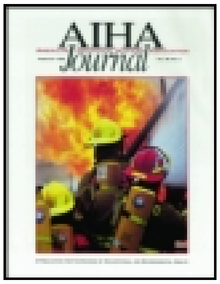

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Commercially available controls for reducing worker exposure to paint overspray were evaluated in six autobody shops and a spray-painting equipment manufacturer's test facility. Engineering control measures included spray-painting booths, vehicle preparation stations, and spray-painting guns. The controls were evaluated by measuring particulate overspray concentrations in the worker's breathing zone, visualizing the airflow in spray-painting booths and vehicle preparation stations, and measuring airflow volumes and velocities. In addition, respirator usage observations were collected at five of the autobody repair shops, and quantitative fit tests were conducted on existing respirators at three shops. Several conclusions were drawn from this study. Downdraft spray-painting booths provide lower particulate overspray concentrations measured on the worker than crossdraft and semidowndraft spray-painting booths. In the latter two booths, the spray-painting gun can disperse as much as half the paint overspray into the incoming fresh air, increasing worker overspray exposure. Vehicle preparation stations have no walls to contain the overspray and, commonly, a single exhaust fan removes air from the painting area. Airflow patterns suggest that these do not control the paint overspray. Switching from a conventional spray-painting gun to a high-volume low pressure spray-painting gun reduced the particulate overspray concentration by a factor of 2 at a manufacturer's test facility. However, this change did not significantly affect solvent concentrations. Finally, respirator usage in five of the six shops studied was inappropriate. Respirators were poorly maintained and/or did not fit the workers, perhaps due to the absence of a formal respirator program.

After structural damage to a car has been repaired, spray painting is used to refinish the car. A spray-painting gun atomizes the paint into droplets, some of which impact on the car and form a surface coating. Those droplets that do not impact on the surface being painted are called paint overspray. The painter is exposed to this overspray and solvent vapors that evaporate from the overspray and the painted surface.

The paint's components pose health hazards to the painter. Exposure to organic solvents affect the central nervous system.[1] However, solvent exposures during autobody repair operations generally are reported to be below recommended exposure limits.[2–5] In addition, some paints contain toxic metals such as lead and chromium.[5] Also, polyisocyanates (which are used to obtain hard, durable surfaces) are frequently used in clear coats. Frequently used polyisocyanates are the isocyanurate trimer or the biuret of 1,6-hexamethylene diisocyanate. Exposure to these HDI-based polyisocyanates are reported to cause skin and eye irritation, respiratory sensitization, asthma, and reduced lung function.[6–10] Occupational exposure limits for HDI-based polyisocyanates have not been developed by the National Institute for Occupational Safety and Health (NIOSH), the Occupational Safety and Health Administration (OSHA), or the American Conference of Governmental Industrial Hygienists (ACGIH). Because of the reported health effects and the number of painters seeking medical attention for respiratory symptoms, the State of Oregon promulgated permissible exposure limits (PEL) for HDI-based polyisocyanates.[11,12] This Oregon PEL includes an 8-hour time-weighted average of 0.5 mg/m^3 and a short-term exposure limit (STEL) of 1.0 mg/m^3 for HDI-based polyisocyanates. Between 1980 and 1990, two-thirds of the personal air samples collected by Oregon OSHA for HDI-based polyisocyanates exceeded the 1.0 mg/m^3 Oregon STEL with a geometric mean of 1.6 mg/m^3.

To develop recommendations for controlling worker exposure to these air contaminants, evaluations of commercially available equipment for controlling worker exposures to paint overspray were conducted in six autobody repair shops and in one spray-painting equipment manufacturer's test facility. The results and details of individual field evaluations are contained in reports that are available from the National Technical Information Service (NTIS).[13–19] This study's purpose was to develop recommendations for controlling worker exposure to air contaminants during spray-painting operations in autobody repair shops.

DESCRIPTION OF OBSERVED CONTROL MEASURES

The types of control measures evaluated included spray-painting booths, vehicle preparation stations, spray-painting guns, and

