IN-DEPTH SURVEY REPORT

CONTROL TECHNOLOGY FOR AUTOBODY REPAIR AND PAINTING SHOPS

AT

Blue Ash Autobody Shop
Blue Ash, Ohio

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DISCLAIMER

SUMMARY

The ability of a spray painting booth and orbital and in-line sanders with high velocity low volume exhaust ventilation was evaluated Air samples collected in the worker's breathing zone for total dust, organic solvents, chromium, cadmium, titanium dioxide, and hexamethylene diisocyanate monomer were below OSHA permissible exposure limits (PELs) and NIOSH recommended exposure limits (RELs) When spray painting was performed outside of the booth, the breathing zone concentration of this polyisocyanate was estimated to be 10 mg/m^3 and a total dust concentration of 30 mg/m^3 was measured Federal OSHA does not have a PEL for polyisocyanates, however, a ceiling limit of 1 mg/m^3 is enforced by Oregon OSHA Spray painting involving isocyanates should not be conducted outside of a properly operated spray painting booth

In a downdraft spray painting booth, air flows into the booth through filters in the ceiling and out of the booth through exhaust grates located in the floor of the booth The car, which is to be painted, is placed in the booth The air is supposed to flow around the car and out through the exhaust grates which are located in the floor of the booth This booth was operating at a flow rate of 7000 to 8000 cfm versus a design airflow rate of 10,000 cfm During data collection, the booth's exhaust filters were absent and the airflow around the car was not uniform

Because the spray painting booth does not completely control the worker's exposure to paint overspray, respiratory protection is needed Quantitative fit tests, conducted on the half-facepiece and full-facepiece air-purifying respirators used in this autobody shop, revealed that four of six of these respirators provided a fit factor of less than 100 A fit factor of 5 was obtained with one full-facepiece respirator To some extent, these low fit factors were caused by lack of a respirator maintenance program In addition, there appeared to be no respirator program as required by OSHA's respiratory protection standard (29 CFR 1910 134) If the shop owner had understood and complied with the requirements of this OSHA standard, the problems with respirator usage in this shop probably would not have occurred

The data collected while the workers used sanders with built-in HVLV ventilation was too limited to develop any definite conclusions about the performance of these sanders During one sanding operation which lasted about an hour, the total dust exposure measured on the worker's lapel was 0 18 mg/m^3 When the ventilation hose was temporarily disconnected, measurements made with an aerosol photometer indicated a noticeable increase in the aerosol concentration

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 and sanding operations are being studied At this particular body shop, a spray paint booth, a disk sander with built-in ventilation, and respirator usage were evaluated This paint booth has a downdraft ventilation arrangement to remove the paint vapors The disk sander has a built-in hood which uses a small volume of air to capture sanding dust at the source Techniques for controlling paint vapors and dust from sanding have applications in many other industries

SHOP DESCRIPTION

This autobody shop employs eleven workers, four doing body work, two painting cars, two performing housekeeping, and three in the office The shop, which opened in 1985, repairs 20 to 25 cars per week The layout of the shop is illustrated in Figure 1 Outside of the painting booth, the cars' structural damage is repaired This involves the repair and replacement of damaged parts During these activities, workers may be exposed to aerosols from sanding, grinding, and welding Some sanding is done with sanders which have built-in high velocity low volume hoods After the cars are repaired, they are prepared for painting in the vehicle preparation area This involves some sanding to remove old paint and to provide a smooth surface for the paint After the surface has been prepared, the areas of the car which are not to be painted are covered with plastic Spray painting is done in a downdraft spray painting booth which exhausts a nominal 10,000 cfm while the worker is painting the car After the car or body part has been painted, the worker leaves the booth and the paint is cured at a temperature of 120° to 140°F During this time period, the booth airflow is reduced and about 90 percent of the exhaust air is recycled

Two 6-inch orbital sanders (Hutchins Model 8650, Hutchins Manufacturing Company, Pasadena, California, and Dynaorbital® DR™, Dynabrade Automotive Products, Clarence, New York) were used The sanders are connected to a central vacuum system Air is exhausted through holes in the sander pads A metal plate is used as a template to punch holes in the sandpaper which is then attached to these sanders The sandpaper for the Hutchins sander had six 0 4-inch diameter holes on a circle 1 5 inches from the edge of the sandpaper The Dynabrade sander had six 0 25-inch diameter holes 1 inch from the edge of the sandpaper The holes in the sandpaper align with the holes in the sander pads

A third sander, a Hutchins Model 4290 in-line sander, was also used with the central vacuum system The abrasive pad of this sander was 2 75 inches wide and 17 5 inches long Along the length of the sandpaper, two rows of nine equally spaced holes were located 0 5 inches from the edge of the sandpaper These holes were 0 45 inches in diameter

The exhaust from these sanders was attached to a vacuum hose The static pressure in the vacuum line connection to the sanders was 7 5 inches Hg The vacuum was supplied by a central vacuum system (Sand'N Vac Model 1035, Inventive Machine Corporation, Bolivar, Ohio) Each workstation had an outlet for the central vacuum system

The spray painting booth (Saico, SPA, Ramsey, New Jersey) was installed when the autobody shop was opened in 1985 This booth is 12 5 feet wide, 24 feet long, and 9 feet high (see Figure 2) Two fans are used in this booth One fan supplies makeup air through two sets of filters The first set of filters

