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IN-DEPTH SURVEY REPORT

CONTROL TECHNOLOGY FOR AUTOBODY REPAIR AND PAINTING SHOPS

at

Team Chevrolet
Colorado Springs, Colorado

REPORT WRITTEN BY
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SIC CODE	7531
SURVEY DATE	December 8-11, 1992
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SUMMARY

The ability of three cross draft spray painting booths to control exposure to air contaminants was evaluated Ventilation measurements were made to document the performance of the ventilation system Air samples were collected on the worker to evaluate the exposure to total dust, organic solvents, and chromium The solvent concentrations measured on the worker were all less than NIOSH recommended exposure limits One of fifteen short-term total dust concentrations exceeded 15 mg/m^3, which is the OSHA PEL for total dust The chromium concentration measured on the worker's lapel ranged between 0 9 and 59 µg/m^3, 11 of 12 samples exceeded the NIOSH REL of 1 µg/m^3 for hexavalent chromium However, all of these samples were less than the OSHA PEL for chromium of 100 µg/m^3 A review of the available material safety data sheets revealed that hexavalent chromium was the only form of chromium listed However, material safety data sheets were not available for the all the surface coatings used during this study and one can not definitely conclude that all the chromium present was hexavalent chromium Efforts to measure the concentration of hexamethylene diisocyanate prepolymers, which are used as paint hardeners, were unsuccessful

In these cross-draft spray painting booths, air enters the booth through filters in the door or through a supply air plenum The air flows parallel to the ground, around the car and toward exit filters located in the back of the car After painting, the cars remain in the booth until they are dry The ages of these booths were unknown Two of these booths were operating at a flow rate of 9,500 cfm (cubic feet per minute) However, one booth, estimated to be at least 22 years old, was operating at a flow rate of about 3,000 cfm The flow rate increased to 7,000 cfm when the exhaust louvers were propped open with a block of wood For the spray painting booths present in this shop, an air flow rate of 12,000 cfm is specified by the OSHA standard for spray painting Because hexamethylene diisocyanate prepolymers are used in this booth, there is a possibility of excessive polyisocyanate concentrations to the worker Based upon total dust concentrations and the composition of the clear coat, the concentration of hexamethylene diisocyanate prepolymer may have exceeded the manufacturer's exposure limit recommendations However, we were unable to document this during the survey because of problems with our sampling and analytical method

Because of health effects associated with polyisocyanate exposure and hexavalent chromium exposure, there is a need for a comprehensive respiratory protection program at this autobody shop Presently, there is an absence of a formal, written respirator program as required by the OSHA respiratory practices standard Compliance with this standard is needed to make sure that respirators actually protect the workers from air contaminants in the spray painting booth

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 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 NIOSH's 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 These control measures are being evaluated 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 body shop, three cross draft spray paint booths were studied In addition, observations about respirator usage at this autobody shop were documented

SHOP DESCRIPTION

This autobody shop employs 13 workers six repair cars, four paint cars, and three work in the office Typically, 30-40 cars per week are repaired and painted at this shop This autobody shop is located in a two-story building that is built into the side of a hill This allows cars to be driven in and out of both levels of this shop Before the cars are painted, structural damage to the cars is repaired on the upper level of this shop which is schematically illustrated in Figure 1 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

After structural damage to the cars has been repaired, they are prepared for painting This involves some sanding, washing the car to remove dirt, and covering parts of the vehicle that are not being painted with either paper or plastic After the cars have been painted, defects in the paint job are removed by buffing In the upper level of the repair shop, vehicle preparation is done next to the spray painting booth The lower level is schematically illustrated in Figure 2

The spray painting booths in the upper level were Trimatic cross draft spray painting booths The manufacturer and date of installation were unknown These booths use one fan to supply air to the booth and another fan to exhaust the booth The air is supplied and exhausted through filters that are mounted in plenums (see Figures 3 and 4) These filters are changed every four to five weeks Before some painting jobs, the filters are wetted down with water This probably reduces the air flow through these filters until the filters dry off

The spray painting booth (Devilbiss type DLFA, Toledo, Ohio) on the lower level was reported to be over 22 years old (see Figures 5 and 6) A single fan draws air through the filters in the door of the spray painting booth and through a second set of exhaust filters located in the back of the booth The fan, which is located behind the booth, exhausts the air through louvers, which are located on the wall of the building The louvers appeared to be stuck in a partially closed position During the last two sampling periods, a block of wood was used to prop these louvers open to increase the air flow in this spray painting booth The blades of the fan appeared to have a coating of paint overspray which may be reducing the efficiency at which this fan is operating 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 The hardener cross-links with the other components of the clear coat to form a hard urethane surface

Half-facepiece, air-purifying respirators that were equipped with organic vapor cartridges and spray painting prefilters were issued to all of the workers All but one worker wore a 3M Easi-Care Dual Cartridge Respirator that had the following NIOSH Approvals TC-23C-859 and TC-23-860 The workers who wore this respirator had a certificate from 3M respirator stating that they had been trained on this respirator and had passed a qualitative fit test In talking with the employees, they distinctly did not remember going through the test exercises specified by NIOSH [1] They told the survey team that they simply conducted the test by wearing the respirators without moving their heads This respirator was used for organic vapors and dusts These respirators are designed to be disposable and these respirators were replaced every one or two weeks

POTENTIAL HAZARDS

Workers involved in autobody repair are potentially 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 [2] 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 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 Because of their chemical reactivity and ability to cross-link, diisocyanates are used in surface coatings, polyurethane foams, adhesives, resins, and sealants Diisocyanates are usually referred to by their specific acronym, e g , IPDI for isophorone