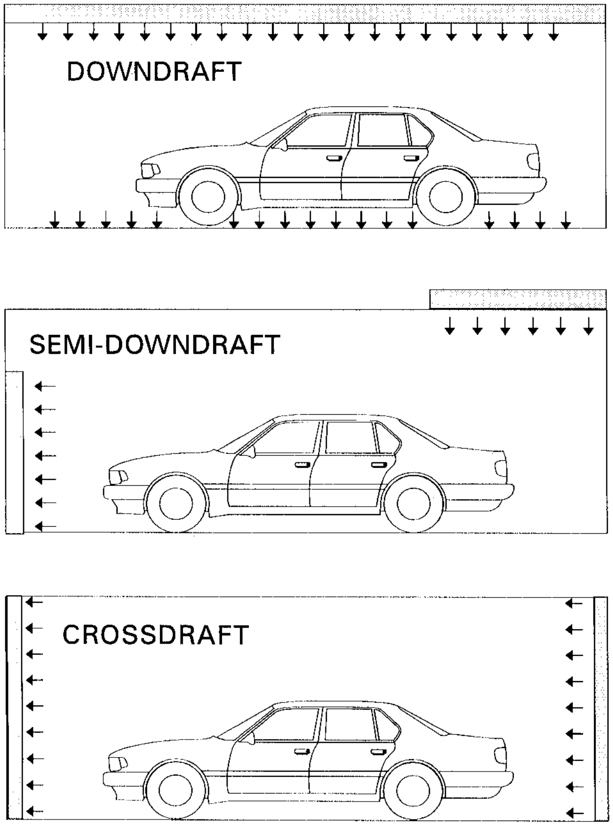

FIGURE 1. Schematic illustration of three types of commercially available spray-painting booths; airflow is indicated by arrows

respirators. Most spray painting was done in spray-painting booths, and limited painting was done at vehicle preparation stations and in the open shop. During this study workers used full-facepiece or half-facepiece air purifying respirators or supplied air hoods. The air purifying respirators were equipped with organic vapor cartridges and prefilters for the paint mist.

Spray-Painting Booths

Three types of commercially available spray-painting booths found in autobody shops are illustrated schematically in Figure 1. Downdraft spray-painting booths are designed to have air enter through filters in the ceiling of the booth and leave through filters that cover trenches under the metal grate floor. In a semi-downdraft booth, air enters through filters in the ceiling of the booth and is exhausted through filters in the back of the booth. In a crossdraft booth, the air enters the booth through filters in the front of the booth and is exhausted through filters in the back of the booth.

Except for some older crossdraft booths, practically all spray-painting booths observed during this study have a painting cycle and a curing cycle. These booths have supply air fans and exhaust air fans. The supply air fan moves air from outside the shop through a heat exchanger or natural gas burners used to heat cold air, through a bank of filters, and into the spray-painting booth. The exhaust fan moves air out of the booth through filters and out of the building. During the painting cycle all of the air entering the booth comes from outside the shop. After completing the paint job and leaving the car in the booth, the painter starts the cure cycle. About 10% of the booth's airflow is from outside the booth and 90% is recycled during curing. To cure the paint and polyisocyanate hardeners, the booth is operated at temperatures as high as 79°C (175°F), although curing temperatures are typically 49 to 60°C (120 to 140°F).

Spray-painting booth ventilation apparently is driven by process rather than health considerations. Downdraft booths are marketed because they provide a cleaner paint job than other types of booths. With other booths, paint or dust particles are more likely to deposit on the car and cause surface imperfections. Less buffing reportedly is required to remove these imperfections when a downdraft spray-painting booth is used.[20]

Vehicle Preparation Stations

Ventilated vehicle preparation stations are sold to provide a relatively dust-free area in which to do small paint jobs and operations to prepare the car for final painting. These preparatory operations include sanding, wiping, masking, and priming small spots. Unlike spray-painting booths, vehicle preparation stations do not have walls and may involve recycled air. An example of a semidowndraft vehicle preparation station is shown in Figure 2. The car being painted or sanded sits under a supply air plenum. During sanding the air is recycled by closing a damper. This directs the airflow into the overhead plenum, through a set of filters, down and horizontally past the object(s) being sanded or painted, and back through the exhaust filters at the floor level. During painting operations the damper is set so that the air is exhausted outside the building, and air is not returned through the supply air plenum. Besides the semidowndraft configuration, downdraft vehicle preparation stations are also marketed. The major difference between these two types of vehicle preparation

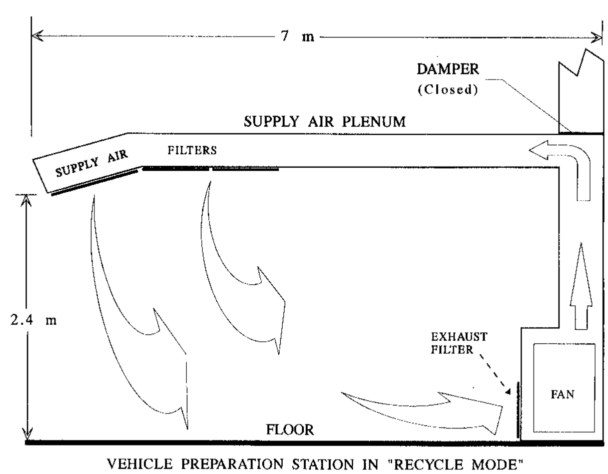

FIGURE 2. Side view of a semidowndraft vehicle preparation station

stations is the location of the exhaust filters. In a downdraft vehicle preparation station, the exhaust filters are located in the floor below the car.