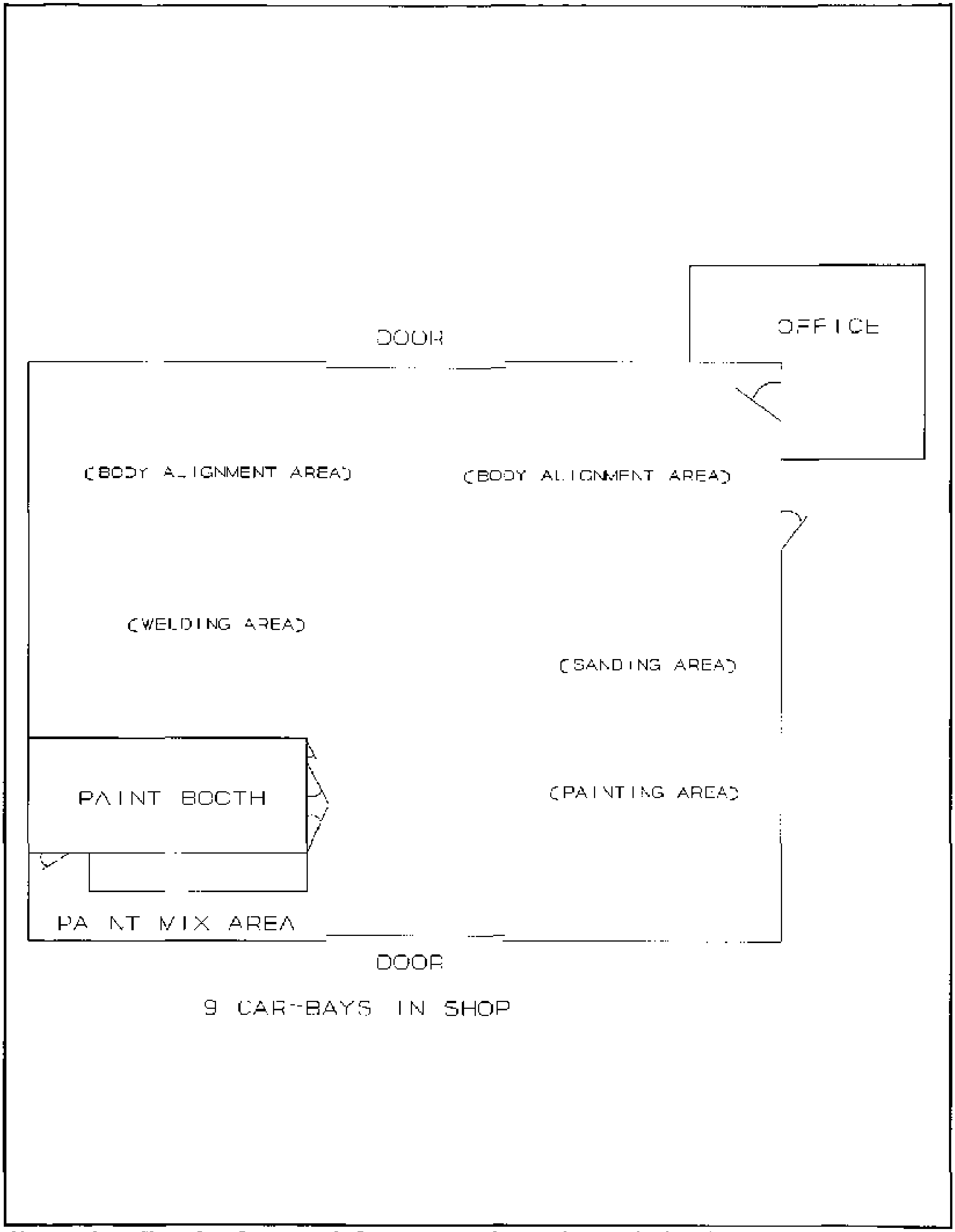

Figure 1 Sketch of general layout at Blue Ash Autobody Shop

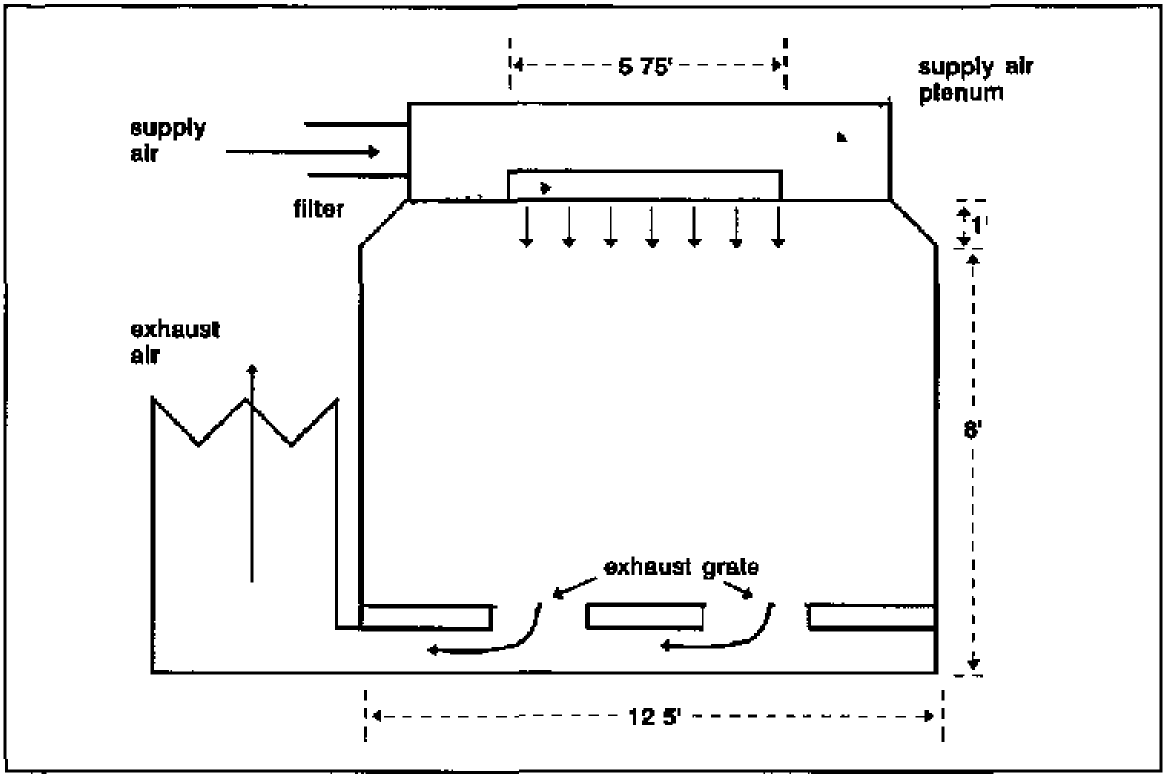

Figure 2 Schematic of spray painting booth

is located in the ductwork between the fan and the air distribution plenum in the ceiling of the booth The second set is located after the distribution plenum in the ceiling of the booth The air flows through these two sets of filters, around the car, and through a third set of filters located in the floor of the booth This third set of filters was not present during this study due to difficulties in obtaining replacement filters These filters would have covered the trench in the floor of the spray painting booth After leaving the booth, the air flowed up a discharge plenum to the roof of the shop On the roof, the discharge plenum made a 90° turn and discharged the air parallel to the ground There were no devices for measuring the static pressure in the booth or the pressure drop across the booth's filters According to the shop owner, the filters in the booth are changed every month The booth is operated at a static pressure of +0 14 inches of water relative to the shop

In the spray painting booth, two types of spray painting guns were used to apply paint to cars or car parts an Optima siphon cup gun (Technical Products Corporation, Lake Zurich, Illinois) and a gravity feed gun (SATA, Ludwigsburg, Germany) One worker used a siphon cup spray painting gun marketed by Optima In the siphon cup gun, the acceleration of the air through an orifice causes a reduction in static pressure The reduced static pressure causes the paint to flow from a cup into the orifice where the paint is atomized In the siphon cup guns, the air pressure at the atomization orifice is typically 65 pounds per square inch (psi) In the gravity feed gun, the paint is contained in a cup on top of the spray painting gun and gravity assists the flow of paint to the orifice where atomization takes place The air pressure at the orifice of a gravity feed gun is typically 40 to 50 psi After the air sampling had been conducted at this shop, the conventional spray painting guns at this shop were replaced with High Volume Low Pressure (HVLP) spray gun painting guns to reduce paint consumption These guns use less than 10 psi to atomize the paint Reportedly, the HVLP spray guns are much more efficient at transferring the paint from the gun to the car than the other two types of spray painting guns [1,2] HVLP spray painting 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 [2,3]

In this shop, most painting jobs involve the application of a primer, a base coat, and a clear coat Typically, the base coat contains colored pigments and carrier solvents Depending upon the paint formulation, these pigments can include chromium, nickel, antimony, titanium, and lead A clear coat is applied over the base coat The clear coat has two components a clear coat and a hardener The clear coat contains polyurethane and acrylic resins The hardener contains polyisocyanates which are trimers of hexamethylene diisocyanate and isophorone diisocyanate The hardener cross-links with the other components of the clear coat to form a hard urethane surface

POTENTIAL HAZARDS

Workers involved in autobody repair can potentially be exposed to a multitude of air contaminants During structural repair, activities such as sanding, grinding, and welding generate aerosols which are released into the worker's breathing zone If the surface of the car being repaired contains toxic metals such as lead, cadmium, or chromium, exposure to these metals is possible Workers who paint cars can be exposed to organic solvents, hardeners which may contain isocyanate resins, and pigments which may contain toxic components

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 "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 Some of the health effects for specific air contaminants are briefly summarized in the following paragraphs

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 [5] To reduce the inhalation exposure to monomers due to evaporation, the isocyanate monomers are prepolymerized into oligomers that are generally trimers 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 during spray painting

Reports indicate that diisocyanates cause irritation to the skin, mucous membranes, eyes, and respiratory tract [6] 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 [7,8] Lung function is reported to decrease with the number of exposures greater than 0 2 mg/m^3 to hexamethylene diisocyanate biuret [9] The most important and most debilitating health effect from exposure to diisocyanates is respiratory and dermal sensitization After sensitization, any exposure, even to levels recognized as safe for the nonsensitized individual, can produce an allergic response that may be life threatening [10,11] The only effective treatment for the sensitized worker is cessation of all diisocyanate exposure [6]

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 [12] Automotive spray painters exposed to organic solvents are reported to have decreases in motor and nerve conduction velocities [13] In addition, organic solvents such as acetone, toluene, and xylene can cause eye, nose, and throat irritation [14] 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 encountered in this facility 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 (12,000 ppm) depress the central nervous system, causing headache, drowsiness, weakness, and nausea Repeated direct skin contact with the liquid acetone may cause redness and dryness of the skin [15] Exposures over 1000 ppm cause respiratory irritation, coughing, and headache [16]

n-Butyl Acetate

At concentrations exceeding 150 ppm, significant irritation of the eyes and respiratory tract are reported in the literature [16] n-Butyl Alcohol

n-Butyl alcohol is an irritant to the eyes and the mucous membranes of nose and throat Exposures over 200 ppm can cause keratitis [16] Eye irritation and headaches occur at concentrations in excess of 50 ppm [16] Exposure to n-butyl alcohol is reported to increase hearing losses for workers who are also exposed to noise

Ethyl Acetate

Ethyl acetate vapor is irritating to the eyes and respiratory passages of humans at concentrations above 400 ppm [16] In animals, it has a narcotic effect at concentrations of over 5000 ppm

Isopropyl Alcohol

At exposure above 400 ppm, irritation to the eyes, nose, and throat are reported Above 800 ppm, the symptoms intensified [16]

Trimethyl Benzene

Trimethyl benzene has been reported to cause nervousness, anxiety, and asthmatic bronchitis [16]

Toluene

Toluene can cause irritation of the eyes and respiratory tract, dermatitis, and central nervous system depression [14] 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 [16] 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 Liquid xylene is irritating to the eyes and mucous membranes, and aspiration of a few milliliters may cause chemical pneumonitis, pulmonary edema, and hemorrhaging Repeated exposure of the eyes to high concentrations of xylene vapor may cause reversible eye damage [14] At concentrations between 90 and 200 ppm, impairment of body balance, manual coordination, and reaction times can occur Acute exposure to xylene vapor may cause central nervous system depression and minor reversible effects upon liver and kidneys [1] Workers exposed to concentrations above 200 ppm complain of loss of appetite, nausea, vomiting, and abdominal pain Brief exposure of humans to 200 ppm has caused irritation of the eyes, nose, and throat [17]

METALS

Toxic metals such as lead, chromium, and cadmium may be used as pigments in some paints Thus, sanding, welding, and spray painting may involve occupational exposure to toxic metals In addition, autobody welding will involve exposure to welding fumes Some health effects attributed to lead, cadmium, chromium, and titanium dioxide are discussed below

Cadmium

Cadmium is a toxic, heavy metal which may enter the body either by ingestion (swallowing) or by inhalation (breathing) of cadmium metal or oxide Once absorbed into the body, cadmium accumulates in organs throughout the body, but major depositions occur in the liver and kidneys [18] Acute inhalation exposure to high levels of cadmium can cause respiratory irritation and pulmonary edema In addition, cadmium exposure causes kidney damage [15] Chronic exposure may lead to emphysema of the lungs and kidney disease which may be associated with hypertension [19] After finding that exposure to cadmium has been associated with excess respiratory cancer deaths among cadmium production workers, NIOSH has concluded that cadmium is a potential occupational carcinogen [20]

Chromium

Some paints may contain chromates, 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 are suspect carcinogens [21]

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 [18] 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 [15] 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 [22,23] Lead exposure is associated with fetal damage in pregnant women [15] Lastly, elevated blood pressure has been positively related to blood lead levels [24,25]

Titanium dioxide

In reviewing the health affects literature on titanium dioxide, ACGIH found no evidence that exposure to titanium dioxide poses a health hazard, as long as the exposure remains below 10 mg/m^3 [16] However, NIOSH reviewed animal testing data which indicates that exposure to titanium dioxide involves some risk of cancer [26]

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 autobody shops 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)

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 [16] It should be noted that the 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 criterion These combined effects are often not considered in the evaluation criteria Also, some substances are absorbed by direct contact with the skin and mucous membranes and thus, potentially increase the overall exposure Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available

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

Table 1 Occupational exposure limits

Substance	NIOSH Recommended Exposure Limit (REL)[27,28]	OSHA Permissible Exposure Limit (PEL)[29]		ACGIH Threshold Limit Value (TLV)[30]	
	TWA[a]	TWA[b]	STEL[c]	TWA[b]	STEL[c]
Acetone	250 ppm	750 ppm	1000 ppm	750 ppm	1000 ppm
n-Butyl Acetate	150 ppm	150 ppm	200 ppm	150 ppm	200 ppm
Cadmium (dust)	0 01 mg/m^3	0 2 mg/m^3	0 6 mg/m^3 (Ceiling)	0 05 mg/m^3	
Chromium (VI)	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 05 mg/m^3	0 5 mg/m^3		0 5 mg/m^3	
Ethyl Acetate	400 ppm	400 ppm		400 ppm	
Isopropyl Alcohol	400 ppm (800 ppm Ceiling)	400 ppm	500 ppm	400 ppm	500 ppm
Hexamethylene diisocyanate (HDI monomer)	0 035 mg/m^3 0 14 mg/m^3 (10-minute Ceiling)			5 ppb	
Particulate (not otherwise regulated) Total Respirable	 10 mg/m^3 5 mg/m^3	 15 mg/m^3 5 mg/m^3		 10 mg/m^3 5 mg/m^3	
Titanium Dioxide	0 2 mg/m^3	10 mg/m^3		10 mg/m^3	
Toluene	100 ppm (200 ppm Ceiling)	100 ppm	150 ppm	100 ppm	150 ppm
Trimethyl Benzene	25 ppm	25 ppm		25 ppm	
Xylene	100 ppm (200 ppm Ceiling)	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 29 CFR 1910 1000 The OSHA PELs listed in Table 1 were the PELs which were enforced at the time of the study and present PELs may be different

