent exposure The analog output of the Microtip is proportional to the concentration of ionizable compounds in the air Because the instrument's response varies with the composition of the organic solvents in the air, the analog output of the Photovac is reported as relative concentrations Because of fire safety considerations, this instrument was located outside of the spray painting booth Teflon® tubing (Alltech Associates, Deerfield, IL), 0 125" inside diameter and 45 feet long, was attached to the worker in his breathing zone A personal sampler pump drew air through this tubing at 3 5 liters per minute and exhausted the sampled air into a glass tee The Photovac then sampled the air in this glass tee

VENTILATION MEASUREMENTS

The exhaust flow rates from the ventilated sanders were measured in the apparatus illustrated in Figure 6 The exhaust flow rate was measured when the sanders were off, when they were on (but not sanding), and when they were sanding metal located on the floor of the apparatus The air velocity in the exhaust duct was measured using a hot wire anemometer (Kurz Digital Air Velocity Meter Model 1440-4, Kurz, Carmel Valley, CA) The exhaust flow rate was calculated as the product of the duct's cross-sectional area and the average velocity in the exhaust duct

At the vehicle preparation stations, the hot wire anemometer was used to measure air velocities at the face of the inflow filters in the overhead arm and at the face of the exhaust filters Airflow volumes were calculated from the measured face velocities and the face area of the inflow and exhaust filters An eighteen-point traverse was made across inflow filters and a 24-point traverse across the exhaust filters The velocities were averaged and the total inflow and exhaust calculated The velocities at 4, 7, and

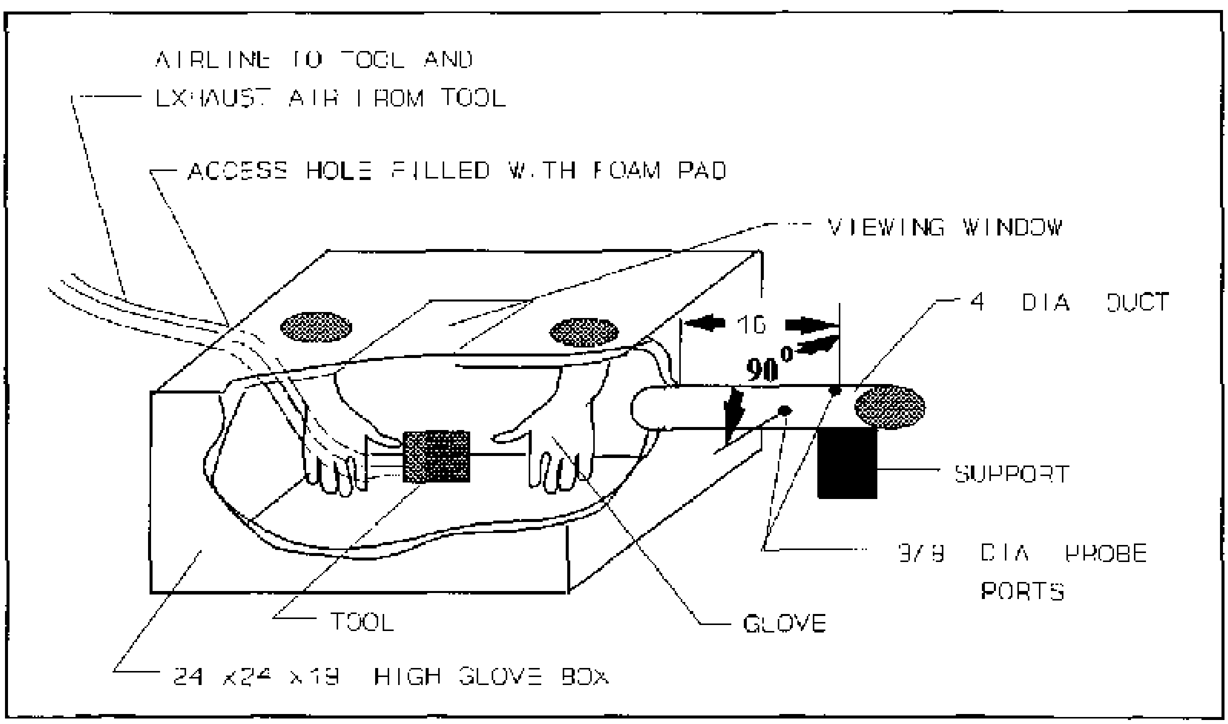

Figure 6 Apparatus for measuring air volumes through ventilated sanders
NOTE The air flows into this box through the 4" diameter duct

14 feet from the exhaust filters and under the overhead arm were also measured while the system was operating in the exhaust mode, recycle off Smoke tubes were used to trace the airflow patterns in the area under the overhead arm

In the spray painting booth, the hot wire anemometer was used to measure air velocities at the face of the inflow filters in the ceiling, the face of the exhaust filters under the grates in the floor, and at several points around a car Air volumes were calculated from the measured face velocities and the face area of the inflow and exhaust channels in the ceiling and floor of the booth A seventy-point traverse was made across ceiling and a 40-point traverse across the exhaust grate in the floor The velocities were averaged and the total inflow and exhaust calculated The velocities at several points, 18" from a vehicle's surface, were also measured Smoke tubes were used to trace the airflow patterns in the spray painting booth An inclined manometer was used to measure the static pressure in the booth during normal painting operations

RESULTS - VENTILATED SANDERS

VENTILATION MEASUREMENTS

Table 2 lists the exhaust flow rates measured for the ventilated sanders Because the compressed air used to drive these sanders is exhausted through the sander's exhaust port, net exhaust ventilation rates decrease somewhat when the sanders are in use

Table 2 Exhaust flow rates for ventilated sanders

Operation	Type of Sander	
	Hutchins Orbital (6" diameter, 6 hole) (cfm)	Hustler In-line (3" x 16", 18 hole) (cfm)
Sander running without touching bottom of box	48	16
Light sanding	27	16
Heavy sanding	26	18

AIR SAMPLING RESULTS

Table 3 summarizes the total dust concentrations measured during sanding operations None of the personal sample measurements exceeded the OSHA PEL of 15 mg/m^3, ranging from 0 22 to 1 9 mg/m^3, (Appendix C, Table C2) Sampling periods ranged from 6 to 27 minutes During the first measurement reported in Table 3, a nonventilated sander was used at the vehicle preparation station with the station's exhaust ventilation on and the recycle off During this time period, the operator kept the dust source between himself and the station's exhaust The parts were set-up at a distance greater than 7 feet from the prep-stations exhaust filters Based upon the ventilation measurements present in Figure 7, the air velocities are too low to control the workers dust exposure The ventilated in-line and orbital sanders were primarily used in the surface body repair area During the last measurement reported in Table 3, a worker used a floor fan to move the airborne dust away from him and toward the area sample During this time period, the floor fan dispersed the visible plume of dust throughout the shop and a concentration of 9 8 mg/m^3 was measured in this plume

Table 3 Summary of dust sampling results during sanding operations

Sander	Surface	Control	N	Range: Personal (mg/m^3)	Range: Area (mg/m^3)
Orbital	paint	Unventilated sanding at the vehicle preparation station	1	1 2	0 12
In-line	body filler compound	Ventilated	3	0 22 - 0 67	0 093 - 0 21
In-line	body filler compound	Unventilated	1	1 9	9 8

VIDEO EXPOSURE MONITORING RESULTS

Figures 7 and 8 depict the relative dust concentrations (based upon aerosol photometer measurements) measured on the worker's chest during two sanding operations on the same door using two ventilated sanders In each case, body filler compound on the same car door was being sanded Also, there was a floor fan blowing air toward the sanding operator Combinations of the floor fan (on and off) and the sander's ventilation (on and off) were compared to a baseline of the average relative exposure during the nonsanding activities With both the floor fan and sander ventilation off, relative dust concentrations were about 20 times higher for both the in-line and rotary sanders than the relative dust concentrations measured with sander ventilation on and the floor fans off Changing the sander paper on the nonventilated

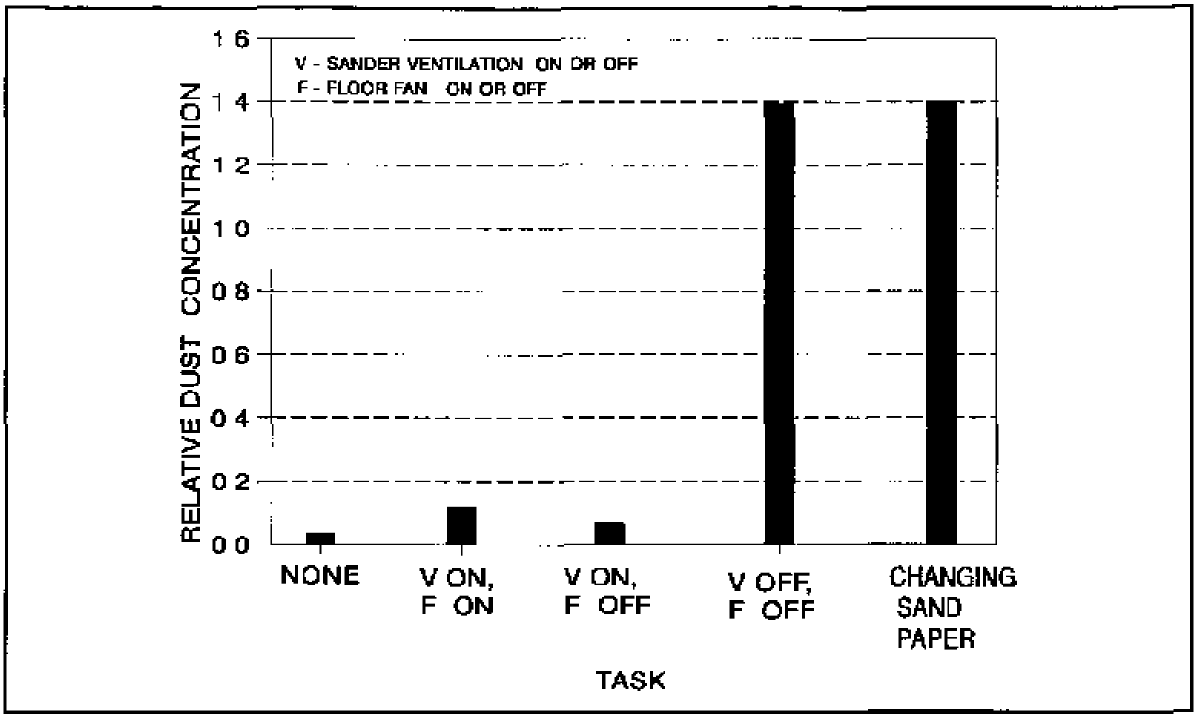

Figure 7 Relative dust concentration when in-line sander is used to smooth body filling compound on the side of a car door

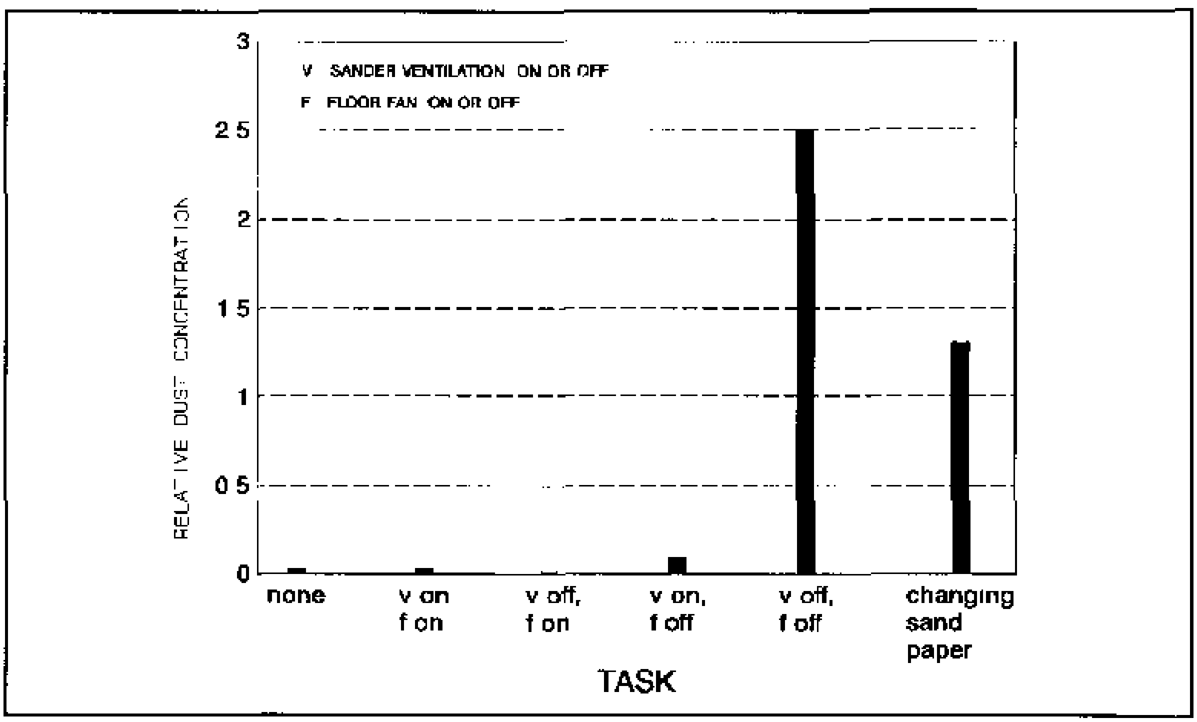

Figure 8 Relative dust concentration when worker is using orbital sander to smooth body filling compound on a car door

sanders causes the relative dust exposure to increase by an order of magnitude over the relative concentrations measured when the ventilated sanders are in use When either the floor fan, the sander ventilation, or both were operating, the relative dust concentrations were within a factor of 2 or 3 of the relative dust concentration measured when there was no activity These results indicate that sanding with the ventilated sanders control dust exposures to approximately 95 percent of levels when the unventilated sander is used When the floor fan is on and the sander ventilation off, dust being generated is dispersed to other areas of the shop and this elevates the dust exposure of all who are in the body shop