Spray-Painting Guns

In autobody repainting operations, spray-painting guns can be classified as either conventional or high volume/low pressure (HVLP) guns. In conventional spray-painting guns, compressed air is accelerated through a nozzle where a reduction in static pressure occurs. The reduced static pressure causes the paint to flow from a cup into an orifice where the atomization occurs. When this cup is below the atomization nozzle, these guns are termed "suction" or "siphon cup" spray-painting guns. When this cup is above the spray-painting gun, the flow of paint is augmented by gravity; such guns commonly are called "gravity feed" spray-painting guns. The pressure in the nozzle of these conventional spray-painting guns is between 350 and 450 kPa (50 and 65 psig). In HVLP spray-painting guns, atomization pressure is less than 69 kPa (10 psig). Spray-painting gun transfer efficiency is the ratio of the mass of paint solids that coat the surface to the mass of paint solids sprayed. HVLP guns are believed to have a transfer efficiency of at least 65%, and conventional spray-painting guns are reported to have a transfer efficiency of 25 to 35%.[21–23] As a result, some air pollution control districts require the use of spray-painting equipment with a transfer efficiency of at least 65%.[24]

PROCEDURES

This section briefly describes the measurement techniques for the results presented here. Further details can be obtained by reviewing the survey plant reports available from NTIS.[13–19]

Air Sampling

NIOSH Method 0500 for total dust was modified to measure particulate overspray concentration.[25] Instead of the specified flow rate of 1.5 to 2.0 L/min, a flow rate of 5.0 L/min was used. In this method a known volume of air is drawn through a preweighed PVC filter. The weight gain of the filter is used to compute the mass of particulate paint overspray per cubic meter of air. These samples were collected at three sampling locations in spray-painting booths:

(1) personal samples on the worker's lapel, outside of any respiratory protection that the worker might be wearing;
(2) on the long side of the spray-painting booth; and
(3) near the exhaust filters. In a downdraft booth, this sampling location was under the object being painted. In a crossdraft or semidowndraft booth, it was in front of the filters on the back of the booth.

In addition to particulate overspray concentration, the concentration of organic solvents, toxic metals, and polyisocyanates was measured. These data are not reported here but are available in the survey reports.[13–18] Because the chemical composition of the overspray varied with painting job and study site, solvent, metal, and polyisocyanate concentrations were not useful for developing conclusions about the utility of spray painting booths and vehicle preparation stations. During the testing conducted at a manufacturer's test facility, the same paints were used to compare the performance of an HVLP and conventional spray-painting gun.[19] This situation enabled some conclusions to be developed about the effect of spray-painting guns on solvent concentrations.

Ventilation Measurements

In the spray-painting booth, supply and exhaust airflow volumes were determined by measuring the face velocities with a hot wire anemometer. The airflow volume is the product of the filter area and the average air velocity at the face of the filter. Air velocities were also measured around the car in the spray-painting booth. Airflow patterns were studied with smoke tubes and soap bubbles generated by a helium bubble generator (Model 33, Sage Action Inc., Ithaca, N.Y.). This device generates helium-filled bubbles that are neutrally buoyant and have a diameter of about 0.3 to 0.6 cm.

Real-Time Exposure Monitoring

During some spray-painting operations, the painter's activities were recorded on videotape, and his solvent exposures were monitored with a Photovac TIP II (Photovac Inc, Thornhill, Ontario, Canada). This was done to identify specific tasks that elevate the worker's exposure to air contaminants.[26,27] The analog output of the Photovac is proportional to the concentration of ionizable compounds in the air. Because the instrument's response varies with the composition of the organic solvents in the air, the analog output of the Photovac is reported in volts. Because of fire safety considerations, this instrument was located outside the spray-painting booth. Teflon® tubing (Alltech Associates, Deerfield, Ill.), 0.3 cm (0.125 inches) inside diameter and 13.7 m (45 ft) long, was attached to the worker in his breathing zone. A personal sample pump drew air through this tubing at 3.5 L/min and exhausted the sampled air into a glass tee. The Photovac then sampled the air in this glass tee. The analog output of the Photovac was recorded on a data logger (Rustrak® Ranger, Gulton, Inc., East Greenwich, R.I.).

Respirator Evaluation

In three autobody repair shops the respirators currently used were quantitatively fit-tested using brass probes provided by the manufacturers. The quantitative fit tests were conducted in the shop's office. The probes were placed in the approximate center of the respirator, above the exhalation valve and between the cartridge holders. After replacing the normal cartridges with HEPA filters, the employees were then instructed to don the respirator as they normally did. A continuous-flow condensation nucleus counter (CNC), the Portacount™ respirator fit tester (TSI, Inc., St. Paul, Minn.), was used to measure a quantitative fit factor for each respirator.[28] The fit factor is the ratio of the condensation nuclei concentrations measured outside of the respirator to the concentration measured inside the respirator.

