IN-DEPTH SURVEY REPORT

CONTROL TECHNOLOGY FOR AUTOBODY REPAIR AND PAINTING SHOPS

at

Valley Paint and Body Shop
Amelia, Ohio

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PLANT SURVEYED	Valley Paint and Body Shop 100 East Main Street Amelia, Ohio 45102
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DISCLAIMER

SUMMARY

At this body shop, the ability of a downdraft spray painting booth, a vehicle preparation station, and respirators to control worker exposure to air contaminants were evaluated The vehicle preparation station and the spray painting booth were used for spray painting cars and autobody parts Some tasks resulted in paint mist concentrations on the worker's lapel that exceeded 15 mg/m^3, which is the OSHA permissible exposure limit for total dust In addition, some concentrations of prepolymerized isocyanates measured on the worker's lapel exceeded exposure limits developed by the state of Oregon and the United Kingdom (OSHA standards and NIOSH recommended exposure limits do not address prepolymerized isocyanates)

In the downdraft spray painting booth, nearly 12,000 cubic feet per minute of air (cfm) flows into the booth through ceiling filters and is exhausted through grates in the floor of the booth When a car is set in this booth, the airflow around the car appears to capture much of the overspray when the side of a car is painted There did not appear to be any eddies that would force contaminated air into the worker's breathing zone However, this booth was frequently used for painting autobody parts that are either suspended from the ceiling or set on tables Relatively high paint mist concentrations measured on the worker's lapel were observed when small objects were painted

The vehicle preparation station consists of two bays, about 5000 cfm of air is exhausted from each bay This results in air velocities lower than the 100 feet per minute (fpm) recommended by OSHA and ACGIH for cross draft spray painting booths When work is done in front of the exhaust filters at the back of this station, airflow patterns can force contaminated air back into the worker's breathing zone and cause a high paint mist concentration to be measured on the worker's lapel During one small painting job at this prep station, a paint mist concentration of 42 mg/m^3 was measured on the worker's lapel

Because the spray painting booth and the vehicle preparation station do not completely control paint overspray, air-supplied hoods are used to control the worker's exposure to paint overspray Half-facepiece, air-purifying respirators are used to control worker exposure to airborne particles during some sanding and welding operations During abrasive blasting operations with crystalline-silica containing sand, a positive pressure air-supplied, half-facepiece respirator is used For abrasive blasting involving silica, the OSHA standard for abrasive blasting requires the use of a supplied air respirator constructed so that it covers the worker's neck, head, and shoulders to protect him from rebounding abrasive The OSHA respiratory practices standard (29CFR1910 134) is not being completely followed There did not appear to be a formal, written program describing the use of respirators Quantitative fit tests revealed that four of the six half-facepiece respirators had fit factors less than 50 and two of the six respirators had fit factors that were less than 10 This result is due to either poor fit or poor respirator maintenance Although the air-supplied hoods appear to protect the workers from paint overspray, the air from these hoods was supplied by an oil-lubricated pump There was no carbon monoxide

alarm or high-temperature alarm, as required by the OSHA respiratory protection standard, to warn of carbon monoxide generation

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 several 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 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 study's objective is to provide autobody repair and painting 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, 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 body shop, a spray paint booth and a vehicle preparation station were evaluated The paint booth has a downdraft ventilation system to remove the paint vapors Air is exhausted from the rear of the vehicle preparation stations The vehicle preparation station was used for one small paint job during this study In addition, respirator usage at this autobody shop was evaluated by conducting quantitative fit tests

SHOP DESCRIPTION

This autobody shop employs seven technicians five repair cars and two paint cars The vehicle preparation station and the downdraft spray painting booth are located in the painting area of the shop Before the cars are painted, structural damage to the cars is repaired elsewhere in the shop This involves the repair and replacement of damaged parts During these activities, the workers may be exposed to aerosols from sanding, grinding, and welding In addition, this shop does some restoration of automobiles

For some jobs, abrasive blasting with sand that contains crystalline silica is used for paint removal This abrasive blasting was conducted in the open After the cars have been repaired, they are brought to the paint shop that is shown schematically in Figure 1 There is some sanding of areas to be painted Parts of the car which are not to be painted are protected with masking The car and autobody parts are painted in either the spray painting booth or in the vehicle preparation station Generally, the vehicle preparation station is used only for small paint jobs or for primer painting It was not used much during this study Both the vehicle preparation station and the spray painting booth were manufactured by Garmat Incorporated (Denver, CO) and were approximately one year old at the time of the study

The vehicle preparation station, shown schematically in Figure 2, has two bays The bays are separated by moveable cloth curtains that were suspended from rods in the ceiling Each bay exhausts air through three filters in the back of the vehicle preparation station The vehicle preparation station was used once during this study

The spray painting booth, illustrated in Figure 3, has two painting cycles During the painting cycle, outside air is passed through a series of filters The final set of filters cover the entire ceiling of the spray painting booth A nominal 12,000 cubic feet per minute of air flows out of the ceiling around the car or object being painted and out of the booth through exhaust grates located in the floor of the booth The booth is 23 feet long, 13 feet wide and 9 feet high The air is exhausted through a 2-foot wide, rectangular slot in the floor that is 17 feet by 6 feet

After the car or body part has been painted, the worker leaves the booth and the paint is cured at a temperature between 120 and 140°F During this period, the airflow in the booth is reduced and about 80 percent of the air flow in the booth is recycled

