IN-DEPTH SURVEY REPORT

CONTROL TECHNOLOGY FOR AUTOBODY REPAIR AND PAINTING SHOPS

AT

Jeff Wyler Autobody Shop
Batavia, Ohio

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Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
Division of Physical Sciences and Engineering
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PLANT SURVEYED	Jeff Wyler Chevrolet Isuzu Autobody Shop State Route 32 Batavia, Ohio 45103
SIC CODE	7532
SURVEY DATE	June 16-19 and July 21, 1992
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DISCLAIMER

SUMMARY

At this autobody shop, NIOSH researchers evaluated two semi-downdraft spray painting booths, dust concentrations during sanding, and respirator usage Air sampling was conducted during spray painting operations and sanding

In a semi-downdraft spray painting booth, air enters the booth through the ceiling near one end and is exhausted from the booth at the opposite end where it is discharged through a duct to the outside of the building Both of these booths operated near their designed flow rate of 9500 cfm resulting in air velocities from 65 to 90 fpm near the vehicle However, even at these velocities, the painters were still being exposed to some overspray Several isocyanate samples in both booths were at or exceeded the Oregon, Sweden, and United Kingdom standards for the isocyanate of HDI (OSHA, NIOSH, and ACGIH have not yet developed exposure limit values for prepolymerized diisocyanates) Three (38 percent) of the samples were at or exceeded Oregon's permissible ceiling exposure limit for polyisocyanates of 1 mg/m^3 The combined personal solvent exposures were within the acceptable range

Nonventilated sanders are used during sanding operations Two (40 percent) of the total dust concentrations measured on the worker's lapel exceeded 15 mg/m^3 Ventilated sanders connected to a central vacuum system could reduce these dust exposures

Because these booths do not completely control the worker's exposure to paint overspray, respiratory protection is needed Quantitative fit tests, conducted on the half-face piece, air purifying respirators used in this autobody shop, revealed that three of the four respirators provided a fit factor of less than 100, two of these being less than 10 These poor fits appear to be due to the lack of good respirator maintenance Also, there is no respirator program, as required by OSHA's respiratory protection standard (29CFR1910 134), at this body shop

INTRODUCTION

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

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

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

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

As part of this overall study, techniques for controlling air contaminants generated during painting operations are being studied At this particular body shop, two unventilated sanders, two spray painting booths with semi-downdraft ventilation systems, and respirator usage were evaluated

SHOP DESCRIPTION

There are 19 workers in this autobody shop, 7 body repair technicians, 7 painters, and 5 office workers The shop was opened in 1984, and repairs and paints 30 to 40 vehicles per week The layout of the shop is illustrated in Figure 1 In the repair area of the building, sanders, grinders, and welders (all nonventilated) are used to repair the vehicle's structural damage Sanding may involve the removal of old paint or excess body filler to provide a smooth surface for the paint After the vehicles are repaired, they are moved to a paint preparation area and readied for painting Some sanding with nonventilated sanders can also take place in this area of the shop After the vehicle's surface has been prepared and masked as needed, it is painted in one of two semi-downdraft spray painting booths

In each booth, there are two 24" fans, each rated at 9150 CFM One fan is on the air supply side and the second fan on the exhaust side of the booth Air from the supply fan is filtered at the intake, passes through duct work into the air distribution plenum on the roof of the booth, and through a second set of filters in the ceiling of the booth (See Figure 2) The air flows down from the ceiling, horizontally pass the vehicle toward the far end of the booth The second fan draws the contaminated air through a third set of filters into the exhaust plenum, and discharges the air through a 24" duct to the roof On the roof, the duct makes a 90° turn and discharges the air parallel to the roof Both semi-downdraft paint booths provide a nominal 10,000 cfm during spray painting One booth has a drive-through configuration (Figure 3), the other has a drive-in, back out configuration (Figure 4)

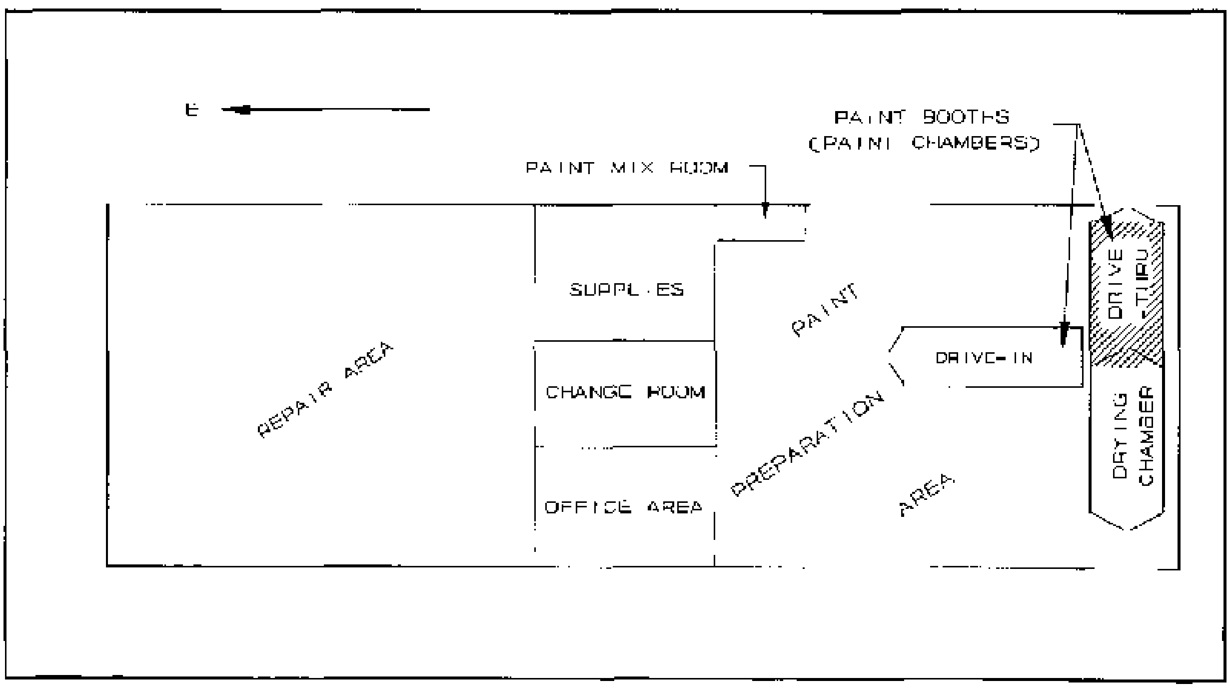

Figure 1 Sketch of the autobody shop and location of the paint booths

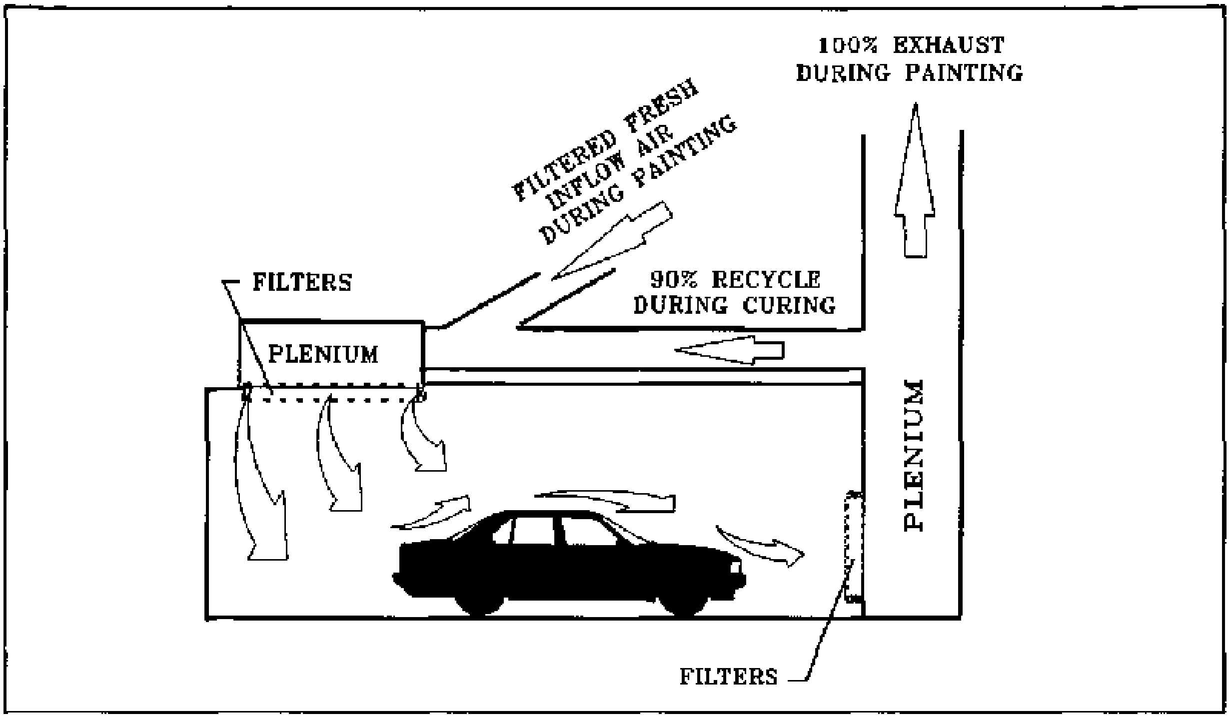

Figure 2 Semi-down draft booth and the general airflow pattern over and around a vehicle