RESULTS - VEHICLE PREPARATION STATION

VENTILATION MEASUREMENTS

Based upon the air velocities at the exhaust filter face and the filter area, the exhaust volume for the left and the right filters were, respectively, 12,200 and 12,400 cfm Because these stations were used for painting, the airflow patterns at the vehicle preparation were characterized with the air being exhausted to the outside of the building These results are shown in Figure 9

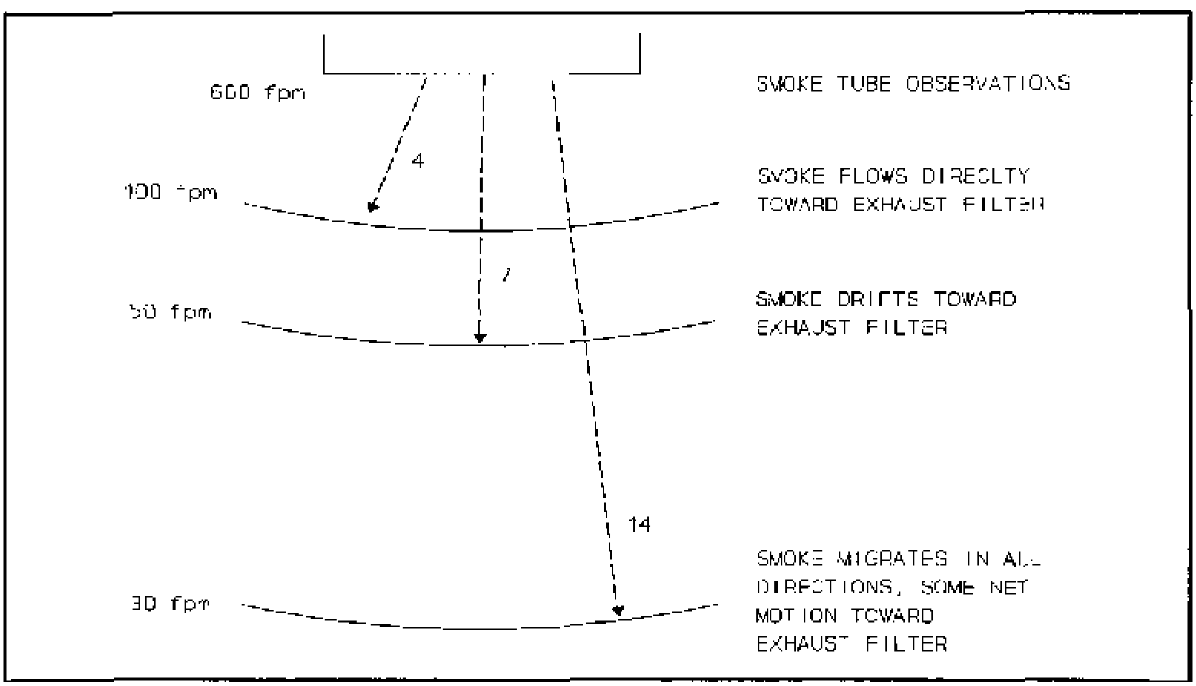

Figure 9 Air velocities and observations of smoke motion at the vehicle preparation station when air shower is not in use

AIR SAMPLING RESULTS - VEHICLE PREPARATION STATION

Table 4 summarizes the total dust concentrations measured at the vehicle preparation area (recycle mode off) during painting operations using a siphon cup spray paint gun At this operation, the concentration measured on the worker was about 50 percent of the concentration measured at the exhaust filter This indicates that the vehicle preparation station's ventilation did not separate the worker from the paint overspray Furthermore, the survey team observed overspray drifting towards other parts of the shop and coating other objects next to the spray painting operation Although not recorded, most of the painting was done at distances greater than 5 to 6 feet from the exhaust filters where the air velocity toward the exhaust filter was less than 50 fpm which is too low to overcome random air motion [20]

Table 4 Summary of Total Dust Concentrations at the Semi Downdraft Vehicle Preparation Station

Location	N	Geometric Mean (GM) (mg/m^3)	Geometric Standard Deviation (GSD)	Range (mg/m^3)	Grouping*
background	3	0 19	3 1	0 10-0 71	A
near filters	3	4 8	2 1	2 7-11	B
personal	5	2 4	3 5	0 32-8 2	B

* Geometric means with different letters differ significantly Multiple comparison test conducted at an overall level of confidence of 95 percent

None of the total dust concentrations measured on the worker exceeded the OSHA PEL of 15 mg/m^3, ranging from 1 8 to 8 2 mg/m^3, (Appendix C, Table C1) Nickel was detected on one personal sample and titanium was detected on a second personal sample at or above the level of their detection limits, 0 5 µg for nickel and 0 3 µg for titanium None of the exposures to metals exceeded the NIOSH RELs

Based upon the combined environmental criteria listed in Table 1, the combined personal exposures (C_E) are less than 1 indicating that the solvent exposures were below acceptable limits One of three samples exceeded the Oregon's ceiling exposure limit standard for HDI polyisocyanates of 1 mg/m^3 None of the samples exceeded the United Kingdom's ceiling exposure limit standard for total HDI prepolymer

RESULTS - SPRAY PAINTING BOOTH

VENTILATION MEASUREMENTS

Based upon air velocities measured at the filter faces in Figure 5 and the filter cross sectional area, the airflow from the ceiling was calculated to be 13,000 cfm and the airflow out the booth through the floor was calculated to be 11,300 cfm The exhaust volume measurements are summarized in Figures 10 and 11 Figure 12 presents two sets of air velocities measured around the car at a height of 3 feet and a distance of 1 5 feet from the car Figure 13 summarizes the air velocities, exhaust volumes, and smoke tube traces made in the spray painting room The airflow is uniformly distributed across the ceiling The air velocity increases from an average of 48 fpm at the ceiling to an average of 84 fpm at a height of 3 feet above the floor and a distance of 1 5 feet from the side of the car After flowing around the car, the air flows through filters located below the metal grate floor As shown in Figure 13, there is a circular eddy next to the walls of the spray painting booth Because the worker does not enter this area, his exposure to air contaminants should not be affected by the accumulation of air contaminants in this eddy

During spray painting, the spray gun's nozzle is held perpendicular or nearly perpendicular to the surface being painted Pressurized air atomizes and propels the spray gun's contents onto the vehicle's surface with some of the spray rebounding and entering the air This is know as overspray When the sides of the car are spray painted, the overspray appears to first move parallel to the floor along the car body After the energy of the jet is dissipated, the overspray appears to flow down toward the filter in the floor of the booth Thus, the overspray appears to stay out of the worker's breathing zone

AIR SAMPLING RESULTS

Based upon the environmental criteria presented earlier in this report, the concentration of air contaminants measured on the worker's lapel were generally acceptable As summarized in Table 5 and listed in Appendix C, the total dust concentrations measured on the worker's lapel were less than the ACGIH TLV for total dust of 10 mg/m^3 as well as the OSHA PEL for total dust of 15 mg/m^3 The metals titanium, lead, chromium, antimony, and nickel were not detected on the personal samples Area sampling results for metals are listed in Appendix C The combined solvent exposures, C_e, for the samples collected on the worker's lapel were all less than 1 which indicates that the overall solvent concentrations are acceptable

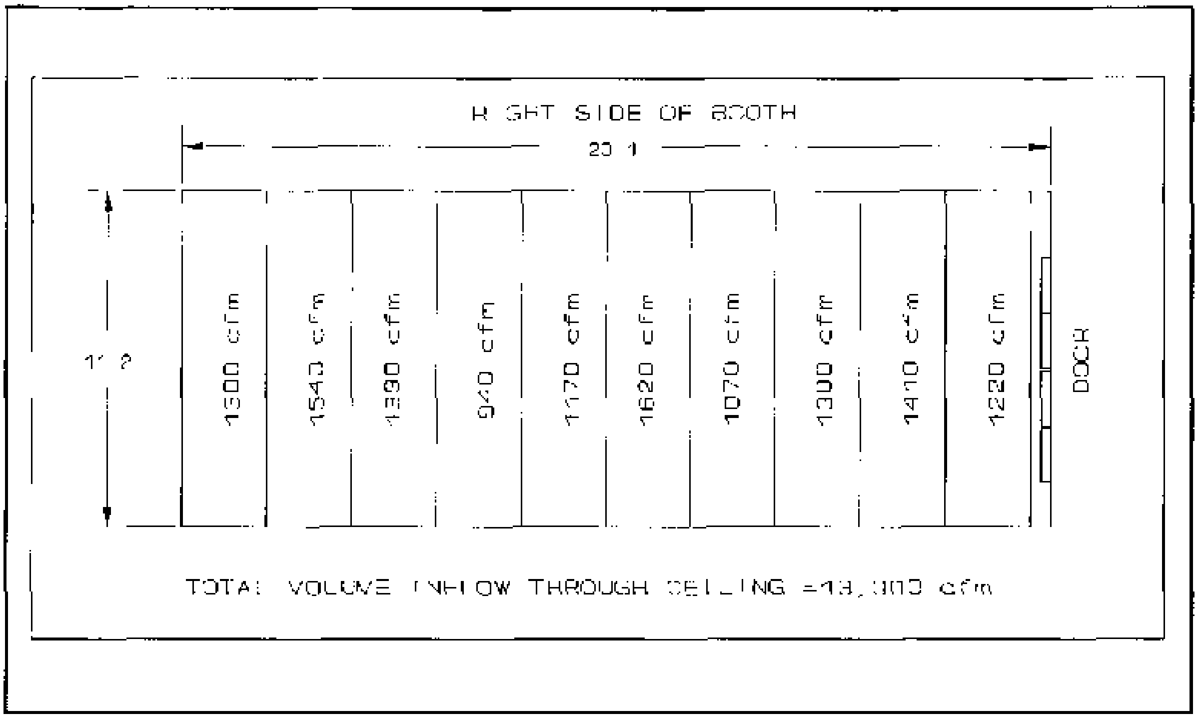

Figure 10 Airflow distribution into the paint booth

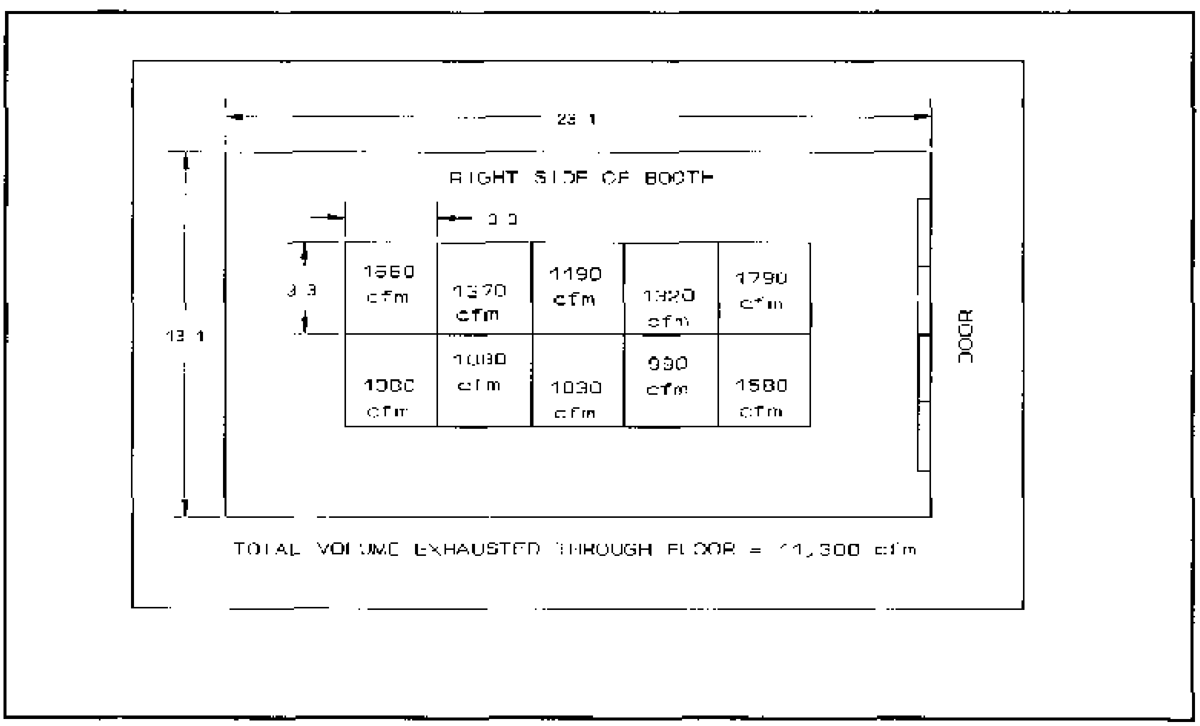

Figure 11 Airflow distribution of the exhaust from the paint booth

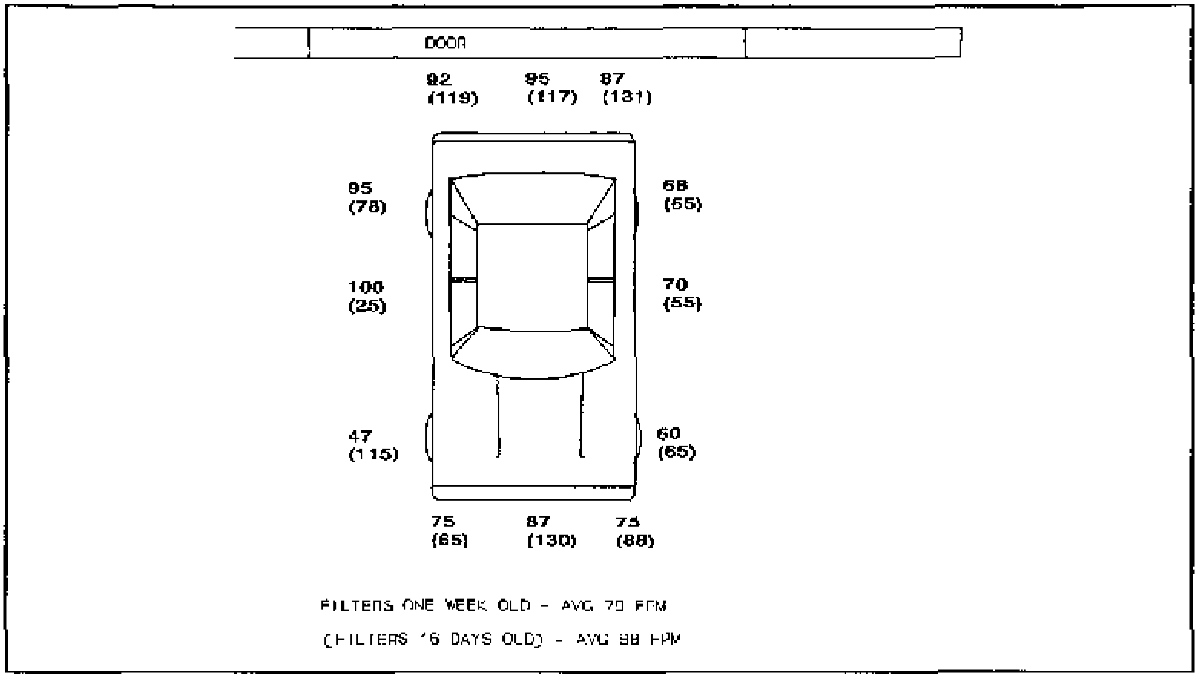

Figure 12 Air velocities around a car on two different days during the study These velocity measurements were taken at a height of 3 feet and a distance of 1 5 feet from the car