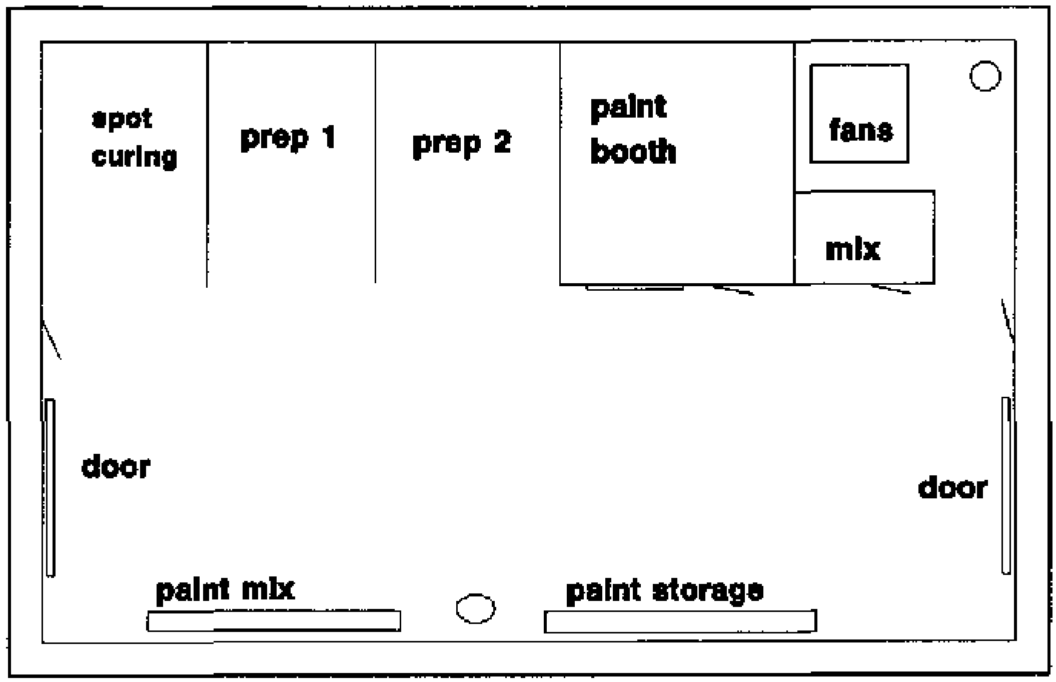

Figure 1   Schematic description of the paint shop

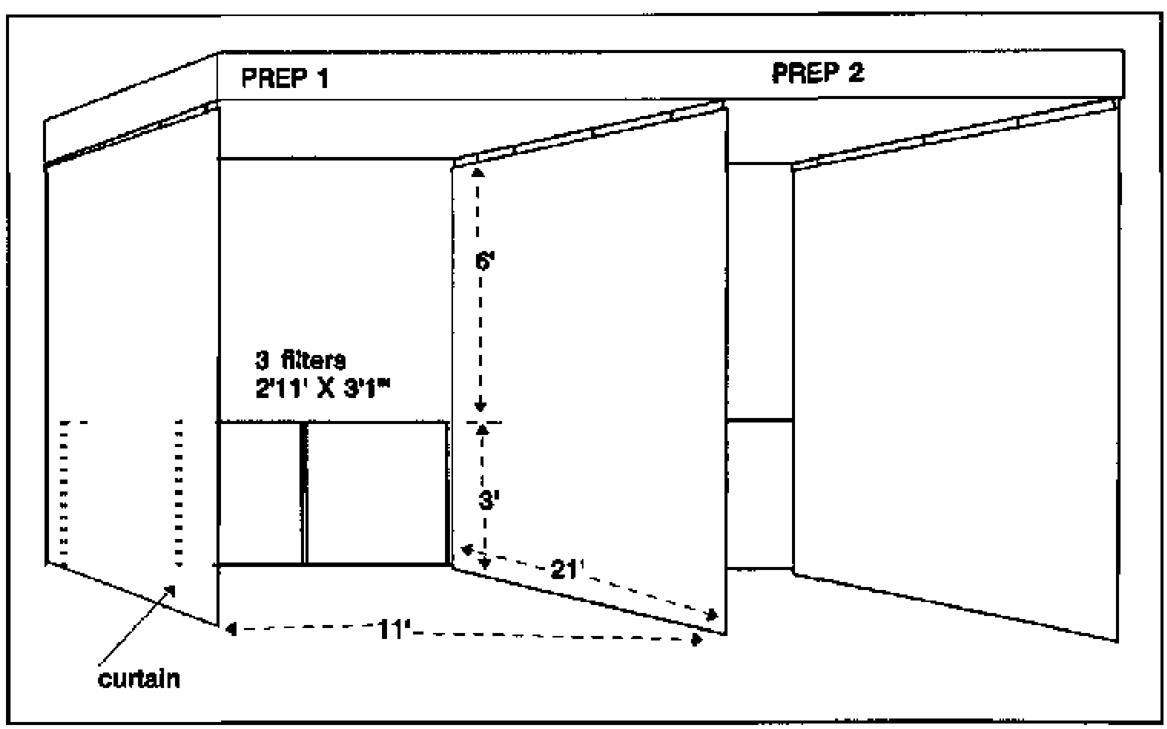

Figure 2   Schematic illustration of vehicle preparation station

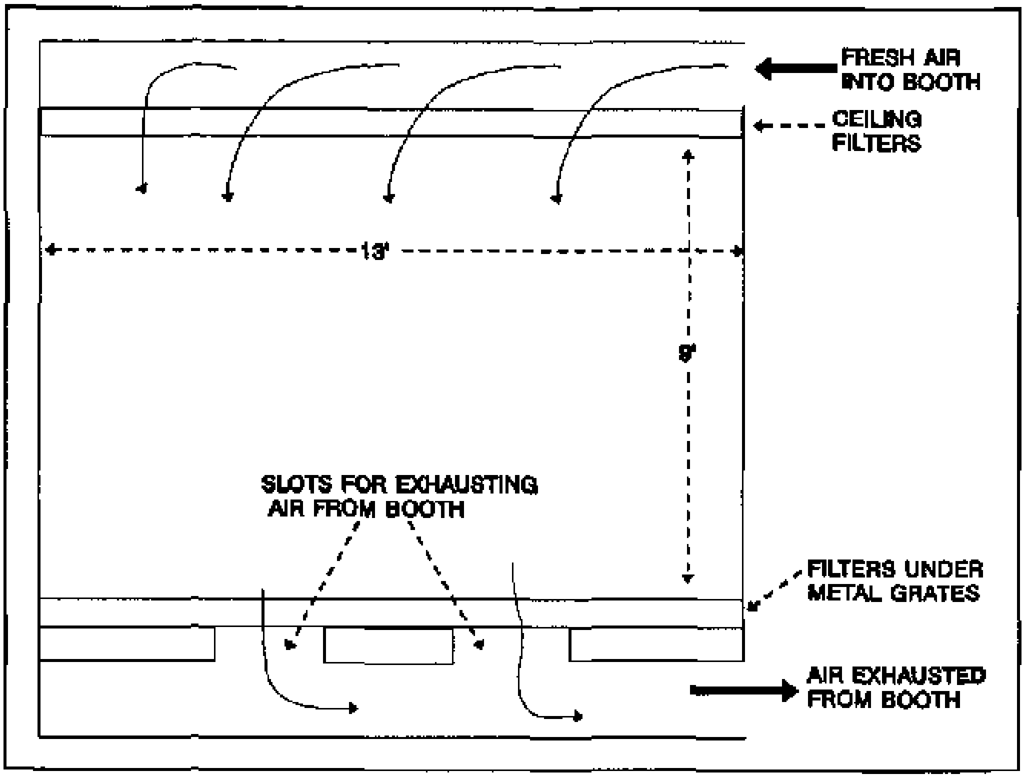

Figure 3 Schematic of spray painting booth

In this shop, spray painting is performed using gravity-fed, HVLP spray painting guns (SATA, Ludwigsburg, Germany) In these guns, gravity causes paint to flow into the orifice where atomization occurs The air pressure at this point is less than 10 psi Reportedly, the HVLP spray guns are much more efficient at transferring the paint from the gun to the car than the other types of spray painting guns [1,2] HVLP spray painting guns are believed to have a transfer efficiency of at least 65 percent, which is the minimum transfer efficiency required by some air pollution control districts [2,3]

In this shop, most painting jobs involve the application of a primer, base coat, and a clear coat Typically, the base coat contains colored pigments and carrier solvents The material safety data sheets listed these hazardous substances as components of pigments chromium, nickel, antimony, and lead A clear coat is applied over the base coat The clear coat is composed of two components a clear coat and a hardener The clear coat contains polyurethane or polyols and acrylic resins The hardener contains polyisocyanates that 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

Three types of respirators were used in this autobody shop Half-facepiece, air-purifying respirators (MSA ComfoII, Pittsburgh, PA) that were equipped with organic vapor cartridges and spray painting prefilters were issued to all of the workers This respirator was used for some primer painting, sanding, and welding During abrasive blasting, a constant flow air line respirator with a half-facepiece (Wilson model 6373, NIOSH approval number TC-21C-379) was used The air was supplied to this respirator through an oil-less pump (Bullard, Catalog number s-1710-1, Sausalito, CA) equipped with a HEPA cartridge In the spray painting area, an air-supplied hood (SATA model 54155, W Germany, NIOSH approval number TC-19C-211) was used to control worker exposure to paint overspray The air for this respirator was supplied by the shop air compressor (Quincy model F-390-20-200) This compressor did not have a high temperature alarm or a carbon monoxide alarm Before flowing into the respirator, the air passes through filters and absorbent According to shop personnel, this absorbent removes carbon monoxide, oil mist, and particulate In addition, the air passes through a refrigeration unit (Model GRF, Great Lakes Air and Refrigeration, Westlake, MI)

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 that 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 that may contain isocyanate resins, and pigments that 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 non-allergic 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 during spray painting from evaporation, the isocyanate monomers are prepolymerized into oligomers that are generally dimers, trimers, and tetrameres of the monomer In commercial spray painting operations, the monomer content is usually less than 2 percent by weight However, the oligomers still pose a hazard to the workers as an aerosol

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 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 below any occupational exposure limit or standard, 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 are briefly summarized

Acetone

Few adverse health effects have been attributed to acetone despite widespread use for many years Awareness of mild eye irritation occurs at airborne concentrations of about 1000 ppm Very high concentrations (12000 ppm) depress the central nervous system, causing headache, drowsiness, weakness, and nausea Repeated direct skin contact with the liquid 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 the nose and throat Exposures over 200 ppm can cause keratitis [14] 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

Ethylene Glycol Monobutyl Ether Acetate (EGBEA)

EGBEA is reported to adversely affecting the blood and hematopoietic systems because it metabolized in the body to form ethylene glycol butyl ether (EGBE) EGBE is known to adversely affect the hematopoietic system [17] EGBEA also causes tissue irritation and central nervous system depression

Propylene Glycol Monomethyl Ether (PGME)

PGME is reported to cause eye, nose, and throat irritation at concentrations of 95-300 ppm [18]

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 200-500 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 that 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 [19]

METALS

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

Cadmium

Cadmium is a toxic heavy metal that 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 [20] Acute inhalation exposure to high levels of cadmium can cause respiratory irritation and pulmonary edema In addition, cadmium exposure causes kidney damage [21] Chronic exposure may lead to emphysema of the lungs and kidney disease that may be associated with hypertension [22] 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 [23]

Chromium

Some paints may contain chromates (hexavalent chromium or chromium VI), 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 [24]

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 [20] 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 [21] 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 [25,26] Lead exposure is associated with fetal damage in pregnant women [21] Lastly, elevated blood pressure has been positively related to blood lead levels [27,28]

Titanium Dioxide

In reviewing the health effects literature, 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 that indicates that exposure to titanium dioxide involves some risk of cancer [29]

CRYSTALLINE SILICA (QUARTZ)

Exposure to crystalline silica particles causes silicosis [30] Once silica particles enter the lung, they become trapped and areas of swelling (or nodules) form around these particles As the condition worsens, due to the accumulation of silica in the lung, the nodules become larger and breathing becomes more difficult Silicosis predisposes the individual to tuberculosis and other lung infections In addition, lung cancer has been reported more frequently among those diagnosed with occupational silicosis

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 that 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 [34] 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 (29CFR1910 1000) In July 1992, the 11th Circuit

Table 1 Occupational Exposure Limits

Substance	NIOSH Recommended Exposure Limit (REL)[31,32]	OSHA Permissible Exposure Limit (PEL)[33]		ACGIH Threshold Limit Value (TLV)[34]	
	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	5 µg/m^3 [35]		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	
Ethylene Glycol Monobutyl Ether Acetate (EGBEA)	5 ppm				
Isopropyl Alcohol	400 ppm (800 ppm Ceiling)	400 ppm	500 ppm	400 ppm	500 ppm
Hexamethylene Diisocyanate (HDI monomer)	0 035mg/m^3 (0 14 mg/m^3)			0 005 ppm	
Particulate (not otherwise regulated) Total Dust 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	
Propylene Glycol Monomethyl Ether (PGME)	100 ppm	100 ppm		100 ppm	
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 29CFR1910 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 work week for a NIOSH Recommended Exposure Limit

[b] TWA - 8-hour Time Weighted Average

[c] STEL - Short-Term Exposure Limit.