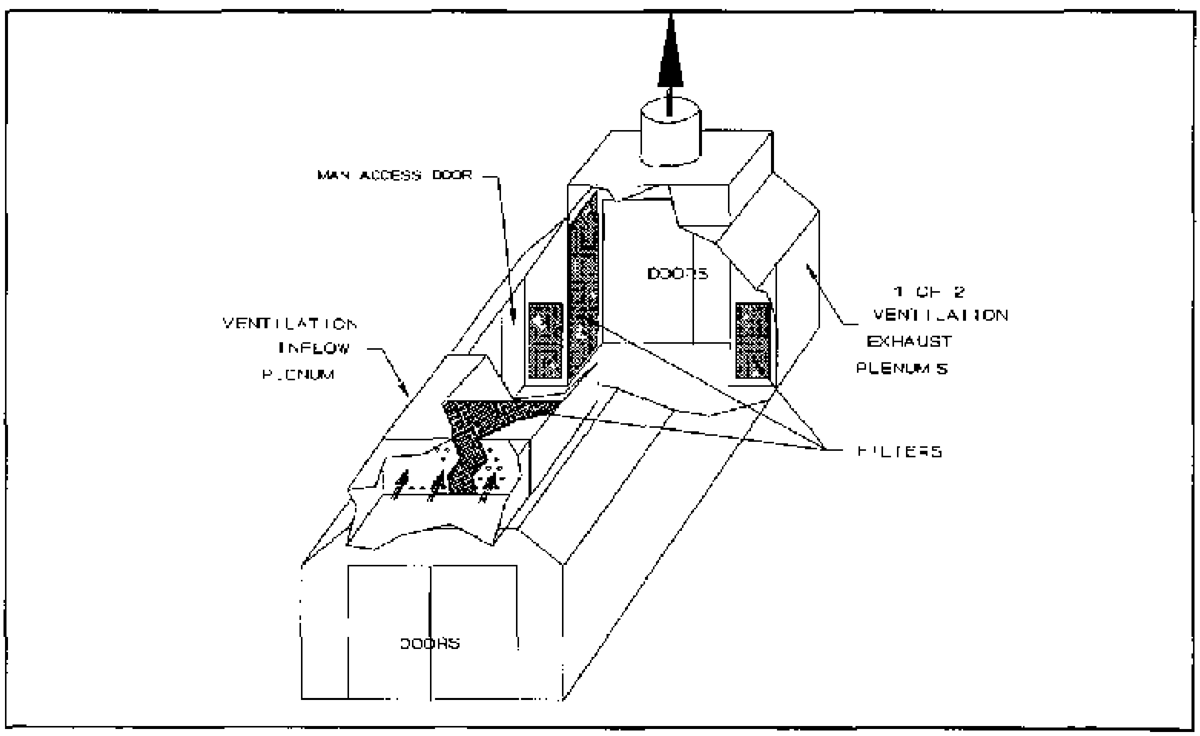

Figure 3 Drive-thru paint booth

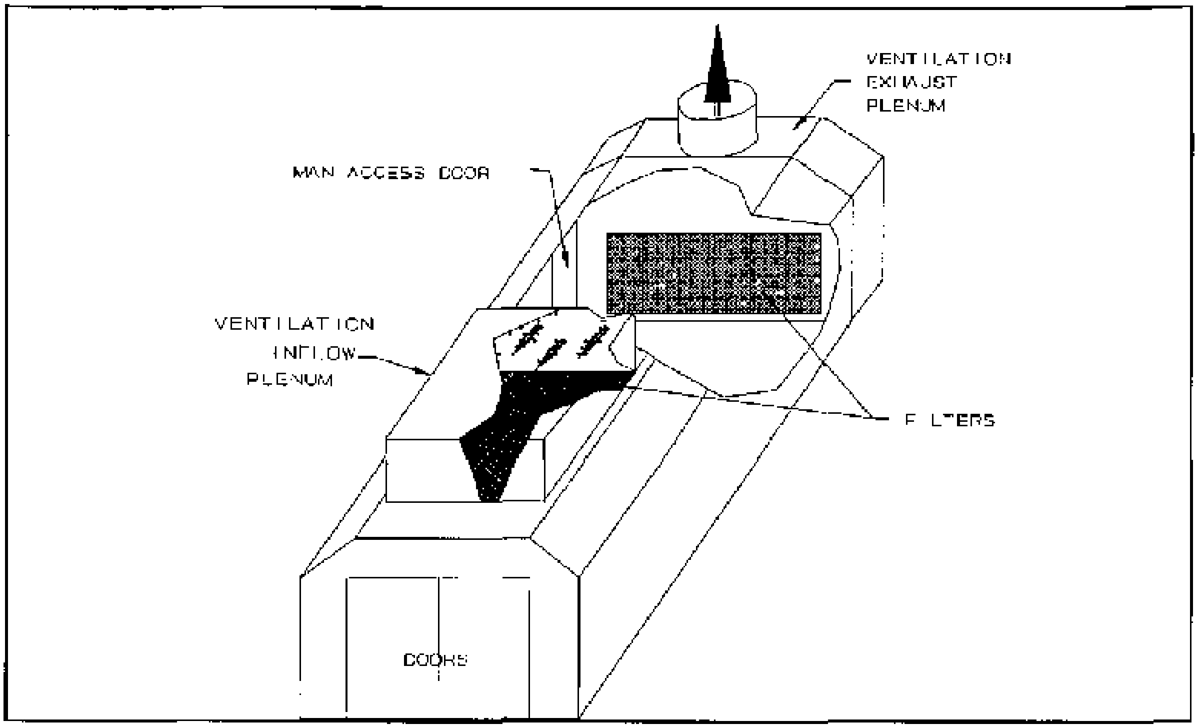

Figure 4 Drive-in paint booth

The drive-thru booth was installed (Figure 3) in 1985 The painting chamber is a DeVilbiss booth (Model SD-D-P-9426-24-08) with an attached drying chamber (Model DOC-9426) and a conversion package (Model KK9462) to change the semi-downdraft to a pressurized (air supplied to the booth's inflow plenum) semi-downdraft in the painting chamber This chamber is 14 feet wide, 26 feet long, and 9 feet high (inside measurements) The vehicle and/or parts are positioned in the painting chamber, the doors closed and the ventilation system turned on After the painter fills his spray gun, he enters the painting chamber and connects the gun to an air line After the vehicle or body part(s) have been painted, the worker either leaves them in the painting chamber to be cured or moves them into the adjacent drying chamber If left in the painting chamber, the painter switches the booth to the curing cycle to cure the paint at temperatures of 120 to 140°F During the curing cycle in the painting chamber, air flow is reduced with about 90 percent of the exhaust air being recycled

In 1988, the drive-in booth was installed (Figure 4) This DeVilbiss booth (Model SD-S-P-9426-24-08) has an attached conversion package (Model KK9462) to change the semi-downdraft to a pressurized semi-downdraft The booth is 14 feet wide, 24 feet long, and 9 feet high (inside measurements) The drive-in paint booth has only one chamber for both painting and curing The vehicle and/or parts are positioned in the booth, the doors closed, and the ventilation system turned on After the painter fills his spray gun, he enters the booth and connects the gun to an air line After the vehicle or body part(s) have been painted, the worker leaves the booth and switches the booth to the curing cycle to cure the paint at temperatures of 120 to 140 °F During the curing cycle, air flow in the booth is reduced with about 90 percent of the exhaust air being recycled as shown in Figure 2

According to the shop manager, the air supply filters are changed every month and the exhaust filters are changed weekly. There is a static pressure gauge (not in use) on the drive-in booth but not on the drive-thru booth The drive-thru booth operated at +0 01 inches of water relative to the shop and the drive-in booth operated at -0 03 inches of water

To apply the primer, paint, and clear coat, a DeVilbiss (Model JGA 502) siphon cup spray gun is used Some painters preferred using a Binks (Model 7) siphon cup spray gun when applying clear coat In a siphon cup gun, the acceleration of the air flow through an orifice causes a reduction in static pressure The reduced static pressure causes the paint to flow from the cup into the orifice where the paint is atomized Air pressure at the atomization orifice is typically 65 pounds per square inch (psi)

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

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

POTENTIAL HAZARDS

The International Agency for Research on Cancer (IARC) has reviewed the health effects associated with painting operations [1] In the IARC publication, the term "painters" included workers who apply paint to surfaces during construction, furniture manufacturing, automobile manufacturing, metal products manufacturing, and autobody refinishing After reviewing a wide range of publications, they concluded "There is sufficient evidence for the carcinogenicity of occupational exposure as a painter " In addition, they noted that painters suffer from allergic and nonallergic contact dermatitis, chronic bronchitis, asthma, and adverse central nervous system effects

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

EXPOSURE EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff use exposure limits as evaluation criteria for assessment of a number of chemical and physical agents These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week, for a working lifetime without experiencing adverse health effects Table 1 summarizes exposure limits for air contaminants which may be present in this autobody shop It is important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels A small percentage may experience adverse health effects because of individual susceptibility, a preexisting medical condition, and/or a hypersensitivity (allergy)

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

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,

Table 1 Occupational Exposure Limits

Substance	NIOSH Recommended Exposure Limit (REL)[2]	OSHA Permissible Exposure Limit (PEL)[3]		ACGIH Threshold Limit Value (TLV)[4]	
	TWA[a]	TWA[b]	STEL[c]	TWA[b]	STEL[c]
Acetone	250 ppm	750 ppm	1000 ppm	750 ppm	1000 ppm
Antimony	0 5 mg/m^3	0 5 mg/m^3		0 5 mg/m^3	
n-Butyl Acetate	150 ppm	150 ppm	200 ppm	150 ppm	200 ppm
Chromium (VI), hexavalent	0 001 mg/m^3	0 1 mg/m^3		0 05 mg/m^3	
Chromium (II) compounds	0 5 mg/m^3	0 5 mg/m^3		0 5 mg/m^3	
Chromium (III)	0 5 mg/m^3	0 5 mg/m^3		0 5 mg/m^3	
Hexyl Acetate	50 ppm	50 ppm		50 ppm	
Hexamethylene diisocyanate (HDI monomer)	0 035 mg/m^3 0 14 mg/m^3 (Ceiling)			5 ppb	
Isopropyl Alcohol	400 ppm (800 ppm Ceiling)	400 ppm	500 ppm	400 ppm	500 ppm
Lead	< 0 100 mg/m^3, Pb concentration to be maintained so that Pb concentration in workers blood remains ≤ 0 060 mg/100 g of whole blood	0 050 mg/m^3		0 15 mg/m^3	
Soluble Nickel Compounds (of Ni metal)	0 015 mg/m^3	0 1 mg/m^3		0 1 mg/m^3	
Total Dust (not otherwise regulated) Total Respirable	 10 mg/m^3 5 mg/m^3	 15 mg/m^3 5 mg/m^3		 10 mg/m^3 5 mg/m^3	
Toluene	100 ppm 150 ppm (Short Term Exposure Limit)	100 ppm	150 ppm	50 ppm	
Xylene	100 ppm 150 ppm (Short Term Exposure Limit)	100 ppm	150 ppm	100 ppm	150 ppm

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

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_g, is computed

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

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

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

OTHER ENVIRONMENTAL EVALUATION CRITERIA

Although health effects are attributed to prepolymerized diisocyanates, OSHA, NIOSH, and ACGIH have not yet developed exposure limit values for these substances [5] 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 [6] 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 [7] In contrast, Sweden has a 5 minute short-term exposure limit of 0 2 mg/m^3 for occupational exposure to hexamethylene diisocyanate biuret [3]

The United Kingdom's Health and Safety Executive (HSE) has specified a control limit for occupational exposure to diisocyanates and oligomers of these diisocyanates [8] 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 [9]

EVALUATION PROCEDURES

The objective of this site visit was to evaluate the effectiveness of two semi-downdraft spray painting booths for controlling worker exposure to air contaminants This was accomplished by measuring air contaminant concentrations and by conducting video exposure monitoring In addition, ventilation measurements were made to document the air flow volumes in these booths Also, total dust concentrations were measured during several sanding operations

AIR CONTAMINANT CONCENTRATION MEASUREMENTS

NIOSH Method 0500 was used to measure the total dust concentration [10] 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 dust per cubic meter of air After weighing, the filters were analyzed for lead, antimony, chromium, and nickel The metals on each filter were analyzed using a modification of NIOSH Method 7300 [11] Modifications to NIOSH Methods 0500 and 7300 are presented in Appendices B1 and B2

Material safety data sheets were reviewed to identify organic solvents which may be present during spray painting Measurements were made for the following solvents, acetone, hexyl acetate, butyl acetate, isopropyl alcohol, toluene, and xylene The samples were collected by placing charcoal tubes (SKC lot 120) in a charcoal tube holder and mounting the charcoal tube holder on the worker Tubing connected the charcoal tube holder to a personal sampler pump (Model 200, Dupont Inc) operating at 200 cm^3/min NIOSH Method 1400 was used to determine the mass of organic solvents absorbed onto the charcoal [12] Modifications to this method are presented in Appendix B3

During spray painting operations involving the use of isocyanate hardeners, the concentration of hexamethylene diisocyanate and its trimer were monitored by using NIOSH method 5521 [13] Although this method specifies a flow rate of 1 liters per minute, air samples were collected at a sampling rate of 2 liters per minute in order to increase the sample volume The impinger contains a solution of 1-(2-methoxyphenyl)piperazine, which reacts with the isocyanate to form ureas, in toluene The concentration is 43 mg/L The ureas are quantitated by high pressure liquid chromatography by NIOSH method 5521

Because analytical standards are not available for trimers of diisocyanate monomers, the NIOSH method extrapolates the calibration curve for the hexamethylene diisocyanate monomer to the prepolymers According to the paint manufacturer, the hardener is manufactured by diluting Desmodur N 3390 (Mobay, Pittsburgh PA) or Tolonate HDT 90 (Rhone Poulenc, Princeton, NJ) with organic solvents According to the material safety data sheets, Demodur N 3390 is 90 percent by mass, respectively, the isocyanurate trimer of HDI (CAS NO 28182-81-2) and Tolonate HDT 90 is 90 percent by mass the trimer of HDI (CAS NO 3779-63-3) [7,9] The HDI monomer is less than 0 2 percent of the total weight of these products The results of NIOSH method 5521 are reported in terms of mass of isocyanate per sample Since monomer standards are used to quantitate the peak areas for the preploymers, a Limit of Detection, LOD, for HDI prepolymers could not be calculated directly Modifications to NIOSH Method 5521 are presented in Appendix B4