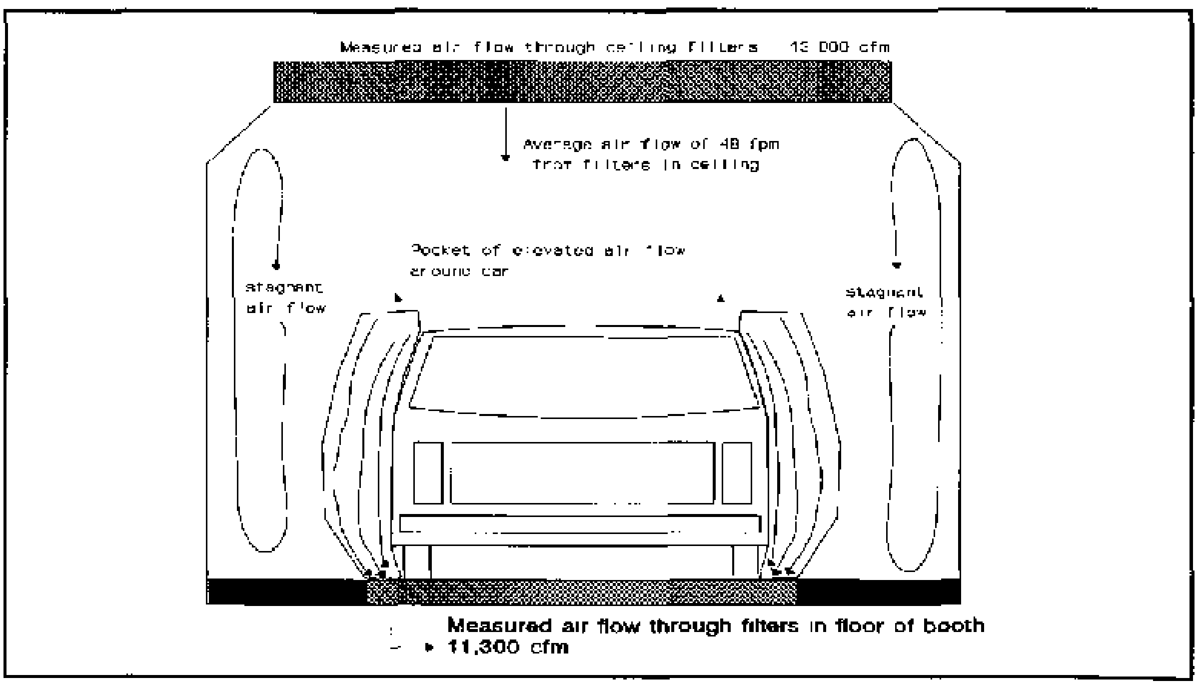

Figure 13 Smoke tube traces and exhaust volumes in the spray painting booth The velocities around the car are shown in Figure 12

Table 5 Summary of total particulate concentrations measured at a spray painting booth

Spray Painting Gun	Location	N*	Geometric Mean (mg/m³)	Geometric Standard Deviation	Range (mg/m³)
HVLP	personal	17	0 53	3 30	<0 1-3 68
HVLP	side of booth	13	0 89	2 94	<0 1-5 34
HVLP	under car	13	2 84	4 98	<0 1-28 38
non-HVLP+	personal	6	0 68	2 24	0 17-1 45
non-HVLP	side of booth	4	0 44	11 27	0 03-7 34
non-HVLP	under car	4	8 25	2 35	2 29-14 08

* - number of samples
+ - non-HVLP spray painting guns The guns were a gravity feed or siphon cup spray painting guns

Note An analysis of least squares means indicated that the total particulate concentration measured under the car was significantly higher than concentrations measured on the worker and next to the wall of the booth Read Appendix D for further discussion

For two impinger samples collected on the worker, an isocyanate group concentration of 28 and 27 μg/m³ was measured with NIOSH method 5521 This number exceeds the UK control limit for isocyanates For these samples, Desmodur N3300 was not detected The NIOSH 5521 method does not report a detection limit for isocyanate oligomers Because the Desmodur N3300, which is essentially 100 percent an isocyanurate trimer of HDI, is the only isocyanate in the paint, the NIOSH 5521 method results discussed here probably represent fluctuations in analytical instrument response rather than the detection of analytes in a field sample Another possibility is sample contamination For these two samples the reported mass of HDI prepolymer (NCO group) was 1 1 and 0 6 μg One of eight field blanks was reported to have 2 0 μg of HDI prepolymer (NCO group) Desmodur N3300 was not detected in any of the field blanks

Statistical Analysis of Total Dust Concentration Data

The total dust concentration data was analyzed using the statistical analysis techniques presented in Appendix C This analysis was done to determine whether sampling location and type of spray painting gun affected the total dust concentration During this analysis, two covariates were found to significantly affect the total dust concentrations The first covariate was the fraction of the sampling period that the worker actually spent spray painting a car Because this fraction changed with every job, the observed concentration differences between spray painting guns in Table 5 is to some extent also a function of fraction of time that the workers spent spray painting the cars during the different sampling periods The second covariate was the coat of paint being applied to the car during the sampling period The coat of paint was either a clear coat, a base coat, or both Because some cars only received a clear coat, the observed differences in geometric mean dust concentrations between the two spray painting guns is to some extent affected by differences in the coats of paint applied to the cars

After including the two covariates in the model of total dust data, sampling location was found to have significantly affected the total dust concentration The samples collected under the car were significantly higher than the samples collected on the worker and near the side of the booth This indicates that the booth is isolating the worker from the overspray

The statistical analysis also found that the spray painting gun used did not significantly affect the total dust concentration measured at all three sampling locations Overall, the concentrations measured when the HVLP spray painting guns were used were a factor of 2 lower than the concentrations measured when the gravity feed and siphon cup guns were used The statistical analysis simply indicates that this observed difference is not larger than the data's variability

VIDEO EXPOSURE MONITORING

Table 6 summarizes the relative solvent concentrations in the spray painting booth during four paint jobs (2 using a HVLP spray paint gun, and one each using a siphon cup and a gravity feed spray paint gun) During each run, various parts of four different cars were painted In order to evaluate the effect of location upon the relative solvent concentration measured on the worker, the booth was divided into 10 areas illustrated in Figure 14 The average relative exposure for each of these areas was determined and compared to the average during nonpainting activities In Table 6, the relative solvent concentration was computed from the Photvac Tip II's analog output for each area as follows

$$100 * \frac{\textit{average analog output while painting an area}}{\textit{average analog output when painting isn't being done}}$$

In Table 6, the average relative concentrations during spray painting are similar to the average relative concentration when there is no activity This indicates that the booth controls much of the overspray However, the booth does not control all of the overspray Figure 15 shows that some very noticeable peak exposures can occur when the worker is painting the side of a car This result simply indicates that overspray can get into the worker's breathing zone

Table 6 Relative exposures of organic compounds within the spray painting booth								
Painting activity, area (1, 2, etc) of the car being painted	HVLP Spray Paint Gun				Siphon Cup Spray Paint Gun		Gravity Feed Spray Paint Gun	
	Run 1		Run 2		Run 3		Run 4	
	Color	Clear	Color	Clear	Color	Clear	Color	Clear
No painting, assume ambient	100	100	100	100	100	100	100	100
(1)[1] Right side	98	95	-	-	90	99	97	132
(3) Left side	99	87	96	98	-	-	-	-
(4) Rear	-	-	-	-	-	-	-	-
(14) Trunk	-	-	95	92	-	-	-	-
(201) Small pieces on stand	102	99	-	-	-	-	-	-

[1] Area of the vehicle being painted as illustrated in Figure 14

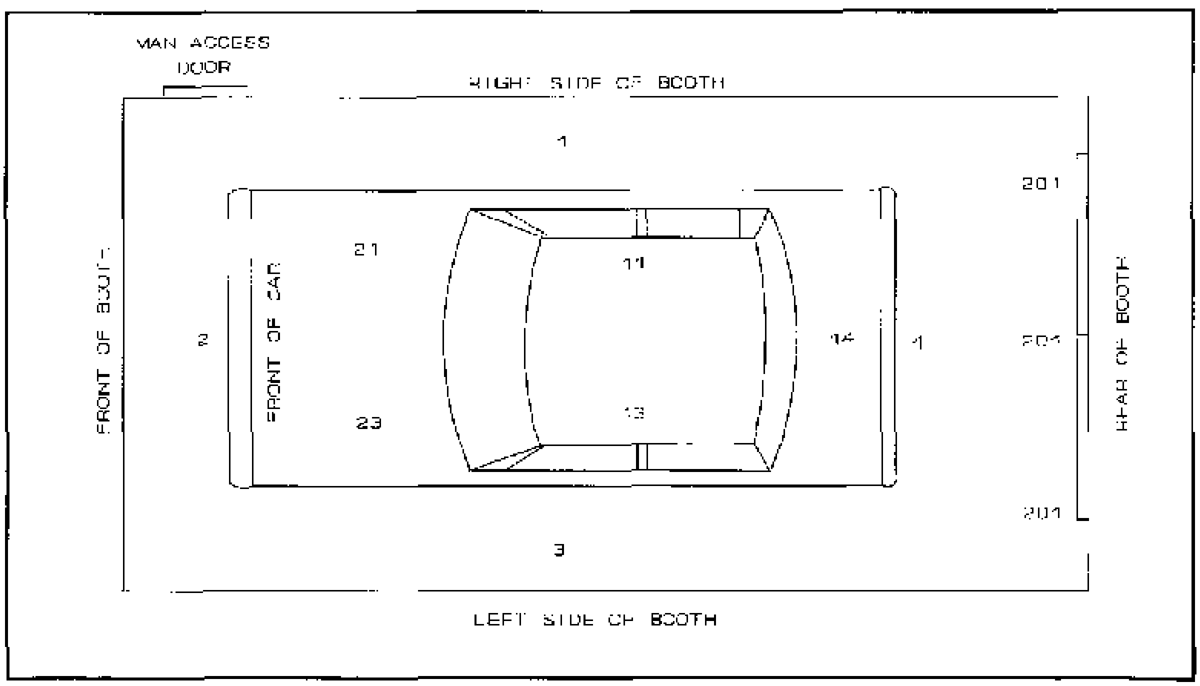

Figure 14 The areas of the car being painted (for example, Area 3 is the left side of the car)

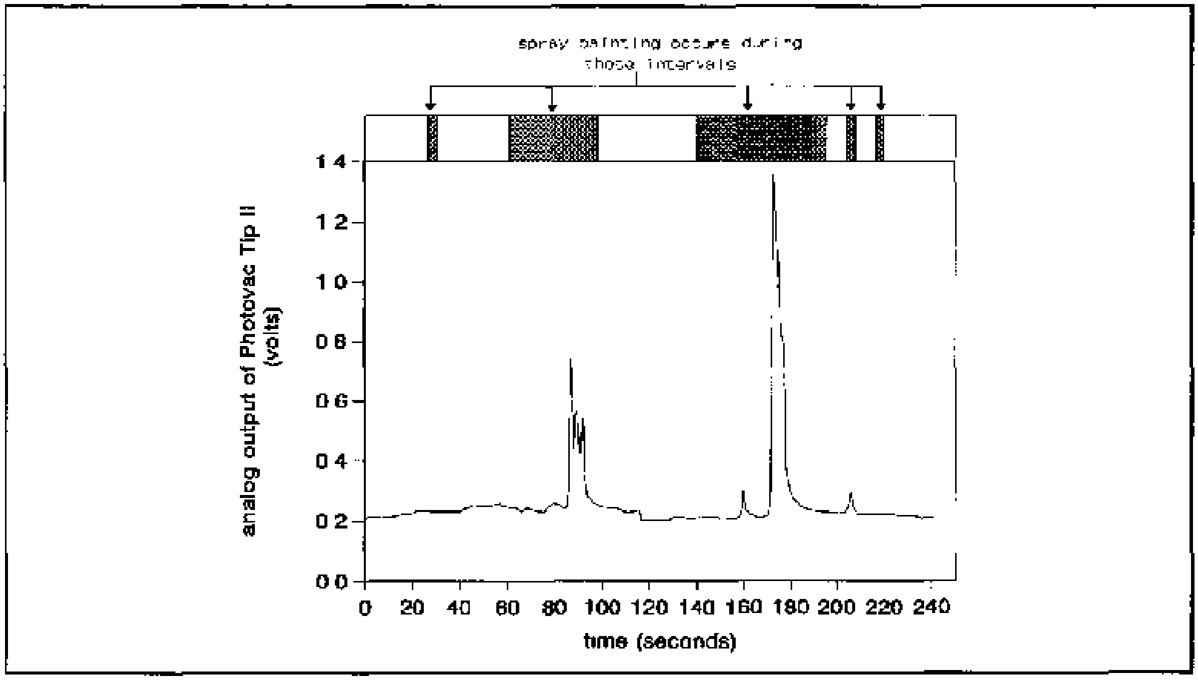

Figure 15 Relative concentration while gravity feed gun was used to apply clear coat to the side of car (run 4) The ventilation does not always keep overspray away from the worker's head