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 eight to ten hour workday Some substances have recommended short-term exposure limits or ceiling values that are intended to supplement the TWA where there are recognized toxic effects from high, short-term exposures

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

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

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

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

EXPOSURE LIMITS FOR PREPOLYMERIZED DIISOCYANTES

Although health effects are attributed to prepolymerized diisocyanates, OSHA, NIOSH, and ACGIH have not developed exposure limits for these substances [36] 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 [37] 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 [38] In contrast, Sweden has a five minute short-term exposure limit of 0 2 mg/m^3 for occupational exposure to hexamethylene diisocyanate biuret [36]

The United Kingdom's Health and Safety Executive (HSE) has specified a control limit for occupational exposure to diisocyanates and oligomers of these diisocyanates [39] In reviewing the health effects associated with isocyanate exposure, the HSE assumed that the health consequences of inhaling aerosols containing -N-C-O (NCO) functional groups are not different from inhaling diisocyanate monomers As a result, the HSE has specified the following control limits for NCO functional groups in the air

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

During spray painting operations, occupational exposure to isocyanates frequently exceed these control limits [39]

EVALUATION PROCEDURES

The objective of this site visit was to evaluate the ability of the vehicle preparation station and the spray painting booth to control worker exposure to air contaminants To do this, air contaminant concentration monitoring and video exposure monitoring were conducted Ventilation measurements were made to document the airflow volumes in the spray painting booth and in the vehicle preparation stations In addition, quantitative fit tests and visual respirator inspections were conducted to evaluate respirator usage

AIR CONTAMINANT CONCENTRATION MONITORING

Total dust concentrations were measured using NIOSH Method 0500 [40] In this method, a known volume of air is drawn through a preweighed PVC filter at a flow rate of 5 0 liters per minute using a personal sampling pump (Aircheck Sampler, Model 224 -- PCXR7, SKC Inc, Eighty Four, PA) The weight gain of the filter is used to compute the milligrams of per cubic meter of air After weighing, selected filters were analyzed for antimony, chromium, nickel, and copper because these substances were identified on material safety data sheets The detection limits for these substances were 1, 0 5, 0 5, and 0 5 μg/filter The metals on each filter were solubilized using a modification of NIOSH Method 7300 [41] Each filter was placed in a 125mL 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 10mL volumetric flask, diluted to 10 mL, and then were analyzed by a simultaneous scanning inductively coupled plasma emission spectrometer In addition, some filters were analyzed for quartz using NIOSH Method 7500 [41]

Material safety data sheets were used to identify the major organic solvents that may be present during spray painting The concentrations of these solvents were measured sec-butanol, n-butanol, n-butyl acetate, toluene, xylenes, ethylene glycol monobutyl ether acetate (butyl cellosolve acetate), propylene glycol monomethyl ether (PGMME), propylene glycol methyl ether acetate (PGMEA), and ethylene glycol monpropyl ether (EGMPE) Concentration 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 connects 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 are desorbed from the charcoal using carbon disulfide and the solvents are quantitated by using a gas chromatograph equipped with a flame ionization detector NIOSH Method 1403 was used with some modifications The modifications are listed below [41]

Desorption Process	Thirty minutes in 1 0 milliliter of methylene chloride with 1 microliter of isooctane per mL of methylene chloride as an internal standard and 5 percent methanol as a desorbing aid
Gas Chromatograph	Hewlett-Packard Model 5890 equipped with a flame ionization detector
Column	30m x 0 32mm fused silica capillary coated, internally with 1 0 μm of DB-5
Oven Conditions	Temperature programming from 35°C (held for 10 minutes) to 180°C at a rate of 10° C/minute

During spray painting operations involving the use of isocyanate hardeners, the concentrations of hexamethylene diisocyanate and its trimer were monitored by using NIOSH Method 5521 [42] In this method, air samples are collected in an impinger at a known sampling rate of 2 liters 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 performance liquid chromatography operated with a UV and an electrochemical detector In addition, a photodiode array detector was used to confirm the presence of isocyanates 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 that, 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 (μg NCO/m^3)

The material safety data sheet reported that the hardener's used in this autobody shop contained 25-35 percent of a polyisocyanate with a Chemical Abstracts Service (CAS) number of 28182-81-2 and 10-20 percent of a polyisocyanate with a CAS number of 53880-05-0 The first CAS number refers to an isocyanurate of HDI which is Desmodur N3300 (Miles Laboratories, Pittsburgh, PA) [37] The UV detector response obtained during the NIOSH Method 5521 analysis was used to obtain the mass of Desmodur N3300 in an air sample Standards were prepared by quantitatively diluting a bulk sample of Desmodur N3300 obtained from the paint manufacturer

The second CAS number refers to a polymeric form of isophrone diisocyanate Because of analytical difficulties, the concentration of the polymeric form of isophrone diisocyanate was not quantitated

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

1 On the worker's lapel, 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 down draft booth, this sampling location was under the object being painted In a cross draft or semi-down draft 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 affected the relative air contaminant concentrations on the workers' lapel [43,44] Relative concentrations on the worker's lapel were monitored with a direct reading instrument, and its analog output was recorded with a data logger (Rustrak Ranger, Gulton, Inc , East Greenwich, RI) Workplace activities were simultaneously recorded on videotape When the data collection was completed, the data logger was downloaded to a portable computer (Compaq Portable III, Compaq Computer Corporation, Houston, TX) for analysis

A Photovac TIP II (PHOTOVAC Inc, Thornhill, Ontario) was used to monitor relative solvent concentrations on the worker's lapel The analog output of the Photovac 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's response is a measure of relative concentration Because of fire safety considerations, the Photovac TIP II was located outside of the spray painting booth Teflon tubing (0 125 inside diameter, 45 feet long, Alltech Associates, Deerfield, IL) 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

In the spray painting booth, airflow volumes were determined by measuring the face velocity and face area at the supply air inlet on the roof, just under the filters in the ceiling of the spray painting booth and in the exhaust air channel in the floor of the spray painting booth In addition, the face velocity and area were also measured at the supply air inlet on the roof

These air velocities were measured with a hot wire anemometer (Kurz, Model 1440-4, Carmel Valley, CA) In addition, static pressure measurements were made at various points in the spray painting booth's air handling system Smoke tubes were used to trace the airflow patterns around objects in the spray painting booth Air velocities were measured around a car in the spray painting booth At the vehicle preparation station, the exhaust air volume was measured by using the velometer to measure the filter's face velocity In addition, air velocities around a car were measured

RESPIRATOR EVALUATION

The respirators currently used 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 evaluate respirator leakage A Portacount™ respirator fit tester (TSI, Inc , P O Box 64394, St Paul, MN 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 [45] 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 [46] 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 [46]

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

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 - SPRAY PAINTING BOOTH

VENTILATION MEASUREMENTS

Airflows in the spray painting booth were measured at the locations listed in Table 2 The airflow measured at the inlet is 30 percent below the air flow at the exit The supply air ducts are not tightly sealed and, apparently, air can leak into the duct The sheet metal for the spray painting booth involves some very noticeable leakage A gap of 0 5 to 1 5 inches between the housing for the exhaust fan and the floor allows 1300 cfm to leak into the exhaust plenum As noted in Figures 4 and 5, a damper used to recirculate air during the curing cycle does not close completely, causing some recirculation of contaminated air

Table 2 Airflow Measurements on/ Spray Painting Booth	
Location	Airflow Rate Cubic Feet per Minute (cfm)
Airflow into entry duct	8200
Airflow from top of booth	13000
Airflow from bottom of booth	11400
Airflow at exhaust stack	11600
Leakage into exhaust air plenum	1300
Recirculation around damper[1]	750

1 – Estimated using equation 1 12 from ACGIH's Manual of Industrial Ventilation[47] and assuming a coefficient of entry of 0 6