The ultra violet (UV) response obtained during the NIOSH 5521 analysis method was used to obtain the mass of the isocyanate trimers in the air sample Analytical standards were prepared by diluting the Desmodur N3390 and Tolonate HDT 90 into the NIOSH Method 5521 impinger solution After sitting for three days these standards were prepared the same as the samples Samples were quantitated by UV detection These results are reported in terms of mass of Desmodur N3390 or Tolonate HDT 90 per sample

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

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

2 On the side of the spray painting booth, and

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

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

VIDEO EXPOSURE MONITORING

Video exposure monitoring was used to determine how specific painting tasks affected the worker's exposure to the air contaminants [14-15] The worker's solvent exposures were monitored using a Photovac TIP II (PHOTOVAC Inc, Thornhill, Ontario), a direct reading instrument This instrument was connected to a data logger (Rustrak Ranger, Gulton, Inc , East Greenwich, RI) to record its analog output Simultaneously, the worker's activities were 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

The Photovac TIP II's analog output 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, it is used as a measure of the relative concentrations (Because of fire safety considerations, this instrument was located outside of the spray painting booth) Teflon tubing, (Alltech Associates, Deerfield, IL), 0 125" inside diameter and 45 feet long, was attached to the worker near his lapel and connected to a personal sampler pump outside the booth This pump drew air through the tubing at 3 5 liters per minute and exhausted the sampled air into a glass tee where the TIP sampled the air

VENTILATION MEASUREMENTS

In the spray painting booths, air flow volumes and velocities were measured at the face of the inflow filters in the ceiling, the exhaust filters at the back of the booths, and at several points near the vehicle A Balometer™ (Alnor, Niles, IL) and a hot-wire anemometer (Kurz Digital AVM Model 1440-4) were used to measure the airflow in each booth The Balometer measured the volumetric air inflow rate through the 2' x 2' sections of the filters in the ceiling of the booth These measurements were summed to obtain the total volume of air entering the booth The hot wire anemometer was used to measure the air velocity at the booth's inflow filters, exhaust filters, and at several points near the vehicle Five-point traverses were made across each exhaust filter and 8-point traverses across each inflow filter The velocity across each filter was averaged and the flow determined and summed to obtain the total inflow and exhaust in each booth The velocity at several points, 18" from the vehicle's surface, were also measured Smoke tubes were used to trace the air flow patterns in the spray painting booth An inclined manometer was used to measure the static pressure in the booth during normal painting operations

RESPIRATOR EVALUATION

The respirators currently utilized by the body shop employees were probed (brass probes provided by the manufacturers) for quantitative fit testing The probes were placed in the approximate center of the respirator, above the exhalation valve and between the cartridge holders The employees were then instructed to don the respirator as they normally did Quantitative fit testing was then conducted to determine respirator facepiece to face sealing characteristics A Portacount™ respirator fit tester (TSI, Inc , P O Box 64394, St Paul, MN 55164) was used to test each respirator 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 [16] 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 [17] 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 [17]

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

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 AND FINDINGS

VENTILATION MEASUREMENTS

Table 2 summarizes the airflow volumetric rates measured in the spray painting booths using a Balometer and an anemometer In the Balometer, the flow contracts from a 4 square foot area to a 14" x 14" area This restriction in the flow may cause some of the air to flow around the Balometer resulting in the lower measurements of the total inflow volume than when measured using the hotwire anemometer Appendix C presents the details of an adjustment of the Balometer readings due to the pressure loss through the Balometer and the pressure loss through the filters in the ceiling of the booth

Table 2 Volumetric Airflow Rates Measured in the Spray Painting Booths

	Drive-In Booth		Drive-Thru Booth	
Instrument Used	Balometer	Anemometer	Balometer	Anemometer
Inflow[1] into Booth (cfm)	7300[3]	8600	9000[3]	9800
Exhaust[1] from Booth (cfm)	-	8200	-	10200
Velocity near Vehicle[2] (fpm)		65 - 75		70 - 90

[1]Measurements are taken at the filter faces inside the booth
[2]Measurements are taken along the sides of the vehicle and about 18" from the vehicle
[3]Adjustment of Balometer readings discussed in Appendix C

Figures 5 and 6 shows the air flow volumes and distribution through the drive-in paint booth From velometer readings and observations of smoke tube traverses and spray mist patterns in both booths, the airflow is not uniformally distributed in the drive-in booth Two-thirds of the air flow is along the left side of this booth The measured velocities around the vehicle (measured 18" from the vehicle and 36" above the floor) ranged from 50 to 70 fpm The air is uniformly exhausted across the full width of this booth In the drive-thru booth (see Figures 7 and 8), the air flow volumes are more uniformly distributed, providing excellent control in most areas but poor control on the end of the vehicle nearest the booth's exhaust The measured velocities around the vehicle in this booth ranged from 40 to 70 fpm

During spray painting, the spray gun's nozzle is held vertical or nearly vertical to the surface being painted Pressurized air atomizes and propels the spray gun's contents onto the vehicle's surface with some of the spray rebounding and entering the air This is known as overspray From