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

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

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

Where C = Exposure to an individual contaminant, and
L = The lowest exposure limit for the corresponding contaminant listed in Table 1

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

EXPOSURE LIMITS FOR PREPOLYMERIZED DIISOCYANATES

Although health effects are attributed to prepolymerized diisocyanates, OSHA, NIOSH, and ACGIH have not developed exposure limit values for these substances [31] 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 [32] 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 [33] In contrast, Sweden has a 5-minute, short-term exposure limit of 0 2 mg/m^3 for occupational exposure to hexamethylene diisocyanate biuret

The United Kingdom's Health and Safety Executive (HSE) has specified a control limit for occupational exposure to diisocyanates and oligomers of these diisocyanates [34] 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 μg/m^3, and

2 A 10-minute ceiling limit of 70 μg/m^3

During spray painting operations, occupational exposure to isocyanates frequently exceed these control limits [34]

EVALUATION PROCEDURES

The objective of this site visit was to evaluate the effectiveness of the ventilated sanders and spray painting booth for controlling worker exposure to air contaminants This was accomplished by measuring air contaminant concentrations and conducting video exposure monitoring In addition, ventilation measurements were made to document the airflow volumes in the spray painting booth and sanders Quantitative fit tests were conducted to evaluate respirator usage

AIR CONTAMINANT EXPOSURE MONITORING

The total dust concentrations were measured using NIOSH Method 0500 [35] In this method, a known volume of air is drawn through a preweighed PVC filter In the spray painting booth, an air sampling flow rate of 5 0 liters per minute using a personal sampling pump (Aircheck Sampler, Model 224 -- PCXR7, SKC Inc, Eighty Four, Pennsylvania) During sanding operations, an air sampling flow rate of 13 lpm was obtained by using a vacuum pump to maintain an absolute pressure less than 15 inches of mercury downstream of a critical flow orifice The weight gain of the filter is used to compute the milligrams of particulate per cubic meter of air After weighing, the filters were analyzed for lead, cadmium, chromium, and titanium The metals on each filter were solubilized using a modification of NIOSH Method 7300 Each filter was placed in a 125-mL beaker and then 1 mL of perchloric acid and 4 mL of nitric acid were added The beakers were placed on a hot plate and heated to approximately 150°C and the sample volume was reduced to nearly 0 5 mL The samples were quantitatively transferred to a 10-mL volumetric flask, diluted to 10 mL, and then were analyzed by a simultaneous-scanning, inductively coupled plasma emission spectrometer

Material safety data sheets were used to identify the major organic solvents which may be present during spray painting Concentration measurements were made for methyl ethyl ketone, toluene, xylene, and n-butyl acetate The measurements were made by placing charcoal tubes (SKC Lot 120) 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 sampler pump (Model 200, DuPont Inc) 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 NIOSH Method 1401 was used for the analysis with the following modifications [36]

Desorption Process	Thirty minutes in 1 0 mL of carbon disulfide with 0 5 μL ethyl benzene/mL CS_2 as an internal standard and 1 percent n-propyl alcohol as a desorbing aid
Gas Chromatograph	Hewlett-Packard Model 5890 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 40° to 120°C at a rate of 4°C/minute

During spray painting operations involving the use of isocyanate hardeners, the concentrations of hexamethylene diisocyanate and its isocyanurate trimer were measured by using NIOSH Method 5521 [37] In this method, air samples are bubbled through an impinger at a sampling rate of 1 liter per minute The impinger contains a solution of 1-(2-methoxyphenyl)piperazine, which reacts with the isocyanate to form ureas, in toluene The concentration of this solution is 43 mg/L The ureas are quantitated by high pressure liquid chromatography operated with a UV or electrochemical detector Because analytical standards are not available for trimers of diisocyanate monomers, this method extrapolates the calibration curve for the hexamethylene diisocyanate monomer to the prepolymers which, according to the material safety data sheet, is the isocyanurate trimer of HDI (CAS NO 28182-81-2) The results of NIOSH Method 5521 are reported in terms of mass of isocyanate group per unit volume ($\mu g\ NCO/m^3$)

The ultraviolet detector response obtained during NIOSH 5521 analysis was used to obtain the mass of harder collected in an air sample A bulk sample of the hardener (929-73 Glassodur MS High Solids Hardener - Normal, BASF, Whitehouse, Ohio) was quantitatively diluted to prepare analytical standards so that instrument response could be related to the mass of hardener in the air sample The material safety data sheet reported that this hardener contained 25 to 35 percent of a polyisocyanate with a Chemical Abstracts Service (CAS) No of 28182-81-2 and 10 to 20 percent of a polyisocyanate with a CAS No of 53880-05-0 The first CAS number refers to an isocyanurate of HDI [31] The second CAS number refers to a polymeric form of isophorone diisocyanate

For spray painting operations, air samples were collected at three 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, 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 in the booth 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 workers' exposure to air contaminants [38,39] Worker exposures were monitored with a direct-reading instrument, and its analog output was 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, Rhode Island) When the data collection was completed, the data logger was downloaded to a portable computer (Compaq Portable III, Compaq Computer Corporation, Houston, Texas) for analysis

During sanding operations, the Hand-held Aerosol Monitor (HAM, PPM Inc , Knoxville, Kentucky) was used to measure relative air contaminant 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 viewed as a measure of relative concentration A personal sampling pump (Aircheck, SKC Inc , Eighty Four, Pennsylvania) 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 concentrations on the worker 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, this instrument also is used as a measure of relative concentration Because of fire safety considerations, this instrument was located outside of the spray painting booth Teflon® tubing (0 125-inch inside diameter, 45 feet long, Alltech Associates, Deerfield, Illinois) 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 3 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 (Model 1040 Digital Air Velocity Meter, Kurz, Carmel Valley, California) The exhaust flow rate was calculated as the product of the duct's cross-sectional area and the average velocity in the exhaust duct

In the spray painting booth, airflow volumes through exhaust grates in the floor of the booth were calculated from the measured face velocities and the face area of the exhaust air channel in the floor of the spray painting booth The hot wire anemometer was used to measure these air velocities In addition, a Balometer™ (Alnor, Niles, Illinois) was used to measure the volumetric airflow rate through 2- by 4-foot sections of the filters in the ceiling of the booth The balometer measurements through each filter were summed to obtain the total volume of air entering the booth through the filters in the ceiling of the booth Smoke tubes were used to trace the airflow patterns in the spray painting booth

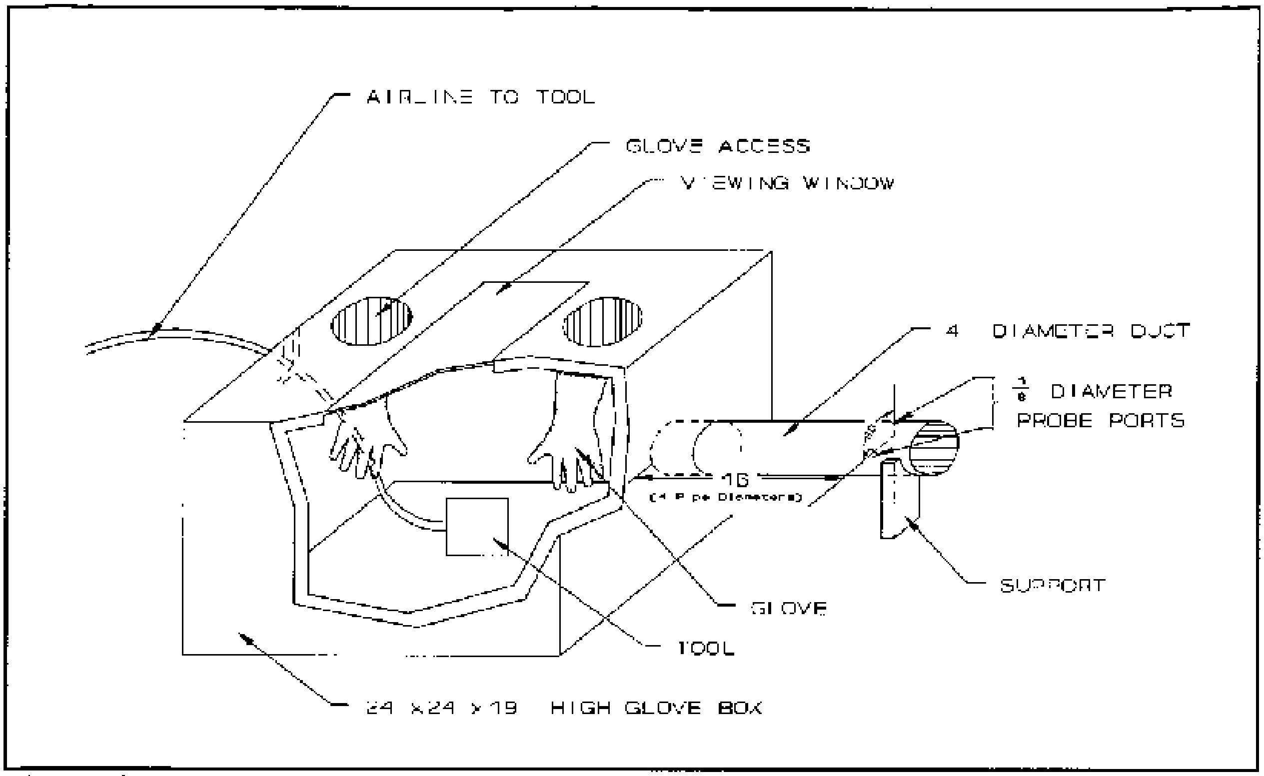

Figure 3   Apparatus for measuring airflow rates of ventilated sanders

Respirator Evaluation

The respirators currently utilized by the body shop employees were probed (brass probes provided by the manufacturers) for quantitative fit testing The probes were placed in the approximate center of the respirator, above the exhalation valve and between the cartridge holders The employees were then instructed to don the respirator as they normally did Quantitative fit testing was then conducted to determine respirator facepiece-to-face-sealing characteristics A Portacount™ respirator fit tester (TSI, Inc , P O Box 64394, St Paul, Minnesota 55164) was utilized to test all respirators The Portacount™ is based on a miniature, continuous-flow condensation nucleus counter (CNC) A CNC takes particles that are too small to be easily detected, grows them to a larger, easily detectable size, and then counts them [40] Quantitative fit factors for this device have been reported, on a group basis, as being highly correlated to those obtained by a recognized photometer quantitative fit test system [41] A complete fit test required the employee to perform the following six exercises normal breathing (NB1), deep breathing (DB), moving head side to side (SS), moving head up and down (UD), talking (TK), and normal breathing (NB2) An overall fit factor (FF) was then calculated using the following equation [41]

$$\text{Overall FF} = 6/[(1/NB1_{FF}) + (1/DB_{FF}) + (1/SS_{FF}) + (1/UD_{FF}) + (1/TK_{FF}) + (1/NB2_{FF})]$$