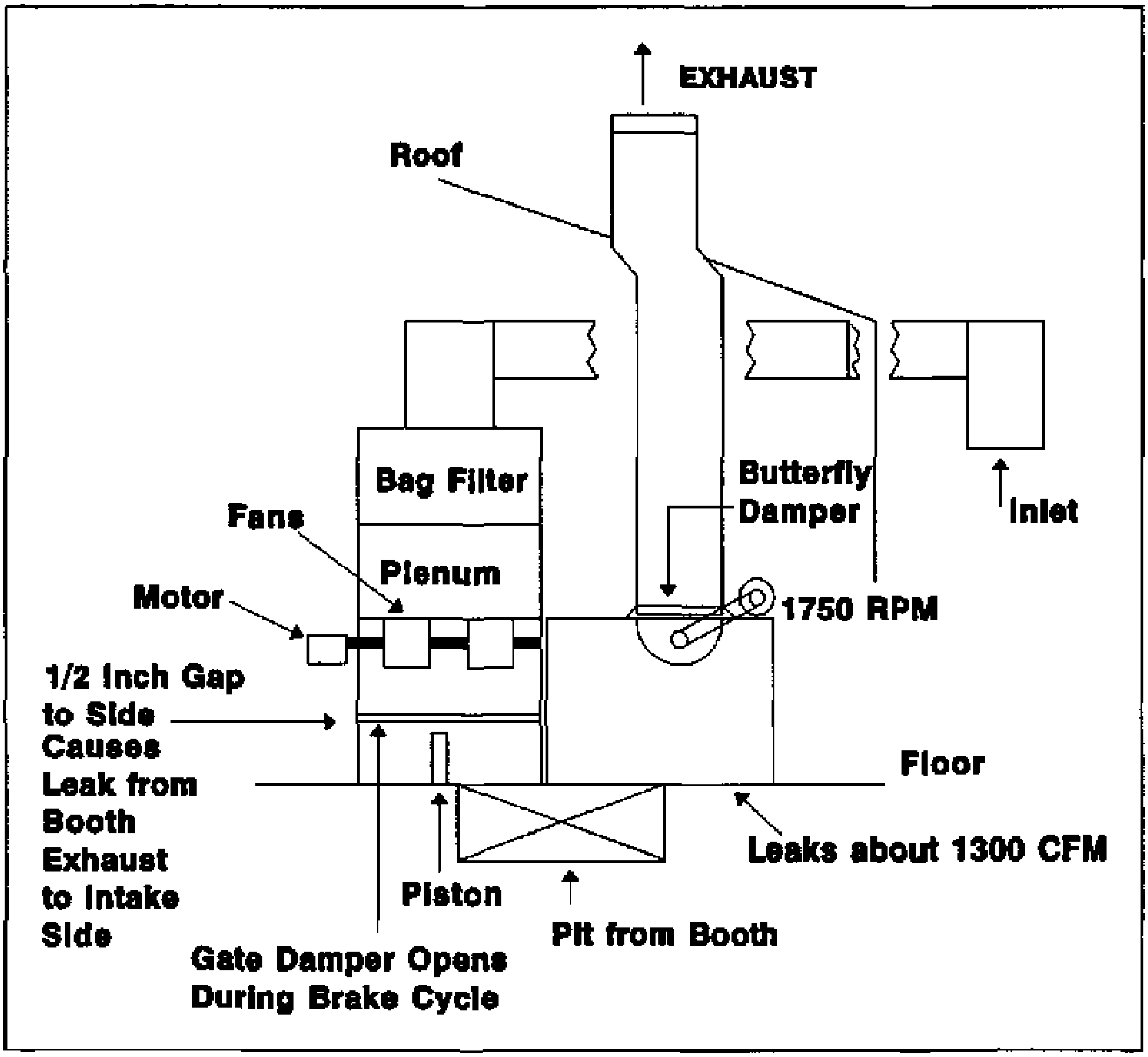

Figure 4 View of the paint booth's ventilation systems

Table 3 lists the static pressures in the spray painting booth's ventilation system at the various points described in Figure 5 Because the difference in static pressure between points D and B is 2 inches of water, an estimated 750 cfm of air is inadvertently recirculated Before the air flows into the prefilters, the static pressure is -0 6 inches of water This pressure loss is caused by three elbows between the fresh air inlet and the filters

Table 3 Static Pressures Relative to Room

Location in Figure 5	Location	Static Pressure
A	Down stream of inlet and 3 elbows	-0 6
B	Just upstream of fan	-2 2
C	Static pressure down stream of fan	0 25
D	Under damper	-0 2
	Before filters in ceiling	0 08
	In booth	0 02

Figure 6 presents air velocities around a car in the spray painting booth At the sides of this car, air velocities averaged 78 feet per minute When air flow patterns were studied with a smoke tube, there was no evidence of eddies that can cause contaminated air to flow into the worker's breathing zone However, some painting was done while objects were set on a 4'X 8' table in the booth When a smoke tube was aspirated in the middle of this table, smoke rose 2-3 feet above the table Thus, painting on the table could cause contaminated air to rise into the worker's breathing zone