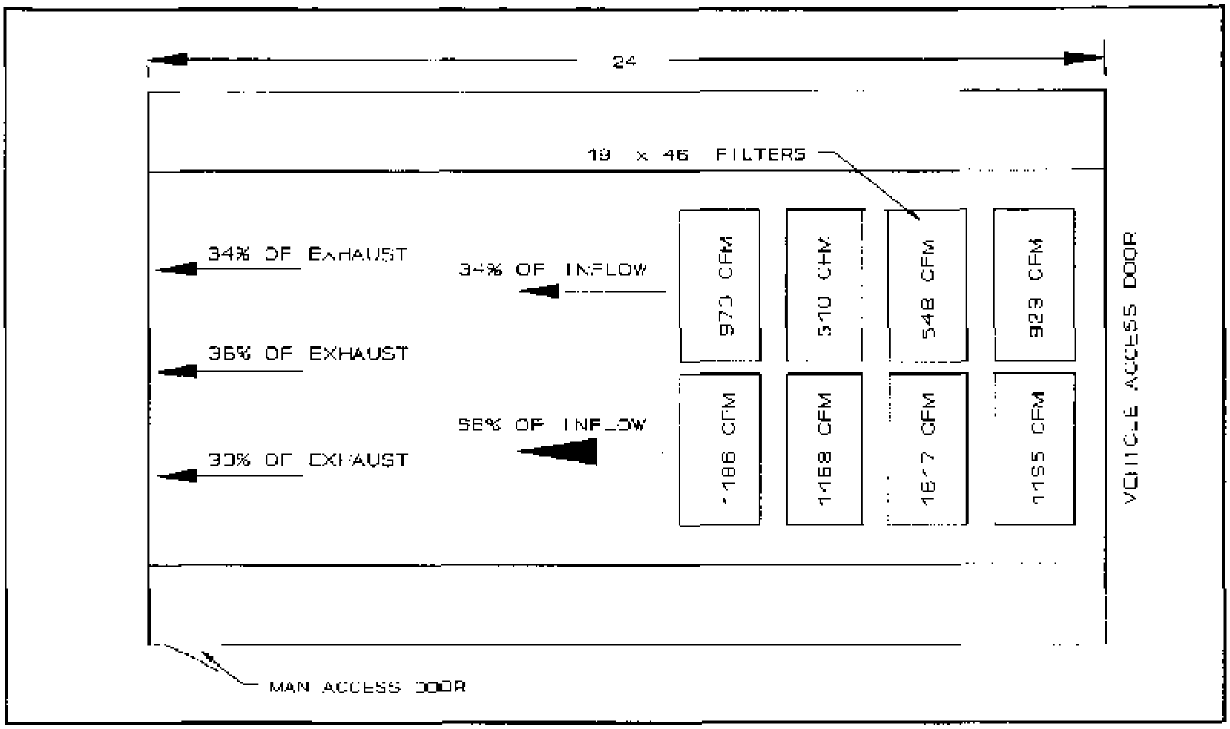

Figure 5 Airflow volume and distribution in the drive-in booth

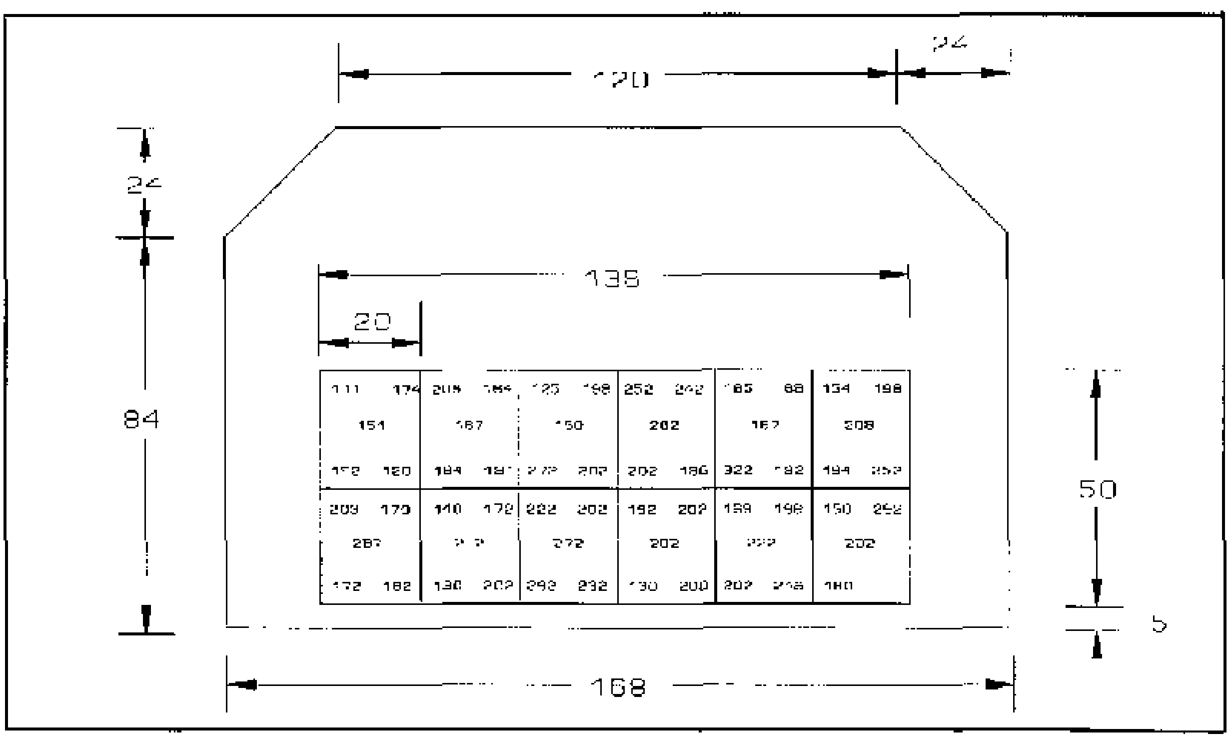

Figure 6 Airflow volume and distribution at the exhaust of the drive-in booth

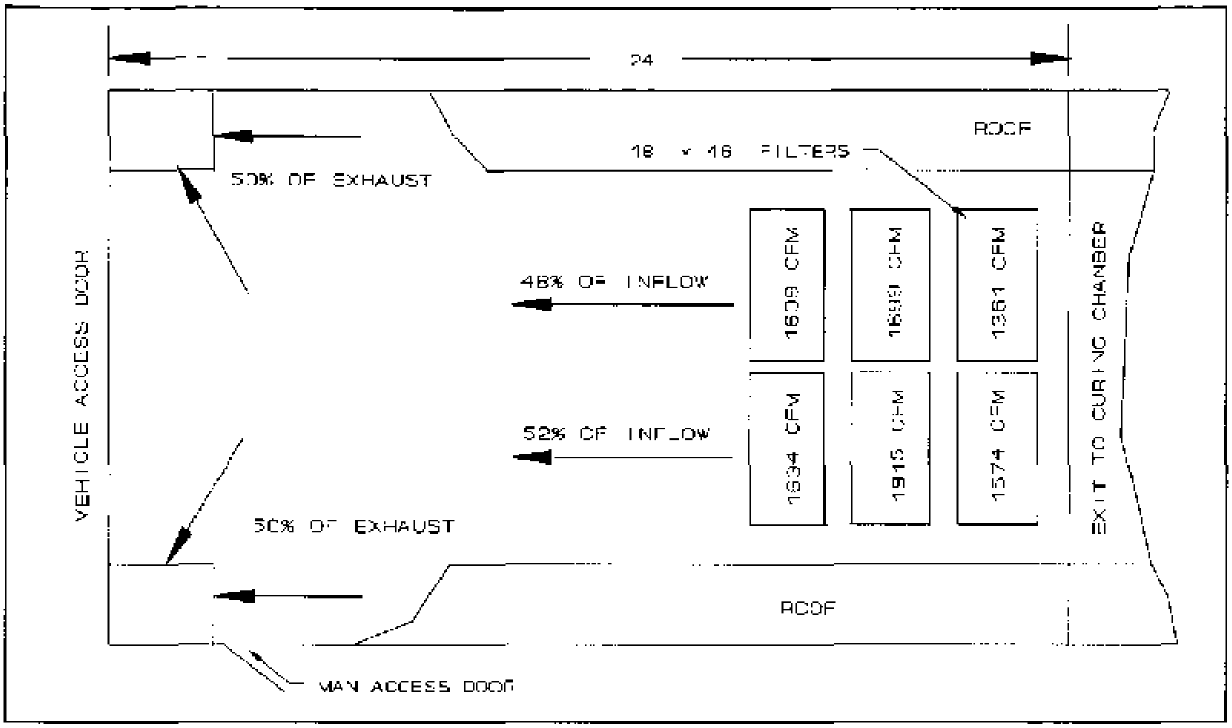

Figure 7 Airflow volume and distribution in the drive-thru booth

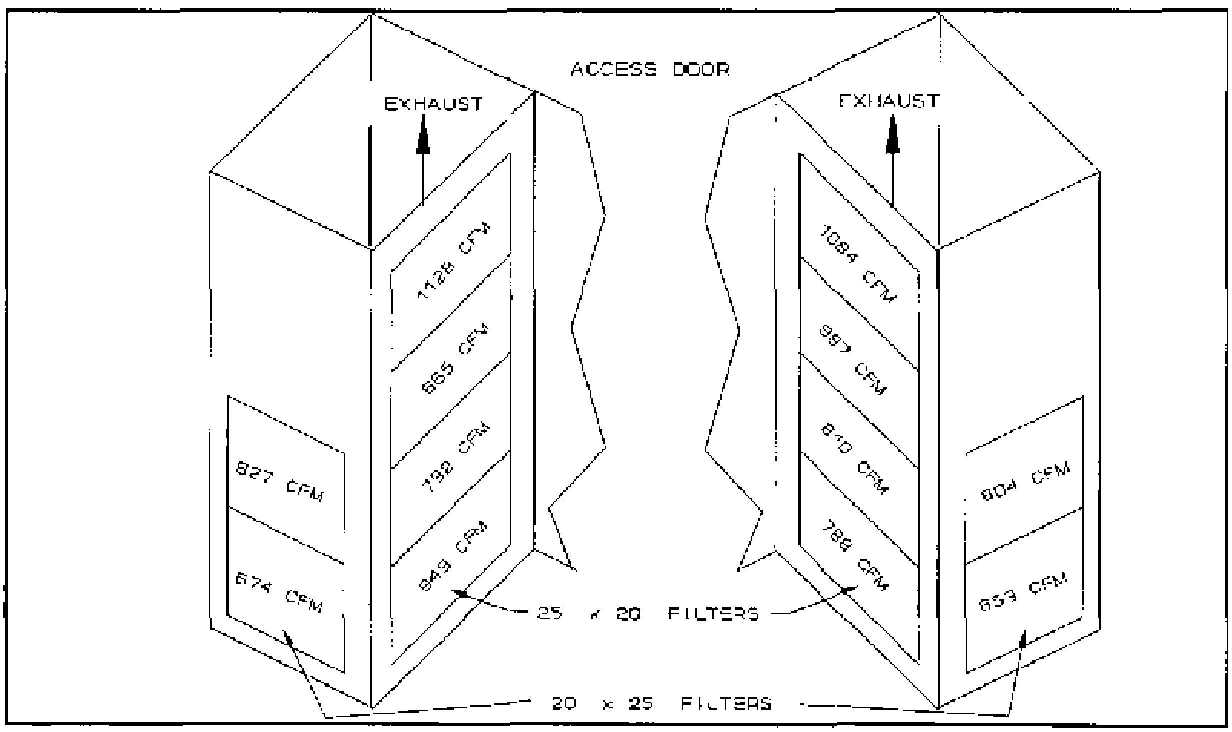

Figure 8 Airflow volume and distribution at the exhaust of the drive-thru booth

observation of the spray paint mist patterns in both booths, most of the overspray is captured by the booth's ventilation system and carried away from the painter However, some overspray was observed to enter the painter's breathing zone depending on his location relative to the direction of the spray and the booth's air stream and the distance between him and the surface being painted (See the following Video Exposure Monitoring section for additional discussion on the painter's relative positions and distances)

AIR SAMPLING RESULTS - SPRAY PAINTING

Table 3 summarizes the total dust concentrations measured in the spray painting booths Total dust concentrations are listed in Appendix D1 Two measurements exceeded the OSHA PEL of 15 mg/m^3 Because this exposure limit is for an eight hour day and painting takes only a fraction of the worker's day, the OSHA PEL for total dust was not exceeded

The statistical analysis summarized in Appendix E showed that sampling location and type of paint affected the total dust concentration The column labelled grouping in Table 3 presents the results of a multiple comparison test which evaluates all the possible differences between the sampling locations The fact that the concentration measured at the exhaust filter was much higher than these other two measurements indicates that the booth does isolate the worker from the paint overspray

Table 3 Summary of Dust Sampling Results

Booth	Sampling Location in Booth	N	Geometric Mean (mg/m^3)	Geometric Standard Deviation	Range (mg/m^3)	Grouping[1]
Drive-In	Painter	7	2 86	3 72	0 29 - 10 52	b
	Side	6	1 39	3 60	0 35 - 12 17	b
	Exhaust	7	21 16	1 61	10 07 - 43 06	a
Drive-Thru	Painter	12	3 34	2 27	1 12 - 24 15	b
	Side	12	2 23	4 78	0 10 - 18 14	b
	Exhaust	12	9 25	2 27	2 27 - 53	a

[1] Geometric means with different letters differ significantly, i e , the Painter Sample does not differ significantly from the Side Sample but the Painter Sample does differ significantly from the Exhaust Sample Tukey's multiple comparison test conducted at an overall level of confidence of 95 percent [46]

Metal concentrations are listed in Table D1 of Appendix D Chromium was detected on some of the samples at levels at or above the detection limit of 0 5 μg The maximum amount of chromium detected on a personal sample was 3 μg As shown in Table 1, exposure limits for chromium vary with its valence Information from the material safety data sheets indicated that two chromium containing compounds were present strontium chromate (CAS No 77897-06-2), and a chrome-antimony-titanium buff-rutile (CAS No 68186-90-3) The latter substance is described by ACS as an inorganic pigment that is the reaction product of high temperature calcination in which titanium (IV) oxide, chromium (III) oxide and antimony oxide are homogeneously and ionically interdiffused to form a crystalline structure of rutile [18] The valence of the chromium in strontium chromate is +6 Furthermore, some of the material safety data sheets listed the chromium compounds as "chromium compounds slightly soluble (CAS NO 18540-29-9) " This particular CAS NO refers to hexavalent chromium Thus, the chromium in this shop can have a valence of +6 or +3 During painting operations, chromium concentrations measured on the worker's label ranged from < 0 0020 to 0 1031 mg/m^3, averaging 0 0137 mg/m^3 in the drive-thru booth and < 0 0031 to 0 0083 mg/m^3, averaging 0 0052 mg/m^3 in the drive-in booth These concentrations are above the NIOSH recommended exposure limit of 0 001 mg/m^3 for chromium (VI) compounds

Table 4 summarizes the combined solvent personal exposures Based upon the combined environmental criteria listed in Table 1, the combined personal exposures (C_R) are less than 1 indicating that the solvent concentrations were below acceptable limits

Table 4 Summary of Solvent Concentrations

Description of activities using a gravity feed spray gun	Date	Sample Time[1] (min)	Personal C_R
Drive-Thru Booth			
Car	6/16	55	0 2
Car, side and hood	6/16	82	0 2
Car, hood (under air shower) and front side	6/16	83	0 1
Van, rear door, rear quarter panel	6/17	38	0 3
Pickup, front end and hood (under air shower)	6/17	43	0 3
Van, rear doors, left side up to passenger door	6/18	80	0 2
Drive-In Booth			
Car, two doors	6/17	39	0 1
Pickup, fender, door, tailgate	6/17	104	0 2
Car, all	6/17	94	0 2
Pickup, bed and tailgate setting on stands	6/18	51	0 3

[1]Sample time is for the personal sample

Tables 5 and 6 summarizes the isocyanate concentrations measured in the spray painting booths Some of these concentrations measured on the worker exceeded Oregon's permissible exposure limit for polyisocyanates (1 mg/m^3 as a ceiling and 8-hour TWA of 0 5 mg/m^3 for exposure to HDI polyisocyanates) and the U K 's control limit for isocyanate exposure to diisocyanates and oligomers of these diisocyanates (an 8-hour TWA of 20 μg/m^3 and a 10-minute ceiling limit of 70 μg/m^3) [5-6] (Neither OSHA, NIOSH nor ACGIH have specified exposure limits for these substances) These results suggest a need to reduce the concentration of the paint overspray in the spray painting booths

Table 5 Polyisocyanate Resin Concentration

	Drive-In Booth		Drive-Thru Booth	
	N	Range (mg/m^3)	N	Range (mg/m^3)
Painter				
Tolonate HDT 90	3	< 0 12 - 1 8	5	< 0 053 - 1 0
Desmodur N3390	0	-	1	0 96
Exhaust				
Tolonate HDT 90	4	< 0 18 - 5 2	5	< 0 074 - 0 18
Desmodur N3390	0	-	1	2 8

Table 6 Isocyanate Functional Group Concentration via NIOSH 5521

	Drive-In Booth		Drive-Thru Booth	
	N	Range (μg NCO/m^3)	N	Range (μg NCO/m^3)
Painter				
HDI	3	7 - < 15	6	< 4 - 67
HDI - Prepolymer	2	ND - 210	2	ND - 120
Exhaust				
HDI	4	9 - 15	6	< 4 - < 9
HDI - Prepolymer	3	ND - 730	3	ND - 410

AIR SAMPLING RESULTS - SANDING

Nonventilated orbital sanders were used in this shop The total dust concentrations measured on the worker ranged from 2 4 to 86 mg/m^3 during six sampling periods, (Appendix D, Table D2) Sampling periods ranged from 9 to 43 minutes The concentrations measured on the worker were greater while sanding plastic body filler compound, than when sanding painted surfaces Chromium was detected on one of eleven samples at a level above the detection limit of 0 5 μg The chromium concentrations measured on the worker ranged from < 0 0009 to 0 013 mg/m^3 The valence of this chromium compound is unknown If this is a chromium (VI) compound, the NIOSH recommended exposure limit of 0 001 mg/m^3 for chromium (VI) compounds was exceeded The lead concentration measured on the worker ranged from < 2 0 to 90 4 $\mu g/m^3$, one sample exceeded OSHA's PEL TWA of 50 $\mu g/m^3$ for lead

VIDEO EXPOSURE MONITORING

Table 7 summarizes relative solvent concentrations measured on the worker during four spray painting jobs During each job, three in the drive-in booth and one in the drive-thru booth, various parts of four different vehicles were painted The vehicle was divided into 10 areas as defined in Figure 9 For example, Area 1 is the right side of the vehicle and Area 11 is the right side of the roof In Table 7, the relative solvent concentration was computed from the Photvac Tip II's analog output for each area as follows

$$100*\frac{\textit{average analog output while painting an area}}{\textit{average analog output when painting is not being done}}$$

