IN-DEPTH SURVEY REPORT

CONTROL TECHNOLOGY FOR AUTOBODY REPAIR
AND PAINTING SHOPS

AT

Blue Ash Autobody Shop
Blue Ash, Ohio

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SUMMARY

The ability of a spray painting booth and orbital and in-line sanders with high velocity low volume exhaust ventilation was evaluated. Air samples collected in the worker's breathing zone for total dust, organic solvents, chromium, cadmium, titanium dioxide, and hexamethylene diisocyanate monomer were below OSHA permissible exposure limits (PELs) and NIOSH recommended exposure limits (RELs). When spray painting was performed outside of the booth, the breathing zone concentration of this polyisocyanate was estimated to be 10 mg/m³ and a total dust concentration of 30 mg/m³ was measured. Federal OSHA does not have a PEL for polyisocyanates, however, a ceiling limit of 1 mg/m³ is enforced by Oregon OSHA. Spray painting involving isocyanates should not be conducted outside of a properly operated spray painting booth.

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

Because the spray painting booth does not completely control the worker's exposure to paint overspray, respiratory protection is needed. Quantitative fit tests, conducted on the half-facepiece and full-facepiece air-purifying respirators used in this autobody shop, revealed that four of six of these respirators provided a fit factor of less than 100. A fit factor of 5 was obtained with one full-facepiece respirator. To some extent, these low fit factors were caused by lack of a respirator maintenance program. In addition, there appeared to be no respirator program as required by OSHA's respiratory protection standard (29 CFR 1910.134). If the shop owner had understood and complied with the requirements of this OSHA standard, the problems with respirator usage in this shop probably would not have occurred.

The data collected while the workers used sanders with built-in HV/LV ventilation was too limited to develop any definite conclusions about the performance of these sanders. During one sanding operation which lasted about an hour, the total dust exposure measured on the worker's lapel was 0.18 mg/m³. When the ventilation hose was temporarily disconnected, measurements made with an aerosol photometer indicated a noticeable increase in the aerosol concentration.
INTRODUCTION

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

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

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

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

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

SHOP DESCRIPTION

This autobody shop employs eleven workers, four doing body work, two painting cars, two performing housekeeping, and three in the office. The shop, which opened in 1985, repairs 20 to 25 cars per week. The layout of the shop is illustrated in Figure 1. Outside of the painting booth, the cars' structural damage is repaired. This involves the repair and replacement of damaged parts. During these activities, workers may be exposed to aerosols from sanding, grinding, and welding. Some sanding is done with sanders which have built-in high velocity low volume hoods. After the cars are repaired, they are prepared for painting in the vehicle preparation area. This involves some sanding to remove old paint and to provide a smooth surface for the paint.

After the surface has been prepared, the areas of the car which are not to be painted are covered with plastic. Spray painting is done in a downdraft spray painting booth which exhausts a nominal 10,000 cfm while the worker is painting the car. After the car or body part has been painted, the worker leaves the booth and the paint is cured at a temperature of 120° to 140°F. During this time period, the booth airflow is reduced and about 90 percent of the exhaust air is recycled.

Two 5-inch orbital sanders (Hutchins Model 8650, Hutchins Manufacturing Company, Pasadena, California, and Dynorbital® DR™, Dynabrade Automotive Products, Clarence, New York) were used. The sanders are connected to a central vacuum system. Air is exhausted through holes in the sander pads. A metal plate is used as a template to punch holes in the sandpaper which is then attached to these sanders. The sandpaper for the Hutchins sander had six 0.4-inch diameter holes on a circle 1.5 inches from the edge of the sandpaper. The Dynabrade sander had six 0.25-inch diameter holes 1 inch from the edge of the sandpaper. The holes in the sandpaper align with the holes in the sander pads.

A third sander, a Hutchins Model 4290 in-line sander, was also used with the central vacuum system. The abrasive pad of this sander was 2.75 inches wide and 17.5 inches long. Along the length of the sandpaper, two rows of nine equally spaced holes were located 0.5 inches from the edge of the sandpaper. These holes were 0.45 inches in diameter.

The exhaust from these sanders was attached to a vacuum hose. The static pressure in the vacuum line connection to the sanders was 7.5 inches Hg. The vacuum was supplied by a central vacuum system (Sand'N Vac Model 1035, Inventive Machine Corporation, Bolivar, Ohio). Each workstation had an outlet for the central vacuum system.