DISCUSSION AND RECOMMENDATIONS

SANDING OPERATIONS

At this shop, the maximum total dust (sanding) concentration for all operations was 1 9 mg/m^3, which was well below the OSHA PEL Individual values of total dust concentration for sanding are listed in Appendix C, Table C2 Ventilated sanders and man-cooling fans are used to reduce worker dust exposure during sanding operations As shown in Figures 7 and 8, changing from a nonventilated to a ventilated sander causes a factor of 20 reduction in relative dust exposure As shown in Figure 8, a similar reduction in exposure can be obtained by using a floor fan However, the use of a floor fan results in dust being dispersed throughout the shop and an increased dust exposure for all the workers in the shop

Sometimes, compressed air was used to blow dust and dirt off the vehicles surface after sanding This is a poor work practice because it increases the workers exposure to airborne dust and any hazardous substance such as lead or chromium that might be in this dust Surfaces should be cleaned by either wiping the surface with a damp cloth or vacuuming the surface

VEHICLE PREPARATION STATION

The vehicle preparation stations were primarily operated in the exhaust mode rather than in the recycle mode The measured flow rate of nearly 12,000 cfm resulted in an air velocity of 100 fpm about 4 feet from the face Beyond 7 feet, the velocity is too low to capture the overspray resulting in the overspray being dispersed throughout the rest of the preparation area As a result, the painter and any other workers in this area would be exposed to this paint overspray An HDI polyisocyanate (Desmodur N3300) concentration of 3 3 mg/m^3 was measured during one spray painting operation at this preparation station This exceeds the Oregon ceiling exposure limit of 1 0 mg/m^3 for HDI polyisocyantes Because the vehicle preparation station provides very minimal control of overspray, others in the area can be exposed to potentially excessive concentrations of HDI polyisocyanates To prevent this from occurring, all painting involving polyisocyanates should be conducted in the spray painting booth

To improve the effectiveness of the preparation station installations, a curtain or a metal partition could be placed between the two stations and a second parallel curtain to enclose the station on the right This would reduce the effects of crossdrafts and direct the airflow along the length of the station

SPRAY PAINTING BOOTHS

The downdraft spray painting booth appeared to be operating at a flow rate of 12,000 cfm This results in air velocity around a vehicle ranging from 50 to 130 fpm While painting the sides of a vehicle, (no roofs were painted during this study) these velocities appear to be sufficient to control and keep the overspray from the painter's breathing zone However, the control of overspray is not perfect and some overspray can enter the worker's breathing zone Because of the good control of the overspray while painting the side of vehicles, air contaminant concentrations measured on the worker did not exceed the available exposure criteria

The air velocity measurements reported in Figure 6 indicated that this booth nearly complies with a French ventilation standard for downdraft autobody spray painting booths This standard has some very specific specifications on the flow of air around a car [21]

> The air velocity around the perimeter of a car is to be measured at 10 points Three points are on each side of the car and two are next to the front and rear of the car These measurements are taken at 0 5 meters (m) from the side of the car and 0 9 meters above the booth's floor The mean value of these 10 points is to be greater than 0 4 m/sec (meters/second) and no point is to have a velocity of less than 0 3 m/sec These measurements are based upon integrated 60 second samples

Compliance with this standard reportedly minimizes worker exposure to hardeners that contain diisocyanates [21 22] The average air velocity around the car was 79 fpm and 88 fpm on two different days Thus, the low polyisocyanate concentrations found in this spray painting booth are consistent with the data which supports the French standard described above

OSHA or ACGIH airflow recommendations for spray painting booths address only crossdraft spray painting booths [23 24] The OSHA recommendation is contained in an OSHA standard which assumes that the spray painting booth has a crossdraft ventilation at a rate of 100 feet per minute per square foot of cross-sectional area of the booth The spray painting booth in this shop does not comply with this standard However, OSHA generally does not enforce this standard unless there is a violation of current OSHA standards for air contaminants [25]

Even though the booth operated at or near its designed ventilation capacity and appears to control the overspray, respirators need to be worn during spray painting jobs Air contaminant concentrations on the worker can be elevated by inadvertently spraying paint into the air or perhaps by painting the roof, hoods, trunks, and autobody parts which are detached from the car Furthermore, the results presented in Figure 15 indicate that the booth's ventilation does not always isolate the worker from the overspray In order to be certain that worker is adequately protected from paint overspray, respirators should be worn during all spray painting operations

SPRAY PAINTING GUNS

Because the spray painting booth appeared to effectively isolate the worker from the overspray, the total dust concentration measured on the worker and at the side of the spray painting booth may not be affected by the choice of a spray painting gun The total dust concentrations presented in Table 5 indicate that the effect of spray painting gun upon the total dust concentration measured on the worker was minor However, the overspray concentration in the spray painting booth was found to be affected by the following two covariates the fraction of the sampling period that the worker spent painting and the coat of paint (clear, base, or both) which was applied to the car The practical significance of the first variable is that concentration could have been computed based upon the time spent painting rather than the actual sampling period (See Appendix C for further discussion of this point) When painting in the booth stops, exposure to the spray painting mist may quickly cease Thus, the observed concentration difference is being affected by the different time periods between applications of coats of paint in the booth After including these two covariates in the statistical analysis included in Appendix C, the use of HVLP spray painting guns were associated with concentrations which were 50 percent lower than when non-HVLP guns were used These concentration differences are consistent with Lingk's results [26] Under the car, the use of the HVLP spray painting guns were associated with concentrations which were 75 percent lower than the concentrations measured when the non-HVLP guns were used The probability of seeing such a large difference due to chance was 0 06 In general, these results indicate that the HVLP spray painting guns may cause reduced emissions and overspray concentrations in the spray painting booth However, these reductions are not larger than the variability in the data Thus, these results are inconclusive as to whether the choice of a spray painting gun actually reduces the concentration of air contaminants in the spray painting booth

RESPIRATORY USAGE

Respirator usage at this autobody shop appeared to be somewhat deficient Workers should not be permitted to have beards which interfere with the seal between the respirator and the worker's face These workers receive little if any protection from the use of respirators At this autobody shop, like every other autobody shop in this study, there did not appear to be a formal respirator program in place The OSHA respirator protection standard 29 CFR 1910 134 (see Appendix E) requires that "Written standard operating procedures governing the selection and use of respirators shall be established "

A complete respiratory protection program as defined in OSHA standards needs to be implemented Minimum OSHA requirements include

1 Written standard operating procedures for selection and use of respirators,
2 Selection of respirators according to hazard,
3 Training in the use and limitations of respirators,
4 Respirator cleaning and disinfection,
5 Proper selection for respirators,
6 Routine Inspection Methods,
7 Workplace exposure monitoring,
8 Evaluation of program effectiveness,
9 Medical monitoring, and
10 Use of certified respirators

PROTECTIVE CLOTHING

Material safety data sheets for the polyisocyanates used in this shop indicate that these isocyanates can cause skin irritation and a sensitization reaction Thus, eye and skin contact should be avoided Eye and skin protection should be worn when handling isocyanates A manufacturer of HDI based polyisocyanates recommends that use of butyl rubber gloves for handling solutions containing these polyisocyanates [27]

CONCLUSIONS AND RECOMMENDATIONS

The downdraft spray painting booth and ventilated sanders appear to effectively control air contaminant exposures The air velocities around the vehicle appears to be high enough to control most overspray However, when the worker aims the spray gun into the booth's oncoming airflow, some overspray can be transported back into the worker's breathing zone When the vehicle preparation station is used in the exhaust mode for small painting jobs, the air velocities appear to be too low to provide effective air contaminant control Respirator use at this autobody shop is inadequate There appears to be a general lack of knowledge of what is proper respirator usage There is a need to read, understand, and implement the OSHA respirator standard that is attached in Appendix E If a formal, written respirator program based upon the OSHA respirator standard were in place, the problems with respirator usage noted in this report may not have occurred

REFERENCES

1 South Coast Air Quality Management District [1991] Regulation XI source specific standards, Rule 1107, coatings of metal parts and products 21865 Copley Drive, Diamond Bar, CA

2 Skretvelt OT, Losiavo JG [1984] Effect of facial hair on the face seal of negative pressure respirators Am Ind Hyg Assoc J 45 63-66

3 CFR [29 CRF 1910 134 (1989)] Code of Federal regulations Washington, DC U S Government Printing Office, Office of the Federal Register

4 International Agency for Research on Cancer [1989] IARC monographs on the evaluation carcinogenic risks to humans, some organic solvents, resin monomers and related compounds, pigments, and occupational exposures in paint manufacture and painting Lyon, France Vol 47

5 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 and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No 92-100

6 CRF [29 CFR 1910 1000 (1989)] Code of Federal regulations Washington, DC U S Government Printing Office, Office of the Federal Register

7 ACGIH [1992] 1992-1993 Threshold limit values for chemical substances and physical agents and biological exposure indices Cincinnati, OH American Conference of Governmental Industrial Hygienists

8 Janko M, McCarty K, Fajer M, Raalte J [1992] Occupational exposure to 1,6-hexamethylene diisocyanate-based polyisocyanates in the State of Oregon, 1980-1990 Am Ind Hyg Assoc J 53 331-338

9 Oregon OSHA [1991] Interim Oregon occupational safety and health code for OAR437, Division 3, general occupational safety and health rules (29 CFR 1910) Department of Insurance and Finance, Salem, OR Occupational Safety and Health Administration

10 Mobay Inc [1991] Material safety data sheet for desmodur N-3300 Pittsburgh, PA Mobay Corp, Coatings Division, 152205-9741

11 CRF [29 CFR 1910 1000 (1989)] Code of Federal regulations Washington, DC U S Government Printing Office, Office of the Federal Register

12 Silk S, Hardy H [1983] Control limits for isocyanates Anals Occup Hyg 27 333-339

13 NIOSH [1984] Nuisance dust total Method 0500 (Issued 2/15/84) In Eller PM, ed NIOSH manual of analytical methods, 3rd rev ed , with supplements 1, 2, 3, and 4 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 84-100

14 NIOSH [1984] Elements (ICP) Method 7300 In Eller PM, ed NIOSH manual of analytical methods, 3rd rev ed , with supplements 1, 2, 3, and 4 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 84-100

15 NIOSH [1984] Alcohols I, Method 1400 In Eller PM, ed NIOSH manual of analytical methods, 3rd rev ed , with supplements 1, 2, 3, and 4 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 84-100

16 NIOSH [1989] Isocyanates Method 5521 In Eller PM, ed NIOSH manual of analytical methods, 3rd rev ed Cincinnati, OH U S Department of Health and Human Services, Public Health Services, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No 84-100

17 Rhone-Poulenc [1989] Material safety data sheet for tolonate HDT(90) Princeton, NJ

18 Gressel MG, Heitbrink WA, McGlothlin JD, Fischbach TJ [1988] Advantages of real-time data acquisition for exposure assessment Appl Ind Hyg 3(*11*) 316-320

19 Gressel MG, Heitbrink WA, McGlothlin JD, Fischbach TJ [1987] Real-time, integrated, and ergonomic analysis of dust exposure during manual materials handling Appl Ind Hyg 2(*3*) 108-113

20 McDermott H [1976] Handbook of ventilation for contaminant control Ann Arbor, MI Ann Arbor Science Publishers p 126

21 INRS [1992] Practical ventilation guide - 9 ventilation of paint stations and cabins Paris, France National Research and Safety Institute p 16

22 Defosse M, Laureillard J [1990] Paint spray booths in bodywork shops in the automobile industry, determination of isocyanates and solvents, conformity to booth specifications Cahiers de notes documentaires 138 65-72

23 CFR [29 CFR 1910 94(c)] Code of Federal regulations Washington, DC U S Government Printing Office, Office of the Federal Register

24 ACGIH [1992] Plate VS-75-04, large drive-through spray paint booth In Industrial Ventilation-A Manual of Recommended Practice, 21st ed Cincinnati, OH American Conference of Governmental Industrial Hygienists

25 AGCA [1992] OSHA field operations manual Washington DC The Associated General Contractors of America Publication No 169

26 Lingk DS [1991] Thesis characterization of paint aerosol exposure using HVLP and conventional air-atomization techniques Fort Collins, CO Colorado State University, Degree of Master of Science

27 Mobay [1987] Health and safety information - hexamethylene diisocyanate (HDI)-based polyisocyanates Pittsburgh, PA pp 11

APPENDICES

APPENDIX A
HEALTH EFFECTS TO SPECIFIC AIR CONTAMINANTS

DIISOCYANATES AND THEIR OLIGOMERS

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 use in surface coatings, polyurethane foams, adhesives, resins, and sealants Diisocyanates are usually referred to by their specific acronym, e g , IPDI for isophorone diisocyanate, or HDI for hexamethylene diisocyanate [28] To reduce the concentration of monomers during spray painting from evaporation, the isocyanate monomers are prepolymerized into oligomers that are generally dimers, trimmers, and tetrameres of the monomer In commercial spray painting operations, the monomer is usually less than 2 percent paint by weight However, the oligomers still pose a hazard to the workers as an aerosol