The results indicate solvent exposures occur in every area However, the greater relative solvent concentrations occurred when the painter was near the exhaust side of the paint booth standing in an area of turbulent airflow that exists on the lee side of the vehicle

In the drive-in booth, large relative solvent concentrations occurred when painting the left front side of the hood of a vehicle (Area 23) Paint mist observations revealed that turbulence at the windshield-hood juncture moves the paint mist towards to the side rather than continuing directly toward the exhaust When painting Area 23, a right-handed painter stands slightly downstream of his spray gun and he reaches across the hood This motion brings his breathing zone close to the hood where overspray is transported into his breathing zone This can cause a drastic increase in relative concentrations, as shown in Figure 10

Table 7 Average Relative Solvent Concentrations Within Spray Painting Booths

Painting activity, area (1, 2, etc) being painted on vehicle and location relative to booth ventilation (air inflow and exhaust)	Drive-In			Drive-Thru
	Run 1 Pickup	Run 2 Car	Run 3 Pickup	Run 4 Utility
No painting, basis for computing relative solvent concentration	100	100	100	100
(1)[1] Right side, near inflow	128	254	149	169
(2) Front, near exhaust	398	-	237	-
(3) Left side, near exhaust	207	246	-	176
(4) Rear, under inflow	265	-	-	-
(11) Right side roof, midway	101	-	-	199
(12) Left side roof, midway	102	-	-	155
(14) Rear, under inflow	133	-	-	-
(21) Right side hood, near exhaust	100	-	285	-
(23) Left side hood, near exhaust	639	-	167	-
(2) Small pieces on stand near exhaust	-	242	-	-
Average for painting activities	247	248	242	174

[1]Area of the vehicle being painted as illustrated in Figure 9

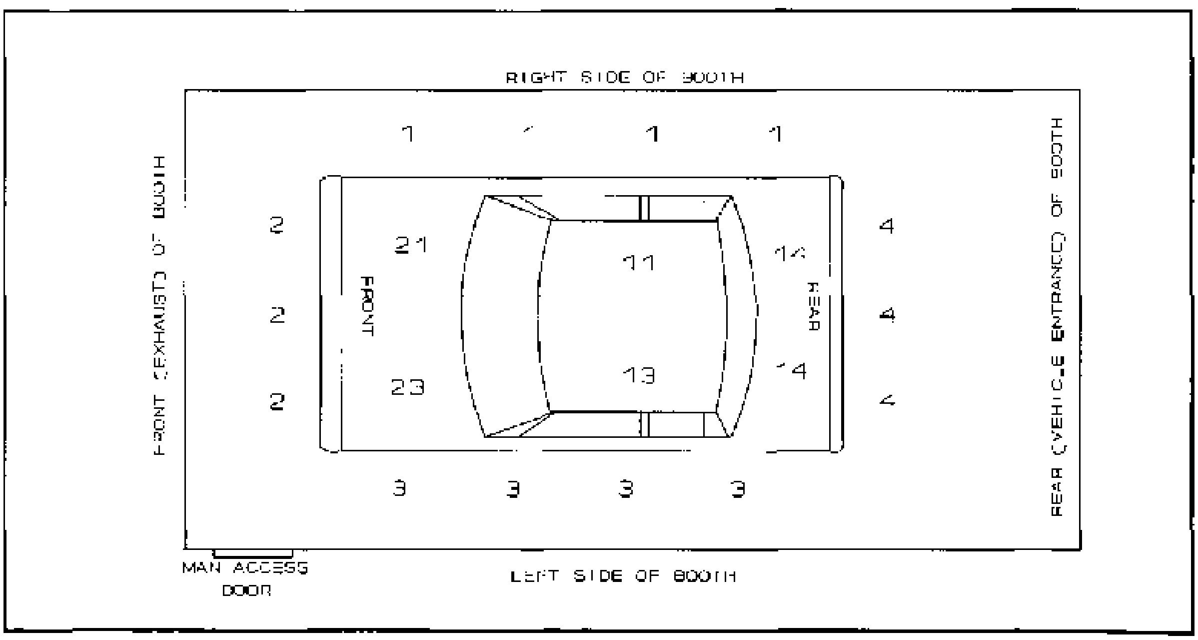

Figure 9 The areas of the car being painted (for example, Area 11 is the right side of the roof)

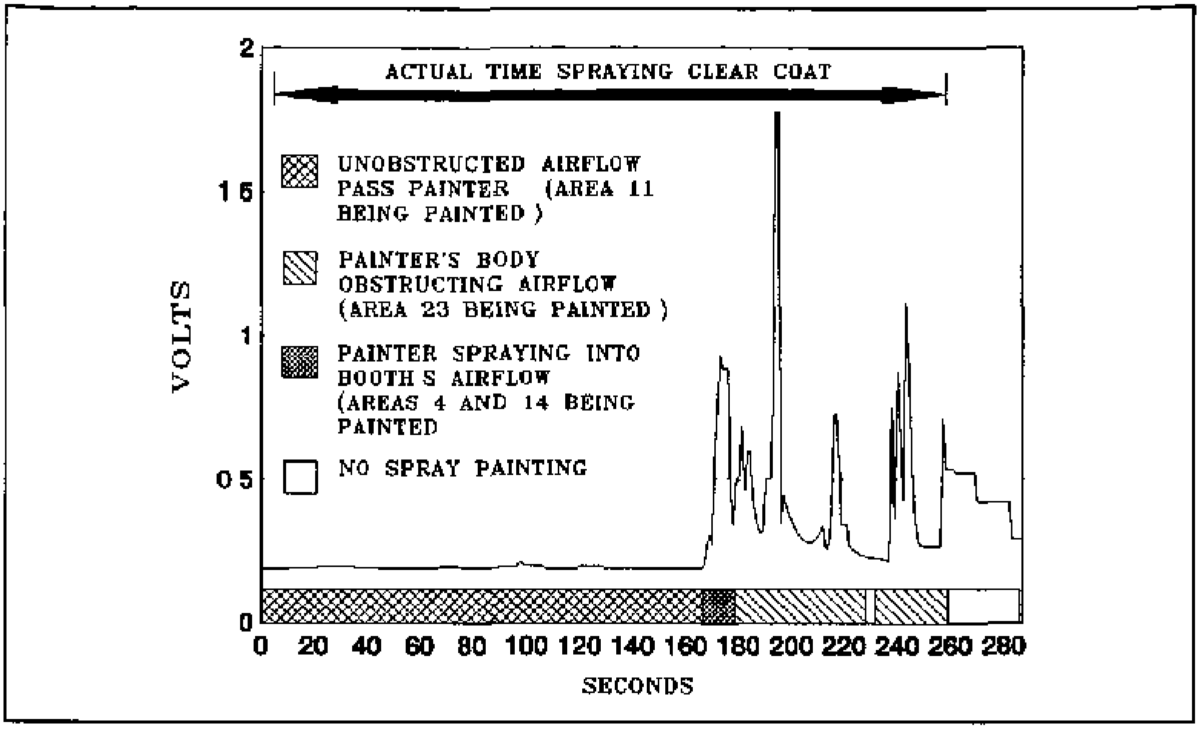

Figure 10 Analog output of Photovac Tip II when areas of the car are painted (for example Area 11 is the right side of the roof as shown in Figure 9)

Another area observed to have higher relative solvent concentrations was when the rear bumper was being painted (Area 4) In this area, the painter stands between the booth's airflow and the overspray His body blocks the airflow forcing the air to curve around him and back towards him As a result, some of this airflow captures overspray and returns it to the painter's breathing zone This effect is reduced when the painter reaches out from his body to paint the more distant areas of the trunk (Area 14) Generally, relative solvent concentrations tend to be lower whenever the spray gun is aimed in the same general direction as the booth's airflow, permitting the booth's ventilation system to effectively carry the overspray away from the painter

RESPIRATOR EVALUATION

The results of the respirator fit tests conducted on workers' half-face piece, air purifying respirators are presented in Table 8 Three of four of the worker's existing respirators had fit factors which were less than 100, the minimum acceptable fit factor in some OSHA standards, as well as recommended by NIOSH [46 47 48] Thus, three of the four respirators tested appear to be inadequately protecting the workers Table 9 summarizes the defects observed during an inspection of the used respirators

Table 8 Comparison of fit factors with old and new half-face piece, air purifying respirators

Worker Tested	Fit Factor Obtained With Worker's	
	Original Respirator	New Respirator
Worker #1	5 2	15860
Worker #2	9 3	252
Worker #3	127	202
Worker #4	67	1304760

Table 9 Summary of defects in inspected respirators

Defect	Number of Respirators with Defect
Facepiece had lost shape or torn This may interfere with seal or cause leakage	4
Inhalation valve does not appear to be seating properly	2
Headbands have lost elasticity, possibly causing poor fit	2

Most of the respirators used by the workers appeared to be poorly maintained and had defects which would interfere with the seal between the face and the respirator This poor maintenance and training probably contributed to the low fit factors reported in Table 8

DISCUSSION AND RECOMMENDATIONS

SPRAY PAINTING BOOTHS

The spray painting booths appeared to be operating near their designed flow rates of 9500 cfm This results in air velocity around the vehicle ranging from 65 to 75 fpm in the drive-in booth and 70 to 90 fpm in the drive-thru booth However, these velocities are too low to prevent some overspray from entering the painter's breathing zone As a result, the painter can receive significant exposure to paint overspray and exposures did exceed the available exposure criteria for total dust and prepolyimerized isocyanates

Even though the booths operated at or near their designed ventilation capacity, they still inadequately control worker exposure to spray paint mist Air samples indicated brief periods when the concentration of various chemicals measured on the painter exceeded the published exposure limits Thus, respirators need to be properly used in order to control worker exposure to air contaminants in the spray painting booth

After data from other shops becomes available, it may become evident that paint overspray concentrations measured on the worker can be reduced by increasing the flow rate through the booth Unfortunately, OSHA or ACGIH air flow recommendations for spray painting booths address only cross draft spray painting booths [19-20] The OSHA recommendation is contained in an OSHA standard which assumes that the spray painting booth has a cross draft ventilation at a rate of 100 feet per minute per square foot of cross-sectional area of the booth 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 [21]

SANDING OPERATIONS

Nonventilated orbital sanders were used in this shop Dust concentrations measured on the worker while he sanded the roof of a car were excessive (Appendix D, Table D2) Based upon results obtained in other autobody shops, ventilated sanders which exhaust air to a central vacuum systems can be used to control the dust exposures generated during sanding [22] This type of control was shown to keep dust concentrations measured on the worker during sanding below 2 mg/m^3 Until this type of control measure can be implemented, respirators need to be properly used during sanding in order to control worker exposure to a dust whose composition is variable and unknown

This shop should consider the purchase of a central vacuum system and ventilated sanders to control dust generated during sanding operations

RESPIRATOR USAGE

Survivair® (Survivair®, Santa Ana, CA 92704) half-face piece air purifying respirators with spray painting prefilters and organic vapor cartridges are used during painting operations at this body shop They are seldom worn while filling the spray guns When not in use, the respirators are stored either in 2 pound coffee cans with a lid (good practice), unused 2 gallon paint cans with a lid (good practice), in a closed drawer of a tool box (poor practice), on the side of a tool box (poor practice), or sitting out on the work bench (poor practice) The last three practices are "poor" because organic vapor cartridges can absorb water which reduces their capacity to absorb organic vapors The first two practices are "good" as long as the shape of the respirator is not distorted

Each worker is responsible for cleaning his respirator and changing the filters and cartridges Cleaning ranges from wiping with a dry or wet rag, to using water, soapy water, or a glass cleaner Most of the painters change their filters and cartridges when paint odors are detected The frequency of these changes varied from twice a week to once every two weeks