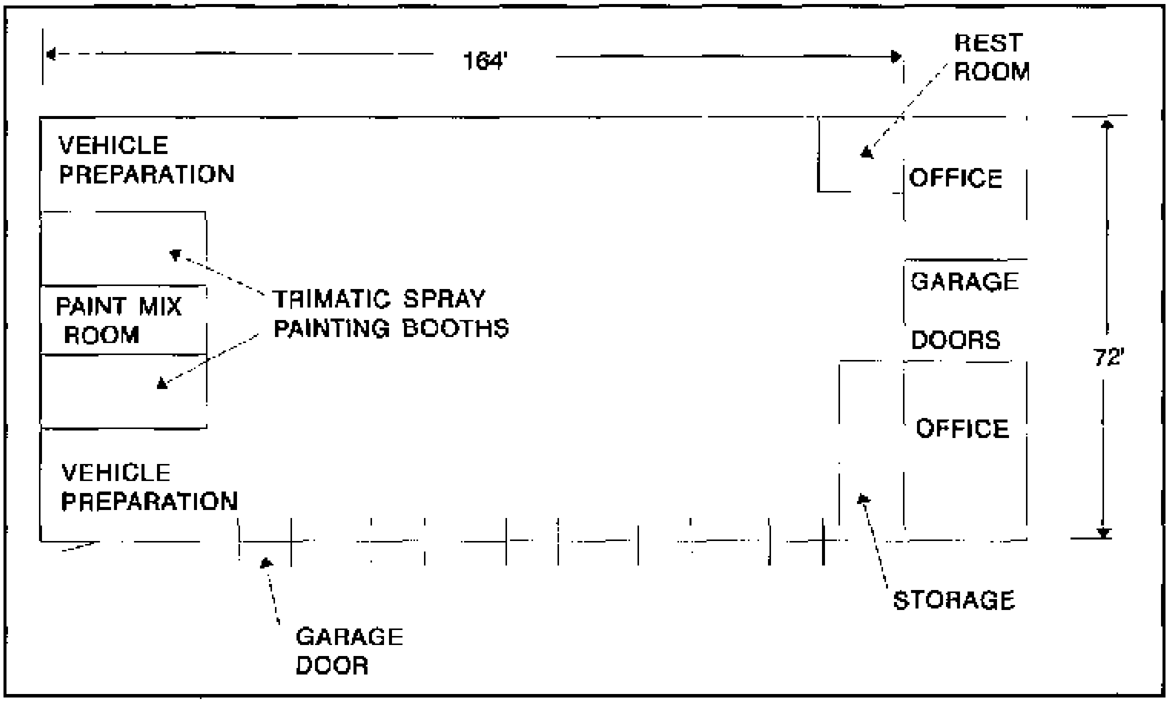
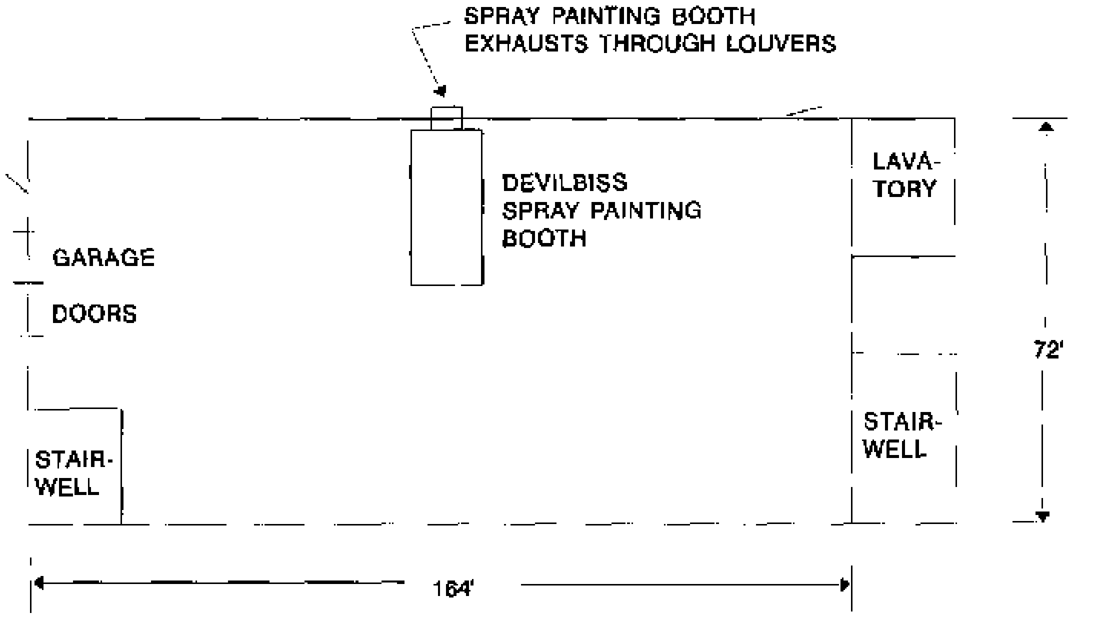


Figure 1 Floor plan for the first floor of the autobody shop



NOTE The exhaust louvers did not completely open during the first four sampling periods During the last two sampling periods, these louvers were propped to a completely open position with a block of wood