During a complete fit test, fit factors were measured while the employee performed 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:[29]

$$\text{OVERALL FF} = \frac{1}{\frac{1}{NB1} + \frac{1}{DB} + \frac{1}{SS} + \frac{1}{UD} + \frac{1}{TK} + \frac{1}{NB2}}$$

where

NB1 = fit factor measured during first normal breathing period;
DB = fit factor measured during deep breathing;
SS = fit factor measured while moving head side-to-side;
UD = fit factor measured while moving head up and down;
TK = fit factor measured while talking; and
NB2 = fit factor measured during second normal breathing period.

After conducting the fit test, the condition (cleanliness, maintenance, etc.) of the employee's original respirator was evaluated by a visual inspection.

RESULTS

Spray-Painting Booths

Table I presents some dimensions of the spray-painting booths studied. Table II summarizes the geometric mean particulate overspray concentrations on the worker during different painting activities. Painters generally left the booth during non-painting activities and tended to be in areas where there was essentially no particulate exposure. To make useful comparisons, each concentration was divided by the fraction of sampling time during which painting occurred. This concentration value is presented in Table II for the purpose of evaluating the effect of the booth on the particulate overspray exposure. Table II also documents the type of spray-painting gun used, the type of booth, the booth's airflow rate, and the geometric mean fraction of the sampling period that the worker spent painting a car in the booth. Particulate overspray concentrations measured on the worker's lapel varied significantly among the booths studied (Prob > F = 0.0001). Table III presents the results of a multiple comparison test conducted to examine concentration differences observed in Table II.

An examination of Tables II and III shows that downdraft booths, except for the poorly maintained Booth F, resulted in noticeably lower paint overspray concentrations measured on the worker than the crossdraft booths in the study. Much of the observed difference in particulate overspray concentration in Table II can be explained by the observed airflow patterns in the different types of booths and the air motion caused by the spray-painting gun. Spray-painting guns use compressed air to atomize the paint, and this compressed air, in the form of a jet (high velocity air flowing from a nozzle), transports the paint droplets toward the surface of the car. At the location where the jet bends and starts to flow along the side of the car, some of the paint coats the car's surface. The remaining paint is considered an air contaminant that is termed "paint overspray." As the jet flows along the side of the car, its energy is diluted by an induced air flow, and this energy eventually is dissipated into turbulence. While a worker was simulating the painting of the side of a car with an empty spray-painting gun outside of a booth, the jet's velocity was 180 m/min (600 ft/min) at a distance of 0.3 m from the area where paint would have been applied to the car. At a distance of 2.40 m, the jet's velocity was 30–15 m/min (100–50 ft/min). The air velocities at the location where the paint is applied to the car are much higher than the booth's air motion, which is supposed to control the paint overspray. Thus, the energy of the spray-painting gun's jet must be dissipated so that the overspray is kept out of the worker's breathing zone. Visual observation of overspray and visualization of air flow patterns in spray-painting booths indicated that downdraft booths and crossdraft booths differ in their ability to keep overspray away from the worker.

Figure 3 shows the airflow patterns in a downdraft booth. These patterns were visualized by using smoke tubes and helium-filled bubbles. The air flowed around the car at a velocity of 30–15 m/min (100–50 ft/min) into the exhaust trench located below the car. The spray-painting guns directed a jet of air toward the car. The effect of this jet on the airflow in the booth is schematically illustrated in Figure 4, which has been annotated to aid in the discussion. Figure 4 presents observations obtained while a worker simulated painting with an empty spray-painting gun. The helium bubble generator was used to disperse helium-filled bubbles into the incoming airflow (Annotation 1). The helium-filled bubbles were approximately 0.5 cm in diameter and were suspended in the air flow. Some of the bubbles were drawn toward the painter and the spray-painting gun (Annotation 2). When the jet from the spray-painting gun

TABLE I. Booth Dimensions

Booth	Type of Booth	Length (m)	Width (m)	Ceiling Height Over Car (m)	Inlet Filter Area (m^2)
A	downdraft	7.0	4.0	2.5	25
B	downdraft	7.3	4.4	2.7	22
C	downdraft	7.0	4.0	2.7	28
D	semidowndraft	7.3	4.3	2.7	3.2
E	semidowndraft	7.3	4.3	2.7	4.2
F	downdraft	7.3	3.8	2.7	12.6
G	crossdraft	8.5	4.3	2.7	6.1
H	crossdraft	8.5	4.3	2.7	8.7