Most of the workers were clean shaven, however, one had a full beard which would interfere with the seal between the respirator and his face [23] This worker, who did not participate in the respirator fit testing, would receive inadequate protection from his respirator The workers were given little or no instructions on how to properly wear or clean their respirators, and none were fit tested There appears to be nearly a complete absence of a respirator program as described by OSHA standards [24]

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 strontium chromate is inappropriate [25] 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 strontium chromate exposure can be eliminated through substitution, respirators are still needed because of the polyisocyanate exposures A half-face piece respirator equipped with a pre-filter for painting and an organic vapor cartridge would be adequate in this case, however, MSDS's from paint manufacturers recommend supplied-air respirators for prepolymerized isocyanates

The quantitative fit test results (in Table 8) indicate that the half-face piece respirators which were used by the workers did not adequately seal against the worker's face Table 8 shows that fit factors for three of four respirators tested are below the NIOSH recommended fit factor for half masks of 100 [26] In addition, OSHA standards for asbestos, benzene, and formaldehyde requires that fit factors be a factor of 10 higher than the assigned protection factor [27,28,29] When the body shop workers were provided with new respirators of their choice and were instructed in proper donning techniques, fit factors increased substantially Inspection of the respirators tested indicated that the reason for these low fit factors were a lack of training and poor respirator maintenance (see Table 9) At this autobody shop, like every other autobody shop in this study, there did not appear to be a formal respirator program in place The OSHA respiratory protection standard 29 CFR 1910 134 (see Appendix F) 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 [30]

Presently, the autobody shop workers wear uniforms which they change at home When paints containing chromium VI or lead are used, their 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 can not be easily removed from the skin [30]

CONCLUSIONS

The semi-downdraft spray painting booths appears to minimize worker exposure to paint overspray while painting most areas of a vehicle The air velocities around the vehicle appears to be high enough to control most overspray However, when the worker aims the spray gun into the booth's oncoming airflow or stands between the booth's air inflow plenum and the area being painted, some overspray is transported back into the worker's breathing zone The high total dust concentrations, which may contain chromium (VI) compounds and lead, during sanding operations point to the need for ventilated sanders Connecting ventilated sanders to a central vacuum system would reduce the total dust levels throughout the shop Respirator use at this autobody shop is inadequate There appears to be a general lack of knowledge of what is proper respirator usage There is a need to read, understand, and implement the OSHA respirator standard that is attached in Appendix F 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
HEALTH EFFECTS TO SPECIFIC AIR CONTAMINANTS

DIISOCYANATES AND THEIR OLIGOMERS

The unique feature of all diisocyanate-based compounds is that they contain two -N=C=O functional groups, which readily react with compounds containing active hydrogen atoms to form urethanes The chemical reactivity of diisocyanates, and their unique ability to cross-link, makes them ideal for use in surface coatings, polyurethane foams, adhesives, resins, and sealants Diisocyanates are usually referred to by their specific acronym, e g , IPDI for isophorone diisocyanate, or HDI for hexamethylene diisocyanate [31] To reduce the concentration of monomers during spray painting from evaporation, the isocyanate monomers are prepolymerized into oligomers that are generally dimers, trimmers, and tetrameres of the monomer In commercial spray painting operations, the monomer is usually less than 2 percent paint by weight However, the oligomers still pose a hazard to the workers as an aerosol

Experience has shown that diisocyanates cause irritation to the skin, mucous membranes, eyes, and respiratory tract Worker exposure to high concentrations may result in chemical bronchitis, chest tightness, nocturnal dyspnea (shortness of breath), pulmonary edema (fluid in the lungs), and reduced lung function [32,33] Lung function is reported to decrease with number of exposures greater than 0 2 mg/m^3 to hexamethylene diisocyanate biuret [34] The most important and most debilitating health effect from exposure to diisocyanates is respiratory and dermal sensitization After sensitization, any exposure, even to levels below any occupational exposure limit or standard, will produce an allergic response that may be life threatening [35,36] The only effective treatment for the sensitized worker is cessation of all diisocyanate exposure [34]

ORGANIC SOLVENTS

Occupational exposure to the organic solvents can cause neurotoxic effects that can include dizziness, headache, an alcohol-like intoxication, narcosis, and death from respiratory failure [37] Automotive spray painters exposed to organic solvents are reported to have decreases in motor and nerve conduction velocities [38] In addition, organic solvents such as acetone, toluene, and xylene can cause eye, nose, and throat irritation [39] 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 [40] Repeated direct skin contact with the liquid may cause redness and dryness of the skin Exposures over 1000 ppm cause respiratory irritation, coughing, and headache [41]

n-Butyl Acetate

At concentrations exceeding 150 ppm, significant irritation of the eyes and respiratory tract are reported in the literature [41]

Hexyl Acetate

Hexyl acetate vapor is irritating to the eyes and throat of humans at concentrations above 50 ppm [41] High concentrations may be mildly irritating to the eyes and upper respiratory track The lethal dose for animals by inhalation is approximately 4000 ppm

Isopropyl Alcohol

At exposures above 400 ppm, irritation to the eyes, nose, and throat are reported Above 800 ppm, the symptoms are intensified [41]

Toluene

Toluene can cause irritation of the eyes and respiratory tract, dermatitis and central nervous system depression [39] At concentrations of 200 ppm or less, complaints of headaches, lassitude, and nausea have been reported At concentrations of 200 to 500 ppm, loss of memory, anorexia, and motor impairment are reported [41] In addition, muscle impairment and increased reaction time can occur at exposures of 100 ppm or more

Xylene

Xylene vapor may cause irritation of the eyes, nose, and throat Repeated or prolonged skin contact with xylene may cause drying and defatting of the skin which may lead to dermatitis Liquid xylene is irritating to the eyes and mucous membranes, and aspiration of a few milliliters may cause chemical pneumonitis, pulmonary edema, and hemorrhaging Repeated exposure of the eyes to high concentrations of xylene vapor may cause reversible eye damage [42] 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 [43]

METALS

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

Chromium

Some paints may contain chromates such as lead chromate, hexavalent chromium, as a pigment These compounds can produce health effects such as contact dermatitis, irritation and ulceration of the nasal mucosa, and perforation of the nasal septum Certain insoluble hexavalent chromium compounds are suspect carcinogens [44]

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 [45] 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 [40] 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 [46 47] Lead exposure is associated with fetal damage in pregnant women [40] Lastly, elevated blood pressure has been positively related to blood lead levels [48,49]

Antimony

Exposure to antimony and its compounds has been associated with numerous health problems, including dermatitis and mucous membrane irritation, pneumoconiosis, electrocardiogram (ECG) alterations, hepatic (liver) involvement, and hematologic changes It can cause gastrointestinal pain, cough, loss of appetite, itching, skin eruptions, and irritation to the skin, eyes, nose, and throat [50] Present evidence in humans is inconclusive regarding an increased risk of lung cancer and reproductive disorders from antimony exposure [13]

Nickel

Lung Cancer and nasal cancer can result from inhalation of nickel [51] Metallic nickel and certain nickel compounds cause sensitization dermatitis "Nickel itch" is a dermatitis resulting from sensitization to nickel In chronic stages, pigmented or depigmented plaques may be formed Nickel sensitivity, once acquired, apparently is not lost, recovery from dermatitis usually occurs within 7 days of cessation of exposure but may take up to several weeks [18] Nickel itself is not very toxic if swallowed, but its soluble salts are quite toxic and, if swallowed, may cause giddiness and nausea [16]

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APPENDIX B
COMMENTS AND MODIFICATIONS ON THE NIOSH ANALYTICAL METHODS USED

APPENDIX B-1 NIOSH METHOD 0500 FOR TOTAL DUST[52]

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

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

2) The backup pads were not vacuum desiccated

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

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

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

Instrumentation and operating conditions during analysis were as follows

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

APPENDIX B-3 NIOSH METHOD 1400 FOR ALCOHOLS I (ORGANIC SOLVENTS)[53]

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

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

APPENDIX B-4 NIOSH METHOD 5521 FOR ISOCYANATES[54]

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

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

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APPENDIX C

ADJUSTMENT OF BALOMETER READINGS

As illustrated in Figure C1, the airflow through the Balometer is constricted in order to measure velocity pressure which the Balometer's meter converts to volumetric flow The pressure losses through ceiling intake filters in spray painting booths appeared to be between 0 03 and 0 08 inches of water According to information presented in the instrument manual, the pressure loss for the air flowing through the Balometer is between 0 005 and 0 02 inches of water Because the pressure loss through the Balometer is not small in relation to the pressure drop through the filters, the air velocity, v_m, through the filter and into the Balometer's inlet will be less than the velocity, v_f, through the filter When air flows through the filter and into the Balometer, the airflow is accelerated to a velocity S_1v_m/S_2 (S_1 and S_2 are areas through which the air flows, respectively, into and out of the Balometer) The kinetic energy of this airflow is lost to friction when it is discharged from the Balometer In addition, the constriction of the air flow in the Balometer and flow around the sensing element in the Balometer causes

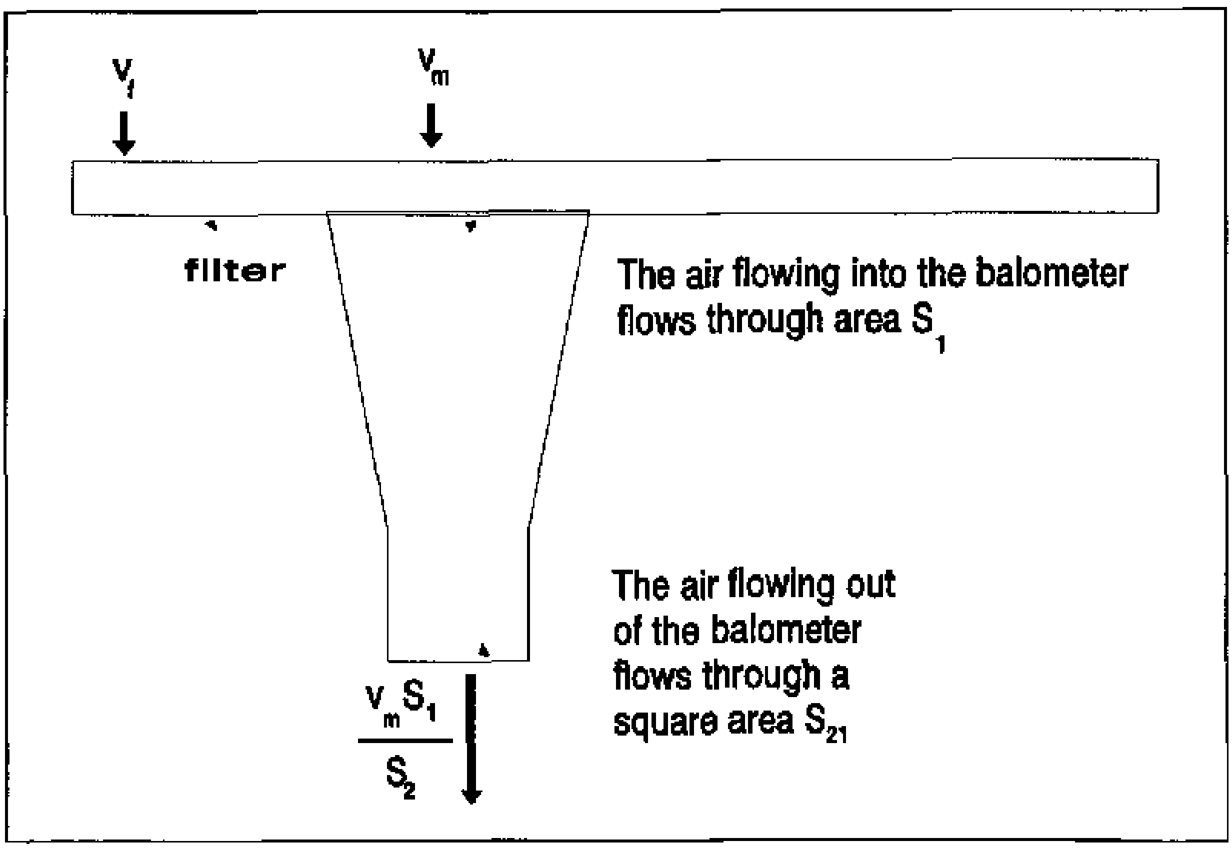

Figure C1. Schematic illustration of balometer used to measure the intake air flow in the ceiling of a booth additional pressure loss As a result, the pressure loss for air flowing through the Balometer is factor of about 1 1 to 1 06 times the velocity pressure at the point of discharge The pressure loss for the sudden expansion at the outlet from the Balometer is 1 velocity pressure The gradual constriction of the air flow and the flow around the sensing element in the Balometer probably adds a pressure loss of 0 06 to 0 1 velocity pressure at the outlet to the Balometer