Figure 2 Layout of the lower level of the autobody repair shop

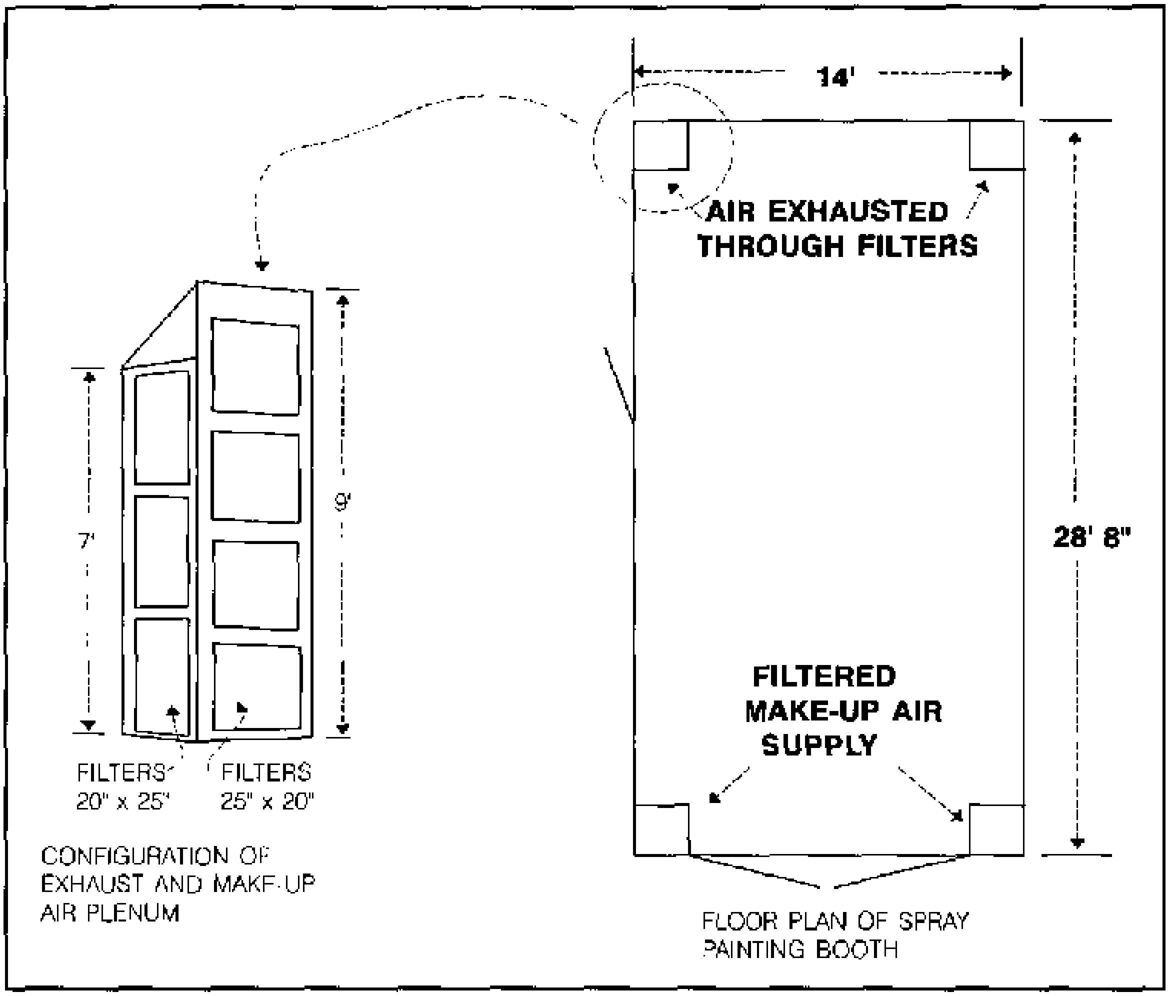


Figure 3 Plan view of TriMatic Spray Painting Booth

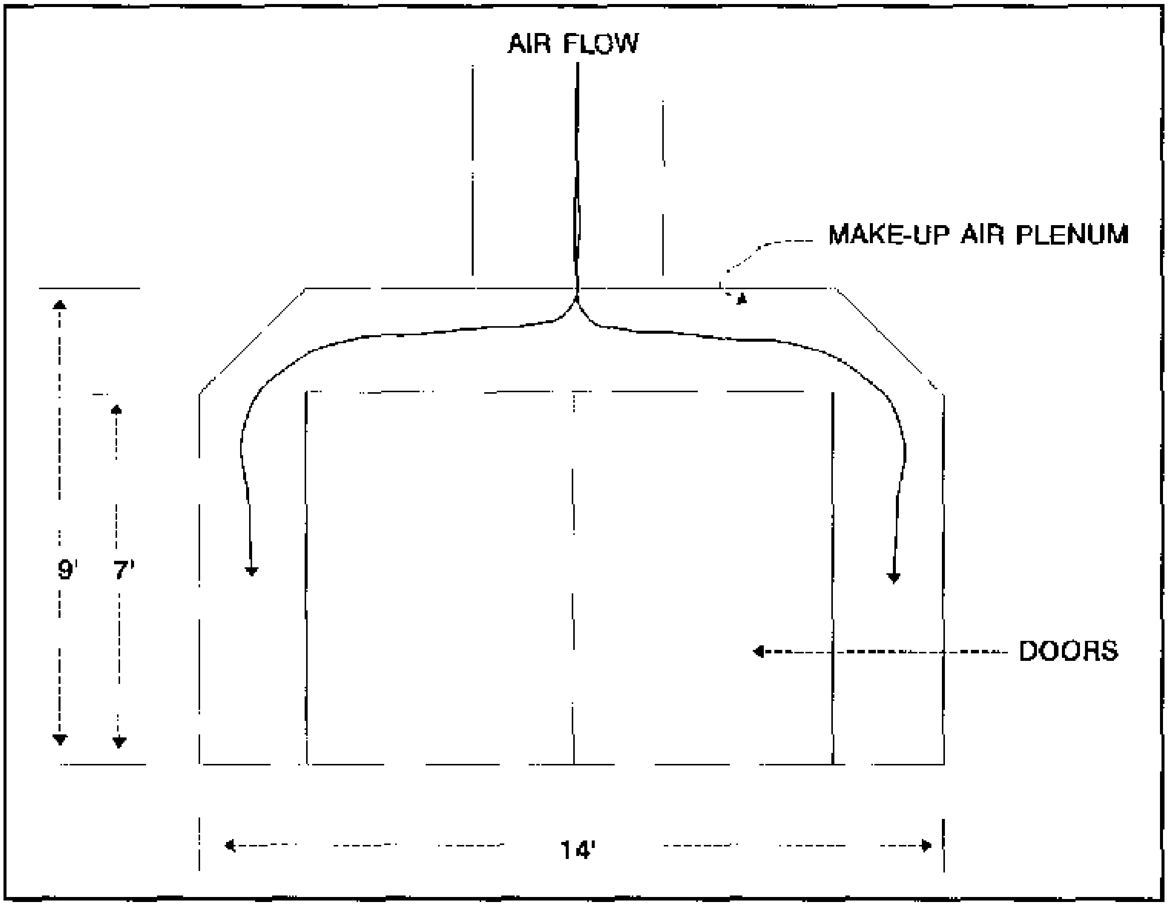


Figure 4 Front view of TriMatic spray painting booth

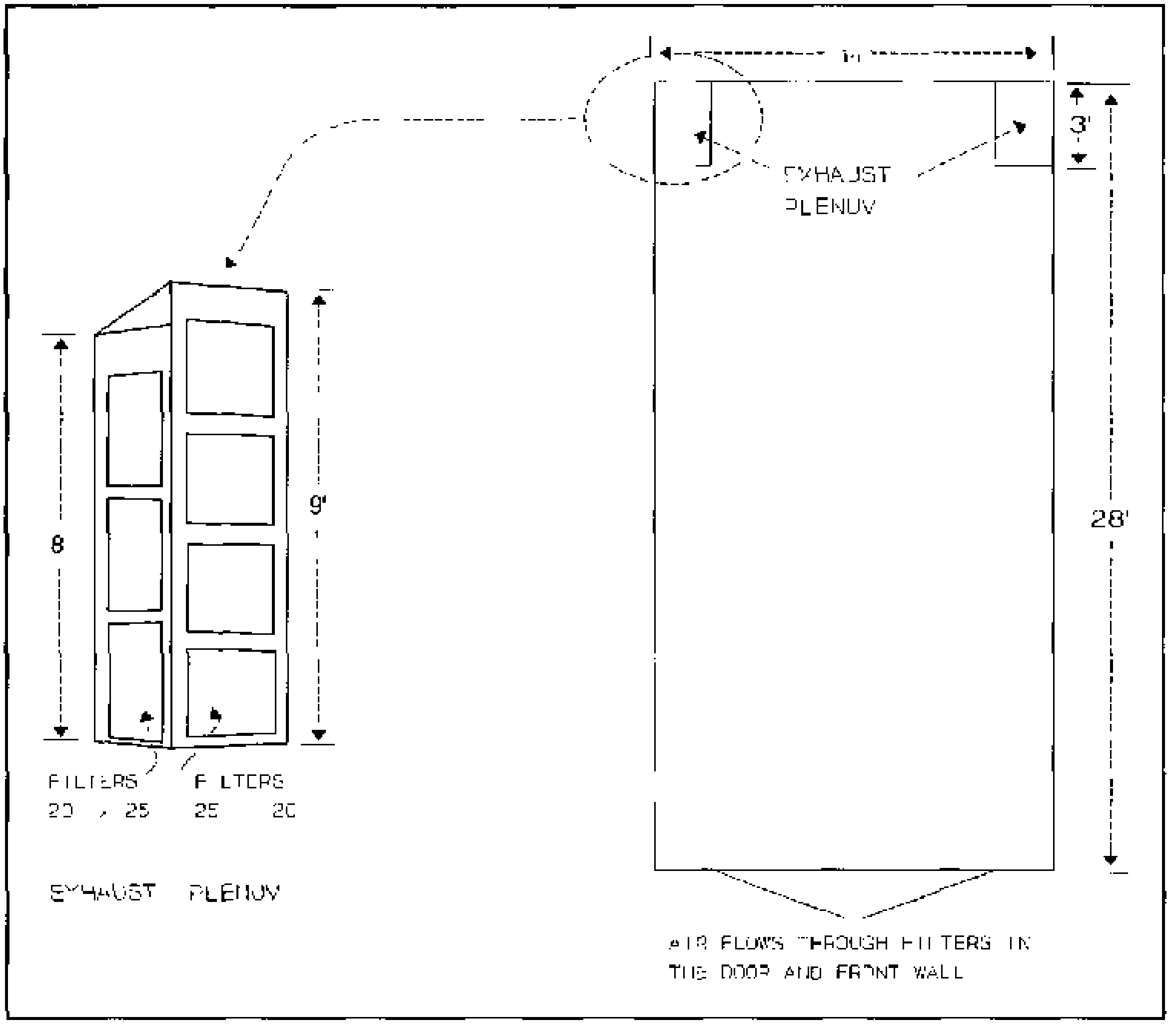


Figure 5 Plan view of Devilbiss (Type DLFA no 501) spray painting booth

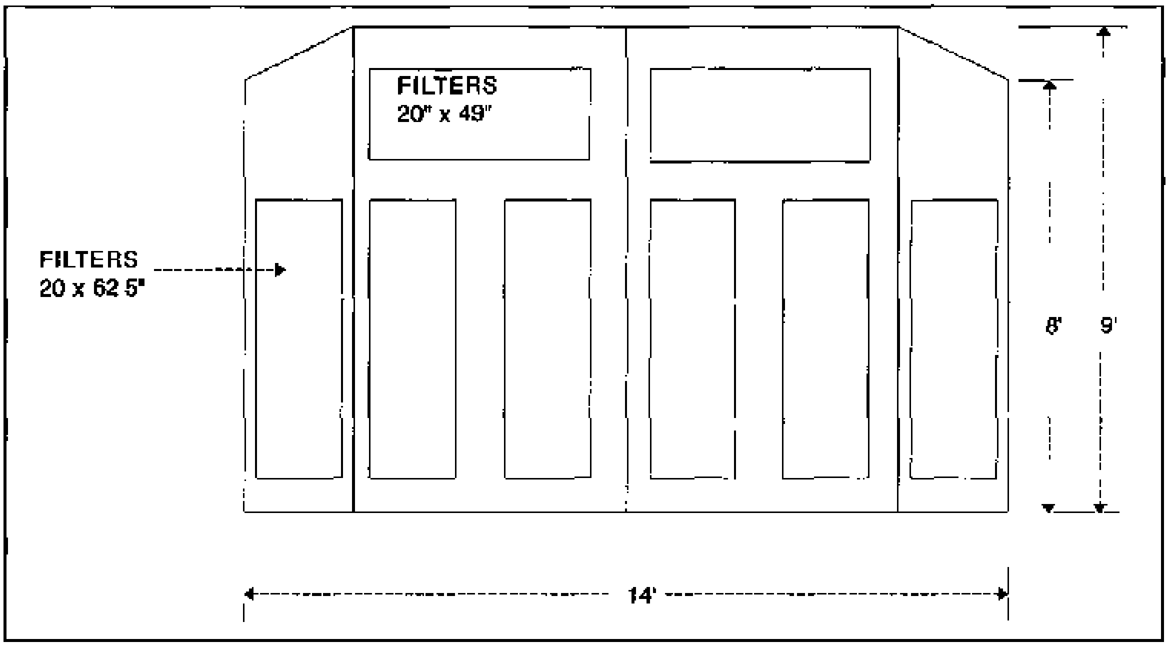


Figure 6 Front view of Devilbiss spray painting booth

diisocyanate or HDI for hexamethylene diisocyanate [3] 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 [4] 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 [5,6] Lung function is reported to decrease with number of exposures greater than 0 2 mg/m^3 to hexamethylene diisocyanate biuret [7] 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 [8,9] The only effective treatment for the sensitized worker is cessation of all diisocyanate exposure [4]