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 (shortness of breath), pulmonary edema (fluid in the lungs), and reduced lung function [29,30] Lung function is reported to decrease with number of exposures greater than 0 2 mg/m^3 to hexamethylene diisocyanate biuret [31] The most important and most debilitating health effect from exposure to diisocyanates is respiratory and dermal sensitization After sensitization, any exposure, even to levels below any occupational exposure limit or standard, will produce an allergic response that may be life threatening [32,33] The only effective treatment for the sensitized worker is cessation of all diisocyanate exposure [34]

ORGANIC SOLVENTS

Occupational exposure to the organic solvents can cause neurotoxic effects that can include dizziness, headache, an alcohol-like intoxication, narcosis, and death from respiratory failure [34] Automotive spray painters exposed to organic solvents are reported to have decreases in motor and nerve conduction velocities [35] In addition, organic solvents such as acetone, toluene, and xylene can cause eye, nose, and throat irritation [36] Dermal exposure to organic solvents can defat the skin and, thereby, increase the uptake of these solvents by the body In addition, dermal exposure can cause dermatitis Some health effects attributed to specific organic solvents are briefly summarized

Acetone

Few adverse health effects have been attributed to acetone despite widespread use for many years Awareness of mild eye irritation occurs at airborne concentrations of about 1000 ppm Very high concentrations (12000 ppm) depress the central nervous system, causing headache, drowsiness, weakness, and nausea [37] Repeated direct skin contact with the liquid may cause redness and dryness of the skin Exposures over 1000 ppm cause respiratory irritation, coughing, and headache [38]

n-Butyl Acetate

At concentrations exceeding 150 ppm, significant irritation of the eyes and respiratory tract are reported in the literature [38]

Hexyl Acetate

Hexyl acetate vapor is irritating to the eyes and throat of humans at concentrations above 50 ppm [38] High concentrations may be mildly irritating to the eyes and upper respiratory track The lethal dose for animals by inhalation is approximately 4000 ppm

Isopropyl Alcohol

At exposures above 400 ppm, irritation to the eyes, nose, and throat are reported Above 800 ppm, the symptoms are intensified [38]

Toluene

Toluene can cause irritation of the eyes and respiratory tract, dermatitis and central nervous system depression [36] At concentrations of 200 ppm or less, complaints of headaches, lassitude, and nausea have been reported At concentrations of 200 to 500 ppm, loss of memory, anorexia, and motor impairment are reported [38] In addition, muscle impairment and increased reaction time can occur at exposures of 100 ppm or more

Xylene

Xylene vapor may cause irritation of the eyes, nose, and throat Repeated or prolonged skin contact with xylene may cause drying and defatting of the skin which may lead to dermatitis [34, 36, 37] Liquid xylene is irritating to the eyes and mucous membranes, and aspiration of a few milliliters may cause chemical pneumonitis, pulmonary edema, and hemorrhaging [34 36 37] Repeated exposure of the eyes to high concentrations of xylene vapor may cause reversible eye damage [39] At concentrations between 90 and 200 ppm, impairment of body balance, manual coordination, and reaction times can occur [34 36 37] Acute exposure to xylene vapor may cause central nervous system depression and minor reversible effects upon liver and kidneys [40] Brief exposure of humans to 200 ppm has caused irritation of the eyes, nose, and throat [40]

METALS

Toxic metals such as lead, chromium and cadmium may be used as pigments in some paints As a result, welding and sanding on these surfaces may involve occupational exposure to toxic metals In addition, autobody welding will involve exposure to welding fumes Some health effects attributed to lead, antimony, chromium, and nickel are discussed below

Chromium

Some paints may contain chromates such as lead chromate, hexavalent chromium, as a pigment These compounds can produce health effects such as contact dermatitis, irritation and ulceration of the nasal mucosa, and perforation of the nasal septum Hexavalent chromium compounds cause lung cancer [5]

Lead

Lead adversely affects several organs and systems The four major target organs and systems are the central nervous system, the peripheral nervous system, kidney, and hematopoietic (blood-forming) system [41] Inhalation or ingestion of inorganic lead can cause loss of appetite, metallic taste in the mouth, constipation, nausea, pallor, blue line on the gum, malaise, weakness, insomnia, headache, muscle and joint pains, nervous irritability, fine tremors, encephalopathy, and colic [34, 36 37] Lead exposure can result in a weakness in the wrist muscles known as "wrist drop," anemia (due to lower red blood cell life and interference with heme synthesis), proximal kidney tubule damage, and chronic kidney disease [42,43] Lead exposure is associated with fetal damage in pregnant women [34, 36, 37] Lastly, elevated blood pressure has been positively related to blood lead levels [44 45]

Antimony

Exposure to antimony and its compounds has been associated with numerous health problems, including dermatitis and mucous membrane irritation, pneumoconiosis, electrocardiogram (ECG) alterations, hepatic (liver) involvement, and hematologic changes It can cause gastrointestinal pain, cough, loss of appetite, itching, skin eruptions, and irritation to the skin, eyes, nose, and throat [46] Present evidence in humans is inconclusive regarding an increased risk of lung cancer and reproductive disorders from antimony exposure [15]

Nickel

Lung Cancer and nasal cancer can result from inhalation of nickel [47] Metallic nickel and certain nickel compounds cause sensitization dermatitis "Nickel itch" is a dermatitis resulting from sensitization to nickel In chronic stages, pigmented or depigmented plaques may be formed Nickel sensitivity, once acquired, apparently is not lost, recovery from dermatitis usually occurs within 7 days of cessation of exposure but may take up to several weeks [18] Nickel itself is not very toxic if swallowed, but its soluble salts are quite toxic and, if swallowed, may cause giddiness and nausea [16]

REFERENCES

28 Seguin P, Allard A, Cartier A, Malo JL [1987] Prevalence of occupational asthma in spray painters exposed to several types of isocyanates, including polymethylene polyphenylisocyanate J Occup Med 29(4) 340-343

29 NIOSH [1978] NIOSH 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

30 Charles J, Bernstein A, Jones B, Jones D, Edwards J, Seal R, Seaton A [1976] Hypersensitivity pneumonitis after exposure to isocyanates Thorax 31(2) 127-136

31 Turnling G, Alexandersson F, Hedenstierna R, Plato N [1990] Decreased lung function and exposure to diisocyanates (HDI and HDI-BT) in car repair painters observations of re-examination 6 years after initial study Am J Ind Med 17(3) 229-310

32 Hardy HL, Devine JM [1979] Use of organic isocyanates in industry - some industrial hygiene aspects Anal Occup Hyg 22(4) 421-427

33 Belin L, Hjortsberg U, Wass U [1981] Life-threatening pulmonary reaction to car paint containing a prepolymerized isocyanate Scand J Work Environ Health 7 310-312

34 NIOSH [1987] Current Intelligence Bulletin 48 organic solvent neurotoxicity 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 87-104

35 Elofsson S, Gamberale F, Hindmarsh T, Iregren A, Isaksson A, Johnson I, Knave B, Lydahl E, Mindus P, Persson H, Philipson B, Stenby M, Struwe G, Soderman E, Wennberg A, Widen L [1980] Exposure to organic solvents -- a cross-sectional epidemiologic investigation on occupationally exposure car and industrial spray painters with special reference to the nervous system Scand J Work Environ Health 6(4) 239-273

36 NIOSH [1971] Occupational diseases-a guide to their recognition 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 77-181

37 Hathaway G, Proctor N, Hughes J, Fischman M [1991] Procter and Hughes' Chemical hazards of the workplace 3rd ed New York, NY Van Nostrand Reinhold, p 666

38 ACGIH [1986] Documentation of the threshold limit values 5th ed Cincinnati, OH American Conference of Governmental Industrial Hygienists

39 NIOSH [1977] Occupational diseases, a guide to their recognition, revised edition 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 77-181

40 NIOSH/OSHA [1981] Occupational health guideline for Xylene In 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

41 Doull J, Klaassen CD, Amdur MD [1980] Metals In Casarett and Doull's toxicology 2nd ed New York, NY MacMillan Publishing Co , Inc , pp 418-420

42 NIOSH [1972] NIOSH criteria for a recommended standard occupational exposure to lead 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 78-158

43 NIOSH/OSHA [1988] Occupational health guideline for inorganic lead In 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

44 Kristensen TS [1989] Cardiovascular diseases and the work environment--a critical review of the epidemiologic literature on chemical factors Scand J Work Environ Health 15(4) 245-264

45 Pirkle JL, Schwartz J, Landis JR, Harlan WR [1985] The relationship between blood lead levels and blood pressure and its cardiovascular risk implications Am J Epidemiol 121(2) 246-58

46 NIOSH [1978] NIOSH criteria for a recommended standard occupational exposure to antimony 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 78-216

47 NIOSH [1977] NIOSH criteria for a recommended standard occupational exposure to inorganic nickel 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 77-164

APPENDIX B
COMMENTS AND MODIFICATIONS ON THE NIOSH ANALYTICAL METHODS USED

APPENDIX B-1 NIOSH METHOD 0500 FOR TOTAL DUST[48]

The weight gain of the filter is used to compute the milligrams of total dust per cubic meter of air Method 0500 was modified as follows

1) The filters are stored in an environmentally controlled room (21 ± 3° and 40 ± 3 percent R H) and are subjected to the room conditions for a long duration for stabilization Therefore, the method's 8 to 16 hour time for stabilization between tare weighing was reduced to 5 to 10 minutes

2) The backup pads were not vacuum desiccated

After weighing, the filters were analyzed for lead, antimony, chromium, and nickel The filters were digested using NIOSH method 7300,[11] were diluted to 10 mL, and then analyzed by a simultaneous scanning inductively coupled plasma emission spectrometer Test results revealed that chromium and antimony quality control samples yielded low recoveries

APPENDIX B-2 NIOSH METHOD 7300 FOR ELEMENTS SUCH AS CHROMIUM IN THE TOTAL DUST

After weighing the PVC filters collected for NIOSH Method 0500, the filters were digested and analyzed for lead, antimony, chromium, and nickel according to NIOSH method 7300 [11] Samples were diluted to 10 mL after digestion Samples wee analyzed using a Thermo Jarrel Ash ICAP 61 simultaneous scanning inductively coupled plasma emission spectrometer controlled by a NEC Personal Computer-AT Test results revealed that chromium and antimony quality control samples yielded low recoveries NIOSH method 7300,[11] directs that, during the digestion of filter samples, the process continue to dryness This may explain the reason for the low recoveries of these two analytes

Instrumentation and operating conditions during analysis were as follows

RF Generator	2 5 KVA controlled, operating at 27 12 MHz with automatic power control and automatic tuning
Nebulizer	Cross-flow pneumatic, sample supplied by peristaltic pump
Torch	Quartz
Spectrometer	0 75 meter polychromator with 41 channels
Optics	0 75 meter Rowland Circle, Paschen-Runge mount, 1510 or 2400 grooves/mm ruled grating at 500 nm
Argon Plasma Gas Flow Rate	15 L/minute, mass controlled
Plasma Observation Height	16 mm above coil
Nebulizer Gas Flow Rate	0 75 L/minute, mass controlled
Radio Frequency Power	1100 Watts
Number of Burns	2
Integration Time	5 seconds

APPENDIX B-3 NIOSH METHOD 1400 FOR ALCOHOLS I (ORGANIC SOLVENTS)[49]

The samples were collected by placing charcoal tubes in a charcoal tube holder and mounting the charcoal tube holder on the worker Tubing connected the outlet of the charcoal tube holder to a personal sampling pump that draws air through the charcoal tube at 200 cm^3/min The collected solvents were desorbed from the charcoal using carbon disulfide and the solvents were quantitated using a gas chromatograph equipped with a flame ionization detector Method 1400 was modified as follows

Desorption Process	Thirty minutes in 1 0 milliliter of carbon disulfide containing 1 microliter/milliliter of hexane as an internal standard and 1 percent isobutanol as a desorbing aid
Gas Chromatograph	Hewlett-Packard Model 5890A equipped with a flame ionization detector
Column	30 m x 0 32 mm fused silica capillary coated internally with 0 5 µm of DB-WAX
Oven Conditions	Temperature programming from 30 °C (held for five minutes) to 200 °C at a rate of 10 °C/minute

APPENDIX B-4 NIOSH METHOD 5521 FOR ISOCYANATES[50]

In this method, air samples are collected in an impinger at a known sampling rate of 2 liters per minute versus the 1 liter per minute specified by the method The impinger contains a 43 mg/L solution of 1-(2-methoxyphenyl)piperazine, which reacts with the isocyanate to form ureas, in toluene The ureas are quantitated by high performance liquid chromatography by NIOSH method 5521 with these conditions

Desorption Process	25 µl acetic anhydride was added to each sample Samples were dried under nitrogen in a hot water bath, followed by 15 minutes of sonication in 5 milliliters methanol
Instrument	HP 1090 equipped with a diode-array detector, ESA 5100A electrochemical detector The use of the diode-array detector is a modification of NIOSH method 5521 and this modification was made to confirm the presence of isocyanates
Column	250 x 4 6 mm Supelcosil LC-18, 5 µ
Mobile Phase	40/60, acetonitrile/[50/50 (methanol/15 g anhydrous sodium acetate per liter of water) adjusted to pH 6 glacial acetic acid]
Flow Rate	1 5 mL/minute
Injection volume	25 µl
Potential	+0 8 volts vs Ag/AgCl
Wavelength	242 nm

REFERENCES

48 NIOSH [1984] Nuisance Dust Total Method 0500 In NIOSH manual of analytical methods 3rd ed (with supplements 1, 2, 3 and 4) 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 84-100

49 NIOSH [1984] Alcohols Method 1400 In NIOSH manual of analytical methods, 3rd ed (with supplements 1, 2, 3, and 4) 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 84-100

50 NIOSH [1989] Isocyanates Method 5521 In NIOSH manual of analytical methods, 3rd ed 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 84-100