TABLE II. Summary of Particulate Overspray Concentrations Measured on the Lapel of Workers Spray Painting Inside of Spray-Painting Booths

Booth	Type of Booth	GM Particulate Overspray Concentration[A] (mg/m^3) and (GSD)	N	GM Fraction of Sampling Period Spent Painting	Type of Spray-Painting Gun	Booth Flow Rate m^3/min (ft^3/min)	Comments
A	downdraft	1.9 (3.0)	23	0.29	HVLP and siphon cup	340 (12 000)	Spray-painting the side of cars
B	downdraft	2.7 (2.0)	16	0.66	gravity feed and HVLP	170 (6000)	Experienced painting instructor repeatedly painting an entire car body
C	downdraft	4.7 (4.6)	7	0.49	HVLP	340 (12 000)	Spray-painting autobody parts that had been set in the booth
D	semidowndraft	7.9 (2.7)	7	0.36	siphon cup	283 (10 000)	Spray-painting parts of the car
E	semidowndraft	9.7 (2.2)	12	0.30	siphon cup	226 (8000)	Spray-painting parts of the car
F	downdraft	13 (2.4)	7	0.60	siphon cup, gravity feed	198 (7000)	Spray-painting parts of the car. This booth operated at 66% of the design exhaust flow rate. There was a maldistribution of the exhause airflow due to the absence of filters at the bottom of the booth.
G	crossdraft	23 (1.8)	5	0.26	siphon cup	254 (9000)	Spray-painting parts of the car
H	crossdraft	30 (1.8)	6	0.19	siphon cup	85, 170 (3000, 6000)	Spray-painting parts of the car. The fan blade was coated with paint and exhaust louvers were stuck shut. The airflow increased from 85 to 170 m^3/min (3000 to 6000 ft^3/min) when these louvers were propped open.

[A] Observed concentrations were divided by fraction of time painting.

impinged on the car, the bubble motion indicated that the jet appeared to split into two directions (Annotation 3). These jets forced the bubbles to move away from the painter. When the energy of the jets was dissipated, the bubbles appeared to flow toward the exhaust grates in the floor of the booth (Annotation 4). As a result of this situation, the paint overspray generally stayed away from the painter while he was painting a car body.

However, when car body parts were painted, as was done at Booth C, the scenario described in Figure 4 did not occur. Instead, the jet from the spray-painting gun appeared to flow around the objects being painted. The jet's energy degenerated into turbulence, which dispersed paint overspray throughout the booth. During one sampling session spray painting autobody parts resulted in a particulate overspray concentration of 18 mg/m^3 on the worker.

When a worker painted the side of the car in a crossdraft booth, the jet of air from the spray-painting gun was observed to disperse overspray into the incoming airflow. These observations are schematically illustrated in Figure 5. To facilitate the discussion, this figure is annotated. One jet flowed toward the exhaust filters (Annotation 1). A second jet (Annotation 2) flowed toward the air inlet into the booth. The overspray in the second jet was dispersed into the incoming airflow (Annotation 3). This diluted overspray (Annotation 4) flowed through the worker's breathing zone as it flowed towards the exhaust filters in the back of the booth. In Booth G this air velocity was 30 m/min (100 ft/min), and in Booth H this velocity was between 20 and 3 m/min (70 to 10 ft/min). The particulate overspray concentration measured on the worker's shirt lapel (Sampling Location 1) was half the concentration measured at the back of the spray-painting booth near the exhaust filters (Sampling Location 3). This situation suggests that crossdraft booths are incapable of separating the worker from the paint overspray when the side of a car is being

TABLE III. Results of Tukey-Kramer Multiple Comparison Test Evaluating Significance of Concentration Differences for Workers in Different Booths (Overall Confidence Level 95%)

Booths	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*
A				s[A]	s	s	s	s
B					s	s	s	s
C								s
D	s							
E	s	s						
F	s	s						
G	s	s						
H	s	s	s					

[A] The letter "s" in the cell indicates that the observed difference in booths was significant.

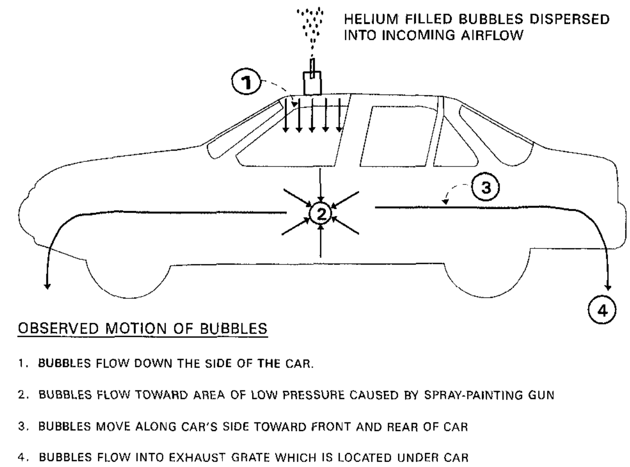

FIGURE 4. Motion of helium bubbles when the painter simulates painting side of car with empty spray-painting guns in a downdraft booth

repainted. Practically all painting jobs during this study involved the side of a car.