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 [10] Automotive spray painters exposed to organic solvents are reported to have decreases in motor and nerve conduction velocities [11] In addition, organic solvents such as acetone, toluene, and xylene can cause eye, nose, and throat irritation [12] 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, which are found in some paints, 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 [13] Exposures over 1000 ppm cause respiratory irritation, coughing, and headache [14]

n-Butyl Acetate and iso-Butyl Acetate

At concentrations exceeding 150 ppm, n-butyl acetate produces significant irritation of the eyes and the respiratory tract [14] Iso-butyl acetate is reported to be slightly less irritating than n-butyl acetate [14] 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 [12] Eye irritation and headaches occur at concentrations in excess of 50 ppm [14] 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 [14] In animals, it has a narcotic effect at concentrations of over 5000 ppm

Isopropyl Alcohol

At exposures above 400 ppm, irritation to the eyes, nose, and throat is reported Above 800 ppm, the symptoms are intensified [14]

Methyl Isobutyl Ketone

Methyl isobutyl ketone is an irritant of the eyes, mucous membranes, and skin Human exposures between 80 and 500 ppm are reported to cause loss of appetite, headache, eye irritation, sore throat, and nausea [15]

Trimethyl Benzene

Trimethyl benzene has been reported to cause nervousness, anxiety, and asthmatic bronchitis [14]

Toluene

Toluene can cause irritation of the eyes and respiratory tract, dermatitis, and central nervous system depression [12] 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 [14] 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 [12] At concentrations between 90 and 200 ppm, impairment of body balance, manual coordination, and reaction times can occur 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 [16]

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 [17] Acute inhalation exposure to high levels of cadmium can cause respiratory irritation and pulmonary edema In addition, cadmium exposure causes kidney damage [18] Chronic exposure may lead to emphysema of the lungs and kidney disease that 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 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 [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 [17] 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 [18] 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 [18] Lastly, elevated blood pressure has been positively related to blood lead levels [24,25]

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 [14] However, NIOSH reviewed animal testing data that 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 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 [30] 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 criteria These combined effects are often not considered in the evaluation criteria Also, some substances are absorbed by direct contact with the skin and mucous membranes and, thus, potentially increase the overall exposure Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available

A Time-Weighted Average (TWA) exposure refers to the average airborne concentration of a substance during a normal 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 specific component 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 [27] 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 [28] 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 [29] In contrast, Sweden has a five minute short-term exposure limit of 0 2 mg/m^3 for occupational exposure to hexamethylene diisocyanate biuret [31]

The United Kingdom's Health and Safety Executive (HSE) has specified a control limit for occupational exposure to diisocyanates and oligomers of these diisocyanates [30] 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 [34]

EVALUATION PROCEDURES

The objective of this site visit was to evaluate the ability of the cross draft spray painting booths to control worker exposure to air contaminants To do this, air contaminant concentration monitoring was conducted Ventilation measurements were made to document the airflow volumes in the spray painting booths

AIR CONTAMINANT CONCENTRATION MONITORING

Total dust concentrations were measured using NIOSH Method 0500 [31] 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 per cubic meter of air After weighing, selected filters were analyzed for chromium, nickel, and lead because these substances were identified on material safety data sheets The detection limits for these substances were 0 3, 0 5, and 1 μg/filter, respectively The metals on each filter were solubilized using a modification of NIOSH Method 7300 [32] 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 that may be present during spray painting The concentrations of these solvents were measured xylene, isobutyl acetate, isopropyl alcohol, acetone, n-butyl acetate, methyl isobutyl ketone, ethyl acetate, and trimethyl benzene (all isomers) In addition, the fraction of the total chromatographic peak area explained by the analytes was evaluated 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 1401 was used with some modifications The modifications are listed below [36]

Desorption Process	Thirty minutes in 1 0 milliliter of carbon disulfide with 1 microliter of hexane per mL of methylene chloride as an internal standard and 1 percent isobutanol as a desorbing aid

Table 1 Occupational Exposure Limits

Substance	NIOSH Recommended Exposure Limit (REL)[33,34]	OSHA Permissible Exposure Limit (PEL)[35]		ACGIH Threshold Limit Value (TLV)[36]	
	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
iso-Butyl Acetate	150 ppm	150 ppm		150 ppm	
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)			0.005 ppm	
Particulate (not otherwise regulated) Total Dust Respirable		 15 mg/m^3 5 mg/m^3		 10 mg/m^3 5 mg/m^3	
Trimethyl Benzene	25 ppm	25 ppm		25 ppm	
Xylene	100 ppm (150 ppm Ceiling)	100 ppm	150 ppm	100 ppm	150 ppm

[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

Gas Chromatograph	Hewlett-Packard Model 5890 equipped with a flame ionization detector
Column	30m x 0 32mm fused silica capillary coated, internally with 0 5 μm of DB-WAX
Oven Conditions	Temperature programming from 45°C (held for 15 minutes) to 150°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 [37] 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 in toluene The piperazine compound reacts with the isocyanate to form ureas 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 polyisocyanates with a Chemical Abstracts Service (CAS) numbers of either 28182-81-2 or 3779-63-3 The first CAS number refers to an isocyanurate of HDI which is Desmodur N3300 (Miles Laboratories, Pittsburgh, PA) [32] The second CAS number is also trimer of hexamethylene diisocyanate which is a manufactured by Rohne-Poulenc as Tolonate HDT 90 [38] The UV detector response obtained during the NIOSH Method 5521 analysis was used to obtain the mass of Desmodur N3300 or Tolonate HDT 90 in an air sample Standards were prepared by quantitatively diluting a bulk samples of Desmodur N3300 or Tolonate HDT 90 obtained from the paint manufacturer

The effort to evaluate the concentration of hexamethylene diisocyanate and hexamethylene diisocyanate prepolymers was unsuccessful due to an error of undetermined origin Apparently, the derivatizing agent, 1-(2-methoxyphenyl) piperazine, was not found in the impinger solution or in the blanks
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 cross draft or semi-down draft booth, in front of the exhaust 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 just before starting 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

VENTILATION MEASUREMENTS

In the spray painting booth, supply and exhaust airflow volumes were determined by measuring the face velocities and face areas The exhaust volume is the product of filter area and average air velocity at the face of the filter These air velocities were measured with a hot wire anemometer (Kurz, Model 1440-4, Carmel Valley, CA) Air velocities were also measured around a car in the spray painting booth

RESULTS

Ventilation Measurements

Air flow supply and exhaust volume measurements in the spray painting booth are summarized in Table 2 When spray painting was conducted in the Devilbiss booth before the louvers were propped open, the paint overspray appeared to accumulate in the booth and this may have slowed the painting down

Table 2 Ventilation measurements

Spray Painting Booth	Air flowing into booth (cfm*)	Air flowing out of booth (cfm)	Air velocities around a car's door post (fpm†)
Trimatic booth A	9000	8600	100 - 130
Trimatic booth B	9100	6500	100 - 130
Devilbiss booth before propping louvers open	3600	2500	10 - 30
Devilbiss booth after propping louvers open	6900	not measured	60 - 70