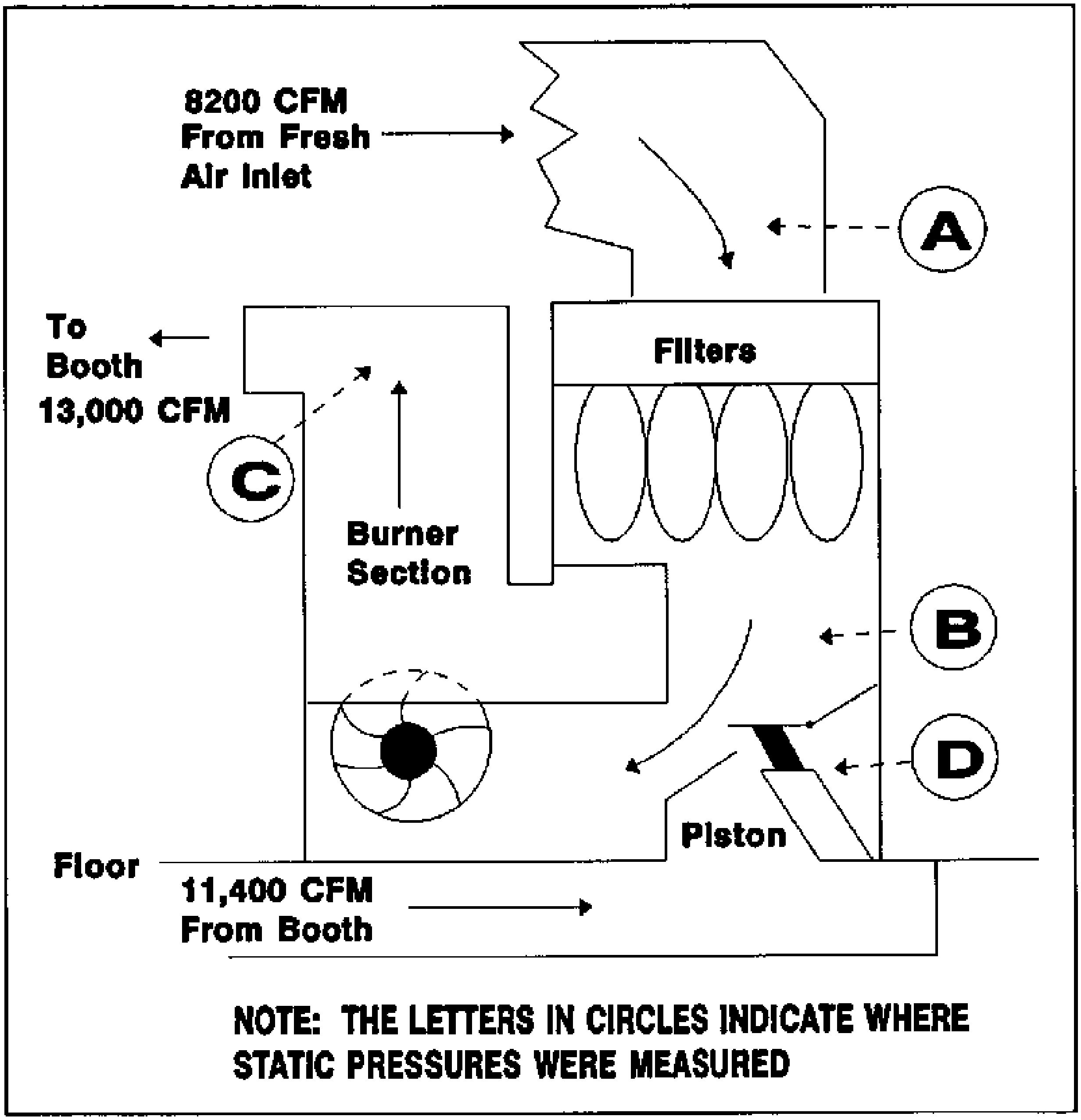

Figure 5 Side view of ventilation system for the spray painting booth

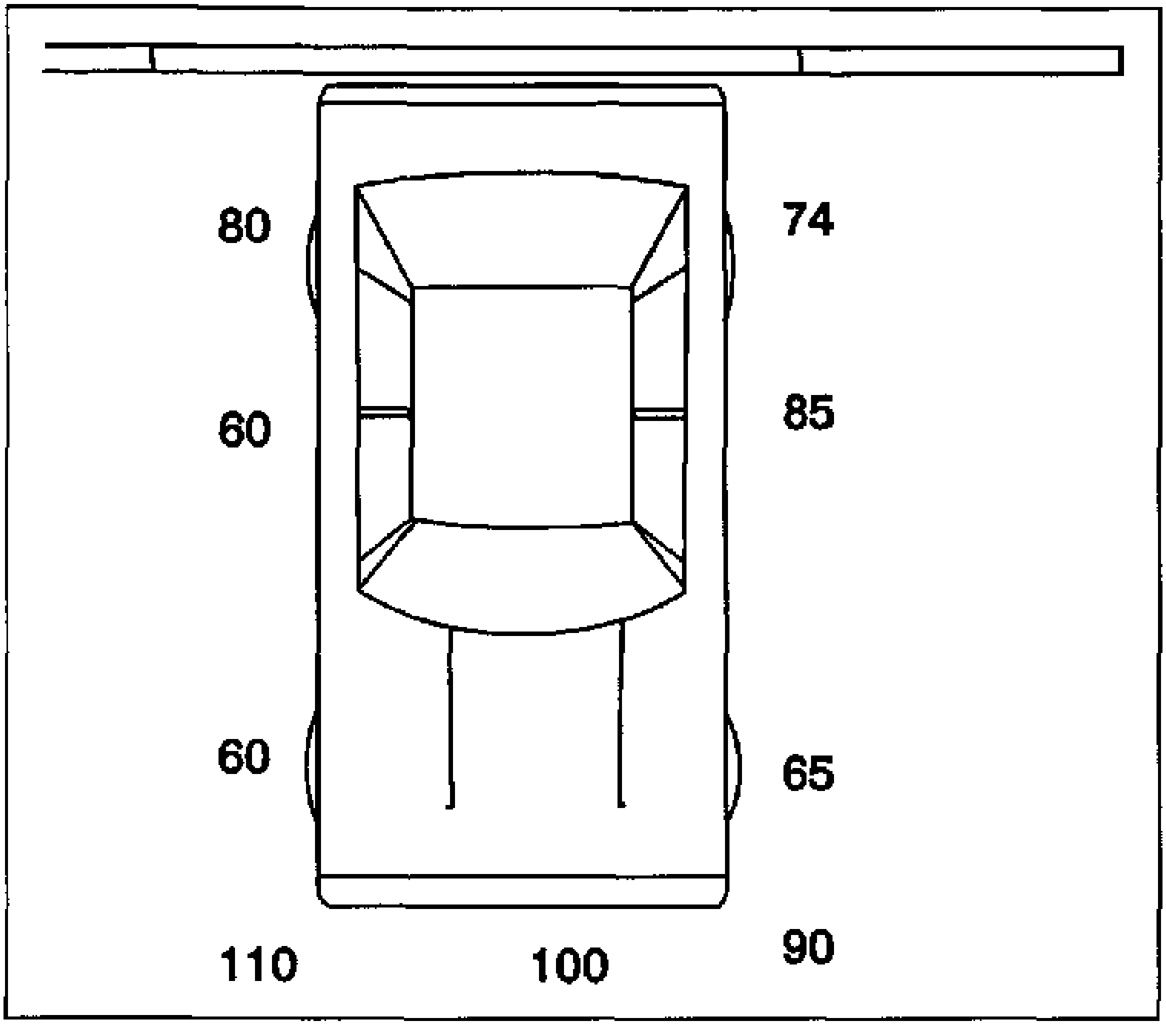

Figure 6 Air velocity (feet per minute) around car at a height of 3 feet and a distance of 1 5 feet from the car

AIR CONTAMINANT CONCENTRATION MEASUREMENTS

Paint mist concentrations measured in the spray painting booth are summarized in Table 4 and are listed in Table A2 of Appendix A Some concentrations measured on the worker's lapel exceeded the OSHA PEL for total dust of 15 mg/m^3 for an 8-hour day Because these samples were taken over a fraction of a full shift of an 8-hour day and this PEL is based upon an 8-hour day, this result does not necessarily indicate that the exposure exceeds the PEL However, this indicates that the spray painting booth does not always control the overspray generated during spray painting

Table 4 summarizes the sampling results at the three sampling locations in the spray painting booth Based upon the statistical analysis summarized in Appendix B, sampling location did not affect the concentration measurements Well-designed, properly used ventilation should separate the worker from the overspray This should result in a much higher concentration under the object being painted than on the worker At this operation, the concentration measured on the worker was about 40 percent of the concentration measured under the object being painted Thus, the ventilation did not isolate the worker from the paint overspray At this autobody shop, body parts are frequently suspended from the ceiling and painted at head height The airflow around these objects did not appear to keep the overspray out of the worker's breathing zone when the objects are at face height

Table 4 Summary of Paint Mist Concentrations in the Spray Painting Booth

Sampling Location	N	Geometric Mean (GM) (mg/m^3)	Geometric Standard Deviation (GSD)	Range (mg/m^3)
Personal	7	2 3	4 3	0 26 - 18
Under Car or Part	7	5 6	1 9	1 9 - 12
Near wall	7	4 3	3 9	0 74 - 21

The solvent concentrations are listed in Table A4 of Appendix A None of the concentrations measured on the worker's lapel exceeded the limits listed in Table 1 All of the combined exposures are less than 1

Table 5 summarizes the isocyanate sampling results and Table A4 in Appendix A lists the isocyanate sampling results Except for one sample, the breathing zone concentration of Desmodur N3300 remained below 1 mg/m^3 When wheels were set on a table and painted (Period D in Appendix A), the concentration of Desmodur N3300 was 1 3 mg/m^3 in the worker's breathing zone Perhaps, the air motion entrained by the spray painting gun or the eddy that was observed above the table might have caused overspray to flow directly back to the painter While painting these wheels, the worker stood directly over the wheels

Table 5 Summary of Isocyanate Sampling Results				
Sampling Location	Number of Samples	GM	GSD	Range
Desmodur N3300				
Personal	4	0 27 mg/m^3	4 20	0 10 - 1 3 mg/m^3
Under Object	4	0 63 mg/m^3	4 36	0 10 - 2 6 mg/m^3
NIOSH Method 5521				
Personal	4	39 μg NCO/m^3	3 84	17 - 190 μg NCO/m^3
Under Object	4	96 μg NCO/m^3	4 11	22 - 390 μg NCO/m^3

Concentration measurements for antimony, chromium, nickel, copper, and silica were made on selected samples These results are listed in Table A2 of Appendix A None of these analytes were detected on the personal samples

VIDEO EXPOSURE MONITORING

Figure 7 presents the response of the Photovac TIP II to the organic vapors generated when a single car part consisting of the hood and front fenders of a two-seater sports car (1960's vintage Jaguar) was painted in the downdraft booth During most of this task, the relative concentration remained relatively constant Annotations in this figure attribute sharp increases in relative concentration to painting above one's head and the possible deflection of the overspray into the worker's breathing zone When the painter spray paints the side of this part, the overspray appeared to flow directly into the exhaust grate without flowing into the worker's breathing zone However, peak concentrations can still occur as illustrated in Figure 7

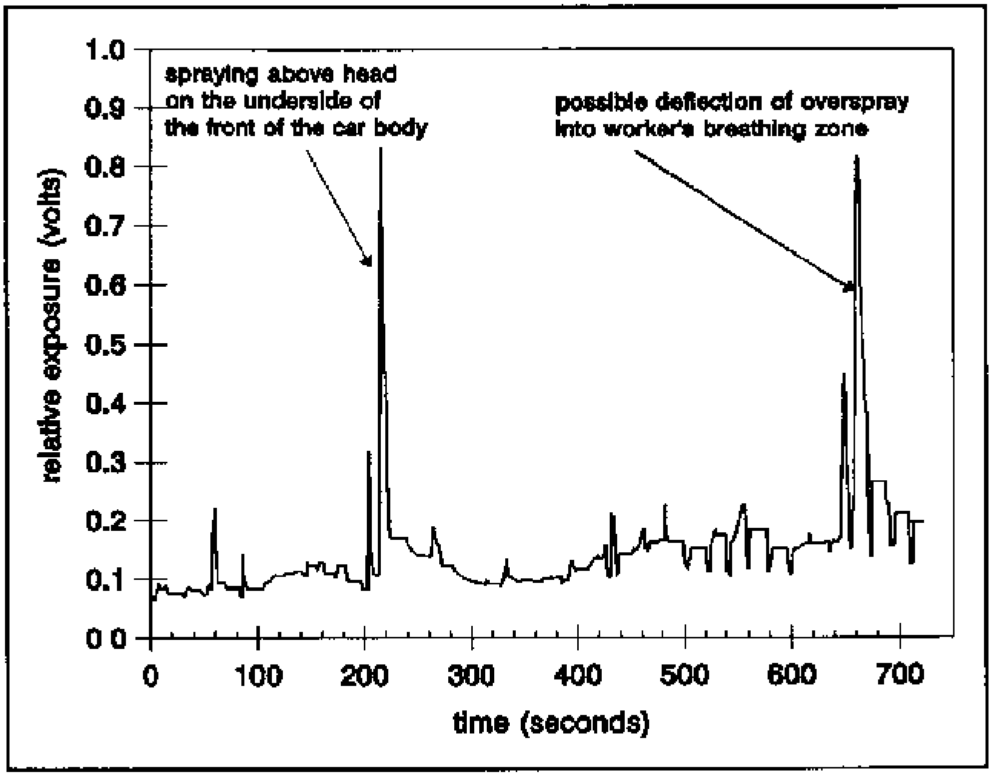

Figure 7 Relative exposure during spray painting in downdraft spray painting booth The front of a car body was being painted

RESULTS - VEHICLE PREPARATION STATION

VENTILATION MEASUREMENTS

The airflow rates at vehicle preparation stations 1 and 2 were respectively, 4900 and 5800 cubic feet per minute Table 6 summarizes air velocities measured at the side of a car that was parked in vehicle preparation station 1 At some locations, air velocities are below 50 fpm, which is too low to provide meaningful control of the air contaminants [48] When work is being done on the end of the car closest to the exhaust filters, the worker's torso and the car's body obstruct the removal of contaminated air from the worker's breathing zone In addition, smoke traces indicated that the flow of the air around the car causes an eddy or a circular flow pattern at the end of the car closest to the booth's filters This eddy can transport paint overspray or sanding dust directly into the worker's breathing zone