Next, the employees were instructed in the proper use and limitations of respiratory protective devices, and were allowed to select a new respirator from several manufacturers (three or more) Quantitative fit tests were then repeated as indicated above The employees were then informed of the difference in fit factors obtained from the two respirators with which they had been tested Finally, the condition (cleanliness, maintenance, etc) of the employee's original respirator was evaluated by a visual inspection

RESULTS

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

Exhaust Flow Rates (cfm)			
Operation	Type of Sander		
	Dynaorbital Circular (6-hole)	Hutchins In-Line (18-hole)	Hutchins Circular (6-hole)
Sander running without touching bottom of box	14	19	19
Light sanding	13	18	16
Heavy sanding	15	19	14

Table 3 summarizes the airflow volumetric rates measured for the spray painting booth The intake airflow measured on the roof is about 14 percent higher than the measurements made in the booth This could be due to either leakage out of the ducts between the fan and the spray painting booth or to measurement variability

Table 3 Volumetric airflow rates measured in spray painting booths

Location of Exhaust Volume Measurement	Instrument	Exhaust Volume (cfm)
Air intake on roof	anemometer	8125
Airflow from filters in ceiling	balometer	6780
Airflow exhausted through filters in floor	anemometer	6700

Figure 4 contains the airflow measurements through the filters in the ceiling of the spray painting booth These measurements indicated that the flow through the filters in the ceiling was uniform In the balometer, the flow contracts from a 6-square-foot area to a 14- by 14-inch area This restriction in the flow may cause some of the air to flow around the balometer resulting in a low measurement of the total exhaust volume

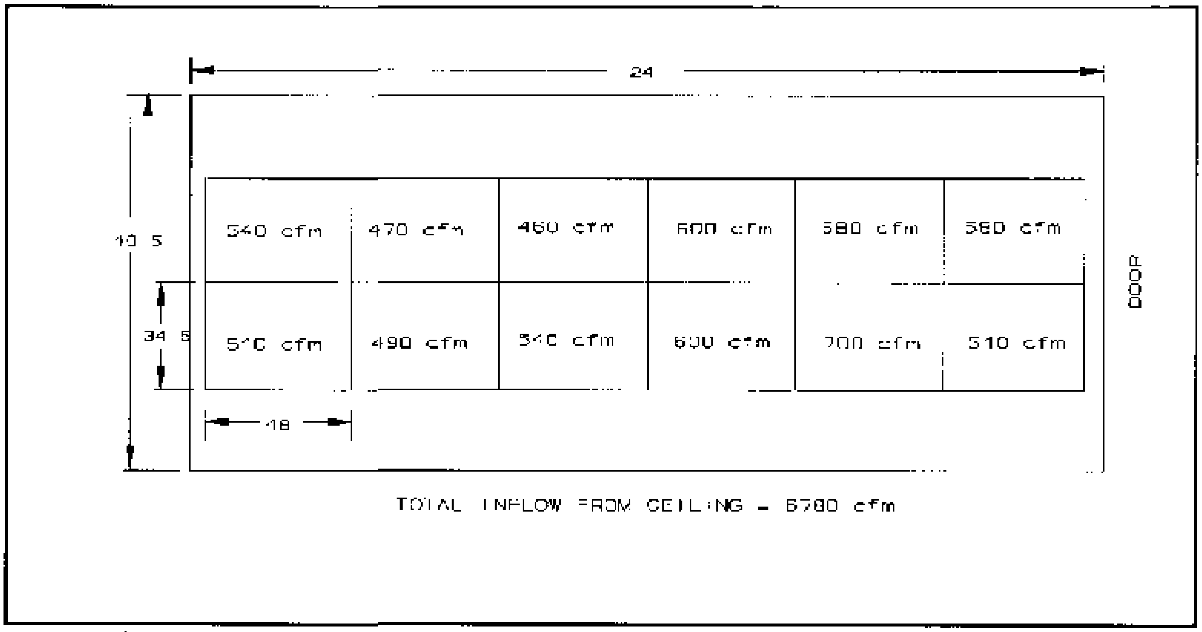

Figure 4 Air flow through filters in ceiling of spray painting booth

Figure 5 shows that more air was exhausted through the exhaust grate on the left hand side of the booth Also, the airflow appears to vary along the length of the booth As summarized in Table 3, the quantity of airflow is consistent with the balometer measurements Replacement of the filters missing in the floor of the booth may provide a more even distribution of the airflow

Figure 6 schematically shows how the spray painting booth provides airflow in some areas and stagnation in other areas The measurements made with the balometer (summarized in Figure 4) show that the airflow across the inlet filters is relatively uniform However, the velometer readings made at the floor (Figure 5) of the booth indicate that most of the exhaust flow occurs on the left hand side of the booth When smoke tube traces were made on the left hand side of the car, the smoke moved quickly toward the grate under the car On the right hand side, the smoke tended to linger where it was released, indicating little air movement toward the exhaust grates in the floor Smoke tube traces indicated the presence of an eddy in the region next to the wall This eddy causes the air to move up the side wall of the booth

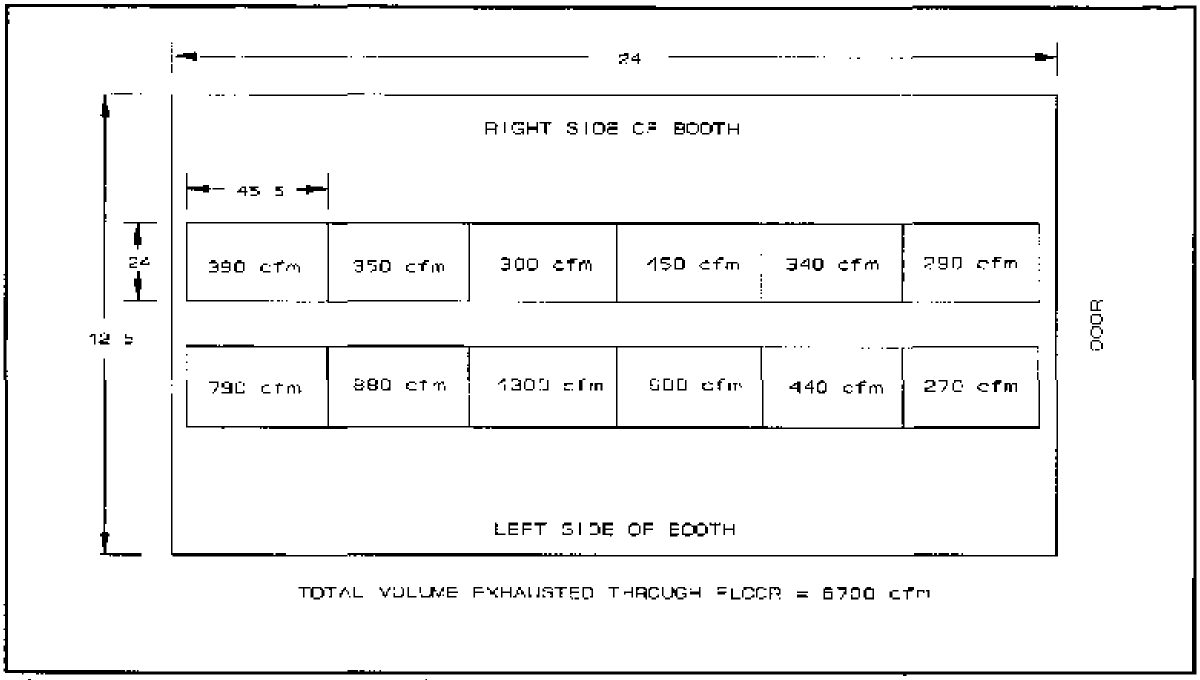

Figure 5 Air flow through the grates in the floor of the spray painting booth

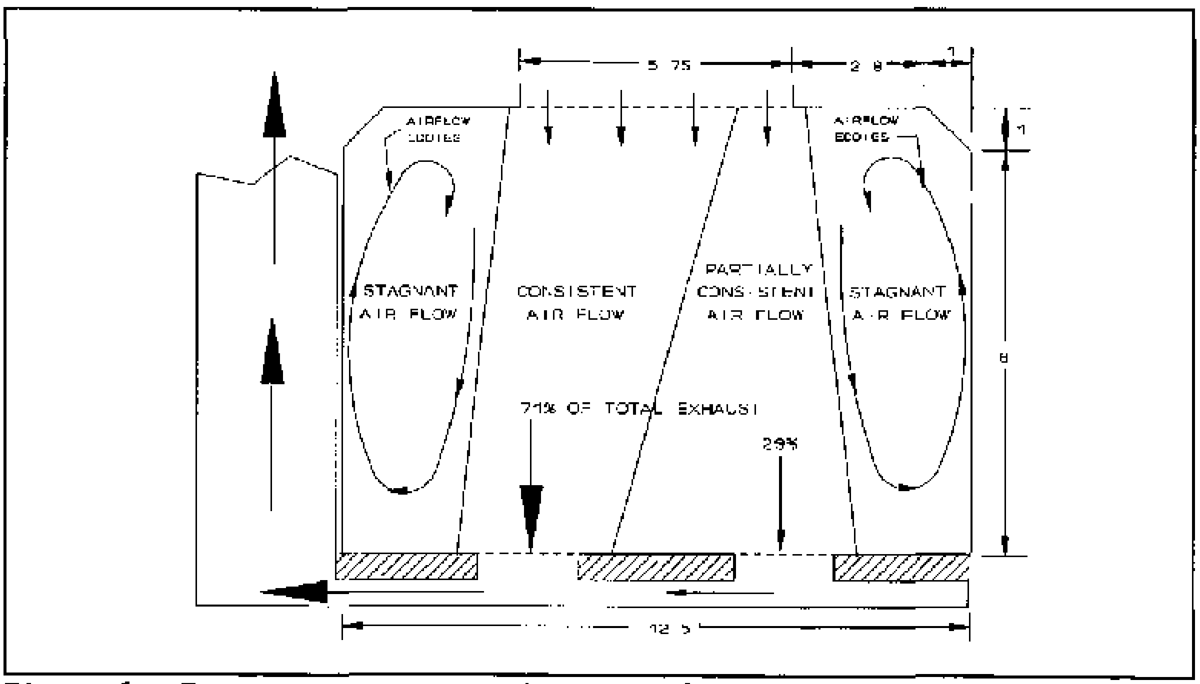

Figure 6 Figure summarizes various ventilation control zones based upon smoke tube traces in the spray painting booth