* cubic feet per minute

† feet per minute

Air Contaminant Concentrations

Table A2 lists the solvent concentrations, percent of peak area, and value of C_E for samples collected on charcoal tubes The value of C_E for the samples collected on the worker were all less than 1 0 indicating that the measured solvent concentrations are below the NIOSH REL or the OSHA PEL Because the percent of the chromatographic peak area explained by the analytes ranged from 30 to 90 percent, the solvent exposure is to some extent being understated

Tables 3 and 4 summarize short-term total dust and chromium concentrations measured in the spray painting booths Individual total dust and chromium concentrations are listed in Table A1 of Appendix A Lead and nickel were not detected on these samples One of fifteen total dust concentration measured on the worker exceeded 15 mg/m^3, which is the PEL for total dust for an 8-hour time-weighted average

In addition to measuring total dust concentration, detectable quantities of chromium were found on every total dust sample As shown in Table 1, exposure limits for chromium vary with its valence Information from the material safety data sheets for the primers indicated some of the chromates present were either strontium chromate (CAS No 77897-06-2) or zinc chromate The valence of the chromium in these compounds is +6 The other material safety data sheets did not list chromium containing compounds However, material safety data sheets were not available for all the paints Thus, at least some and possibly all of the chromium exposure involves hexavalent chromium which has a NIOSH REL and OSHA PEL of 1 and 100 µg/m^3, respectively

Table 3 Summary Statistics on Short-Term Total Dust Concentration

Booth	TYPE	N	Geometric Mean mg/m^3	Geometric Standard Deviation	Range mg/m^3
Trimatic	Exhaust	6	10 6	2 6	3 2 -24
	Personal	5	6 8	1 6	3 7 - 11
	Side of booth	6	10 1	2 0	3 5- 22
Devilbiss	Exhaust	5	18 0	3 1	4 6 - 62
	Personal	6	6 0	2 0	3 1- 17
	Side of booth	6	11 6	3 2	1 7- 39

Table 4 Summary Statistics on Short-Term Chromium Concentrations

Booth	Sampling location	N	Geometric mean $\mu g/m^3$	Geometric Standard Deviation	range $\mu g/m^3$
Trimatic	Exhaust	6	40 6	4 1	3 2 - 159
	Personal	6	8 9	5 6	0 9 - 59
	Side of booth	6	6 7	5 6	0 6 - 51
Devilbiss	Exhaust	5	1 8	2 7	0 4 - 4 7
	Personal	6	2 5	3 6	1 1 - 32
	Side of booth	6	2 3	8 3	0 1 - 41

The statistical analysis presented in Appendix B was done to evaluate whether total dust concentrations varied with type of spray painting booth (Trimatic or Devilbiss) and sampling location The fraction of the sampling period spent in the spray painting booth painting was used as a covariate in this analysis The spray painting booth and the sampling location did not have a significant effect upon the measured dust concentration The fraction of the sampling period spent in the booth affected the measured total dust concentration Total dust concentration measured on the worker were lower than the dust concentration measured near the exhaust filter This indicates that the worker is using the booth to isolate himself from the overspray Because there is only a factor of two difference between the dust concentration measured on the worker and the concentrations measured near the exhaust filter, the booth does not appear to provide much isolation from the overspray Observation of overspray in the booth revealed that half of the overspray flows toward the inlet filters and this overspray is dispersed in the incoming fresh air This probably explains why the dust concentration measured on the worker is half the dust concentration measured near the exhaust filters

Between the fourth and the fifth sampling session in the Devilbiss cross draft booth, the louvers for the exhaust fan were propped open This increased the ventilation rate for the booth from 3,000 cfm to 7,000 cfm At a flow rate of 3,000 cfm, the total dust concentrations measured on the worker ranged between 4 2 and 17 5 mg/m^3 At 7,000 cfm, two total dust concentrations measured on the worker were approximately 3 mg/m^3 The number of samples is too small to evaluate whether the increased flow rate caused a statistically significant reduction in total dust concentrations in the Devilbiss cross draft booth Also, before the flow rate was increased, the overspray accumulation in the booth was observed to obscure vision in this spray painting booth to a much greater extent than at other booths in this study

DISCUSSION AND RECOMMENDATIONS

Spray Painting Booth

Based upon observation of overspray in the spray painting booth, the following qualitative description of how exposure to overspray occurs in a cross draft booth can be stated In these cross draft spray painting booths, air enters through filters in the front of the booth The air flows across the car, parallel to the floor, and exits the booth through filters located in the back of the booth When the sides of the car are spray painted, a jet of air containing paint droplets impinges on the surface of the car Some of the paint coats the car, the remaining paint, called overspray, is dispersed by jets of air from the spray painting gun As illustrated in Figure 7, the spray pattern on the painted surface is elliptical, and the jet of air from the spray painting gun appears to be split into two jets at the surface being painted When the side of the car is painted, one jet flows toward the exhaust filters The other jet flows into the incoming fresh air, dispersing the overspray in this incoming air The dissipation of the energy of this second jet probably increases the turbulence of the incoming air and probably causes the overspray in this second jet to be dispersed in the incoming air flow This explains why the concentration measured on the worker is half the concentration measured at the back of the spray painting booth near the exhaust filters If the preceding reasoning is true, cross drafts booths may not be capable of separating the painter from the overspray

The data collected during this study were inadequate to determine whether the polyisocyanate and chromium concentrations in this booth are excessive The measurement of polyisocyanate concentration at this autobody shop was unsuccessful Review of the available material safety data sheets for clear coats revealed that the hardener used in this autobody shop contains an isocyanurate trimer of hexamethylene diisocyanate Base upon a knowledge of the solid content of the two components of the clear and the ratio of hardener to clear, the maximum concentration of this isocyanurate trimer should be about one third to one fourth the total dust concentration measured on the worker Thus, concentrations of the isocyanurate trimer of hexamethylene diioscyanate may be as high as 5 mg/m^3 In the absence of better information, one must assume that the concentrations of the isocyanurate trimer of hexamethylene diioscyanate (Desmodur N3300) is excessive and that respiratory protection is needed to control worker exposure to air contaminants in this shop

There is a need to evaluate the extent to which the airborne chromium in this autobody shop is hexavalent chromium This should be done by obtaining and reviewing current material safety data sheets for the chromium content of substances used in spray painting Because hexavalent chromium is considered to be an occupational carcinogen, it is NIOSH policy to recommended that exposure to such substances be minimized to the greatest extent possible Clearly, replacing products that contain hexavalent chromium with products