APPENDIX C SAMPLE RESULTS

Table C1 Particulate Concentrations During Painting

Job Number Type of Vehicle - (% Painted), Parts Painted [Spray Gun]	Sample Site	Date July 1992	Sampling Time (min)	Painting Time (min)	Type of Coat	Mass of Paint Used (g)	Total Dust Concentration (mg/m^3)	metal	metal concentration $\mu g/m^3$
Paint Booth									
1 Car (66%), roof, hood, upper doors [HVLP]	Pers	28th	26	5	Color	548 3	0 12		
	Under						3 9		
	Side						0 43	titanium	3 85
	Pers		19	8	Clear	1404	0 91		
	Under						16		
	Side						1 2		
2 Car (66%), hood, doors [HLVP]	Pers	29th	32	11	Color	565	0 16		
	Under						2 5	chromium	5 6
	Side						0 66		
	Pers		14	6	Clear	800 9	<0 01		
	Under						8 5		
	Side						1 9		
3 Mini Van (50%), 2 panels [Siphon Cup]	Pers	29th	17	5	Clear	605 4	1 0		
	Under						16		
	Side						7 5		
4 Car (25%), door, fender [Siphon Cup]	Pers	29th	20	3	Color and Clear Mixed	343 3	0 16		
	Under						14	titanium	4 16
	Side						0 16		

Table C1 Particulate Concentrations During Painting - cont

Job Number Type of Vehicle - (% Painted), Parts Painted [Spray Gun]	Sample Site	Date July 1992	Sampling Time (min)	Painting Time (min)	Type of Coat	Paint Used (g)	Total Dust Concentration (mg/m³)	metal	metal concentration μg/m³
Paint Booth									
5 Car (33%), hood, fender, bumper [HLVP]	Pers	29th	20	6	Color	476 4	0 76		
	Under						0 46		
	Side						0 46	titanium	5
	Pers		12	5	Clear	755 8	0 10		
	Under						4 3		
	Side						4 8		
6 Car (33%), hood, fender, bumper [HLVP]	Pers	30th	21	7	Color	471 4	<0 01		
	Under						<0 01		
	Side						1 2		
	Pers		13	5	Clear	????*	0 56		
	Under						5 2		
	Side						5 3		
7 Car (25%), door, rear panel [Siphon Cup]	Pers	30th	44	6	Color then Clear	125 6 then 126 1	0 39		
	Under						2 8	titanium	18
	Side						0 028		
8 Car (50%), 2 panels, bumper, trunk [HLVP]	Pers	30th	20	6	Color	489 7	0 66		
	Under						<0 01		
	Side						<0 01		
	Pers		12	4	Clear	538 2	1 8		
	Under						5 6		
	Side						0 94		

*Not recorded

Table C1 Particulate Concentrations During Painting - cont

Job Number Type of Vehicle - (% Painted), Parts Painted (Spray Gun)	Sample Site	Date July 1992	Sampling Time (min)	Painting Time (min)	Type of Coat	Paint Used (g)	Total Dust Concentration (mg/m³)	metal	metal concentration µg/m³
Paint Booth									
9 Car (25%), fender, door [HLVP]	Pers	30th	19	4	Color	170 8	0 066		
	Under						4 1		
	Side						0 49		
	Pers		9	3	Clear	325 0	0 14		
	Under						28		
	Side						1 2		
10 Car (20%), ½ door panel, fender [HLVP]	Pers	30th	22	6	Color then Clear	101 0 then ????	0 78		
	Under						4 1	titanium	3 7
	Side						0 42		
11 Car (25%), 2 door, panels [Siphon Cup]	Pers	31st	12	4	Color then Clear	101 8 then 60 7	1 4		
	Under						12		
	Side						1 3		
Vehicle Preparation Station									
12 hood setting on barrels [Siphon Cup]	Pers	28th	8	-	Color	542 2	8 2		
	Exhst						9 9		
	Area						<0 01		

Table C1 Particulate Concentrations During Painting - cont

Job Number Type of Vehicle - (% Painted), Parts Painted [Spray Gun]	Sample Site	Date July 1992	Sampling Time (min)	Painting Time (min)	Type of Coat	Paint Used (g)	Total Dust Concentration (mg/m³)	metal	metal concentration
Vehicle Preparation Station									
13 hood and 2 fenders [Siphon Cup]	Pers	28th	30	11 and 6	Color and Clear	409 9	2 2		
	Exhst						8 0	titanium	14
	Area						<0 01		
14 door [Siphon Cup]	Pers	28th	17	5 and 3	Color and Clear	97 1 and ????	4 7	titanium	3 53
	Exhst						3 6	titanium	4 71
	Area						<0 01	titanium	3 53
15 bumper on a barrel [Siphon Cup]	Pers	31st	15	12	Color	189 1	1 8	nickel	12
	Pers		5	5	Clear	????	3 8		
Spray Painting Primer in Repair Area									
16 2' by 2' area [Siphon Cup]	Pers	28th	6	2	Color and Clear	77 5	5 2		
	Under						1 9		

Table C2 Total dust sampling concentrations during sanding						
# Part Being Sanded, Area Sanded	Sample Site	Date July 1992	Sanding Time (min)	Material Being Sanded	Sander Used, Controlled or Uncontrolled	Total Dust Concentrations (mg/m³)
Sanding Operations						
17 Hood, 2 fenders, 15 sq ft	Pers	28th	23	Paint	Hand, Orbit Unctr	1 2
	Area					0 12
18 Door, 3 sq ft	Pers	28th	23	Body filler	In-Li Contr	0 45
	Area					0 21
19 Not recorded	Pers	30th	15	Body filler	In-Li Contr	0 67
	Area					0 20
20 Side of car	Pers	29th	6	Body filler	In-Li Unctr	1 9
	Area					9 8
21 Not recorded	Pers	30th	27	Body filler	In-Li Contr	0 22
	Area					0 093

Table C3 Isocyanate Concentration Measurements

Job number Type of Vehicle - (% Painted), Parts Painted [Spray Paint Gun]	Site	Date July 1992	Actual Spray Time (min)	Type of Coat	Paint Used (g)	Concentrations HDI Total Prepolymer (μg NCO/m³)	Concentrations DES N-3300 (mg/m³)
Paint Booth							
1 Car (66%), roof, hood, doors [HVLP]	Pers	28th	5	Clear	1404	28	<1 0
	Under					55	1 8
2 Car (66%), hood, doors [HVLP]	Pers	29th	6	Clear	800 9	0	<0 42
	Under					18	0 52
3 Mini Van (50%), 2 panels [Siphon Cup]	Pers	29th	5	Clear	605 4	0	<1 2
	Under					140	4 4
4 Car (25%), door, fender, [Siphon Cup]	Pers	29th	2	Color and Clear	343 3	0	<1 1
	Under					120	3 7
5 Car (33%), hood, fender, bumper [HVLP]	Pers	29th	5	Clear	755 8	0	<1 3
	Under					38	<1 3
6 Car (33%), hood, fender, bumpler [HVLP]	Pers	30th	5	Clear	????	0	<1 8
	Under					77	2 3
7 Car (25%), door, rear panel [Siphon Cup]	Pers	30th	6	Clear	126 1	0	<0 77
	Under					0	<0 77
8 Car (50%), 2 panels	Pers	30th	4	Clear	538 2	27	<1 8
	Under					0	<1 8
9 Car (25%), fender, door [HVLP]	Pers	30th	3	Clear	325 0	0	<1 8
	Under					130	4 1

Table C3 Isocyanate Concentration Measurements - cont

Job Number Type of Vehicle - (% Painted), Parts Painted [Spray Paint Gun]	Site	Date July 1992	Actual Spray Time (min)	Type of Coat	Paint Used (g)	Concentrations: HDI Total Prepolymer (μg NCO/m^3)	Concentrations: DES N-3300 (mg/m^3)
Paint Booth							
10 Car (20%), ½ door panel, fender [HVLP]	Pers	30th	2	Clear	????	0	<2 2
	Under					100	3 3
11 Car (25%), 2 door panels [Siphon Cup]	Pers	31st	4	Clear	60 7	0	<1 7
	Under					360	14
Prep Station							
12 hood, 2 fenders [Siphon Cup]	Pers	28th	4	Color and Clear	409 9	0	<4 0
	Under					110	<5 0
13 door [Siphon Cup]	Pers	28th	6	Color and Clear	????	230	3 3
	Under					0	<3 3
14 bumper on a barrel [Siphon Cup]	Pers	31st	5	Clear	????	0	<4 0
	Under					0	<4 0
Open Area in Repair Area							
16 2' by 2' area [Siphon Cup]	Pers	30th	2	Color and Clear	77 5	nd	<1 3
	Under					nd	<1 3

???? - weight of paint missed

Table C4 Solvent Concentrations

Job No Type of Vehicle - % Painted, Parts Painted [Spray Gun]	Site	Date July 1992	Time (min)	Type of Coat	Paint Used (g)	Solvent Concentration (ppm) Butyl Acetate	Ethyl Acetate	Toluene	Xylene	C_x
PAINT BOOTH										
1 Car - (66%), roof, hood, upper doors [HVLP]	Pers	28th	5	Color	548 3	5 3	6 4	7 2	1 3	0 14
	Under					11	4 2	1 5	2 4	0 12
	Side					1 2	<0 5	<0 5	<0 4	0 01
	Pers		8	Clear	1404	3 6	5 7	5 0	1 2	0 10
	Under					14	16	5 9	5 8	0 25
	Side					1 1	1 5	<0 7	<0 6	0 01
2 Car - (66%) hood, doors [HVLP]	Pers	29th	11	Color	565	2 4	3 6	0 5	0 7	0 04
	Under					5 3	4 2	1 5	1 1	0 07
	Side					<0 3	<0 4	11	<0 4	0 11
	Pers		6	Clear	800 9	6 8	7 7	2 8	<0 8	0 03
	Under					2 3	3 0	1 0	0 8	0 04
	Side					3 2	2 0	<1 0	<0 8	0 03
3 Mini Van - (50%), 2 panels [Siphon Cup]	Pers	29th	5	Clear	605 4	<0 6	<0 8	14	<0 7	0 14
	Under					15	<0 8	7 8	6 6	0 24
	Side					4 9	<0 8	<0 8	2 0	0 05
4 Car - (25%) door, fender [Siphon Cup]	Pers	29th	3	Color and Clear Mixed	343 3	1 0	1 4	1 3	<0 6	0 02
	Under					9 0	<0 7	<0 7	6 9	0 13
	Side					<0 5	<0 7	4 2	<0 6	0 04

Table C4 Solvent Concentrations - cont

Job No Type of Vehicle - % Painted, Parts Painted [Spray Gun]	Site	Date July 1992	Time (min)	Type of Coat	Paint Used (g)	Solvent Concentration (ppm)				C_x
						Butyl Acetate	Ethyl Acetate	Toluene	Xylene	
PAINT BOOTH										
5 Car - (33%), hood, fender bumper [HVLP]	Pers	29th	6	Color	476 4	3 2	3 5	2 4	1 2	0 07
	Under					2 4	1 4	<0 7	0 6	0 03
	Side					2 3	1 4	<0 7	<0 6	0 02
	Pers		5	Clear	755 8	<0 9	1 2	1 1	<1 0	0 01
	Under					7 9	11	3 3	3 4	0 15
	Side					3 9	4 7	2 2	1 9	0 08
6 Car - (33%), hood, fender bumper [HVLP]	Pers	30th	7	Color	471 4	<0 5	<0 7	<0 6	<0 6	0 00
	Under					1 8	0 7	0 6	<0 6	0 02
	Side					3 2	1 3	1 3	0 6	0 04
	Pers		5	Clear	????	<0 8	<1 1	<1 0	<0 9	0 00
	Under					5 2	7 5	2 0	2 7	0 10
	Side					3 6	4 0	2 0	1 8	0 07
7 Car - (25%), door, rear panel [Siphon Cup]	Pers	30th	6	Color then Clear	125 6 then 126 1	1 3	2 2	2 6	0 5	0 05
	Under					<0 2	<0 3	<0 3	<0 3	0 00
	Side					<0 2	<0 3	<0 3	<0 3	0 00
8 Car - (50%), 2 panels, bumper, trunk [Siphon Cup]	Pers	30th	6	Color	489 7	7 9	9 7	10	2 2	0 20
	Under					<0 5	<0 7	<0 7	<0 6	0 00
	Side					<0 5	<0 7	<0 7	<0 6	0 00
	Pers		4	Clear	538 2	<0 9	<1 2	3 6	<1 0	0 04
	Under					4 0	5 3	2 2	1 9	0 08
	Side					<0 9	<1 2	<1 1	<1 0	0 00

Table C4 Solvent Concentrations - cont

Job No Type of Vehicle - % Painted, Parts Painted [Spray Gun]	Site	Date July 1992	Time (min)	Type of Coat	Paint Used (g)	Solvent Concentration (ppm) Butyl Acetate	Ethyl Acetate	Toluene	Xylene	C_E
PAINT BOOTH										
9 Car - (25%), fender, door [HVLP]	Pers	30th	4	Color	170 8	2 3	3 6	2 9	0 6	0 06
	Under					18	8 0	2 9	4 9	0 22
	Side					4 2	0 7	5 3	<0 6	0 08
	Pers		3	Clear	325 0	<1 2	<1 5	1 5	<1 3	0 01
	Under					21	29	9 9	8 2	0 39
	Side					<1 2	<1 5	<1 5	<1 3	0 00
10 Car - (20%), ½ door panel, fender [HVLP]	Pers	30th	6	Color then Clear	101 0 then ????	1 4	2 1	2 2	<0 5	0 04
	Under					7 7	5 9	5 6	2 1	0 14
	Side					<0 5	<0 6	<0 6	<0 5	0 00
11 Car - (25%), 2 door panels [Siphon Cup]	Pers	31st	4	Color then Clear	101 8 then 60 7	1 8	5 0	8 8	<1 0	0 11
	Under					5 0	6 6	3 3	1 9	0 10
	Side					<0 9	<1 2	<1 1	<1 0	0 00
Preparation Stations										
12 hood setting on barrels [Siphon Cup]	Pers	28th	-	Color	542 2	5 3	3 5	3 3	2 9	0 11
	Exhst					7 0	5 2	3 3	2 9	0 12
	Area					<1 3	<1 7	<1 7	<1 4	0 00
13 hood and 2 fenders [Siphon Cup]	Pers	28th	11 and 6	Color and Clear	409 9	2 5	3 8	5 3	0 8	0 09
	Exhst					5 6	4 4	1 6	1 2	0 08
	Area					1 5	0 9	<0 4	<0 4	0 01