AIR SAMPLING RESULTS

Tables 4, 5, and 6 summarize the air contaminant concentrations measured in the spray painting booth The raw data are listed in Appendix A For samples collected during spray painting operations, the concentration computation was based upon the actual time spent spray painting Because the worker left the booth between spray painting coats, the worker's exposure to air contaminants during this time would have been minimal

Table 4 Summary of total dust concentrations during spray painting

Location	Number of Samples	Geometric Mean (GM) (mg/m^3)	Geometric Standard Deviation (GSD)	Range (mg/m^3)	Grouping*
Painter	6	6 2	2 0	2 3 - 17	B
Under car**	5	45	2 6	13 - 200	A
Wall	5	12	3 1	2 8 - 47	AB

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

** One measurement was deleted because it appeared to be an outlier Deleting this one measurement resulted in normally distributed residuals during statistical analysis

Table 5 Summary of isocyanate concentrations

Sample Location	Hardener Concentration Based Upon Bulk Sample of BASF 923-73				Total Isocyanate Concentration via NIOSH Method 5521			
	n	GM mg/m^3	GSD	Range	n	GM μg NCO/m^3	GSD	Range μg NCO/m^3
Personal	3	1 5	4 0	0 8-7 89	3	690	1 5	330-910
Under Car	4	29	1 9	9 0-40	4	1200	1 3	890-1500
Outside Booth	1	38	-	-	1	4400	-	-

Table 6   Summary of personal solvent exposures

Description of Activities During Personal Sampling	Date	Sample Start Time	Sample Stop Time	C_E*
Painting side of car on well-ventilated side of spray painting booth using a gravity feed gun	1/28/92	12 55	13 12	0 01
Painting side of car on well-ventilated side of spray painting booth using a gravity feed gun	1/28/92	14 13	14 52	0 07
Painting hood of car at front of booth with a gravity feed spray painting gun	1/31/92	7 32	8 04	0 09
Painting two front fenders, hood, and a bumper with a siphon cup spray painting gun	2/4/92	11 40	12 08	0 09
Painting both sides of car, hood, and parts which were not attached to the car with a siphon cup spray painting gun	1/31/92	10 20	11 50	0 38
Painting two front fenders, hood, and a bumper with a siphon cup spray painting gun	2/4/92	12 39	13 13	0 03

* See Equation 1, Page 10

Total Dust Concentrations

In Table 4, some of the total dust concentrations measured on the worker exceeded the OSHA PEL of 15 mg/m^3 Because this exposure limit is for an 8-hour day and painting takes only a small fraction of the worker's day, the OSHA PEL for total dust has not been exceeded

The statistical analysis, summarized in Appendix B, showed that sampling location and type of spray painting gun affected the total dust concentration in the spray painting booth The column labelled "Grouping" in Table 4 presents the results of a multiple comparison test which evaluates all the possible differences between the sampling locations During spray painting, the worker actually stands between the car and wall in a space which has stagnant airflow (see Figure 6) Since the geometric mean for the concentration measured on the worker and the geometric mean for the area sample collected next to the wall did not differ significantly, at least some of the overspray accumulates in the area where the worker stands The fact that the concentration under the car was much higher than these other two measurements indicates that much of the air overspray leaves the spray painting booth without contaminating the worker's breathing zone

The statistical analysis also indicated that the type of spray painting gun had an effect upon total dust concentrations As illustrated in Figure 7, the use of the gravity feed spray painting gun was associated with mean concentrations which were nearly a factor of four lower than the concentrations measured when the siphon cup spray painting guns were used Whether this difference in concentration is solely attributable to the change in spray painting guns is unclear The guns were used by two different workers Furthermore, the worker who used the gravity feed spray painting gun painted only on the side of the booth which had a greater airflow Thus, the effects of spray painting gun, worker, and side of the booth are confounded

Isocyanates

Some of the isocyanate concentrations measured on the worker, shown in Table 5, exceeded the U K 's control limit for isocyanate exposure [34] Although the concentration measurements for the BASF Hardener 923-73 are included in this table for the sake of completeness and full disclosure, these results are not believed to be reliable Examination of the chromatograms of a bulk sample of the hardener and the field samples revealed that the field sample chromatogram had more peaks than the bulk sample of the pure hardener (BASF 923-73) In contrast, the chromatogram of the polyisocyanate resin used to make the hardener had only one peak and this resin is reported to be a nearly pure isocyanurate trimer of HDI The peak area for this isocyanurate trimer of HDI may have only contributed 20 percent of the peak area for the

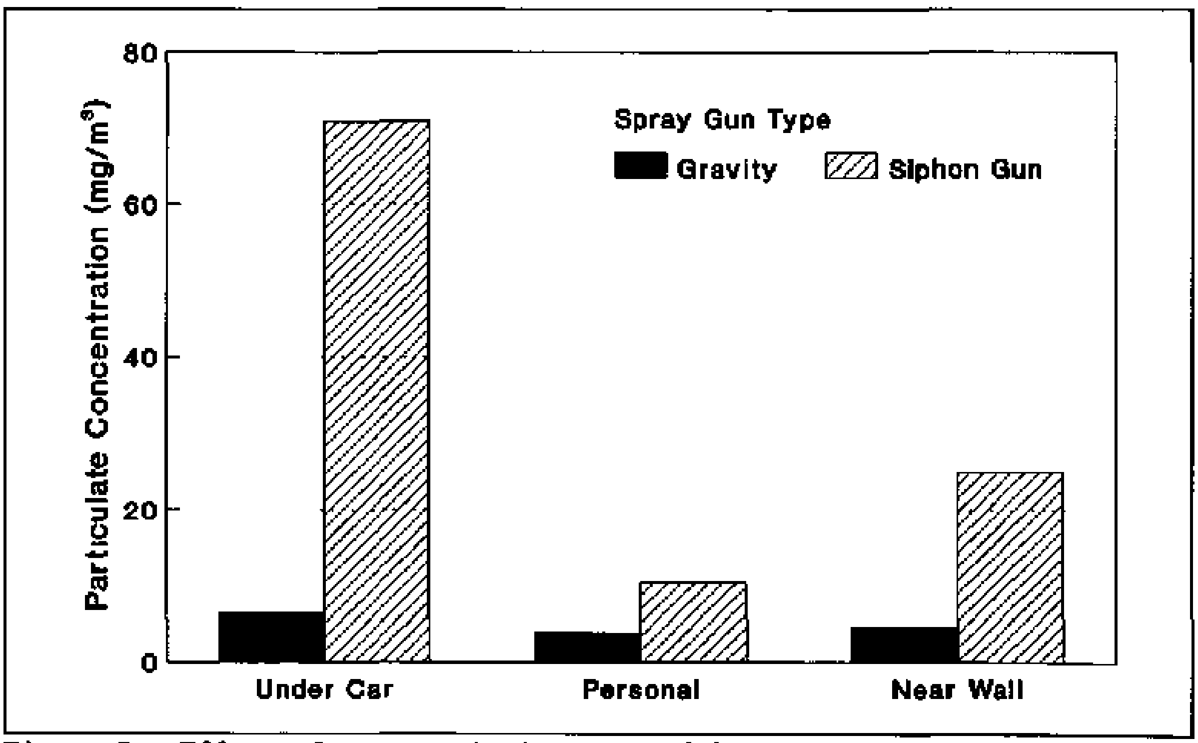

Figure 7 Effect of spray painting gun and location upon geometric mean particulate concentrations

field samples The source and identities of other peaks are unknown Inspection of the material safety data sheets for the clear coat and the hardener suggested that other organic compounds could have caused the UV detector response Organic solvents used as diluents for the hardener are also used as diluents in the clear coat Possibly, the diluents used in the clear coat interfered with the analysis for the hardener

Solvent Concentrations

The combined solvent exposures listed in Table 6 are less than 1, indicating that the solvent exposures were all acceptable based upon the combined environmental criteria listed in Table 1

Metals

Metal concentrations are listed in Table A1 of Appendix A Lead and cadmium were not detected on any of the samples The detection limits for lead and cadmium were 1 and 0 1 micrograms (μg) per filter, respectively Chromium was detected on some of the samples at levels at or just above the detection limit of 0 3 μg The maximum amount of chromium detected on a filter was 0 4 μg The limit of detection for titanium was 0 2 μg

As described in Table 1, exposure limits for chromium vary with its valence Information from the material safety data sheets indicated that only chromium (III) should be present during painting operations The chromium compounds listed in the material safety data sheets were chrome oxide green (CAS No 1308-38-9) and a chrome-antimony-titanium buff-rutile (CAS No 68186-90-3) The latter substance is described by the American Chemical Society (ACS) as an inorganic pigment that is the reaction product of high temperature calcination in which titanium oxide, chromium (III) oxide, and antimony oxide are homogeneously and ionically interdiffused to form a crystalline structure of rutile [42] This suggests that during painting operations, the chromium concentrations measured on the worker were below NIOSH RELs During sanding operations, a chromium concentration of 0 4 $\mu g/m^3$ was measured on the worker (Appendix A, Table A1) The valence of this chromium is unknown However, the concentration is below the NIOSH recommended exposure limit of 1 $\mu g/m^3$ for chromium (VI) compounds The chromium concentrations measured on the worker appeared to be below NIOSH recommended exposure limits

The material safety data sheets for the base coats used in this autobody shop list titanium dioxide as a component Thus, the titanium found on the samples is assumed to be titanium dioxide One titanium concentration measured on the worker was 300 $\mu g/m^3$ Based upon the ratio of the molecular weights of titanium dioxide to the atomic weight of titanium, this concentration measurement corresponds to a titanium dioxide concentration of 0 5 mg/m^3 The other concentration measurements made on the worker resulted in titanium dioxide concentrations which were less than 37 $\mu g/m^3$ of titanium, which corresponds to a titanium dioxide concentration of 0 076 mg/m^3 of titanium dioxide Because these concentrations are based upon short-term samples, the worker's 8-hour time-weighted average exposure to titanium dioxide would be less than 0 2 mg/m^3 which is specified by the NIOSH recommended exposure limit for titanium dioxide