The spray painting booth (Saico, SPA, Ramsey, New Jersey) was installed when the autobody shop was opened in 1985. This booth is 12.5 feet wide, 24 feet long, and 9 feet high (see Figure 2). Two fans are used in this booth. One fan supplies makeup air through two sets of filters. The first set of filters
Figure 1 Sketch of general layout at Blue Ash Autobody Shop
is located in the ductwork between the fan and the air distribution plenum in the ceiling of the booth. The second set is located after the distribution plenum in the ceiling of the booth. The air flows through these two sets of filters, around the car, and through a third set of filters located in the floor of the booth. This third set of filters was not present during this study due to difficulties in obtaining replacement filters. These filters would have covered the trench in the floor of the spray painting booth. After leaving the booth, the air flowed up a discharge plenum to the roof of the shop. On the roof, the discharge plenum made a 90° turn and discharged the air parallel to the ground. There were no devices for measuring the static pressure in the booth or the pressure drop across the booth's filters. According to the shop owner, the filters in the booth are changed every month. The booth is operated at a static pressure of +0.14 inches of water relative to the shop.

In the spray painting booth, two types of spray painting guns were used to apply paint to cars or car parts: an Optima siphon cup gun (Technical Products Corporation, Lake Zurich, Illinois) and a gravity feed gun (SATA, Ludwigsburg, Germany). One worker used a siphon cup spray painting gun marketed by Optima. In the siphon cup gun, the acceleration of the air through an orifice causes a reduction in static pressure. The reduced static pressure causes the paint to flow from a cup into the orifice where the paint is atomized. In the siphon cup guns, the air pressure at the atomization orifice is typically 55 pounds per square inch (psi). In the gravity feed gun, the paint is contained in a cup on top of the spray painting gun and
gravity assists the flow of paint to the orifice where atomization takes place. The air pressure at the orifice of a gravity feed gun is typically 40 to 50 psi. After the air sampling had been conducted at this shop, the conventional spray painting guns at this shop were replaced with High Volume Low Pressure (HVLP) spray gun painting guns to reduce paint consumption. These guns use less than 10 psi to atomize the paint. Reportedly, the HVLP spray guns are much more efficient at transferring the paint from the gun to the car than the other two types of spray painting guns. HVLP spray painting guns are believed to have a transfer efficiency of at least 65 percent. Some air pollution control districts require the use of spray painting equipment with a transfer efficiency of at least 65 percent.

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

POTENTIAL HAZARDS

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

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

DIISOCYANATES AND THEIR OLIGOMERS

The unique feature of all diisocyanate-based compounds is that they contain two \(-\text{N} = \text{C} = \text{O}\) 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.
Disocyanates are usually referred to by their specific acronym, e.g., IPDI for isophorone diisocyanate, or HDI for hexamethylene diisocyanate. To reduce the inhalation exposure to monomers due to evaporation, the isocyanate monomers are prepolymerized into oligomers that are generally trimers of the monomer. In commercial spray-painting operations, the monomer is usually less than 2 percent paint by weight. However, the oligomers still pose a hazard to the workers as an aerosol during spray painting.

Reports indicate that disocyanates 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. Lung function is reported to decrease with the number of exposures greater than 0.2 mg/m³ to hexamethylene diisocyanate. The most important and most debilitating health effect from exposure to disocyanates is respiratory and dermal sensitization. After sensitization, any exposure, even to levels recognized as safe for the nonsensitized individual, can produce an allergic response that may be life-threatening. The only effective treatment for the sensitized worker is cessation of all disocyanate exposure.

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. Automotive spray painters exposed to organic solvents are reported to have decreases in motor and nerve conduction velocities. In addition, organic solvents such as acetone, toluene, and xylene can cause eye, nose, and throat irritation. Dermal exposure to organic solvents can defat the skin and, thereby, increase the uptake of these solvents by the body. In addition, dermal exposure can cause dermatitis. Some health effects attributed to specific organic solvents encountered in this facility are briefly summarized.

Acetone

Few adverse health effects have been attributed to acetone despite widespread use for many years. Awareness of mild eye irritation occurs at airborne concentrations of about 1000 ppm. Very high concentrations (12,000 ppm) depress the central nervous system, causing headache, drowsiness, weakness, and nausea. Repeated direct skin contact with the liquid acetone may cause redness and dryness of the skin. Exposures over 1000 ppm cause respiratory irritation, coughing, and headache.

n-Butyl Acetate

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

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

Ethyl Acetate

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

Isopropyl Alcohol

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

Trimethyl Benzene

Trimethyl benzene has been reported to cause nervousness, anxiety, and asthmatic bronchitis.