Table C4 Solvent Concentrations - cont

Job No Type of Vehicle - Y Painted, Parts Painted [Spray Gun]	Site	Date July 1992	Time	Type of Coat	Paint Used (g)	Solvent Concentration				C_h
						Butyl Acetate	Ethyl Acetate	Toluene	Xylene	
Preparation Stations										
14 door [Siphon Cup]	Pers	28th	5 and 3	Color and Clear	97 1 and ????	11	6 8	4 2	2 9	0 16
	Exhst					6 2	3 2	1 6	2 0	0 09
	Area					<0 6	<0 8	<0 8	<0 7	0 00
15 bumper on a barrel [Siphon Cup]	Pers	31st	12	Color	189 1	4 5	4 6	8 1	1 5	0 14
	Pers		5	Clear	???	6 3	9 7	72	<2 3	0 78
Open Area in Shop Repair Area										
16 2' by 2' area [Siphon cup]	Pers	28th	2	Color and Clear	77 5	0 4	0 2	0 4	<0 2	0 01
	Under					0 4	0 2	0 4	<0 2	0 01
Paint Mix Room										
Area Samples Collected in Paint Mix Room	Area	31st	58			3 3	3 8	4 6	4 0	0 12
	Area	31st	60			4 4	2 0	11	1 6	0 16
	Area	31st	85			6 1	4 1	2 0	2 0	0 09
	Area	31st	48			2 8	3 8	3 0	0 9	0 07
	Area	31st	107			1 6	1 4	5 8	0 6	0 08
	Area	31st	84			2 8	5 0	6 0	1 0	0 10

APPENDIX D

STATISTICAL ANALYSIS OF TOTAL DUST CONCENTRATION DATA

The concentration data was log transformed before any data analysis Negative concentrations were replaced by concentrations of 0 1 mg/m^3 Negative concentrations indicate that the sample filter lost more weight than the average of the blanks Thus a negative concentration simply means that the measured concentration was low and below the limit of detection (LOD) These measurements occurred when the concentrations were measured at the side of the booth and on the worker when the HVLP spray painting gun was in use The assigned value of 0 1 mg/m^3 was chosen because it reflects a relatively low total dust concentration which is somewhat higher than ambient air pollution Furthermore, this assigned value is between 1 and 2 standard deviations below the geometric mean listed in the summary table This makes the assigned value consistent with the data Simply dropping this data would bias these geometric means to a higher value [51]

Figures D1 and D2 presents the results of an analysis of variance used to test whether the independent variables (sampling location, spray painting gun, the coat of paint, and faction of time spent painting) affected the concentration measurement This analysis was conducted using the SAS General Linear Models procedure [52] In using this procedure, the natural logarithm of the total dust concentration (lconc) was modelled as a function of the dependent variables as follows

$$lconc = \beta_0 + \beta_1 G + \beta_2 C_1 + \beta_3 C_2 + \beta_4 L_1 + \beta_5 L_2 + \beta_6 LF\ TIME + \beta_7 GL_1 + \beta_8 GL_2 + \epsilon$$

Where

lconc = the natural logarithm of concentration,

C_1 = 1 if a base coat is being applied, otherwise 0 ,

C_2 = 1 if a base coat and a clear coat is being applied, otherwise 0,

L_1 = 1 if the sample was taken on the worker, otherwise 0,

L_2 = 1 if the sample taken on the side of the booth, otherwise 0,

G = 1 if the hvlp spray painting gun was used, otherwise 0,

β_{0-8} = regression coefficients, the numerical values of these coefficients are listed under item 2 in Figure D1

LFTIME = natural logarithm of the fraction of the time that the worker spent painting during the sampling periods

ε = the residual, the difference between the measured and modelled value of concentration This term has a mean value of zero and it is assumed to be normally distributed

General Linear Models Procedure

Dependent Variable. LCONC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	67 49381199	8 43672650	6.04	0 0001
Error	48	67 06563631	1.39720076		
Corrected Total	56	134 55944830			

R-Square	C.V.	Root MSE	LCONC Mean
0 501591	1251.071	1.182032	0.09448168

item 1

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GUN1	1	2 43867178	2 43867178	1 75	0 1927
COAT	2	10 41982679	5.20991340	3.73	0 0312
LOC	2	38 52171363	19.26085682	13.79	0 0001
LFTIME	1	8.68610401	8 68610401	6 22	0 0162
GUN1*LOC	2	5 01911415	2.50955707	1.80	0 1769

item 2

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	(β_0)	4 399682542 B	4.56	0.0001	0.96574644
GUN1	hvlp (β_1)	-1.474422001 B	-1.98	0 0534	0 74460736
	nhvlp	0 000000000 B		.	.
COAT	b (β_2)	-0.955947006 B	-2.65	0.0110	0.36131936
	bc (β_3)	-0.607835589 B	-1.24	0.2214	0.49060520
	c	0 000000000 B	.	.	
LOC	p (β_4)	-2.508283824 B	-3.26	0 0020	0.76851338
	s (β_5)	-2.960836896 B	-3 54	0.0009	0.83582317
	u	0.000000000 B	.	.	
LFTIME	(β_6)	1.201244166	2 49	0 0162	0 48177935
GUN1*LOC	hvlp p (β_7)	0 728244168 B	0.82	0 4140	0.88374769
	hvlp s (β_8)	1 798186485 B	1.88	0 0660	0.95580037
	hvlp u	0 000000000 B	.	.	
	nhvlp p	0 000000000 B			
	nhvlp s	0 000000000 B			
	nhvlp u	0 000000000 B			

NOTE: The X'X matrix has been found to be singular and a generalized inverse was used to solve the normal equations. Estimates followed by the letter 'B' are biased, and are not unique estimators of the parameters.

Report authors' annotation: Location p is the personal sample, location s refers to the side of the booth, and location u refers to under the car Coat b is the base coat, coat c is the clear coat, and coat bc indicates that both base coat and clear coat were applied during the sampling period. For the variable GUN, hvlp refers to the high volume low pressure spray painting gun and nhvlp refers to other spray painting guns.

Figure D1: Selected SAS output, the analysis of variance and regression analysis output

Least Squares Means

GUN1	LCONC LSMEAN	T / Pr > |T| H0 LSMEAN1=LSMEAN2
hvlp	-0.05378676	-1.32114
		0.1927
nhvlp	0.57849169	

COAT	LCONC LSMEAN	T for H0: LSMEAN(i)=LSMEAN(j) / Pr > |T| i/j	1	2	3
b	-0.17233368	1	.	-0.64234	-2.64571
				0.5237	0.0110
bc	0.17577774	2	0.642342		-1.23895
			0.5237		0.2214
c	0.78361333	3	2.645712	1.238951	
			0.0110	0.2214	

LOC	LCONC LSMEAN	T for H0: LSMEAN(i)=LSMEAN(j) / Pr > |T| i/j	1	2	3
p	-0.47984081	1	.	-0.18643	-4.85001
				0.8529	0.0001
s	-0.39742273	2	0.186427		-4.31417
			0.8529		0.0001
u	1.66432093	3	4.850015	4.314172	.
			0.0001	0.0001	

GUN1	LOC	LCONC LSMEAN	LSMEAN Number
hvlp	p	-0.85292973	1
hvlp	s	-0.23554048	2
hvlp	u	0.92710993	3
nhvlp	p	-0.10675190	4
nhvlp	s	-0.55930497	5
nhvlp	u	2.40153193	6

Least Squares Means for effect GUN1*LOC
T for H0: LSMEAN(i)=LSMEAN(j) / Pr > |T|

Dependent Variable: LCONC

i/j	1	2	3	4	5	6
1	.	-1.41347	-4.07527	-1.17476	-0.39688	-4.39892
		0.1640	0.0002	0.2459	0.6932	0.0001
2	1.413467	.	-2.5077	-0.20091	0.434812	-3.54156
	0.1640		0.0156	0.8416	0.6656	0.0009
3	4.075269	2.507705	.	1.612802	1.99624	-1.98013
	0.0002	0.0156		0.1133	0.0516	0.0534
4	1.174758	0.200907	-1.6128		0.588868	-3.26381
	0.2459	0.8416	0.1133		0.5587	0.0020
5	0.39688	-0.43481	-1.99624	-0.58887	.	-3.54242
	0.6932	0.6656	0.0516	0.5587		0.0009
6	4.398916	3.541561	1.980134	3.263813	3.54242	.
	0.0001	0.0009	0.0534	0.0020	0.0009	

NOTE. To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used

Figure D2: Selected SAS output, the least squares means and t-tests to evaluate differences among the means

The column labelled "Pr > F" (item 1 in Figure D1 is the probability that chance could have caused the observed differences A probability below 0 05 indicates that it is unlikely that chance caused the observed differences in concentration and thus one concludes that the variable really affected concentration Thus, the analysis of variance shows that the variables sampling location (LOC), coat of paint (coat), and LFTIME affected concentration The type of spray painting gun (G) and the interaction between spray painting gun and sampling location were not significant This simply indicates that the effect due to the type of spray painting gun is small in comparison to the experimental variability

Inspection of the regression coefficients indicates that beneath the car, the concentrations were lower when the HVLP spray painting gun was used In Figure D1, item 2, the regression coefficient β_6 is the magnitude of the difference in lnconc caused by the spray painting gun under the car and it is different from 0 at about the 95 percent level of confidence From β_6, the percentage reduction in the concentration measured beneath the car (100 $(1-\exp_e(\beta_1))$ was computed to be 77 percent This suggests that the HVLP spray painting gun is reducing the amount of overspray

The regression coefficient for the variable LFTIME was 1 2±0 96 This indicates that concentration is roughly proportional to the fraction of time that the worker is spray painting Because the fraction of time spent painting varied from task to task, examining the concentration differences among observed geometric medians may be misleading

In order to evaluate the concentration differences caused by sampling location and spray painting gun, the least squares means option of the SAS General Linear Models procedure was specified to evaluate the concentration difference attributed to the spray painting guns at the different sampling locations This option uses the statistical model listed above to estimate the means which would be expected if the experimental design had been completely balanced and all the other variables in the statistical model (such as the fraction of time painting) are at their mean value This computation is necessary because the fraction of time spent painting and the coat of paint being applied were found to affect the total particulate concentration Consider the summary statistics presented in Table D1 for the different combinations of sampling location and spray painting gun There was no attempt to control the type of paint applied to the car or the fraction of the sampling time the worker actually spent painting To some extent, these two covariates affect the observed differences in concentration due to the type of spray painting gun in Table D1 The least square means option is used to compensate for the fact that these two covariates affected the observed concentrations and thus they may affect the observed difference between the spray painting guns These results are shown in Figure D2 and in Table D1 For the variable sampling location, the samples under the car where higher than samples collected at the other two sampling locations

The medians computed by taking the inverse logarithm of the least squares means for the different combinations of sampling location and type of spray painting gun are listed in Table D1 The probabilities for the concentration differences between the two spray painting guns for the three sampling locations are shown as item 1 in Figure D2 For the personal sample, there is about a factor of 2 difference in medians listed in Table D1 However, this difference was not significant (Probability of a larger |T| = 0 19) This simply indicates that the difference was not larger than the variability in the data This implies that this study had insufficient power of test to evaluate whether the HVLP guns can cause a factor of 2 or 3 reduction in exposure

Table D1 Median concentrations (mg/m^3) based upon least squares means

Sampling Location	Mattson Spray Gun	non-HVLP Spray Guns	Difference
personal	0 43	0 90	not significant
on side of booth	0 79	0 57	not significant
under the car	2 51	10 9	significant

The SAS General Linear Models procedure was used to evaluate whether sampling location affected the total particulate concentration at the vehicle preparation station Before the data was analyzed, the natural logarithms of the concentration data was taken The data analysis was performed on logarithms of concentration data The analysis was conducted to evaluate whether sampling location (LOC) affected the logarithm of the total particulate concentration (LCONC) The output from SAS is presented in Figure D3 The column labelled "Prob > F" is the probability that the observed differences in LCONC among the different location could be explained by chance These results indicate that the sampling location affected LCONC Tukey's Studentized Range Test was used to examine how the concentration differed among the sampling locations at the vehicle preparation station

```
                                   SAS    11:09 Monday, November 23, 1992   3

                    General Linear Models Procedure

Dependent Variable: LCONC
                                      Sum of            Mean
Source                    DF         Squares          Square    F Value      Pr > F

Model                      2     17.88235906      8 94117953       7.08      0 0170
Error                      8     10 10212089      1.26276511
Corrected Total           10     27 98447995

                    R-Square             C V        Root MSE             LCONC Mean

                    0.639010        292 5873        1.123728             0 38406600

Dependent Variable: LCONC

Source                    DF     Type III SS     Mean Square    F Value      Pr > F

LOC                        2     17 88235906      8 94117953       7.08      0 0170


          Tukey's Studentized Range (HSD) Test for variable: LCONC
       NOTE: This test controls the type I experimentwise error rate
          Alpha= 0.05  Confidence= 0.95  df= 8  MSE= 1 262765
               Critical Value of Studentized Range= 4.041
    Comparisons significant at the 0.05 level are indicated by '***'.

                         Simultaneous               Simultaneous
                            Lower     Difference       Upper
               LOC        Confidence    Between      Confidence
            Comparison      Limit        Means          Limit

           f    - p        -1.664        0.681          3.026
           f    - b         0.596        3.218          5.840    ***
           p    - f        -3 026       -0.681          1.664
           p    - b         0.192        2.537          4.882    ***
           b    - f        -5.840       -3.218         -0.596    ***
           b    - p        -4 882       -2 537         -0.192    ***

Author's annotation   Location "f" refers to samples collected near the filter.  Location "p" refers
to the personal samples and location "b" refers to the background sampling location
```