Table 6 Air Velocities Measured Around a Car Positioned in Vehicle Preparation Station 1				
Right side - 4 feet between car and curtain				
Height (feet)	Front Wheel		Door Post	Back Wheel Well
4	65		20	20
3	78		10	40
2	28		25	32
Left side- 2 feet between car and curtain				
4	150		67	50
3	60		80	40
2	60		80	60

AIR CONTAMINANT CONCENTRATIONS

During one sampling period (Period B in Appendix A), the worker was spray painting the side and rear trunk of a car at the vehicle preparation station A total dust concentration of 43 mg/m^3 was measured on the worker Apparently, the paint overspray followed directly into the sampler that was mounted on the worker The total dust and charcoal tube sampling results are listed in Tables A2 and A3 of Appendix A During this sampling period, the solvent exposures were below NIOSH RELs

VIDEO EXPOSURE MONITORING

Figures 8-11 present the response of the Photovac TIP II to the organic vapors that were generated during the sampling period described in the preceding paragraph During each coat of paint, the worker painted the side of the car and then the back of the trunk These figures illustrate that when the worker painted the trunk of the car, the relative concentration increased This is consistent with the observation that the flow pattern located between the worker's torso and the back of the car can cause overspray to accumulate in the worker's breathing zone

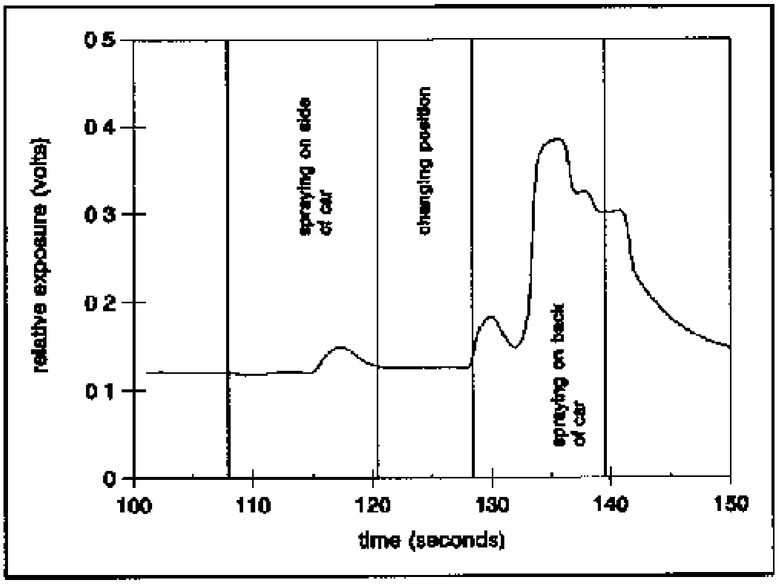

Figure 8 Relative exposure while spray painting car at the vehicle preparation station

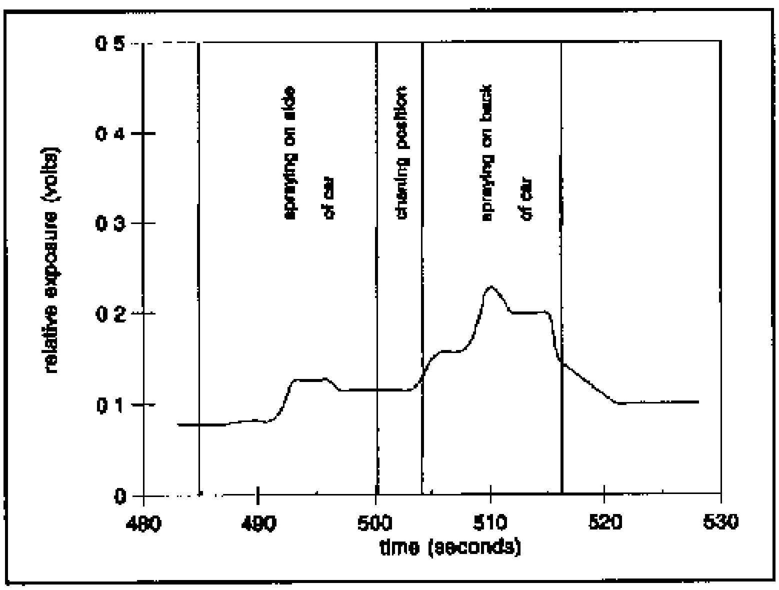

Figure 9 Relative exposure while spray painting car at the vehicle preparation station

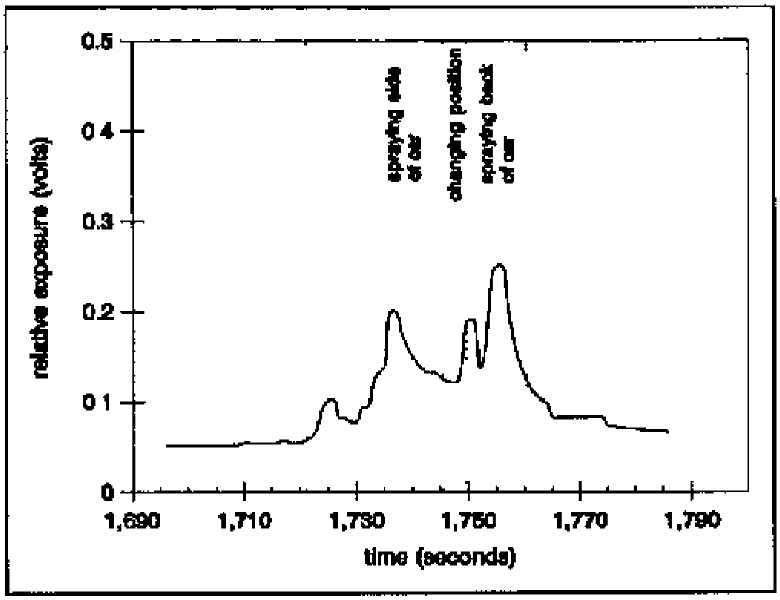

Figure 10 Relative exposure while spray painting car at the vehicle preparation station

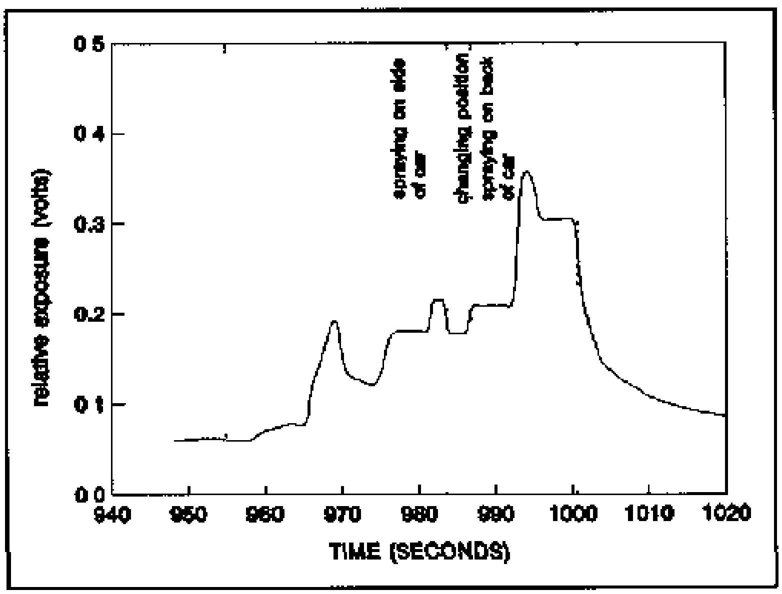

Figure 11 Relative exposure while spray painting car at the vehicle preparation station

RESULTS - RESPIRATORY PROTECTION

The results of the respirator fit tests are presented in Table 7 These respirators were all half-facepiece, air-purifying respirators Four of the six worker's existing respirators had fit factors that were less than 100, which is the minimum acceptable fit factor recommended by NIOSH and specified in some OSHA standards for specific air contaminants [49,50,51] Thus, four of the six respirators tested were inadequately protecting the workers Table 8 summarizes defects that were observed in the worker's original respirators This defect list suggests that poor respirator maintenance contributed to the poor performance of the original respirators during the quantitative fit test The number of defects suggests that workers' original respirators had exceeded their useful life and needed to be replaced

In addition to performing quantitative fit tests upon the half-facepiece respirators, quantitative fit tests were done on the supplied air hoods The tubing from the quantitative fit tester was placed in the hood near the worker's mouth Fit factors of 19,000 and 5,000 were obtained for the two painters This indicates that the supplied air respirator is supplying sufficient airflow to overcome the painter's breathing rate

Table 7 Quantitative Fit Testing Results for Original Respirators Replacement Respirators

	Fit Factor Original Respirator	Fit Factor New Respirator
Worker #1	8	2162
Worker #2	18	25507
Worker #3	344	2798
Worker #4	31	18535
Worker #5	5	985
Worker #6	2943	4958
Worker #7	-	56446*