Unfortunately, the pressure loss across the filters in ceiling of the drive-thru booth was measured to be 0 04 ± 0 01 inches of water and across the filters in the ceiling of the drive-in booth was 0 07 ± 0 01 inches of water As a result, some air will flow around the Balometer rather than through it The purpose of this Appendix is to use Bernouli's equation to estimate a correction for the measured air flow through the Balometer The derivation for this correction is presented in the following paragraphs

The pressure loss, ΔP, through the filter in the ceiling is assumed to be proportional to the air velocity, v_f, through the filter [55] The term v_f is the face velocity of the filter As a result, one can state that $\Delta P = k\,v_f$, where k is a constant and since the total area of the ceiling filters is large in relation to area S_1, $k = \Delta P/v_f$ Because the flow through the Balometer involves some additional pressure losses, the air velocity through the filter and into the Balometer will be reduced to a value which is termed v_m Bernouli's equation can be applied to describe the pressure losses for the air flowing through the Balometer and the relationship between v_m and v_f [56]

$$\Delta P + 0\ 5\rho v_m^2 - 0\ 5\rho(S_1 v_m/S_2)^2 = \Delta P v_m/v_f + 0\ 1\rho(S_1 v_m/S_2)^2 \qquad \text{(C1)}$$

Where.
- S_1 = The area through which the air flows into the Balometer
- S_2 = The area through which the air flows out of the Balometer
- v_m = The air velocity through area S_1
- ρ = The density of air

The first term (going from left to right) of equation C1 is the pressure loss through the filter and Balometer which are in series The second term is the kinetic energy per volume of air flowing into the Balometer The third term is the kinetic energy per volume of air flowing out of the Balometer (kinetic energy lost due to the discharge of air from the Balometer) Note, the dimensions of pressure loss and kinetic energy are the same (mass/distance/time^2) The terms on the right hand side of equation are the pressure loss through the filter and the pressure loss caused by contraction of airflow in the Balometer

Equation C1 can be reorganized to compute the ratio v_m/v_f

$$\frac{v_m}{v_f} = 1 - \frac{0\ 5(1\ 1(S_1/S_2)^2 - 1)\,v_m^2}{\Delta P/\rho}$$

The adjusted Balometer flow rate is computed by dividing the observed Balometer flow rate by the ratio v_m/v_f

Because of the low pressure losses through the filters, this correction factor is very sensitive to slight errors in the measured pressure loss across the filters in the ceiling This is illustrated in Tables C1 and C2 which list the airflow measured by the velometer, the Balometer, the adjusted Balometer reading at the measured filter pressure loss and pressure losses 0 01 inches of water higher and lower than the measured pressure loss

Table C1 Measured and adjusted intake air volumes for the drive-in booth

Air inflow volumes	Volume (cfm)
measured by velometer	8,600
measured by Balometer	6,900
adjusted Balometer measurement for the measured pressure loss of 0 07 inches of water	7,300
adjusted Balometer measurement assuming a pressure loss of 0 08 inches of water	7,200
adjusted Balometer measurement assuming a pressure loss of 0 06 inches of water	7,450

Table C2 Measured and adjusted intake air volumes for the drive-thru booth

Air inflow volumes	Volume (cfm)
measured by velometer	9,800
measured by Balometer	6,900
adjusted Balometer measurement for the measured pressure loss of 0 04 inches of water	9,000
adjusted Balometer measurement assuming a pressure loss of 0 06 inches of water	8,500
adjusted Balometer measurement assuming a pressure loss of 0 03 inches of water	10,000

The measurements and development presented in this appendix indicate that Balometer measurements can be affected by the pressure loss through the ceiling filters in a spray painting booth These measurements, together with the velometer measurements, indicate that the booths are operating at flow rates which are 80 to 100 percent of the design value

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APPENDIX D
SAMPLE RESULTS

Table D1 Total dust sampling results during painting

Description of Painting Activity	Sample Location	Date	Painting Duration (min)	Total Dust Conc (mg/m³)	Chromium Conc (mg/m³)	Nickel Conc (mg/m³)	Antimony Conc (mg/m³)
"DRIVE-THRU" SEMI DOWNDRAFT PAINT BOOTH							
(P1) Car sealer	Worker	06/16/92	5	24 15	0 1031	< 0 0154	< 0 031
	Exhaust			6 31	< 0 0008	< 0 0154	< 0 031
	Wall			< LOD	< 0 0007	< 0 0143	< 0 029
(P1) Car, 3 coats of color	Worker	06/16/92	21	8 75	0 0250	< 0 0250	< 0 050
	Exhaust			105 50	0 2200	< 0 0250	< 0 050
	Wall			5 50	0 0125	< 0 0250	< 0 050
(P1) Car. 3 coats of clear	Worker	06/16/92	11	1 49	< 0 0021	< 0 0043	< 0 009
	Exhaust			24 38	< 0 0021	< 0 0042	< 0 008
	Wall			0 65	< 0 0022	< 0 0043	< 0 009
(P2) Car, side and hood, 4 coats of color	Worker	06/16/92	11	1 40	< 0 0020	< 0 0040	< 0 008
	Exhaust			7 52	< 0 0017	< 0 0034	< 0 007
	Wall			2 83	< 0 0017	< 0 0034	< 0 007
(P2) Car, side and hood, 3 coats of clear	Worker	06/16/92	7	4 69	< 0 0031	< 0 0063	< 0 013
	Exhaust			4 73	< 0 0033	< 0 0067	< 0 013
	Wall			16 97	< 0 0032	< 0 0065	< 0 013
(P3) Car, hood and half of front side, sealer, 2 coats of color	Worker	06/16/92	14	1 13	< 0 0021	< 0 0042	< 0 008
	Exhaust			3 35	< 0 0023	< 0 0047	< 0 009
	Wall			0 74	< 0 0023	< 0 0047	< 0 009

Table D1 Total dust sampling results during painting

Description of Painting Activity	Sample Location	Date	Painting Duration (min)	Total Dust Conc (mg/m³)	Chromium Conc (mg/m³)	Nickel Conc (mg/m³)	Antimony Conc (mg/m³)
(P3) Car, hood and half of front side, 3 coats of clear	Worker	06/16/92	23	2 69	< 0 0029	< 0 0057	< 0 011
	Exhaust			13 89	< 0 0028	< 0 0056	< 0 011
	Wall			2 83	< 0 0028	< 0 0056	< 0 011
(P4) Van, rear door and rear quarter panel, sealer, 2 coats of color	Worker	06/17/92	3	2 00	< 0 0053	< 0 0105	0 042
	Exhaust			9 41	< 0 0059	< 0 0118	< 0 024
	Wall			4 67	< 0 0056	< 0 0111	< 0 022
(P4) Van, rear door and rear quarter panel, sealer, 3 coats of clear	Worker	06/17/92	7	15 89	< 0 0053	< 0 0105	< 0 021
	Exhaust			14 26	< 0 0043	< 0 0087	< 0 017
	Wall			9 90	< 0 0048	< 0 0095	< 0 019
(P6) Pickup, front end and hood, sealer, 3 coats of color	Worker	06/17/92	5	1 50	< 0 0042	< 0 0083	< 0 017
	Exhaust			5 90	0 0225	< 0 0050	< 0 010
	Wall			4 79	< 0 0026	< 0 0053	< 0 011
(P6) Pickup, front end and hood 2 coats of clear	Worker	06/17/92	4	2 53	< 0 0053	< 0 0105	< 0 021
	Exhaust			9 10	< 0 0050	< 0 0100	< 0 020
	Wall			0 10	< 0 0048	< 0 0095	< 0 019
(P7) Van, rear doors, one side from rear to passenger door, sealer, 3 coats of color	Worker	06/17/92	14	3 55	0 0150	< 0 0050	< 0 010
	Exhaust			6 84	0 0560	< 0 0040	< 0 008
	Wall			1 48	0 0024	< 0 0040	0 016
(P7) Van, rear doors, one side from rear to passenger door, sealer, 3 coats of clear	Worker	06/17/92	9	3 90	< 0 0025	< 0 0050	< 0 010
	Exhaust			2 13	< 0 0031	< 0 0063	< 0 013
	Wall			10 31	< 0 0031	< 0 0063	< 0 013

Table D1 Total dust sampling results during painting

Description of Painting Activity	Sample Location	Date	Painting Duration (min)	Total Dust Conc (mg/m^3)	Chromium Conc (mg/m^3)	Nickel Conc (mg/m^3)	Antimony Conc (mg/m^3)
"DRIVE-IN" SEMI DOWNDRAFT PAINT BOOTH							
(P5) Car, 2 doors, sealer, 2 coats of color	Worker	06/17/92	13	1 78	< 0 0037	< 0 0074	< 0 015
	Exhaust			10 07	< 0 0037	< 0 0074	< 0 015
	Wall			2 30	< 0 0037	< 0 0074	< 0 015
(P5) Car, 2 doors, sealer, 3 coats of clear	Worker	06/17/92	7	6 00	< 0 0083	< 0 0167	< 0 033
	Exhaust			22 00	< 0 0077	< 0 0154	< 0 031
	Wall			12 17	< 0 0083	< 0 0167	< 0 033
(P8) Pickup, fender, door, tailgate, sealer, 3 coats of color	Worker	06/17/92	20	1 03	0 0061	< 0 0028	< 0 006
	Exhaust			15 84	0 0630	< 0 0027	< 0 005
	Wall			0 44	0 0027	< 0 0027	< 0 005
(P8) Pickup, fender, door, tailgate, sealer, 3 coats of clear	Worker	06/17/92	13	5 63	< 0 0031	< 0 0063	< 0 013
	Exhaust			27 59	< 0 0029	< 0 0059	< 0 012
	Wall			1 24	< 0 0029	< 0 0059	< 0 012
(P9) Car, all, sealer, 3 coats of color	Worker	06/17/92	18	0 29	0 0070	< 0 0032	< 0 006
	Exhaust			14 15	0 0354	< 0 0025	< 0 005
	Wall			0 35	0 0023	< 0 0025	< 0 005
(P9) Car, all, sealer, 3 coats of clear	Worker	06/17/92	11	10 52	< 0 0032	< 0 0065	< 0 013
	Exhaust			43 06	< 0 0031	< 0 0063	< 0 013
	Wall			1 38	< 0 0031	< 0 0063	< 0 013
(P10) Pickup, bed and tailgate setting on stands, sealer, 3 coats of clear/color	Worker	06/17/92	22	8 35	0 0051	< 0 0039	< 0 008
	Exhaust			32 15	0 1282	< 0 0026	< 0 005
	Wall			- 0 51	< 0 0013	< 0 0026	< 0 005

Table D2 Total dust sampling results during sanding						
Description of Sanding Activity	Sample Location	Date	Sanding Duration (min)	Total Dust Conc (mg/m³)	Chromium Conc (μg/m³)	Lead Conc (μg/m³)
(S1) Hood and fender panels on a stand, removing paint	Personal	06/16/92	9	2 4	< 4 3	17 1
	Area			1 6	< 4 3	17 1
(S2) Car, all, removing paint	Personal	06/16/92	27	3 5	< 1 4	17 1
	Area			0 37	< 1 4	< 2 9
(S2) Car, all, removing paint	Personal	06/16/92	38	4 5	< 1 0	16 2
	Area			0 49	< 1 0	2 0
(S3) Car, sanding plastic body filler compound	Personal	06/18/92	17	17	< 2 3	4 6
	Area			0 143	< 2 3	< 4 6
(S4) Car, roof, sanding plastic body filler compound	Personal	06/19/92	40	86	12 7	2 0
	Area			1 6	< 1 0	< 1 9
(S4) Car, roof, sanding plastic body filler compound	Personal	06/19/92	43			90 4
	Area			3 0	< 0 9	< 1 8