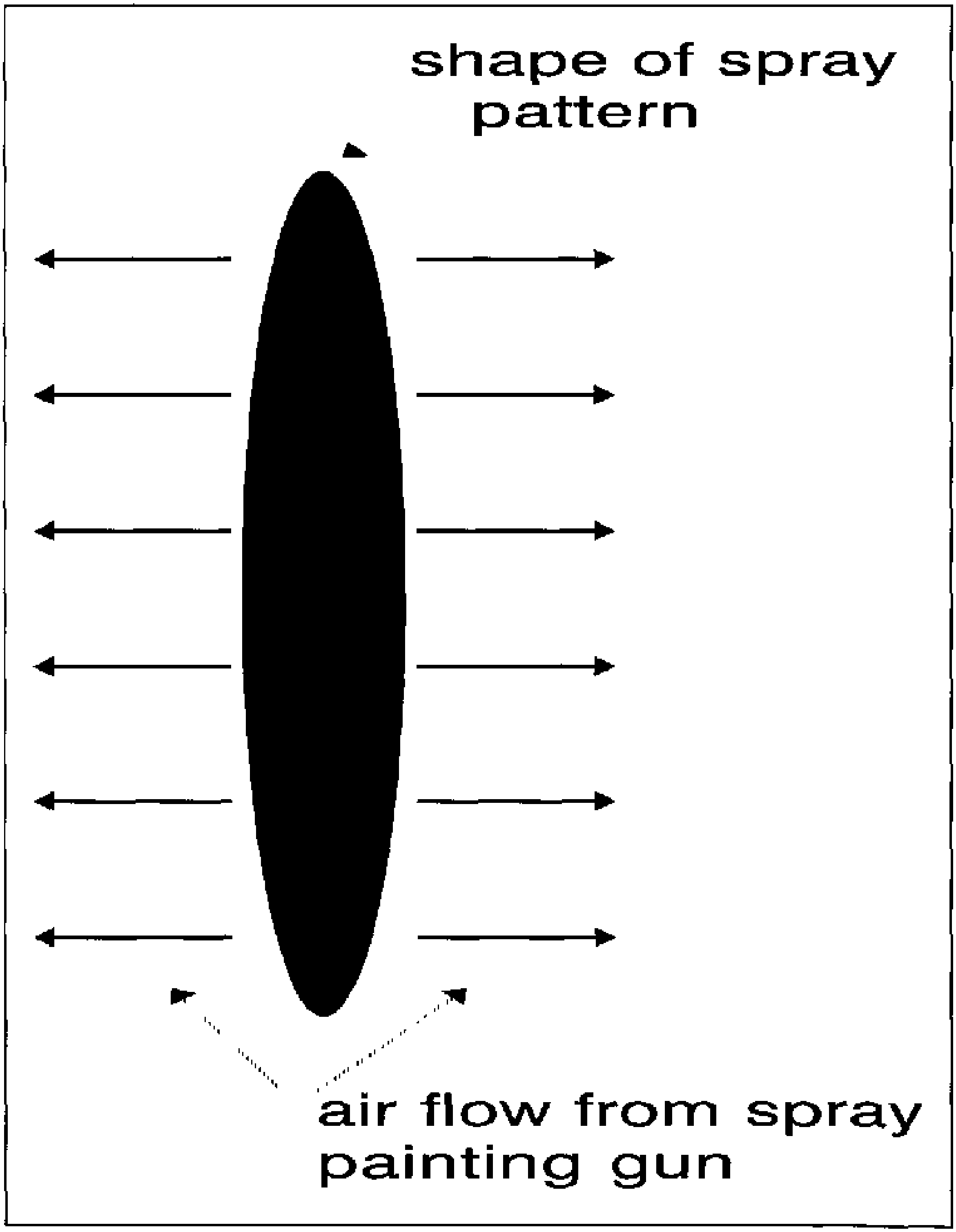


Figure 7 Schematic illustration of observed spray painting pattern and suspected air flow away from the painted surface

that do not contain hexavalent chromium would provide the greatest exposure reduction

If substitutions cannot be made, the exposure to hexavalent chromium from each product needs to be evaluated As prelude to such an effort, current material safety data sheets for surface coatings used in this autobody shop need to be obtained and reviewed for the presence of hexavalent chromium Then, air samples need to be specifically taken for hexavalent chromium while each product is being used

In order to reduce worker exposure to overspray which may contain excessive concentrations of polyisocyanates and hexavalent chromium, the air flow in the spray painting booths needs to be increased to the volumes recommended by OSHA or ACGIH [39,40] Both recommendations specify a ventilation rate of 100 feet per minute per square foot of cross-sectional area of the booth Thus, the recommended flow rate for these spray painting booths is 12,000 cfm The spray painting booths in this shop do not comply with this standard However, OSHA generally does not enforce this standard unless there is a violation of current OSHA standards for air contaminants [41] In addition to increasing the flow rate through these booths, the flow rate through these booths needs to be checked monthly in order to prevent further reductions in the exhaust air flows

Respirator Usage

Presently, half face piece air purifying respirators are used to reduce worker exposure to paint overspray in the spray painting booths Based upon the criteria presented in the NIOSH guide to industrial respiratory protection, the use of half-face piece respirators during the application of a primer which contains hexavalent chromium is inappropriate [42] It is NIOSH policy to recommend supplied-air respirators operated in a positive pressure mode such as pressure-demand mode when exposures to carcinogens occur If the hexavalent chromium exposures (strontium chromate and zinc chromate) can be eliminated through substitution, respirators are still needed because of the polyisocyanate exposures According to Mobay (Now Miles Laboratories), a half-face piece respirator equipped with a pre-filter for painting and an organic vapor cartridge would be adequate in this case if the concentration of Desmodur N3300 remains below 10 mg/m^3 for a 15 minute period or 5 mg/m^3 for an eight hour shift [43] However, MSDS's from paint manufacturers recommend supplied-air respirators for prepolymerized isocyanates

At this autobody shop, like every other autobody shop in this study, a formal respirator program was not in place The OSHA respiratory protection standard 29 CFR 1910 134 (see Appendix C) requires that

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

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

1 Written standard operating procedures for selection and use of respirators
2 Selection of respirators according to hazard
3 Training in the use and limitations of respirators
4 Respirator cleaning and disinfection
5 Proper selection for respirators
6 Routine Inspection Methods
7 Workplace exposure monitoring
8 Evaluation of program effectiveness
9 Medical monitoring
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 [44]

Presently, the autobody shop workers wear uniforms, which they change at home Because paints containing chromium VI or lead are used or sanded, work clothing should not be brought home Workers should shower and change clothes at work This work clothing needs to be cleaned at work This will prevent the workers from contaminating their homes with these substances During spray painting, Mobay recommends that workers wear eye protection and cover much of their exposed skin with clothing because cured coating cannot be easily removed from the skin [44]

CONCLUSIONS

In this autobody shop, the ability of cross draft spray painting booths to separate the worker from paint overspray is somewhat limited In autobody repair shops, much of the painting is done on the sides of the car body As a result, half of the overspray appears to be directed toward the exhaust filters in the back of the booth and the other half appears to be directed toward the incoming fresh air

Although the ability of cross draft spray painting booths to reduce worker exposure to overspray may be limited, overspray exposure can be reduced by using the ventilation rate specified by the OSHA standard for spray painting Furthermore, periodic monitoring of exhaust flow volumes is needed as part of spray painting booth maintenance Such monitoring is needed to insure that the air flow rate through the booth is adequate Thus, the air flow exhaust and supply volumes need to be checked monthly

This autobody shop needs to establish a formal, respirator program There is a need to read, understand, and implement the OSHA respirator standard that is attached in Appendix C

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Appendix A
Sampling Results

TABLE A1 LISTING OF TOTAL DUST AND CHROMIUM CONCENTRATIONS

JOB	DATE	LOCATION	COMMENT	SAMPLING TIME (min)	ACTUAL START TIME	ACTUAL STOP TIME	ACTUAL TIME PAINTING (min)	TOTAL DUST CONCENTRATION (mg/m^3)	CHROMIUM (all valences) CONCENTRATION ($\mu g/m^3$)
A1	12/8	EXHAUST		111	3 09	5 30	50	24 34	127 45
A1	12/8	PERS		111	3 38	5 29	50	4 34	13 93
A1	12/8	SIDE		111	3 10	5 31	50	11 51	46 37
A2	12/9	EXHAUST		107	9 41	11 33	15	8 49	21 93
A2	12/9	PERS	COMBINED AND TREATED AS ONE SAMPLE DURING ANALYSIS	39	10 51	11 31	8	4 52	1 20
A2	12/9	PERS		107	9 43	10 51	7	3 53	8 29
A2	12/9	SIDE		112	9 40	11 33	15	15 03	51 31
AB	12/9	AREA	NEAR BOOTH A	1017	10 25	sampling time from pump timer	--	0 19	0 40
AB	12/10	AREA		504	8 15	18 30	--	0 29	0 45
B1	12/8	EXHAUST		29	9 44	10 17	4 5	3 44	3 68
B1	12/8	PERS		29	9 48	10 17	4 5		0 92
B1	12/8	SIDE		29	9 44	10 17	4 5	6 27	2 99