The airflow patterns in the semidowndraft booth did not appear to completely separate the worker from the paint overspray. Air flowing toward the sides of the booth appeared to form eddies near the side of the car. Such eddies can push contaminated air back toward the painter. In addition, the dispersion of overspray by the spray-painting gun was probably similar to that observed for a crossdraft booth.

The results indicate that downdraft spray-painting booths minimize overspray exposure better than the other two types of booths that were studied. Most of the overspray appeared to have been contained in the air motion induced by the spray-painting gun's jet. Downdraft booths did not control the spray-painting gun's jet, but instead allowed the energy of the jet to be dissipated so that the overspray moved away from the worker and was exhausted from the booth before the overspray could be mixed into the incoming fresh air. However, if the car body's surface deflects this jet along with its induced air motion into the incoming airflow, exposure to paint overspray can occur. When real-time exposure monitoring was done in a downdraft spray-painting booth, exposure peaks did occur (as shown in Figure 6). Regardless of the source of these exposure peaks, the

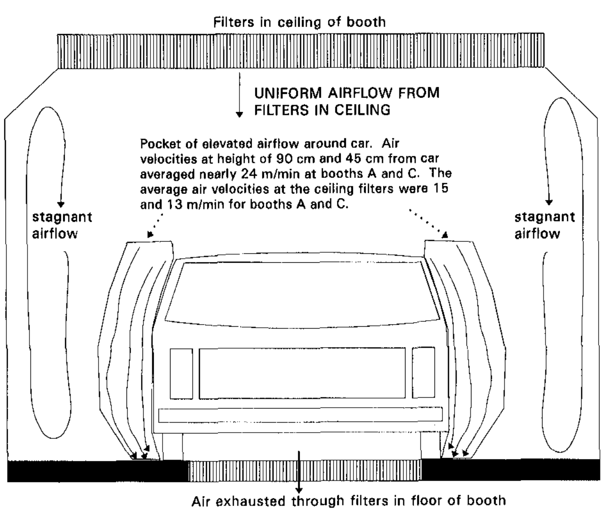

FIGURE 3. Schematic illustration of airflow patterns in a downdraft booth

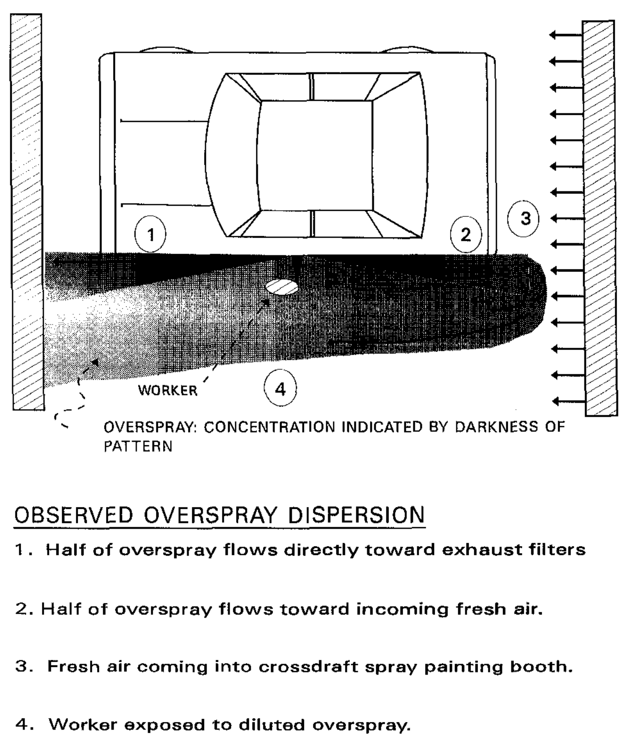

FIGURE 5. Observed dispersion of overspray when worker paints side of car in a crossdraft spray-painting booth

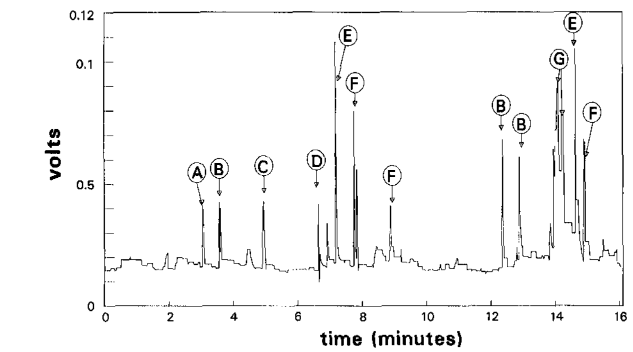

FIGURE 6. Analog output of a Photovac Tip II when a conventional spray-painting gun is used to spray paint a car in a downdraft booth with an exhaust flow rate of 226 m³/min (8000 ft³/min)

data in Figure 6 indicate that downdraft booths do not provide complete control of the paint overspray. Thus, some respiratory protection may always be needed to prevent inadvertent worker exposure to paint overspray.