Figure D3: Selected SAS output from the analysis of the total particulate concentrations at the vehicle preparation stations

References

51 Helsel, D [1990] Less than obvious-statistical treatment of data below the detection limit Environ Sci Technol 24 1767-1774

52 SAS Institute [1988] SAS/STAT users guide Cary, NC Release 6 03

APPENDIX E

RESPIRATORY PROTECTION
(Code of Federal Regulations, 29 CFR 1910 134)

(a) Permissible practice (1) In the control of those occupational diseases caused by breathing air contaminated with harmful dusts, fogs, fumes, mists, gases, smokes, sprays, or vapors, the primary objective shall be to prevent atmospheric contamination This shall be accomplished as far as feasible by accepted engineering control measures (for example, enclosure or confinement of the operation, general and local ventilation, and substitution of less toxic materials) When effective engineering controls are ot feasible, or while they are being instituted, appropriate respirators shall be used pursuant to the following requirements

(2) Respirators shall be provided by the employer when such equipment is necessary to protect the health of the employee The employer shall provide the respirators which are applicable and suitable for the purpose intended The employer shall be responsible for the establishment and maintenance of a respiratory protective program which shall include the requirements outlined in paragraph (b) of this section

(3) The employee shall use the provided respiratory protection in accordance with instructions and training received (b) Requirements for a minimal acceptable program (1) Written standard operating procedures governing the selection and use of respirators shall be established

1910 134(b)(2)

(2) Respirators shall be selected on the basis of hazards to which the worker is exposed

(3) The user shall be instructed and trained in the proper use of respirators and their limitations

(4) [Reserved]

(5) Respirators shall be regularly cleaned and disinfected Those used by more than one worker shall be thoroughly cleaned and disinfected after each use

(6) Respirators shall be stored in a convenient, clean, and sanitary location

(7) Respirators used routinely shall be inspected during cleaning Worn or deteriorated parts shall be replaced Respirators for emergency use such as self-contained devices shall be thoroughly inspected at least once a month and after each use

(8) Appropriate surveillance of work area conditions and degree of employee exposure or stress shall be maintained

(9) There shall be regular inspection and evaluation to determine the continued effectiveness of the program

(10) Persons should not be assigned to tasks requiring use of respirators unless it has been determined that they are physically able to perform the work and use the equipment The local physician shall determine what health and physical conditions are pertinent The respirator user's medical status should be reviewed periodically (for instance, annually)

1910 134(b)(11)

(11) Approved or accepted respirators shall be used when they are available The respirator furnished shall provide adequate respiratory protection against the particular hazard for which it is

designed in accordance with standards established by competent authorities The U S Department of Interior, Bureau of Mines, and the U S Department of Agriculture are recognized as such authorities Although respirators listed by the U S Department of Agriculture continue to be acceptable for protection against specified pesticides, the U S Department of the Interior, Bureau of Mines, is the agency now responsible for testing and approving pesticide respirators

(c) Selection of respirators Proper selection of respirators shall be made according to the guidance of American National Standard Practices for Respiratory Protection Z88 2-1969

(d) Air quality (1) Compressed air, compressed oxygen, liquid air, and liquid oxygen used for respiration shall be of high purity Oxygen shall meet the requirements of the United States Pharmacopoeia for medical or breathing oxygen Breathing air shall meet at least the requirements of the specification for Grade D breathing air as described in Compressed Gas Association Commodity Specification G-7 1-1966 Compressed oxygen shall not be used in supplied-air respirators or in open circuit self-contained breathing apparatus that have previously used compressed air Oxygen must never be used with air line respirators

1910 134(d)(2)

(2) Breathing air may be supplied to respirators from cylinders or air compressors

(i) Cylinders shall be tested and maintained as prescribed in the Shipping Container Specification Regulations of the Department of Transportation (49 CFR Part 178)

(ii) The compressor for supplying air shall be equipped with necessary safety and standby devices A breathing air-type compressor shall be used Compressors shall be constructed and situated so as to avoid entry of contaminated air into the system and suitable in-line air purifying sorbent beds and filters installed to further assure breathing air quality A receiver of sufficient capacity to enable the respirator wearer to escape from a contaminated atmosphere in event of compressor failure, and alarms to indicate compressor failure and overheating shall be installed in the system If an oil-lubricated compressor is used, it shall have a high-temperature or carbon monoxide alarm, or both If only a high-temperature alarm is used, the air from the compressor shall be frequently tested for carbon monoxide to insure that it meets the specifications in paragraph (d)(1) of this section

(3) Air line couplings shall be incompatible with outlets for other gas systems to prevent inadvertent servicing of air line respirators with nonrespirable gases or oxygen

1910 134(d)(4)

(4) Breathing gas containers shall be marked in accordance with American National Standard Method of Marking Portable Compressed Gas Containers to Identify the Material Contained, Z48 1-1954, Federal Specification BB-A-1034a, June 21, 1968, Air, Compressed for Breathing Purposes, or Interim Federal Specification GG-B-00675b, April 27, 1965, Breathing Apparatus, Self-Contained

(e) Use of respirators (1) Standard procedures shall be developed for respirator use These should include all information and guidance necessary for their proper selection, use, and care Possible emergency and routine uses of respirators should be anticipated and planned for

(2) The correct respirator shall be specified for each job The respirator type is usually specified in the work procedures by a qualified individual supervising the respiratory protective program The individual issuing them shall be adequately instructed to insure that the correct respirator is issued

(3) Written procedures shall be prepared covering safe use of respirators in dangerous atmospheres that might be encountered in normal operations or in emergencies Personnel shall be familiar with these procedures and the available respirators

1910 134(e)(3)(i)

(i) In areas where the wearer, with failure of the respirator, could be overcome by a toxic or oxygen-deficient atmosphere, at least one additional man shall be present Communications (visual, voice, or signal line) shall be maintained between both or all individuals present Planning shall be such that one individual will be unaffected by any likely incident and have the proper rescue equipment to be able to assist the other(s) in case of emergency

(ii) When self-contained breathing apparatus or hose masks with blowers are used in atmospheres immediately dangerous to life or health, standby men must be present with suitable rescue equipment

(iii) Persons using air line respirators in atmospheres immediately hazardous to life or health shall be equipped with safety harnesses and safety lines for lifting or removing persons from hazardous atmospheres or other and equivalent provisions for the rescue of persons from hazardous atmospheres shall be used A standby man or men with suitable self-contained breathing apparatus shall be at the nearest fresh air base for emergency rescue

(4) Respiratory protection is no better than the respirator in use, even though it is worn conscientiously Frequent random inspections shall be conducted by a qualified individual to assure that respirators are properly selected, used, cleaned, and maintained

1910 134(e)(5)

(5) For safe use of any respirator, it is essential that the user be properly instructed in its selection, use, and maintenance Both supervisors and workers shall be so instructed by competent persons Training shall provide the men an opportunity to handle the respirator, have it fitted properly, test its face-piece-to-face seal, wear it in normal air for a long familiarity period, and, finally, to wear it in a test atmosphere

(i) Every respirator wearer shall receive fitting instructions including demonstrations and practice in how the respirator should be worn, how to adjust it, and how to determine if it fits properly Respirators shall not be worn when conditions prevent a good face seal Such conditions may be a growth of beard, sideburns, a skull cap that projects under the facepiece, or temple pieces on glasses Also, the absence of one or both dentures can seriously affect the fit of a facepiece The worker's diligence in observing these factors shall be evaluated by periodic check To assure proper protection, the facepiece fit shall be checked by the wearer each time he puts on the respirator This may be done by following the manufacturer's facepiece fitting instructions

(ii) Providing respiratory protection for individuals wearing corrective glasses is a serious problem A proper seal cannot be established if the temple bars of eye glasses extend through the sealing edge of the full facepiece As a temporary measure, glasses with short temple bars or without temple bars may be taped to the wearer's head Wearing of contact lenses in contaminated atmospheres with a respirator shall not be allowed Systems have been developed for mounting corrective lenses inside full facepieces When a workman must wear corrective lenses as part of the facepiece, the facepiece and lenses shall be fitted by qualified individuals to provide good vision, comfort, and a gas-tight seal

1910 134(e)(5)(iii)

(iii) If corrective spectacles or goggles are required, they shall be worn so as not to affect the fit of the facepiece Proper selection of equipment will minimize or avoid this problem

(f) Maintenance and care of respirators (1) A program for maintenance and care of respirators shall be adjusted to the type of plant, working conditions, and hazards involved, and shall include the following basic services

(i) Inspection for defects (including a leak check),

(ii) Cleaning and disinfecting,

(iii) Repair,

(iv) Storage

Equipment shall be properly maintained to retain its original effectiveness

(2) (i) All respirators shall be inspected routinely before and after each use A respirator that is not routinely used but is kept ready for emergency use shall be inspected after each use and at least monthly to assure that it is in satisfactory working condition

(ii) Self-contained breathing apparatus shall be inspected monthly Air and oxygen cylinders shall be fully charged according to the manufacturer's instructions It shall be determined that the regulator and warning devices function properly

1910 134(f)(2)(iii)

(iii) Respirator inspection shall include a check of the tightness of connections and the condition of the facepiece, headbands, valves, connecting tube, and canisters Rubber or elastomer parts shall be inspected for pliability and signs of deterioration Stretching and manipulating rubber or elastomer parts with a massaging action will keep them pliable and flexible and prevent them from taking a set during storage

(iv) A record shall be kept of inspection dates and findings for respirators maintained for emergency use

(3) Routinely used respirators shall be collected, cleaned, and disinfected as frequently as necessary to insure that proper protection is provided for the wearer Respirators maintained for emergency use shall be cleaned and disinfected after each use

(4) Replacement or repairs shall be done only by experienced persons with parts designed for the respirator No attempt shall be made to replace components or to make adjustment or repairs beyond the manufacturer's recommendations Reducing or admission valves or regulators shall be returned to the manufacturer or to a trained technician for adjustment or repair

1910 134(f)(5)

(5) (i) After inspection, cleaning, and necessary repair, respirators shall be stored to protect against dust, sunlight, heat, extreme cold, excessive moisture, or damaging chemicals Respirators placed at stations and work areas for emergency use should be quickly accessible at

all times and should be stored in compartments built for the purpose The compartments should be clearly marked Routinely used respirators, such as dust respirators, may be placed in plastic bags Respirators should not be stored in such places as lockers or tool boxes unless they are in carrying cases or cartons

(ii) Respirators should be packed or stored so that the facepiece and exhalation valve will rest in a normal position and function will not be impaired by the elastomer setting in an abnormal position

(iii) Instructions for proper storage of emergency respirators, such as gas masks and self-contained breathing apparatus, are found in "use and care" instructions usually mounted inside the carrying case lid

(g) Identification of gas mask canisters (1) The primary means of identifying a gas mask canister shall be by means of properly worded labels The secondary means of identifying a gas mask canister shall be by a color code

1910 134(g)(2)

(2) All who issue or use gas masks falling within the scope of this section shall see that all gas mask canisters purchased or used by them are properly labeled and colored in accordance with these requirements before they are placed in service and that the labels and colors are properly maintained at all times thereafter until the canisters have completely served their purpose

(3) On each canister shall appear in bold letters the following

(i) - Canister

for ______________________________

(Name for atmospheric contaminant)

or

Type N Gas Mask Canister

(ii) In addition, essentially the following wording shall appear beneath the appropriate phrase on the canister label "For respiratory protection in atmospheres containing not more than _______ percent by volume of ______________________ "

Name of atmospheric contaminant)

1910 134(g)(4)

(4) Canisters having a special high-efficiency filter for protection against radionuclides and other highly toxic particulates shall be labeled with a statement of the type and degree of protection afforded by the filter The label shall be affixed to the neck end of, or to the gray stripe which is around and near the top of, the canister The degree of protection shall be marked as the percent of penetration of the canister by a 0 3-micron-diameter dioctyl phthalate (DOP) smoke at a flow rate of 85 liters per minute

(5) Each canister shall have a label warning that gas masks should be used only in atmospheres containing sufficient oxygen to support life (at least 16 percent by volume), since gas mask canisters are only designed to neutralize or remove contaminants from the air

(6) Each gas mask canister shall be painted a distinctive color or combination of colors indicated in Table I-1 All colors used shall be such that they are clearly identifiable by the user and clearly distinguishable from one another The color coating used shall offer a high degree of resistance to chipping, scaling, peeling, blistering, fading, and the effects of the ordinary atmospheres to which they may be exposed under normal conditions of storage and use Appropriately colored pressure sensitive tape may be used for the stripes

TABLE I-1

Atmospheric contaminants to be protected against	Colors assigned(1)
Acid gases	White
Hydrocyanic acid gas	White with 1/2-inch green stripe completely around the canister near the bottom
Chlorine gas	White with 1/2-inch yellow stripe completely around the canister near the bottom
Organic vapors	Black
Ammonia gas	Green
Acid gases and ammonia gases	Green with 1/2-inch white stripe completely around the canister near the bottom
Carbon Monoxide	Blue
Acid gases and organic vapors	Yellow
Hydrocyanic acid gas and chloropicrin vapor	Yellow with 1/2-inch blue stripe completely around the canister near the bottom
Acid gases, organic vapors, and ammonia gases	Brown
Radioactive materials, excepting tritium and noble gases	Purple (Magenta)
Particulates (dusts, fumes, mists, fogs, or smokes) in combination with any of the above gases or vapors	Canister color for contaminant, as designated above, with 1/2-inch gray stripe completely around the canister near the top
All of the above atmospheric contaminants	Red with 1/2-inch gray stripe completely around the canister near the top

Footnote(1) Gray shall not be assigned as a main color for a canister designed to remove acids or vapors

NOTE Orange shall be used as a complete body, or stripe color to represent gases not included in this table The user will need to refer to the canister label to determine the degree of protection the canister will afford

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