JOB	DATE	LOCATION	COMMENT	SAMPLING TIME (min)	ACTUAL START TIME	ACTUAL STOP TIME	ACTUAL TIME PAINTING (min)	TOTAL DUST CONCENTRATION (mg/m^3)	CHROMIUM (all valences) CONCENTRATION ($\mu g/m^3$)
B2	12/8	EXHAUST		60	2 54	4 02	27	24 76	62 44
B2	12/8	PERS		60	2 59	3 59	27	7 5	21 11
B2	12/8	SIDE		60	2 55	4 02	27	3 46	3 44
B3	12/9	EXHAUST		90	10 20	11 50	23	3 20	59 41
B3	12/9	PERS		90	10 20	11 50	23	10 48	59 41
B3	12/9	SIDE		46	11 04	11 50	23	22 04	0 58
B4	12/10	EXHAUST		90	2 50	4 48	30	21 20	99 41
B4	12/10	PERS		90	3 18	4 48	30	11 29	26 07
B4	12/10	SIDE		90	2 50	4 48	30	13 18	13 85
C1	12/8	EXHAUST		59	8 29	9 31	10 5	62 50	3 84
C1	12/8	PERS		59	8 30	9 29	10 5	17 55	1 13
C1	12/8	SIDE		59	8 29	9 31	10 5	39 83	2 15
C2	12/8	EXHAUST		60	3 06	4 08	12	20 13	0 44
C2	12/8	PERS		60	3 06	4 08	12	4 26	1 44
C2	12/8	SIDE		60	3 06	4 08	12	31 16	0 11
C3	12/9	EXHAUST		135	1 45	4 00	42		
C3	12/9	PERS		135	1 45	4 00	42	9 61	32 20
C3	12/9	SIDE		135	1 45	4 04	42	8 11	41 09

JOB	DATE	LOCATION	COMMENT	SAMPLING TIME (min)	ACTUAL START TIME	ACTUAL STOP TIME	ACTUAL TIME PAINTING (min)	TOTAL DUST CONCENTRATION (mg/m^3)	CHROMIUM (all valences) CONCENTRATION ($\mu g/m^3$)
C4	12/10	EXHAUST		25	8 40	9 31	9	48 50	1 87
C4	12/10	PERS		25	9 04	9 29	9	6 50	1 07
C4	12/10	SIDE		25	8 40	9 31	9	6 98	1 87
C5	12/10	EXHAUST		141	1 53	4 19	15	4 61	2 60
C5	12/10	PERS		141	1 56	4 18	15	3 12	2 17
C5	12/10	SIDE		141	1 53	4 19	15	1 73	1 18
C6	12/11	EXHAUST		80	8 18	9 41	11	6 83	4 83
C6	12/11	PERS		80	8 21	9 41	11	3 20	1 83
C6	12/11	SIDE		80	8 18	9 41	11	20 48	15 08

Table A2 Continued

TABLE A2 SOLVENT CONCENTRATIONS (PPM)

JOB	DATE	LOCA - TION	START	STOP	% OF PEAK AREA	TOLUENE (ppm)	XYLENE (ppm)	ISOBUTYL ACETATE (ppm)	ACETONE (ppm)	ISO-PROPYL ALCOHOL (ppm)	N-BUTYL ACETATE (ppm)	METHYL ISOBUTYL KETONE (ppm)	TRI-METHYL BENZENE (ppm)	ETHYL ACETATE (ppm)	C_E
A1	12/8	E	3 09	5 30	63	18 17	3 07	1 13	12 59	3 08	NR	NR	NR	NR	0 28
A1	12/8	P	3 38	5 29	80	7 46	1 41	0 54	15 17	2 35	NR	NR	NR	NR	0 16
A1	12/8	S	3 10	5 31	42	3 92	1 58	0 64	6 67	1 47	NR	NR	NR	NR	0 09
A2	12/9	E	9 41	11 33	63	4 23	0 58	0 52	6 24	0 45	NR	NR	NR	NR	0 08
A2	12/9	P	9 43	11 31	71	5 21	0 94	0 78	10 13	1.49	NR	NR	NR	NR	0 11
A2	12/9	S	9 40	11 33	60	2 95	0 73	0 72	8 42	0 62	NR	NR	NR	NR	0 08
B1	12/8	E	9 44	10 17	31	1 28	< 0 3	< 0 3	1 74	< 0 6	NR	NR	NR	NR	0 02
B1	12/8	P	9 48	10 17	80	6 95	0 64	0 58	13 35	2 81	NR	NR	NR	NR	0 14
B1	12/8	S	9 44	10 17	15	15 74	< 0 3	0 58	2 03	< 0 6	NR	NR	NR	NR	0 17
B2	12/8	E	2 54	4 02	27	5 31	3 38	0 60	5 33	1 98	NR	NR	NR	NR	0 12
B2	12/8	P	2 59	3 59	67	11 85	1.40	0 63	9 26	3 26	NR	NR	NR	NR	0 18
B2	12/8	S	2 55	4 02	32	0 53	0 15	< 0 1	0 56	< 0 3	NR	NR	NR	NR	0 01
B3	12/9	E	10 20	11 50	40	8 85	8 60	1 58	7 11	4 52	NR	NR	NR	NR	0 22

Abbreviations S - Side of booth , P - Personal, PR - paint room , E - Exhaust, NR - not requested for analysis

Table A2 Continued

JOB	DATE	LOCA - TION	START	STOP	% OF PEAK AREA	TOLUENE (ppm)	XYLENE (ppm)	ISOBUTYL ACETATE (ppm)	ACETONE (ppm)	ISO-PROPYL ALCOHOL (ppm)	N-BUTYL ACETATE (ppm)	METHYL ISOBUTYL KETONE (ppm)	TRI-METHYL BENZENE (ppm)	ETHYL ACETATE (ppm)	C_i
B3	12/9	P	10 20	11 50	52	4 95	2 15	0 79	5 24	2 71	NR	NR	NR	NR	0 10
B3	12/9	S	11 04	11 50	44	3 00	1 48	< 0 2	1 68	< 0 4	NR	NR	NR	NR	0 05
B4	12/10	E	2 50	4 48	38	8 85	4 81	1 58	5 61	5 06	NR	NR	NR	NR	0 18
B4	12/10	P	3.18	4 48	65	10 85	2 56	1 03	11 60	4 88	NR	NR	NR	NR	0 20
B4	12/10	S	2 50	4 48	39	2 24	1 54	0 28	2 62	0 89	NR	NR	NR	NR	0 05
C1	12/8	E	8 29	9 31	38	5 76	NR	NR	NR	NR	18 48	NR	NR	NR	0 18
C1	12/8	P	8 30	9 29	37	3 06	NR	NR	NR	NR	6 11	NR	NR	NR	0 07
C1	12/8	S	8 29	9 31	54	< 0 2	NR	NR	NR	NR	< 0 1	NR	NR	NR	0 00
C2	12/8	E	3 06	4 08	65	13 27	8 14	NR	NR	NR	7 41	0 33	0 52	NR	0 29
C2	12/8	P	3 06	4 08	71	12 38	2 76	NR	NR	NR	1 82	0 57	0 14	NR	0 18
C3	12/9	E	1 45	4 00	65	7 31	1 16	NR	NR	NR	8 70	0 14	0 29	NR	0 16
C3	12/9	P	1,45	4 00	63	11 79	65 51	NR	NR	NR	4 78	0 54	0 18	NR	0 82
C3	12/9	S	1 45	4 04	63	1 34	1 43	NR	NR	NR	1 06	< 0 1	< 0 1	NR	0 03
C4	12/10	E	8 40	9 31	72	21 23	16 58	NR	NR	NR	4 36	4 69	0 98	NR	0 54

Abbreviations S - Side of booth , P - Personal, PR - paint room , E - Exhaust, NR - not requested for analysis