In Spray-Painting Booths F and G in Table II, lack of maintenance probably increased the particulate overspray concentrations measured on the painters. At the 20-year-old Spray-Painting Booth G, the fan blades and exhaust louvers were coated with overspray. The exhaust louvers would not open completely, but when the exhaust louvers were propped open, the airflow increased from 85 to 170 m³/min (3000 to 6000 ft³/min). Furthermore, the paint residue, which accumulated in the cup of the fan blade, probably reduced the fan's ability to move air. Spray-Painting Booth F was operating at about two-thirds of the design flow rate. In addition, this downdraft booth operated without exhaust filters in the floor of the booth. This caused poor distribution of the exhaust air, poor control of overspray in some locations, and an overall increase in particulate overspray concentrations.

Vehicle Preparation Stations

Only the semidowndraft vehicle preparation station described in Figure 2 was evaluated during this study. This station was used to do relatively small painting jobs involving autobody parts with no air recirculation. The geometric mean and geometric standard deviation for the five particulate paint overspray concentrations measured on the painter were, respectively, 2.4 and 3.5 mg/m³. Because of the limited sample size and the fact that car body parts were painted instead of cars, these concentration measurements cannot be used to compare the performance of vehicle preparation stations and the spray-painting booths listed in Table II. However, a study of airflow patterns around the vehicle preparation station indicated it did not control paint overspray. The vehicle preparation station studied had an exhaust flow rate of 340 m³/min (12 000 ft³/min), which is a typical ventilation rate for a spray-painting booth. Observations of smoke released at the vehicle preparation station are shown in Figure 7. At distances greater than 2.1 m (7 ft) from the exhaust filters, the air velocities appeared to be too low to control paint overspray. When painting was done at the preparation station, paint overspray was observed to be dispersed throughout the vehicle preparation area.

The vehicle preparation station described did not appear to control worker exposure to air contaminants. When air was recirculated, this station did not have alarms or continuous monitors to warn of excessive aerosol or solvent concentrations caused by failure of the air-cleaning equipment or an accumulation of dust or paint overspray in the recycled air. Such alarms and monitors are recommended by ACGIH.[30] When these stations are used for painting, air is exhausted only from the back of the preparation station, and it does not flow from the supply air plenum shown in Figure 2. Also, there are no walls to contain the overspray or prevent drafts from dispersing the paint overspray throughout an autobody repair shop.

Spray-Painting Guns

As part of this study, an experimental comparison of a gravity-feed, conventional spray-painting gun and a gravity-feed, HVLP spray-painting gun was conducted by repeatedly painting a car body shell.[19] This testing was conducted in a downdraft spray-painting booth located in a spray-painting equipment manufacturer's test facility. The results showed that there was a smaller difference in the transfer efficiency of the two spray-painting guns than was expected based on published estimates of transfer efficiency. The type of spray-painting gun did not affect the solvent concentrations measured in the booth. When the HVLP spray-painting gun was used, there was a factor

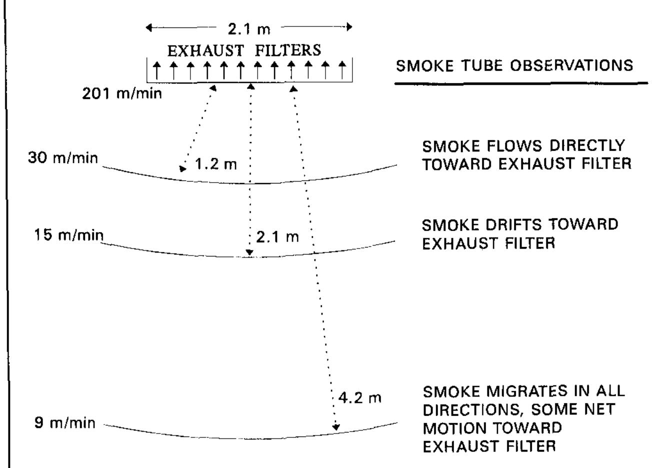

FIGURE 7. Air velocities and observations of smoke motion at the vehicle preparation station when air shower is not in use

of 2 reduction in the particulate overspray concentration and a 30% increase in the ratio of paint film thickness to mass of paint applied. These differences were significant at a level of confidence greater than 95%. In an experimental comparison of HVLP and conventional siphon-feed spray-painting guns, similar concentration differences have been reported.(31) Thus, using an HVLP spray-painting gun can reduce paint usage and overspray production, resulting in noticeably lower worker exposure to particulate overspray.