Spray Painting Outside of the Spray Painting Booth

When spray painting was conducted outside of the spray painting booth, a short-term dust concentration of over 30 mg/m^3 was measured on the worker The material safety data sheet indicates that the hardener is 60 to 70 percent volatile organic compounds and about 25 to 35 percent isocyanurate of HDI The material safety data sheet indicated that the clear had a volatility of 60 to 70 percent The ratio of clear to hardener was 2 1 From this information, the exposure to isocyanurate of HDI was estimated to be about 10 mg/m^3 Because of random air currents in the body shop, the overspray, which contains isocyanates, may be dispersed throughout the shop Thus, all workers in this shop have a potential exposure to isocyanates when spray painting is done outside of a spray painting booth Thus, spray painting outside of a spray painting booth with isocyanates should not be tolerated

VIDEO EXPOSURE MONITORING IN SPRAY PAINTING BOOTH

Figure 8 shows the results of the video exposure monitoring of organic compounds in the spray painting booth during two time periods called Trial 1 and Trial 2 For each activity, the average response is displayed as a percentage of the overall average during the trial Two activities appeared to elevate the relative solvent concentration measured on the worker's lapel by the Photovac Tip II painting the car's hood and painting a small object suspended from the ceiling at head height Painting the sides of the car tends to minimize the worker's exposure Other activities did not consistently elevate the worker's exposure

Video Exposure Monitoring During Sanding

Figure 9 displays the results of video exposure monitoring for dust conducted while the orbital sander was in use Sanding on the side of the car with the ventilation on caused a noticeable reduction in the relative dust concentration as compared to sanding with no ventilation However, there are still some relative dust concentration peaks which occur when the worker sanded surfaces which were not flat, such as at edges When the worker sanded the car's roof without ventilation, airborne dust generation was observed, however, the dust did not appear to enter the worker's breathing zone When sanding is done on the roof, the sander is further from the worker's breathing zone causing a noticeable reduction in the worker's dust exposure Two relatively large relative dust concentration peaks occurred while the worker brushed the surface of the car to inspect the surface smoothness This relatively gentle motion caused a noticeable dust exposure because the worker's face was close to the surface in order to visually inspect the surface

RESPIRATOR EVALUATION

The results of the respirator fit tests are presented in Table 7 In this shop, the workers used half- or full-facepiece air-purifying respirators with paint mist filters and organic vapor cartridges Four out of six original

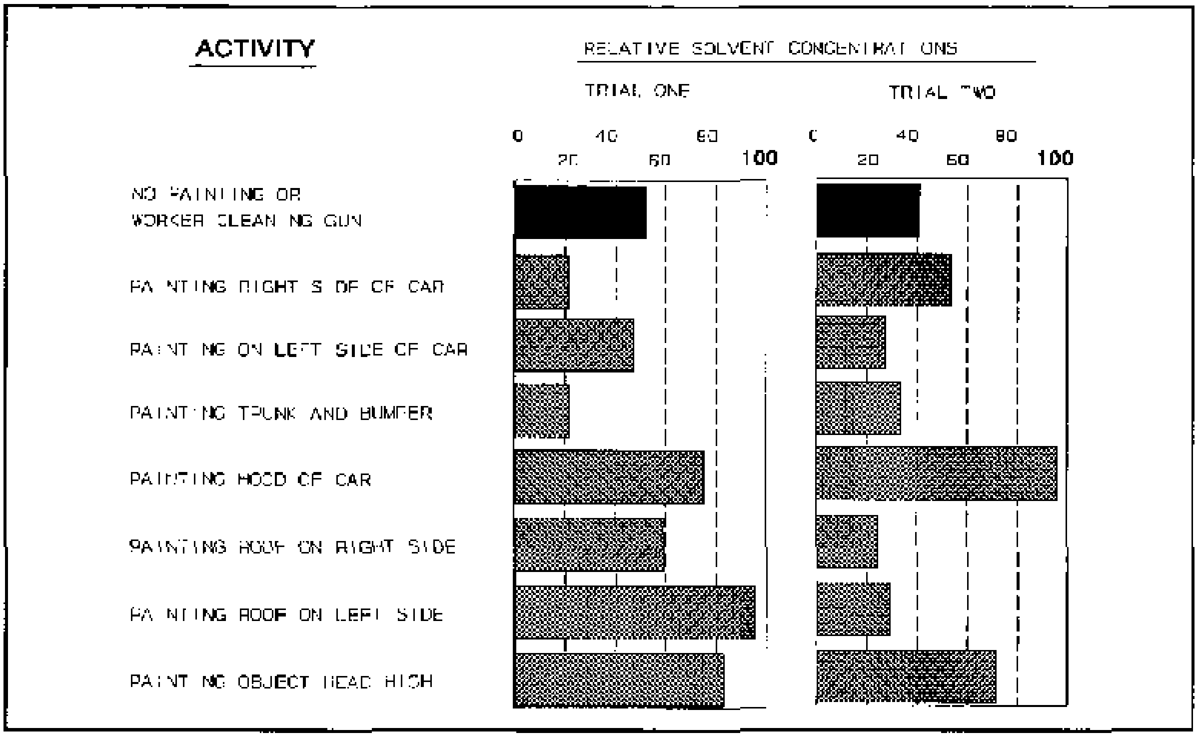

Figure 8 Summary of relative exposures during two different time periods

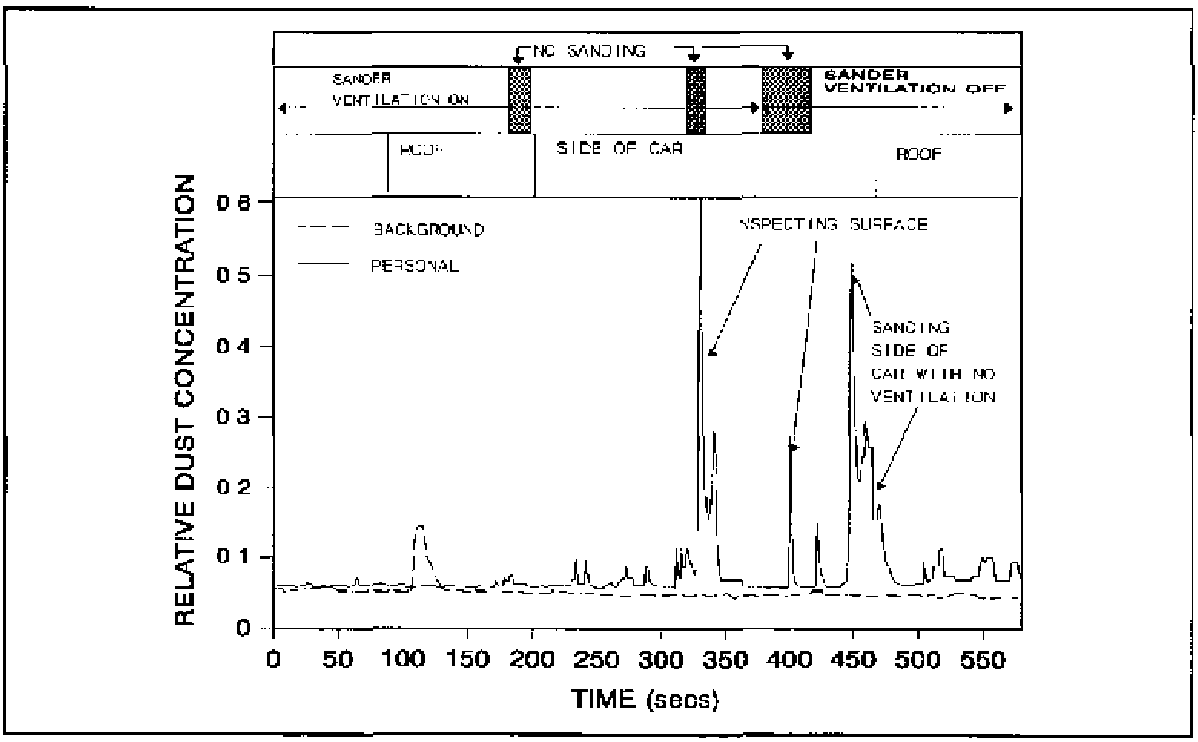

Figure 9 Response of HAM to aerosol concentration while sanding with a Dynaorbital sander on the side and roof of a car

Table 7 Comparison of fit factors with old and new full- and half-facepiece air-purifying respirators

Worker Tested	Fit Factor Obtained With Worker's Original Respirator	Fit Factor With New Respirator
Worker #1	5*	4125*
Worker #2	37	9916
Worker #3	93	3575
Worker #4	638	9632
Worker #5	144	32811
Worker #6	74	5431

* Full-facepiece, others are half-facepiece respirators

respirators had fit factors below 100, which is less than the minimum acceptable fit factor mentioned in some OSHA standards for specific air contaminants [43,44,45] Thus, four of the six respirators tested appear to be inadequately protecting the workers Table 8 summarizes the defects observed during an inspection of the used respirators Most of the respirators used by the workers appeared to be poorly maintained and they had defects which would interfere with the seal between the face and the respirator This poor maintenance may have contributed to the low fit factors reported in Table 7

Table 8 Summary of observed defects in the six inspected respirators

Defect	Number of Respirators With Defects
Facepiece had lost shape This may interfere with seal between the respirator and the face	5
Inhalation valve does not appear to be seating properly	5
Exhalation valve does not appear to be seating properly	5
Headbands have lost elasticity, possibly causing poor fit	5

DISCUSSION AND RECOMMENDATIONS

The ventilated orbital sanders appear to provide dust control during sanding operations The dust concentrations measured on the workers, reported in Appendix A, indicate that dust exposures during the two sanding operations were 1 25 and 0 18 mg/m^3, which is below the OSHA PEL of 15 mg/m^3 for total dust The first dust measurement involved hand sanding, the use of an in-line Hutchinson sander, and the use of compressed air to blow dust off of the car The second measurement was taken when a Dynabrade sander was used to sand a replacement door prior to painting The measurements taken with the HAM indicate that the ventilated sander does reduce the total dust concentration measured near the worker's lapel during sanding However, because the ventilated sanders are used very infrequently, the results from all of the field evaluations of ventilated sanders will need to be combined to generate conclusive recommendations for controlling dust generated during sanding operations

Total dust concentrations measured on the painters in this spray painting booth are somewhat higher than measurements made in other facilities in this study Some of the isocyanate concentrations measured near the worker's lapel during spray painting operations are estimated to have exceeded 1 0 mg/m^3 (the ceiling limit enforced in Oregon) Thus, worker exposure to paint overspray and isocyanate exposure needs to be minimized through the proper use of the spray painting booth and respirators Spray painting involving isocyanates should not be permitted outside of a spray painting booth There is simply too much risk of inadvertently exposing others to a relatively high concentration of isocyanate prepolymers