* = New Employee, First Time to Wear a Respirator

DISCUSSION AND RECOMMENDATIONS

SPRAY PAINTING BOOTH

The air velocity measurements reported in Figure 6 indicated that this booth nearly complies with a French ventilation standard for downdraft autobody spray painting booths Compliance with this standard reportedly minimizes worker exposure to hardeners that contain diisocyanates [52,53] This standard has some very specific specifications on the flow of air around a car

> The air velocity around the perimeter of a car is to be measured at ten 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 ten 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

The average air velocity around the car illustrated in Figure 6 was 78 fpm or 0 39 m/sec The fact that this booth is very close to meeting this standard, suggests that paint overspray concentrations should be well controlled when cars are being spray painted in this booth The total dust breathing zone concentrations of below 1 mg/m^3 during some paint jobs and the video exposure monitoring results presented in Figure 7 indicate that the booth does control the paint overspray during some jobs When painting is done on the side of a car, the overspray appears to stay out of the painter's breathing zone However, this French standard assumes that an assembled car is being refinished During six of the seven sampling periods listed in Table A1 of Appendix A, autobody parts that were painted were either suspended from the ceiling or set on a table in the spray painting booth When objects were suspended from the ceiling at head height, the air velocity around the parts is only 43 fpm, which is too low to provide meaningful control of air contaminants [48] Because the car is large in relation to the booth, the air velocities are higher around a car The highest total dust concentration, 18 mg/m^3, occurred when autobody parts were suspended from the ceiling and primed This situation suggests that this booth is not particularly well-suited for painting autobody parts Because this booth does not completely control paint overspray, respiratory protection is needed during spray painting operations

OSHA and ACGIH airflow recommendations for spray painting booths address only crossdraft spray painting booths [54,55] They both specify 100 feet per minute per square foot of cross sectional area of flow into the booth To comply with this recommendation, this booth would require a total airflow of nearly 30,000 cfm Although this booth does not comply with the OSHA ventilation standard, OSHA generally does not enforce this standard unless there is a violation of current OSHA standards for air contaminants [56] None of the personal air samples indicated that OSHA standards for air contaminants were exceeded

VEHICLE PREPARATION STATION

The vehicle preparation station appears to be inadequately designed for use during spray painting During one spray painting job, a concentration of 42 mg/m^3 was measured on the worker when the worker was painting the side and rear of a car Video exposure monitoring indicated a peak in the relative concentration measured on the worker's lapel when the rear of the car was being painted The car was situated so that the rear of the car was about 3-4 feet from the exhaust filters in the vehicle preparation station When the painter stands facing the rear of the car, the airflow pattern can transport air contaminants directly into the samplers mounted on his lapel The air velocities along the side of the car (Table 6) are generally well below the 100 fpm recommended by ACGIH and specified by OSHA To meet these recommendations, each bay of the vehicle preparation station would need to be operated at an airflow of nearly 10,000 cubic feet per minute As mentioned earlier, OSHA does not enforce ventilation standards unless an air contaminant exposure limit has been exceeded Because short-term concentrations can be quite high during spray painting operations at these vehicle preparation stations, respiratory protection is needed during spray painting operations Furthermore, painting should be done as much as possible in the spray painting booth

RESPIRATOR USAGE

At this body shop, respiratory protection is needed and used during spray painting and abrasive blasting operations The material safety data sheets for the hardeners that contain Desmodur N3300 recommend the use of air-supplied respirators [57] During abrasive blasting operations involving silica, respiratory protection is the primary control measure For abrasive blasting involving silica, the OSHA standard for abrasive blasting requires the use of supplied air respirators constructed so that it covers the worker's neck, head, and shoulders to protect him from rebounding abrasive [58] In addition, respirators are used to minimize worker air contaminant exposure during welding and sanding operations Respirators need to be properly used in order to control worker exposures to air contaminants There was not a formal, written respirator program at this autobody shop

In order to insure that the respirators are actually protecting the worker's, a formal, written respirator program is needed Furthermore, the OSHA respirator standard (29CFR1910 134), which is included as Appendix C, specifically requires that

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

Table 9 summarizes OSHA's minimum requirements for a respirator program If the respirators were properly maintained as required by Item 6 in Table 9, the defects observed (Table 8) would not have occurred and perhaps the worker's original respirators would have given better performance during the quantitative fit tests

Table 8 Results of Respirator Inspections for Defects on Original Respirators	
Defect	Number of Used Respirators With This Defect
Facepiece had lost shape or torn This may interfere with seal or cause leakage	5
Inhalation valve does not appear to be seating properly	4
Exhalation valve does not appear to be seating properly	1
Headbands have lost elasticity, possibly causing poor fit	2

Table 9 OSHA Requirements For a Respirator Program	
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 of Respirators
7	Workplace exposure monitoring
8	Evaluation of program effectiveness
9	Medical monitoring
10	Use of certified respirators

The proper selection of a respirator involves some form of a fit test Possibly, the worker's original respirators did not fit the workers' faces contributing to the poor quantitative fit test results (Table 7) When the bodyshop workers were provided with new respirators of their choice and were instructed in proper donning techniques, fit factors increased substantially This result shows a fit test can be used to make sure that each worker has a respirator that fits his or her face The OSHA respiratory protection standard specifies that respirators be selected in accordance with ANSI standard Z88 2-1969 [59] Although this standard does not require fit tests for respirator selection, a revision of this standard, ANSI standard Z88 2-1980, specifies the use of either qualitative or quantitative fit tests to select respirators [60] NIOSH recommends only quantitative fit testing

In addition to using half-facepiece respirators, the painters routinely used a supplied-air hood during spray painting operations Although this hood provides more protection than the half-facepiece, air purifying respirators, there is a potential for carbon monoxide poisoning Air for this hood is obtained from an oil-lubricated compressor that can generate carbon monoxide The OSHA respiratory standard states in 29CFR1910 134(d)(2)(ii) " If an oil-lubricated compressor is used, it shall have a high-temperature or carbon monoxide alarm, or both "

ABRASIVE BLASTING

After discussing the health hazards of silica, the shop owner indicated a willingness to eliminate the use of silica sand at this shop After the field work was completed, the shop owner tried unsuccessfully to purchase a silica-free abrasive This abrasive manufacturer was unwilling to ship small quantities of the silica-free abrasive directly to the body shop and the local supplier for autobody shops was unwilling to market this silica-free abrasive

PERSONAL PROTECTIVE CLOTHING

Material safety data sheets for the isocyanates 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 Butyl rubber gloves are recommended for handling solutions containing isocyanates [6] At this shop, the painters routinely wore rubber gloves while handling paints Because the painters wore disposable clothing during spray painting, it is unlikely that work clothing is contaminated with toxic substances and that the painters need to take a shower and change clothing before returning home

CONCLUSIONS

The downdraft spray painting booth appears to minimize exposure to paint overspray when the sides of cars are painted However, this type of booth does not appear to be very effective in controlling the overspray when individual autobody parts are painted The air velocities around the car at a vehicle preparation station appear to be too low to provide meaningful control of paint overspray In some situations, the configuration of the vehicle preparation station can generate airflow patterns that transport overspray directly into the worker's breathing zone Respirator usage at this autobody shop is inadequate Although the shop owner has good intentions, his ability to insure proper respirator usage is hindered by a lack of knowledge There is a need to read, understand, and implement the OSHA respirator standard that 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 may not have occurred

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APPENDIX A
Listing of Concentration Data

Table A1 Description of Activities During Sampling Periods				
Sampling Period Code	Date	Time of Personal Sample for Total	Time Spent Painting (minutes)	Description of Activity
A	5/11	10 27-10 46	14	Painting parts on a table in spray painting booth
B	5/11	10 48 - 11 06	10	Painting rear of car at vehicle preparation station
C	5/12	2 54 - 3 13 3 39 - 3 58	24	Painting four wheels which are set on a table in spray painting booth
D	5/12	4 30 - 4 48	7	Painting four wheels which are set on a table in the spray painting booth
E	5/13	10 43 - 11 21	15	Painting rear bumper, small part of side of car in (less than 2 square feet), and hood which was suspended from the ceiling of the spray painting booth
F	5/13	3 29 - 5 00	27	Painting cowl and door on a car and hood which was vertically suspended from the ceiling of the spray painting booth
G	5/14	8 52 - 9 09	6	Painting a car door on a car in the spray painting booth
H	5/14	3 45 - 4 30	27	Painting car parts which were suspended from the ceiling of the spray painting booth