Respirator Usage

Respirator usage in the shops studied appeared to be inappropriate. Quantitative fit tests were conducted on 15 half-facepiece air purifying respirators and 1 full-facepiece respirator that were used in three of the autobody shops. Five respirators, including the full-facepiece model, had fit factors of less than 10 that were determined from quantitative fit tests. Another five half-facepiece respirators had fit factors between 10 and 100. A fit factor of 100 is the minimum acceptable fit factor for half-facepiece air purifying respirators specified in some OSHA standards.(32–34) These poor fit factors appeared to be due to lack of maintenance. Most of these respirators were in poor shape, with deformed facepieces and respirator straps that were no longer elastic. None of these shops had a formal, written respirator program.

The respirator usage reported here is consistent with information reported elsewhere. In a study of Australian autobody repair workers, only 32% (11 of 34 painters) had half-facepiece air purifying respirators that did not leak.(35) A review of all OSHA citations in the autobody repair industry from January 1983 to September 1993 showed that the second most-cited paragraph from all the OSHA standards was 29 CFR 1910.134B.(36) This is the part of the OSHA respirator standard that specifies minimum requirements for a formal respirator program.

DISCUSSION AND RECOMMENDATIONS

In the autobody repair industry the control of worker exposure to paint overspray requires a comprehensive program involving the proper selection of spray-painting equipment, a properly designed and operated spray-painting booth, and personal protective equipment and program. A 50% reduction in particulate overspray exposure can be obtained by substituting HVLP spray-painting guns for conventional spray-painting guns. Of the three types of spray-painting booths studied, downdraft spray-painting booths appeared to provide the lowest worker exposure to paint overspray. Because overspray can be directed inadvertently toward the worker, respirators are needed. Finally, formal programs involving training and maintenance are needed to ensure that all of this equipment operates properly.

The OSHA ventilation standard for spray painting specifies an air flow of 30 m/min (100 ft/min) for crossdrafts of less than 15 m/min (50 ft/min).(37) This standard applies to all of the booths described in Figure 1. The current ACGIH recommendations for autobody spray-painting ventilation assume a crossdraft spray-painting booth.(38) Unfortunately, the current study found that this type of spray-painting booth contributes to worker overspray exposure. These standards and recommendations need to be revised to provide recommendations for downdraft spray-painting booths used for autobody repainting. The Institut National de Recherche et de Sécurité (INRS) has some specific requirements for the airflow around a car being repainted in a downdraft booth:(39)

> The air velocity around the perimeter of a car is to be measured at 10 points. Three points are on each side of the car and two are next to the front and rear of the car. These measurements are taken 0.5 meters (m) from the side of the car and 0.9 meters above the booth's floor. The mean value of these 10 points is to be greater than 0.4 m/sec (meters/second) and no point is to have a velocity of less than 0.3 m/sec. These measurements are based upon integrated 60 second samples.

Compliance with the INRS standard reportedly minimizes worker exposure to hardeners that contain hexamethylene diisocyanate prepolymers.(4) Booths A and C almost complied with this standard.

In the autobody repair industry, the major air contaminant exposure appears to be to polyisocyanate. Except for the testing conducted at the manufacturer's test facility, all study sites used some surface coatings that contained HDI-based polyisocyanates. During the applications of clear coats the HDI-based polyisocyanates were about one-third of the paint solids by weight. Applying a factor of one-third to the particulate overspray concentrations listed in Table II suggests that the Oregon ceiling limit of 1 mg/m^3 can be exceeded frequently. As mentioned earlier, the reported geometric mean concentrations of polyisocyanates during spray painting in autobody repair shops and in other painting operations involving trucks, aircraft, and railroad rolling stock were between 2 and 3 mg/m^3.(2,12) Because of poor respirator usage in many autobody repair shops, workers may not be adequately protected from polyisocyanate exposure.

CONCLUSIONS

Currently available spray-painting booths do not completely control worker exposure to paint overspray. Particulate paint overspray exposure can be minimized by using HVLP spray-painting guns and downdraft spray-painting booths that comply with INRS recommendations.(39) Downdraft spray-painting booths do a better job of controlling worker exposure to paint overspray than either semidowndraft or crossdraft booths. Based on data collected during this study and on other information sources, respirator usage may be inadequate at many autobody repair shops. As a result spray painters may needlessly be risking adverse health effects due to exposure to HDI-based polyisocyanates and other paint constituents. Thus, the proper use of engineering controls and respirators needs to be encouraged in the autobody repair industry.

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