SPRAY PAINTING BOOTH VENTILATION

Spray painting mist concentrations can be further minimized by improving the ventilation in the spray painting booth The booth was operating at a flow rate between 7000 and 8000 cfm, which is considerably less than the design flow rate of 10,000 cubic feet per minute In addition, the maintenance of the booth was somewhat deficient The filters in the floor of the booth were absent and this caused an uneven distribution of airflow in the booth These filters should be maintained and replaced as needed to obtain a uniform airflow distribution

The documentation for the engineering of the spray painting booth was inadequate The manual for the booth did not include a copy of the fan curve so that if troubleshooting is necessary, an accurate estimate of the theoretically expected flow rate through the booth can be made In addition, the owner indicated that he had modified the booth and these changes were not documented in the manual Originally, this booth had only one fan upstream of the spray painting booth Because of the positive pressure inside the booth, the doors on the spray painting booth would pop open To overcome this problem, the owner added a fan on the exhaust side of the spray painting booth and adjusted the fan speed of the fan on the upstream side of the spray painting booth The owner did not have the fan curves (documentation on the effect of pressure drop on the flow rate) for either fan Consequently, there is no way of knowing whether the two fans are sized properly and adjusted to have the appropriate airflow rates

Generally, airflow recommendations for controlling occupational exposure to air contaminants can be obtained by reviewing the ACGIH publication on ventilation manual and OSHA standards [46,47] Unfortunately, OSHA and ACGIH airflow recommendations for spray painting booths address only crossdraft spray painting booths 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 Although this booth does not comply with this standard, OSHA generally does not enforce this standard unless there is a violation of current OSHA standards for air contaminants [48] There is a French standard for downdraft spray painting booths which is reported to greatly minimize worker exposure to isocyanates during spray painting in autobody repair shops [49,50] This standard has some very specific specifications on the flow of air around a car [49]

> 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 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

Based on this study and experiences at other body shops, a flow rate of at least 12,000 cfm may be needed to comply with this recommendation One reason for conducting this study in a number of autobody shops is to evaluate the appropriateness of recommendations such as this French standard for spray painting booths

RESPIRATOR USAGE

The quantitative fit test results (in Table 7) indicate that the respirators, which were used by the workers, did not adequately seal against the worker's face or were poorly maintained Table 7 shows that fit factors for four of the six respirators tested are below the NIOSH-recommended fit factor for half masks of 100 and 500 for full-face respirators [51] In addition, OSHA standards for asbestos, benzene, and formaldehyde requires that fit factors be a factor of 10 higher than the assigned protection factors [43,44,45] The assigned protection factor for full-facepiece, air-purifying respirators is 100 and for half-facepiece, air-purifying respirators, this factor is 10 [52] When the body shop workers were provided with new respirators of their choice, and were instructed in proper donning techniques, fit factors increased substantially Inspection of the respirators tested indicated that one of the reasons for these low fit factors was poor respirator maintenance (see Table 8) Lack of training was also a contributing factor

This autobody shop, like every other autobody shop in this study, did not have a formal respirator program in place The OSHA respirator standard (29 CFR 1910 134), which is reproduced in Appendix C, requires that

> "Written standard operating procedures governing the selection and use of respirators shall be established "

OSHA policy is to issue a citation for violations of this standard even when there is no violation of air contaminant exposure limits [48] A complete respiratory protection program as defined in OSHA standards needs to be implemented Minimal 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 and maintenance

7 Workplace exposure monitoring

8 Evaluation of program effectiveness

9 Medical monitoring

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 the use of butyl rubber gloves for handling solutions containing these polyisocyanates [6]

CONCLUSIONS

The downdraft spray painting booth appears to minimize air contaminant exposures This booth is being operated at a flow rate between 7000 and 8000 cfm To further reduce the air contaminant concentrations in this booth, the flow rate could be increased to as much as 12,000 cfm in order to comply with a French standard for downdraft spray painting booths The ventilated sanders appear to effectively control dust generated during sanding operations Respirator usage at this autobody shop is inadequate There is a need to read, understand, and comply with the OSHA respirator standard which is attached as Appendix C If a formal, written respirator program based upon the OSHA respirator standard were in place, the problems with respirator usage noted in this report probably would not have occurred

REFERENCES

1 Burns M, Fritz A, Grimes T, Inventors, Raasburg Corporation Paint Spray Gun U S Patent 5,090,623 February 25, 1992 11 pp

2 Johnson BW [1990] HVLP --- Shoot for profit Unpublished paper presented at the National Autobody Congress and Exposition, New Orleans, LA, November 29-December 2, 1990

3 South Coast Air Quality Management District [1991] Regulation XI Source Specific Standards, Rule 1107, Coatings of Metal Parts and Products Diamond Bar, CA South Coast Air Quality Management District, August 2

4 IARC [1989] IARC monographs on the evaluation of carcinogenic risks to humans some organic solvents, resin monomers and related compounds, pigments, and occupational exposures in paint manufacture and painting Vol 47 Lyon, France World Health Organization, International Agency for Research on Cancer, p 424

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

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

7 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, Centers for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No 78-215

8 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

9 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

10 Hardy H, Devine J [1979] Use of organic isocyanates in industry - some industrial hygiene aspects Annals Occ Hyg *22*(4) 421-427

11 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

12 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

13 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 exposed car and industrial spray painters with special reference to the nervous system Scand J Work Environ Health *6*(4) 239-273

14 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

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

16 ACGIH [1986] Documentation of the threshold limit values and biological exposure indices 5th ed Cincinnati, OH American Conference of Governmental Industrial Hygienists

17 NIOSH/OSHA [1981] Occupational health guideline for xylene In NIOSH/OSHA Occupational health guideline 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

18 Hammond P, Beliles R [1980] Metals In Doull J, Klassen C, Amdur M, eds Casarett and Doull's Toxicology 2nd ed New York, NY McMillan Publishing Company, pp 409-468

19 Webb M [1975] Cadmium Br Med Bull *31*(3) 246-50

20 NIOSH [1984] Current Intelligence Bulletin 42 cadmium 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 84-116

21 NIOSH [1975] NIOSH criteria for a recommended standard occupational exposure to chromium (VI) Cincinnati, OH U S Department of Health, Education, and Welfare, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No 76-129

22 NIOSH [1972] Criteria for a recommended standard occupational exposure to lead Cincinnati, Ohio 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

23 NIOSH [1988] Occupational safety and health guideline for inorganic lead In NIOSH 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 88-119

24 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

25 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

26 NIOSH (1988) Testimony to DOL on the Occupational Safety and Health Administration's proposed rule on air contaminants by R A Lemen, August 1, 1988 U S Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health, NTIS Publication No PB-91-115337

27 NIOSH [1990] NIOSH pocket guide to 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 90-117

28 NIOSH [1992] NIOSH recommendations for occupational safety and health - compendium of policy documents and statements Cincinnati, OH U S Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No 92-100

29 CFR [29 CFR 1900 1000 (1989)] Code of Federal Regulations Washington, DC U S Government Printing Office, Office of the Federal Register

30 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

31 Janko M, McCarthy 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*(5) 331-338

32 Oregon Occupational Safety and Health Administration [1992] Interim Oregon Occupational Safety and Health Code for OAR437, Division 3, General Occupational Safety and Health Rules (29 CFR 1910) Salem, OR Department of Insurance and Finance

33 Mobay [1991] Material safety data sheet for Desmodur N-3300 Pittsburgh, PA Mobay Corporation, Coatings Division March 8, 1991

34 Silk S, Hardy H [1983] Control limits for isocyanates Annals of Occ Hyg *27*(4) 333-339

35 NIOSH [1984] Nuisance dust total, Method 0500 (issued 2/15/84) In Eller PM, ed 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

36 NIOSH [1984] Alcohols II, Method 1401 (issued 2/15/84) In Eller PM, ed 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

37 NIOSH [1984] Isocyanates, Method 5521 (issued 5/15/89) In Eller PM, ed 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

38 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

39 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

40 TSI Incorporated [1989] Portacount™ Operation and Service Manual St Paul, MN TSI Incorporated

41 Rose JC, Oestenstad RK, Rose VE [1990] A comparison of respirator fit factors determined by portable condensation nuclei counting and forward light-scattering photometric methods Appl Occup Environ Hyg *5*(11) 792-797

42 ACS [1992] Chemical Abstracts Registry Database, Registry No 68186-90-1 Columbus, OH American Chemical Society

43 CFR [29 CFR 1910 1001 (1989)] Code of Federal regulations Washington, DC U S Government Printing Office, Office of the Federal Register

44 CFR [29 CFR 1910 1028 (1989)] Code of Federal regulations U S Government Printing Office, Office of the Federal Register

45 CFR [29 CFR 1910 1048 (1989)] Code of Federal regulations Washington, DC U S Government Printing Office, Office of the Federal Register

46 CFR [29 CFR 1910 94 (1989)] Code of Federal regulations Washington, DC U S Government Printing Office, Office of the Federal Register

47 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

48 AGCA [1992] OSHA field operations manual Washington D C The Associated General Contractors of America, Publication No 169

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

50 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

51 Bollinger N [1992] Telephone conversation on December 9, 1992, between N Bollinger, Division of Respiratory Disease Studies, and W Heitbrink, Division of Physical Sciences and Engineering, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Public Health Service, U S Department of Health and Human Services

52 NIOSH [1985] NIOSH guide to industrial respiratory protection 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 87-116