Table A2 Listing of Sampling Results for the Spray Painting Booth							
Activity Code (see Table A1)	Location (note Locations Marked With * Were Taken at the Vehicle Preparation Station)	Date	Start	Stop	Total Dust Concentration (mg/m³)	Other Analytes	Concentration (µg/m³)
A	Worker	5/11	10:27	10 46	0.26		
	Under car	5/11	10:27	10 46	7 0		
	Near wall	5/11	10:27	10 46	2 26		
B	Worker*	5/11	10:48	11:06	42.2		
	Near filters *	5/11	10:50	11.06	6 33		
	Near wall*	5/11	10:50	11 06	1 13		
C	Worker	5/12	2 54 3 39	3 13 3.58	2 54		
	Under car	5/12	2 54 3 39	3 13 3.58	6 93		
	Near wall	5/12	2 54 3 39	3 13 3 58	0 74		
D	Worker	5/12	4 30	4 48	0.50		
	Under car	5/12	4 30	4 48	11 9		
	Near wall	5/12	4 30	4 48	1.16		
E	Worker	5/13	10:43	11 21	5 64		
	Under car	5/13	10:43	11 21	1 93		
	Near wall	5/13	10:43	11 21	21.2	chromium	2 9
F	Worker	5/13	3.29	5:00	5 63		
	Under car	5/13	3 29	5:00	2 61		
	Near wall	5/13	3 29	5 00	12.59		
G	Near wall	5/14	8 50	9.10	3.0	antimony	23 5
	Under car	5/14	8 50	9 10	7 58		
	Worker	5/14	8 52	9 09	1 94		
H	Worker	5/14	3 55	4 20	18 3		
	Under car	5/14	3 45	4 30	8 94	crystalline silica	0 22
	Near wall	5/14	3 44	4 30	19 5	crystalline silica	0 28
	Mean weight change of 4 blank filters				-0 025		
	Standard deviation				0 021794		

Table A3 Listing of Solvent Concentrations

Activity Code (see Table A1)	Location	Date	Sample Start Time	Sample Stop Time	Xylene ppm	PGMEA	Toluene ppm	EGMPE	PGMME	n-butanol	sec-butanol	EGBEA	n-butyl acetate	Combined Exposure
A	Worker	5/11	10 27	10 46	LT 0 606	LT 0 487	8 39	LT 0 618	NR	NR	NR	NR	NR	0 08
	Under car	5/11	10 27	10 46	LT 0 606	LT 0 487	7 69	LT 0 618	NR	NR	NR	NR	NR	0 08
	Near wall	5/11	10 27	10 46	LT 0 606	LT 0 487	16 78	LT 0 618	NR	NR	NR	NR	NR	0 17
B	Worker	5/11	10 48	11 06	LT 0 768	1.23	55 81	1 56	NR	NR	NR	NR	NR	0.56
	Near filter	5/11	10 50	11 06	LT 0 768	0 62	40 75	0 78	NR	NR	NR	NR	NR	0 41
	Near wall	5/11	10 50	11 06	LT 0 768	LT 0 617	8.06	LT 0 782	NR	NR	NR	NR	NR	0 08
C	Worker	5/12	2 54 3 39	3-13 3 58	0 37	0 30	NR	NR	0.44	LT 0.532	LT 0 532	NR	1.02	0 01
	Under car	5/12	2 54 3 39	3-13 3 58	5 20	4 48	NR	NR	4.20	4.26	2 93	NR	11.90	0 29
	Near wall	5/12	2 54 3 39	3 13 3 58	1 11	1 10	NR	NR	0.44	1.06	LT 0 532	NR	29.92	0 24
D	Worker	5/12	4 30	4-48	1 92	1 03	NR	NR	NR	NR	NR	NR	3.81	0 04
	Under car	5/12	4 30	4 48	4 54	2.41	NR	NR	NR	NR	NR	LT 0 424	8.78	0 10
	Near wall	5/12	4 30	4 48	LT 0 640	LT 0 514	LT 0 738	LT 0 652	LT 0 753	LT 0.916	LT 0 916	LT 0.424	LT 0.585	0 00

Table A3 - Continued

Table A3 Listing of Solvent Concentrations

Activity Code (see Table A1)	Location	Date	Sample Start Time	Sample Stop Time	Xylene ppm	PGMEA	Toluene ppm	EGMPE	PGMME	n-butanol	sec-butanol	EGBEA	n-butyl acetate	Combined Exposure
E	Worker	5/13	10:43	11 21	0 91	0 58	0 55	NR	NR	NR	NR	LT 0 159	2 20	0 03
	Under car	5/13	10 43	11 21	0 98	0 66	LT 0 277	NR	NR	NR	NR	LT 0.159	2 42	0.03
	Near wall	5/13	10 43	11 21	5.28	3 66	0 55	NR	NR	NR	NR	0 54	12 73	0.14
F	Worker	5/13	3 29	5 00	1 58	0 91	1 22	NR	NR	NR	NR	0 22	4 75	0.06
	Under car	5/13	3 29	5 00	1.07	0 63	0 13	NR	NR	NR	NR	0.22	3.10	0.03
	Near wall	5/13	3 29	5 00	4 85	2 72	0 26	NR	NR	NR	NR	0 82	13.43	0 14
G	Near wall	5/14	8 50	9 10	1 35	0 54	0 78	NR	NR	NR	NR	LT 0 449	1.24	0 03
	Under car	5/14	8:50	9 10	2 98	1 09	1.56	NR	NR	NR	NR	LT 0 449	2.60	0 06
	Worker	5/14	8 52	9 09	LT 0 677	LT 0.544	0 78	NR	NR	NR	NR	LT 0.449	1 24	0.02
H	Worker	5/14	3 55	4 20	7 24	3.17	NR	NR	10 85	5 65	8.48	NR	10 84	0.45
	Under car	5/14	3 45	4:30	4 28	2 01	NR	NR	6 20	3 49	4 38	NR	6 62	0 26
	Near wall	5/14	3 44	4:30	3 95	1 90	NR	NR	6 20	3 30	4 24	NR	6 32	0.25

LT - less than
NR - not requested for analysis

Table A4 Isocyanate Sampling Results						
Activities Code (Table A1)	Date	Sampling Location	Sample Start Time	Sample Stop Time	mg/m³ of Desmodur N3300 via the Nobay Approach	µg/m³ of NCO/m³ via NIOSH Method 5521
D	5/12	Personal	4 30	4-48	1.27	188
		Under car	4 30	4 48	2.55	388
E	5/13	Personal	10 43	11 21	0.10	19
		Under car	10 43	11 21	0.10	17
F	5/14	Personal	3 26	5 00	0.14	22
		Under car	3 26	5 00	0.35	52
G	5/14	Personal	8 52	9 09	0 26	29
		Under car	8 52	9 09	1 70	244

APPENDIX B

Statistical Analysis of Total dust Concentration Data

The SAS General Linear Models procedure was used to evaluate whether sampling location affected the total dust concentration in the spray painting booth [61] Before the data was analyzed, the natural logarithms of the concentration data was taken The data analysis was performed on logarithms of concentration data The analysis was conducted to evaluate whether sampling location (LOC) and sampling period (R) affected the logarithm of the total dust concentration (LTP) The output from SAS is presented in Figure B1 The column labelled "Prob > F" is the probability that the observed differences in LTP could be explained by chance These results indicate that neither the sampling location or the sampling period affected the total dust concentration

General Linear Models Procedure

Dependent Variable LTP

Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOC	2	2 95237140	1 47618570	1 11	0 3615
R	6	11 03071821	1 83845303	1 38	0 2979

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOC	2	2 95237140	1 47618570	1.11	0 3615
R	6	11 03071821	1 83845303	1 38	0 2979

Figure B1 Output from SAS General Linear Models Procedure

Reference

61 SAS Institute [1988] SAS/STAT Users Guide, Release 6 03 Cary, NC

APPENDIX C
Copy of OSHA Standard 29CFR1910 134

Part Number 1910

Standard Number 1910 134

Title Respiratory protection

(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)

(ii) Approved or accepted respirators shall be used when they are available The respirator furnished shall provide adequate respiratory protection against the particular hazard for which it is designed in accordance with standards established by competent authorities The U S Department of Interior, Bureau of Mines, and the U S Department of Agriculture are recognized as such authorities Although respirators listed by the U S Department of Agriculture continue to be acceptable for protection against specified pesticides, the U S Department of the Interior, Bureau of Mines, is the agency now responsible for testing and approving pesticide respirators

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

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

1910 134(d)(2)

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

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

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

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

1910 134(d)(4)

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

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

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

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

1910 134(e)(3)(i)

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

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

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

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

1910 134(e)(5)

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

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

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

1910 134(e)(5)(iii)

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

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

(i) Inspection for defects (including a leak check),
(ii) Cleaning and disinfecting,
(iii) Repair,
(iv) Storage

Equipment shall be properly maintained to retain its original effectiveness

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

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

1910 134(f)(2)(iii)

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

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

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

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

shall be returned to the manufacturer or to a trained technician for adjustment or repair

1910 134(f)(5)

(5) (i) After inspection, cleaning, and necessary repair, respirators shall be stored to protect against dust, sunlight, heat, extreme cold, excessive moisture, or damaging chemicals Respirators placed at stations and work areas for emergency use should be quickly accessible at all times and should be stored in compartments built for the purpose The compartments should be clearly marked Routinely used respirators, such as dust respirators, may be placed in plastic bags Respirators should not be stored in such places as lockers or tool boxes unless they are in carrying cases or cartons

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

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

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

1910 134(g)(2)

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

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

(i) -

Canister for____________________
(Name for atmospheric contaminant)

or

Type N Gas Mask Canister

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

(Name of atmospheric contaminant)

1910 134(g)(4)

(4) Canisters having a special high-efficiency filter for protection against radionuclides and other highly toxic s 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)
particulate (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

(Approved by the Office of Management and Budget under control number 1218-0099)

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