Table A2 Continued

JOB	DATE	LOCA - TION	START	STOP	% OF PEAK AREA	TOLUENE (ppm)	XYLENE (ppm)	ISOBUTYL ACETATE (ppm)	ACETONE (ppm)	ISO-PROPYL ALCOHOL (ppm)	N-BUTYL ACETATE (ppm)	METHYL ISOBUTYL KETONE (ppm)	TRI-METHYL BENZENE (ppm)	ETHYL ACETATE (ppm)	C_E
C4	12/10	P	9 04	9 29	71	11 89	5 16	NR	NR	NR	1 64	< 0 4	< 0 3	NR	0 18
C4	12/10	S	8 40	9 31	70	11 89	4 05	NR	NR	NR	1 21	1 33	< 0 3	NR	0 19
C5	12/10	E	1 53	4 19	67	4 89	3 14	NR	NR	NR	2 68	0 14	0 12	0 79	0 11
C5	12/10	P	1 56	4 18	70	6 10	2 35	NR	NR	NR	1 25	0 30	0 12	0 71	0 11
C5	12/10	S	1 53	4 19	65	2 94	1 63	NR	NR	NR	1 13	0 14	0 12	0 39	0 06
C6	12/11	E	8 18	9 41	68	7 30	4 61	NR	NR	NR	2 52	0 92	0 20	NR	0 16
C6	12/11	P	8 21	9 41	61	7 70	2 07	NR	NR	NR	1 26	0 61	< 0 1	NR	0 12
C6	12/11	S	8 18	9 41	72	< 0 1	< 0 1	< 0 1	< 0 2	< 0 2	< 0 1	< 0 1	< 0 1	< 0 1	0 00
	12/10	PR			89	12 53	1 04	0 94	26 22	5 60	1 51	0 61	< 0 1	0 55	0 28
	12/10	PR			90	33 62	3 38	2 66	12 07	11 66	2 94	1 95	< 0 1	1 41	0 52
	12/10	PR			88	17 16	2 30	1 82	23 57	5 15	2 80	1 14	< 0 1	1 31	0 36

Abbreviations S - Side of booth , P - Personal, PR - paint room , E - Exhaust, NR - not requested for analysis

Appendix B

Statistical Analysis

Figures B1 and B2 presents the results of an analysis of variance used to test whether the independent variables sampling location, spray painting booth, and faction of time spent painting) affected the concentration measurement This analysis was conducted using the SAS General Linear Models procedure [45] In using this procedure, the natural logarithm of the total particulate concentration was modelled as a function of the dependent variables as follows

$$LTP2 = \beta_0 + \beta_1(Lfrac) + \beta_2 B + \beta_3 L_1 + \beta_4 L_2 + \beta_5 BL_1 + \beta_6 L_2 + \epsilon_i$$

Where

LTP2 = the natural logarithm of concentration,

B = 1 if new booths (TriMatic) were used, otherwise 0,

L_1 = 1 if the sample was taken on the near the exhaust filters, otherwise 0,

L_2 = 1 if the sample taken on the worker, otherwise 0,

β_{0-6} = regression coefficients, the numerical values of these coefficients are listed under item 2 in Figure B1

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

ϵ_i = the residual This is the difference between the observed concentration and concentration computed using the statistical model The residual has a mean value of 0 and it is assumed to be normally distributed The mean square error from the analysis is its estimated variance

The column labelled "Pr > F" (item 1 in Figure B1 is the probability that chance could have caused the observed differences in LTP2 A probability below 0 05 indicates that it is unlikely that chance caused the observed differences in concentration and thus one reasons that the variable really affected concentration Thus, the analysis of variance shows that only LFRAC affected concentration The other variables, booth and the interaction between the booth and the sampling location, were not significant This simply indicates that the affect due to these variables is small in comparison to the experimental variability

The regression coefficient for the variable LFRAC was 0 7±0 6 This indicates that concentration is roughly proportional to the fraction of time that the worker is spray painting Because the fraction of time spent painting varied from task to task, examining the concentration differences among observed geometric medians may be misleading An observed difference in geometric means may be due to a difference in the fraction of the time that was spray painting rather than the variable

In order to examine differences caused by sampling location, the least squares means option of the SAS General Linear Models procedure was specified to evaluate the concentration difference attributed to the sampling locations This option uses the statistical model listed above to estimate the means which would be expected if the experimental design had been completely balanced and all the other variables in the statistical model (such as the fraction of time painting) are at their mean value This computation is necessary because the fraction of time spent painting varied with each job These results are presented as Item 2 in Figure B1 For the variable sampling location, the concentrations measured on the worker were less than the concentrations measured near the exhaust filters

REFERENCE

45 SAS Institute (1988) SAS/STAT Users Guide, Release 6 03 Cary, NC

General Linear Models Procedure

Dependent Variable LTP2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	7 72899262	1 28816544	1.86	0 1240
Error	27	18.65754579	0.69102021		
Corrected Total	33	26.38653841			

R-Square	C.V.	Root MSE	LTP2 Mean
0 292914	36.46068	0 831276	2 27992505

ITEM 1

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LFRAC	1	3.58472825	3 58472825	5 19	0.0309
BOOTH	1	1.65217698	1.65217698	2 39	0.1337
LOCATION	2	3 79409074	1 89704537	2 75	0.0822
LOCATION*BOOTH	2	0 64876260	0 32438130	0 47	0 6304

Parameter		Estimate	T for H0 Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		3.626698176 B	5 89	0.0001	0 61611655
LFRAC		0 720761308	2 28	0 0309	0.31645264
BOOTH	new	-0 441661955 B	-0.89	0 3831	0.49813686
	old	0.000000000 B			
LOCATION	EXHAUST	0 505943113 B	1.00	0 3245	0.50419312
	PERS	-0 662508484 B	-1.38	0 1788	0 47993757
	SIDE	0.000000000 B		.	
LOCATION*BOOTH					
	new EXHAUST	-0.410144378 B	-0 59	0.5603	0.69552490
	new PERS	0 274915848 B	0 40	0 6957	0 69549582
	new SIDE	0 000000000 B			
	old EXHAUST	0.000000000 B	.	.	
	old PERS	0 000000000 B		.	.
	old SIDE	0 000000000 B		.	.

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

ITEM 2

Least Squares Means

LOCATION	LTP2 LSMEAN	i/j	1	2	3
EXHAUST	2 66339909	1		2 311219	0 861532
				0 0287	0.3965
PERS	1.83747761	2	-2.31122		-1.50986
			0 0287		0 1427
SIDE	2 36252817	3	-0.86153	1.50986	.
			0 3965	0 1427	

(T for H0: LSMEAN(i)=LSMEAN(j) / Pr > |T|)

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

Authors annotation, the sampling locations "EXHAUST", "PERS", and "SIDE" refer to, respectively, samples collected near the exhaust filters, on the worker and next to the side of the booth. The "new" booths are the Trimatic booths and the "old" booth is the Devilbiss booth.

Figure B1 Selected output from the statistical analysis of total dust concentrations in the spray painting booths

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 face-piece-to-face seal, wear it in normal air for a long familiarity period, and, finally, to wear it in a test atmosphere

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

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

1910 134(e)(5)(iii)

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

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

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

(ii) Cleaning and disinfecting,

(iii) Repair,

(iv) Storage

Equipment shall be properly maintained to retain its original effectiveness

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

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

1910 134(f)(2)(iii)

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

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

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

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

1910 134(f)(5)

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

marked Routinely used respirators, such as dust respirators, may be placed in plastic bags Respirators should not be stored in such places as lockers or tool boxes unless they are in carrying cases or cartons

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

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

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

1910 134(g)(2)

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

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

(i) - Canister

for ______________________________

(Name for atmospheric contaminant)

or

Type N Gas Mask Canister

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

Name of atmospheric contaminant)

1910 134(g)(4)

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

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

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

TABLE I-1

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

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

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

(Approved by the Office of Management and Budget under control number 1218-0099) [39 FR 23502, June 27, 1974, as amended at 43 FR 49748, Oct 24, 1978, 49FR 5322, Feb 10, 1984, 49 FR 18295, Apr 30, 1984]2222