APPENDICES

APPENDIX A

LISTINGS OF THE CONCENTRATION MEASUREMENTS

Table A1 Dust sampling results

Description of Activity	Sample Location	Date	Sample Start Time	Sample Stop Time	Painting Duration (min)	Total dust Conc (mg/m³)	Chromium Conc (µg/m³)	Titanium Conc (µg/m³)
P1 Painting side of car on well-ventilated side of spray painting booth using a gravity feed spray painting gun	under car	01/28/92	12 55	13 12	17	0 47	4 71	4 71
	worker	01/28/92	12 55	13 12	17	2 35	< 3 53	2 35
	next to wall	01/28/92	12 55	13 12	17	2 82	3 53	7 06
P2 Painting side of car on well-ventilated side of spray painting booth using a gravity feed spray painting gun	under car	01/28/92	14 14	14 53	11	42 3	5 45	< 3 64
	worker	01/28/92	14 12	14 52	11	4 72	< 5 45	7 27
P3 Painting hood of car at front of booth with a gravity feed spray painting gun	under car	01/31/92	07 09	08 20	30	13 5	< 2 00	< 1 33
	worker	01/31/92	07 39	08 04	30	5 33	< 2 00	< 1 33
	next to wall	01/31/92	07 15	08 20	30	7 13	2 00	< 1 33
P4 Spray painting hood outside of shop with siphon cup gun	worker	01/31/92	08 06	08 12	6	30 67	< 10 00	< 6 67
P5 Painting both sides of car, hood, and parts which were not attached to the car Spray painting done with a siphon spray painting gun	under car	01/31/92	10 58	12 00	38	37 7	< 1 58	< 1 05
	worker	01/31/92	10 20	11 50	38	17 77	2 11	300 00
	next to wall	01/31/92	10 56	11 59	38	33 2	2 11	631 58
P6 Painting two front fenders, hood, and a bumper with a siphon cup spray painting gun	under car	02/04/92	11 40	12 04	19	49 61	< 3 16	37 89
	worker	02/04/92	11 40	12 05	19	11 03	3 16	7 37
	next to wall	02/04/92	11 40	12 05	19	10 45	< 3 16	4 21
P7 Painting two front fenders hood, and a bumper with a siphon cup spray painting gun	under car	02/04/92	12 24	13 14	10	202	6 00	< 4 00
	worker	02/04/92	12 39	13 13	10	5 2	< 6 00	< 4 00
	next to wall	02/04/92	12 24	13 14	10	47 4	< 6 00	< 4 00
S1 Sanding body filler with Hutchinson in-line sander hand sanding, and using compressed air to blow dust off car	area	12/23/91	10 06	11 15	69	1 163	0 33	2 01
	worker	12/23/91	10 06	11 15	69	1 25	0 56	< 0 22
S2 Sanding a door panel with a rotating sander (Dynabrade)	area	01/09/92	12 55	14 16	60	0 16	< 0 38	1 09
	worker	01/09/92	12 55	14 16	60	0 181	< 0 39	1 29

Table A2 Isocyanate concentration measurements

Description of Activity	Sample Location	Date	Sample Start Time	Sample Stop Time	BASF 929-73 (mg/m³)	HDI Prepolymers Method (µg NCO/m³)
Painting side of car on well-ventilated side of spray painting booth using a gravity feed spray painting gun	worker	01/28/92	13 52	14 13	< 0 83	916
	under car	01/28/92	13 52	14 13	24 1	1541
Painting hood of car at front of booth with a gravity feed spray painting gun	worker	01/31/92	lost	lost		
	under car	01/31/92	07 32	08 04	9 06	1125
Spray painting hood outside of booth with a siphon cup gun	worker	01/31/92	08 06	08 12	38 3	4333
Painting both sides of car, hood, and parts which were not attached to the car Spray painting done with a siphon spray painting gun	worker	01/31/92	11 11	11 50	7 89	894
	under car	01/31/92	11 11	11 50	14 2	894
Painting two front fenders, hood and a bumper with a siphon cup spray painting gun	worker	02/04/92	12 39	13 13	1 25	430
	under car	02/04/92	12 39	13 13	40 6	1500

Table A3 Summary of solvent concentration measurements

Description of Activity	Sample Location	Date	Sample Time (min)	Sample Rate (l/min)	Sampling times		Painting Duration (min)	Solvent Concentration (ppm)				Combined Solvent Exposure (ppm)
					start	stop		Xylene	Toluene	Butyl Acetate	Ethyl Acetate	
Painting side of car on well-ventilated side of spray painting booth using a gravity feed gun	Wall	1/28/92	17	0 2	12 55	13 12	17	1	NA	NA	NA	0 01
	Personal	1/28/92	17	0 2	12 55	13 12	17	1	NA	NA	NA	0 01
	Under Car	1/28/92	17	0 2	12 55	13 12	17	10	NA	NA	NA	0 10
Painting side of car on well-ventilated side of spray painting booth using a gravity feed gun	Wall	1/28/92	34	0 2	13 46	14 20	11	LT 0 7	LT 0 8	LT 0 3	LT 0 4	0 00
	Personal	1/28/92	34	0 2	14 13	14 52	11	LT 0 7	6	2	LT 0 4	0 07
	Under Car	1/28/92	34	0 2	13 46	14 20	11	15	LT 0 8	33	LT 0 4	0 32
	Under Car	1/28/92	33	0 2	13 45	14 18	11	LT 0 7	LT 0 8	LT 0 3	LT 0 4	0 00
	Under Car	1/28/92	34	0 2	13 46	14 20	11	22	5	44	LT 0 4	0 49
	Under Car	1/28/92	31	0 2	13 46	14 40	11	LT 0 7	LT 0 8	LT 0 3	LT 0 4	0 00
	Under Car	1/28/92	32	0 2	13 45	14 17	11	19	LT 0 8	41	LT 0 4	0 40
	Under Car	1/28/92	31	0 2	13 46	14 17	11	16	LT 0 9	35	LT 0 4	0 34
Painting hood of car at front of booth with a gravity feed spray painting gun	Wall	1/31/92	65	0 2	7 15	8 20	30	3	7	3	4	0 12
	Personal	1/31/92	32	0 2	7 32	8 04	30	2	4	4	3	0 09
	Under Car	1/31/92	69	0 2	7 09	8 18	30	18	20	18	11	0 50
	Under Car	1/31/92	69	0 2	7 09	8 18	30	10	49	10	7	0 66
	Under Car	1/31/92	70	0 2	7 09	8 18	30	10	41	10	7	0 57
	Under Car	1/31/92	71	0 2	7 09	8 21	30	17	26	17	9	0 53
	Under Car	1/31/92	48	0 2	7 30	8 18	30	9	49	9	8	0 65
	Under Car	1/31/92	70	0 2	7 09	8 19	30	11	155	11	7	1 73
Painting two front fenders, hood, and a bumper with a siphon cup spray painting gun	Wall	2/4/92	28	0 2	11 40	12 08	19	5	LT 0 9	9	LT 0 5	0 09
	Personal	2/4/92	28	0 2	11 40	12 08	19	2	3	8	LT 0 5	0 09

Table A3 Continued

Description of Activity	Sample Location	Date	Sample Time (min)	Sample Rate (l/min)	Sampling times		Painting Duration (min)	Solvent Concentration (ppm)				Combined Solvent Exposure (ppm)
					start	stop		Xylene	Toluene	Butyl Acetate	Ethyl Acetate	
Painting both sides of car, hood and parts which were not attached to the car Spray painting done with a siphon cup gun	Wall	1/31/92	93	0 2	10 56	11 59	61	12	15	16	24	0 40
	Personal	1/31/92	90	0 2	10 20	11 50	61	8	21	10	17	0 38
	Under Car	1/31/92	93	0 2	10 56	11 59	61	12	13	16	22	0 38
	Under Car	1/31/92	90	0 2	10 56	11 58	61	12	15	17	19	0 41
	Under Car	1/31/92	90	0 2	10 58	11 58	61	LT 0 3	LT 0 3	LT 0 1	LT 0 1	0 00
	Under Car	1/31/92	90	0 2	10 57	11 57	61	12	13	16	21	0 39
	Under Car	1/31/92	90	0 2	10 57	11 57	61	13	17	18	24	0 44
	Under Car	1/31/92	90	0 2	10 56	11 56	61	13	15	18	24	0 43
Painting two front fenders, hood, and a bumper with a siphon cup spray painting gun	Wall	2/4/92	50	0 2	12 39	13 29	32	4	LT 0 5	8	LT 0 3	0 08
	Personal	2/4/92	33	0 2	12 39	13 13	32	LT 0 7	2	1	LT 0 4	0 03
	Under Car	2/4/92	50	0 2	12 39	13 29	32	15	LT 0 5	32	LT 0 3	0 31
	Under Car	2/4/92	50	0 2	12 39	13 29	32	23	LT 0 5	46	LT 0 3	0 46
	Under Car	2/4/92	50	0 2	12 39	13 29	32	22	LT 0 5	46	LT 0 3	0 45
	Under Car	2/4/92	50	0 2	12 39	13 29	32	1	4	1	LT 0 2	0 06
	Under Car	2/4/92	54	0 2	12 39	13 13	32	20	LT 0 5	43	LT 0 24	0 42
	Under Car	2/4/92	33	0 2	12 39	13 13	32	19	LT 0 8	43	LT 0 40	0 41

LT Less than the detection limit
NA No analysis, substance not listed on material safety data sheet

APPENDIX B

STATISTICAL ANALYSIS OF TOTAL DUST DATA

Figure B1 lists selected items from the statistical analysis of the total dust concentrations The data was analyzed using the SAS General Linear Models (GLM) procedure [53] The analysis was conducted to determine whether the spray painting gun, sampling location, or some combination of these two variables affected exposure Before data analysis, the logarithm of the concentration data was taken in order to obtain normally distributed residuals One value of concentration measured under the car on January 28 from 12 55 to 13 12 was excluded from the analysis as an outlier The concentration value for this measurement was 0 47 mg/m^3 and this appears to be a relatively low measurement for being located under the car Furthermore, when this concentration value was included in the analysis, the residuals were not normally distributed, indicating that there is something different about this measurement

Item I in Figure B1 displays the results of the analysis of variance which evaluates whether the sampling location, spray painting gun, or some combination of these two variables explained a significant fraction of the variability in the concentration data For each independent variable (e g , sampling location, spray painting gun, or the interaction between spray painting gun and sampling location), the GLM procedure estimates the probability of a larger F value, i e , the probability that chance could have caused the observed differences in the total dust concentration in the test chamber A low probability in the column labelled "Pr > F" indicates that the variable affected concentration The results in Item 1 leads to the conclusion that spray painting gun and sampling location affected concentration The effect of spray painting gun upon concentration did not vary with the sampling location Item 2 presents the results of a multiple comparison test which evaluates the concentration differences among the three sampling locations This multiple comparison test was conducted at an overall level of confidence of 95 percent

REFERENCES

53 SAS Institute, Inc [1988] The GLM procedure In SAS/STAT user's guide release 6 03 Cary, NC SAS Institute, Inc , pp 549-640

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General Linear Models Procedure

ITEM 1

Dependent Variable Ln(CONC)

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GUN	1	6 15443042	6 15443042	12 04	0 0060
LOCATION	2	9 87583485	4 93791743	9 66	0 0046
GUN*LOCATION	2	0 44163399	0 22081700	0 43	0 6609

ITEM 2

Comp Tukey's Studentized Range (HSD) Test for variable LCONC

comparisons significant at the 0 05 level are indicated by '***'

LOCATION Comparison	Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
C - W	0 058	1 298	2 537	***
C - P	0 817	2 004	3 191	***
W - C	-2 537	-1 298	-0 058	***
W - P	-0 481	0 706	1 893	
P - C	-3 191	-2 004	-0 817	***
P - W	-1 893	-0 706	0 481	

Note location C is under the car, location P is the personal sample, and location W is next to the wall of the spray painting booth

Figure B1 Listing of selected items from the statistical analysis of particulate data

APPENDIX C

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 not 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 facepiece-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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