Table D3 Isocyanate Concentration Measurements

Description of Painting Activity	Sample Location	Date	Painting Duration (min)	Tolonate HDT 90 Conc ($\mu g/m^3$)	HDI Conc ($\mu g/m^3$)	HDI Prepolymer s Conc ($\mu g/m^3$)	DES N-3390 Conc ($\mu g/m^3$)
"DRIVE-THRU" SEMI DOWNDRAFT PAINT BOOTH							
(P1) Car, 3 coats of clear	Personal	06/16/92	11	< 53	< 4	ND	
	At Exhaust			177	< 4	73	
(P2) Car, side and hood. 3 coats of clear	Personal	06/16/92	14	< 89	< 7	ND	
	At Exhaust			< 74	< 6	ND	
(P3) Car, hood and half of front side, 3 coats of clear	Personal	06/16/92	23	1000	< 7	121	
	At Exhaust			< 86	< 7	ND	
(P4) Van, rear door and rear quarter panel, sealer, 3 coats of clear	Personal	06/17/92	7	< 125	< 10	ND	
	At Exhaust			5238	< 10	643	
(P6) Pickup, front end and hood, 2 coats of clear	Personal	06/17/92	4	< 125	< 10	ND	
	At Exhaust			< 114	< 9	ND	
(P7) Van, rear doors, one side from rear to passenger door, sealer, 3 coats of clear	Personal	06/17/92	9	< 83	67	ND	
	At Exhaust			94	< 6	86	
"DRIVE-IN" DOWNDRAFT PAINT BOOTH							
(P5) Car, 2 doors, sealer, 3 coats of clear	Personal	06/17/92	7	1808	< 15	212	
	At Exhaust			< 179	< 14	ND	
(P8) Pickup, fender, door, tailgate, sealer, 3 coats of clear	Personal	06/17/92	13	1448	7	167	
	At Exhaust			1667	9	318	
(P9) Car, all, 3 coats of clear	At Exhaust	06/17/92	11	5000	15	729	
(P10) Pickup, bed and tailgate setting on stands, sealer, 3 coats of clear/color	Personal	06/18/92	22		< 6	118	955
	At Exhaust				< 5	413	2750

ND - not detected

Table D4 Summary of solvent concentration measurements

Description of Painting Activity	Sample Location	Date	Painting Duration (min)	Solvent Concentration (ppm)						Combined Solvent Exposure
				Acetone	n-Butyl Acetate	Hexyl Acetate	Isopropyl Alcohol	Toluene	Xylene	
"DRIVE-THRU" SEMI DOWNDRAFT PAINT BOOTH										
(P1) Car, 3 coats of clear	Personal	06/16/92	11		2 9	< LOD	< LOD	8 5	2 7	0 2
	At Exhaust				28 2	1 5		35 6	30 9	1 2
	Wall				0 7	< LOD		1 0	0 8	< 0 1
(P2) Car side and hood, 3 coats of clear	Personal	06/16/92	14		2 3	0 1		7 5	2 8	0 2
	At Exhaust				9 2	0 9		13 7	12 7	0 5
	Wall				2 1	0 3		2 8	2 8	0 1
(P3) Car, hood and half of front side, 3 coats of clear	Personal	06/16/92	23		1 1	< LOD		3 5	1 3	0 1
	At Exhaust				6 3	0 6		15 6	8 5	0 5
	Wall				1 0	< LOD		1 6	1 2	0 1
(P4) Van, rear door and rear quarter panel, sealer, 3 coats of clear	Personal	06/17/92	7		2 8	< LOD		11 5	3 3	0 3
	At Exhaust				7 4	0 6		24 9	9 5	0 7
	Wall				2 4	< LOD		4 8	3 0	0 1
(P6) Pickup, front end and hood, 2 coats of clear	Personal	06/17/92	4		3 2	< LOD	5 2	11 4	2 9	0 3
	At Exhaust				4 4	0 3	2 4	4 6	4 8	0 2
	Wall				4 3	< LOD	2 5	2 7	2 9	0 1
(P7) Van, rear doors, one side from rear to passenger door, sealer, 3 coats of clear	Personal	06/17/92	9		2 5	< LOD	2 5	6 3	2 4	0 2
	At Exhaust				4 1	0 2	2 3	4 4	4 4	0 2

Table D4 Summary of solvent concentration measurements

Description of Painting Activity	Sample Location	Date	Painting Duration (min)	Solvent Concentration (ppm)						Combined Solvent Exposure
				Acetone	n-Butyl Acetate	Hexyl Acetate	Isopropyl Alcohol	Toluene	Xylene	
"DRIVE-IN" SEMI DOWNDRAFT PAINT BOOTH										
(P5) Car, 2 doors, sealer 3 coats of clear	Personal	06/17/92	7	< 0 0003	2 2	< LOD		4 4	2 4	0 1
	At Exhaust			< 0 0003	10 3	0 4		12 3	10 9	0 4
	Wall			< 0 0004	4 3	0 2		5 8	5 0	0 2
(P8) Pickup fender, door, tailgate, sealer, 3 coats of clear	Personal	06/17/92	13		2 5	0 2	2 2	4 9	2 8	0 2
	At Exhaust				18 7	1 1	15 0	19 9	19 4	0 8
	Wall				0 2	< LOD	< LOD	0 2	0 3	< 0 1
(P9) Car, all 3 coats of clear	Personal	06/17/92	11	< 0 0003	4 4	0 2		5 2	4 2	0 2
	At Exhaust			0 0006	13 3	0 8		13 2	13 5	0 5
	Wall			< 0 0003	0 3	< LOD		0 2	0 3	< 0 1
(P10) Pickup bed and tailgate setting on stands, sealer, 3 coats of clear/color	Personal	06/17/92	22	0 0017	2 9			13 5	3 6	0 3
	At Exhaust			< 0 0004	< 0 1			< LOD	< LOD	< 0 1
	Wall			0 0005	0 6			1 6	1 1	< 0 1

< LOD - less than limit of detection

APPENDIX E
STATISTICAL ANALYSIS OF TOTAL DUST DATA

Statistical analysis was performed on the natural logarithms of the total dust exposures which are termed "lnconc" in the analysis presented in this appendix An analysis of variance using the SAS General Linear Models Procedure was performed to evaluate whether these variables affected lnconc [57]

BOOTH — This variable describes whether the car was painted in the drive-in or drive-through booth

PAINT — This variable describes whether a base coat, clear coat, or an enamel was applied to the car

LOC — The sampling location The sampling locations were on the worker, next to the wall, and at the exhaust filters

BOOTH*LOC — This term is included in the statistical analysis to evaluate whether the effect sampling location and booth are inter-related

Figure E1 presents the results of this analysis The column labelled "Pr > F" under Item 1 lists the probability that chance could have caused the observed differences in lnconc A probability below 0 05 indicates that it is unlikely that chance caused the observed differences in concentration, and thus one concludes that the variable actually affects concentration In this study, the variables LOC and Paint are thought to affect total dust concentration measurements

A t-test involving least squares means was used to evaluate the concentration differences among the sampling location and with the different types of paint applied The SAS listing of these results are presented in Figure E2 The total dust concentrations measured at the exhaust filters are significantly greater than the samples measured near the wall and on the worker Also, the total dust concentration was higher when a clear coat was being applied than when a base coat was being applied

A multiple comparison test, Tukey's HSD test,[46] was used to evaluate the concentration differences among the sampling location and with the different types of paint applied This test evaluates the differences among means at an overall level of confidence of 95 percent The results of Tukey's test are presented in Figure E3 The results are the same as for the tests involving the least squares means

REFERENCES

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

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General Linear Models Procedure

Dependent Variable LCONC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	53 94685830	6 74335729	6 09	0.0001
Error	50	55 35313512	1 10706270		
Corrected Total	58	109 29999342			

R-Square	C V	Root MSE	LCONC Mean
0 493567	72 28661	1 052170	1 45555380

ITEM 1

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOC	2	37 89003860	18 94501930	17 11	0 0001
COAT	2	7 87200606	3 93600303	3 56	0 0360
BOOTH	1	0 37943610	0 37943610	0 34	0 5609
LOC*BOOTH	2	3 48990057	1 74495028	1 58	0 2169

Figure E1 Selected output from SAS

General Linear Models Procedure
Least Squares Means

LOC	LCONC LSMEAN	T for H0 i/j	LSMEAN(i)=LSMEAN(j) / Pr > |T| 1	2	3
exhaust filters	2 81828894	1		4 320007 0 0001	5 536284 0 0001
personal	1 31150876	2	-4 32001 0 0001		1 381759 0 1732
near wall	0 81036687	3	-5 53628 0 0001	-1 38176 0 1732	

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

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General Linear Models Procedure
Least Squares Means

COAT	LCONC LSMEAN	T for H0 i/j	LSMEAN(i)=LSMEAN(j) / Pr > |T| 1	2	3
base coat	1 02531203	1		-1 33771 0 1870	-2 54609 0 0140
enamel with hardener	2 13748416	2	1 337711 0 1870		0 440115 0 6618
clear coat	1 77736838	3	2 546086 0 0140	-0 44012 0 6618	

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

Figure E2 The SAS listings for t-tests based upon least squares means

SAS

General Linear Models Procedure
Tukey's Studentized Range (HSD) Test for variable LCONC
NOTE This test controls the type I experiment wise error rate
Alpha= 0 05 Confidence= 0 95 df= 50 MSE= 1 107063
Critical Value of Studentized Range= 3 416
Comparisons significant at the 0 05 level are indicated by '***'

LOC Comparison	Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
e - p	0 555	1 359	2 163	***
e - w	1 045	1 859	2 673	***
p - e	-2 163	-1 359	-0 555	***
p - w	-0 314	0 500	1 314	
w - e	-2 673	-1 859	-1 045	***
w - p	-1 314	-0 500	0 314	

Note Location "e" refers to the exhaust filters, location "p" refers to the personal sample collected on the worker, and location "w" refers to the sample collected near the wall

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

NOTE This test controls the type I experiment wise error rate

Alpha= 0 05 Confidence= 0 95 df= 50 MSE= 1 107063
Critical Value of Studentized Range= 3 416

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

COAT Comparison	Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
bc - c	-0 929	0 934	2 796	
bc - b	-0 059	1 797	3 653	
c - bc	-2 796	-0 934	0 929	
c - b	0 189	0 863	1 537	***
b - bc	-3 653	-1 797	0 059	
b - c	-1 537	-0 863	-0 189	***

NOTE The coat code "bc" refers to an enamel which contained are hardener, coat code "b" refers to a base coat, and coat code "c" refers to a clear coat

Figure E3 The SAS printout from Tukeys' HSD test

APPENDIX F

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

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

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

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

1910 134(b)(2)

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

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

(4) [Reserved]

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

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

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

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

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

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

1910 134(b)(11)

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

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

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

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

1910 134(d)(2)

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

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

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

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

1910 134(d)(4)

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

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

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

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

1910 134(e)(3)(i)

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

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

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

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

1910 134(e)(5)

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

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

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

1910 134(e)(5)(iii)

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

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

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

(ii) Cleaning and disinfecting,

(iii) Repair,

(iv) Storage

Equipment shall be properly maintained to retain its original effectiveness

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

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

1910 134(f)(2)(iii)

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

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

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

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

1910 134(f)(5)

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

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

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

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

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

1910 134(g)(2)

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

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

(i) - Canister

for ______________________________

(Name for atmospheric contaminant)

or

Type N Gas Mask Canister

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

Name of atmospheric contaminant)

1910 134(g)(4)

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

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

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

TABLE I-1

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

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

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

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