Toluene

Toluene can cause irritation of the eyes and respiratory tract, dermatitis, and central nervous system depression. 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. 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. 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. 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.

METALS

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

Cadmium

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

Chromium

Some paints may contain chromates, hexavalent chromium, as a pigment. These compounds can produce health effects such as contact dermatitis, irritation and ulceration of the nasal mucosa, and perforation of the nasal septum. Hexavalent chromium compounds are suspect carcinogens.

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. 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. 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. Lead exposure is associated with fetal damage in pregnant women. Lastly, elevated blood pressure has been positively related to blood lead levels.

Titanium dioxide

In reviewing the health effects literature on titanium dioxide, ACGIH found no evidence that exposure to titanium dioxide poses a health hazard, as long as the exposure remains below 10 mg/m³. However, NIOSH reviewed animal testing data which indicates that exposure to titanium dioxide involves some risk of cancer.

EXPOSURE EVALUATION CRITERIA

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

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

At the time of this study, OSHA was enforcing the exposure limits listed in Table 1. Most of these exposure limits were revised in a 1989 revision to the Air Contaminants Standard (29 CFR 1910 1000). In July 1992, the 11th Circuit Court of Appeals vacated this standard. OSHA is currently enforcing the version of the Air Contaminants Standard which was in effect before 1989, however, some states operating their own OSHA-approved job safety and health programs will continue to enforce the 1989 limits. OSHA continues to encourage employers to follow the 1989 revisions.

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes and thus, potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

A Time-Weighted Average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits or ceiling values that are intended to supplement the TWA where there are recognized toxic effects from high, short-term exposures.
### Table 1  Occupational exposure limits

<table>
<thead>
<tr>
<th>Substance</th>
<th>NIOSH Recommended Exposure Limit (RKL) (^{13,14})</th>
<th>OSHA Permissible Exposure Limit (PEL) (^{15})</th>
<th>ACGIH Threshold Limit Value (TLV) (^{16})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TWA (^a)</td>
<td>STEL (^c)</td>
<td>TWA (^a)</td>
</tr>
<tr>
<td>Acetone</td>
<td>250 ppm</td>
<td>750 ppm</td>
<td>1000 ppm</td>
</tr>
<tr>
<td>n-Butyl Acetate</td>
<td>150 ppm</td>
<td>150 ppm</td>
<td>200 ppm</td>
</tr>
<tr>
<td>Cadmium (dust)</td>
<td>0.01 mg/m(^3)</td>
<td>0.2 mg/m(^3)</td>
<td>0.6 mg/m(^3) (Ceiling)</td>
</tr>
<tr>
<td>Chromium (VI)</td>
<td>0.001 mg/m(^3)</td>
<td>0.1 mg/m(^3)</td>
<td>0.05 mg/m(^3)</td>
</tr>
<tr>
<td>Chromium (II) compounds</td>
<td>0.5 mg/m(^3)</td>
<td>0.5 mg/m(^3)</td>
<td>0.5 mg/m(^3)</td>
</tr>
<tr>
<td>Chromium (III)</td>
<td>0.05 mg/m(^3)</td>
<td>0.5 mg/m(^3)</td>
<td>0.5 mg/m(^3)</td>
</tr>
<tr>
<td>Ethyl Acetate</td>
<td>400 ppm</td>
<td>400 ppm</td>
<td>400 ppm</td>
</tr>
<tr>
<td>Isopropyl Alcohol</td>
<td>400 ppm (800 ppm Ceiling)</td>
<td>400 ppm</td>
<td>400 ppm (400 ppm Ceiling)</td>
</tr>
<tr>
<td>Hexamethylene diisocyanate (EDI monomer)</td>
<td>0.035 mg/m(^3)</td>
<td>0.14 mg/m(^3)</td>
<td>5 ppm</td>
</tr>
<tr>
<td>Particulate (not otherwise regulated)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Respirable</td>
<td>10 mg/m(^3)</td>
<td>15 mg/m(^3)</td>
<td>10 mg/m(^3)</td>
</tr>
<tr>
<td>Respirable</td>
<td>5 mg/m(^3)</td>
<td>5 mg/m(^3)</td>
<td>5 mg/m(^3)</td>
</tr>
<tr>
<td>Titanium Dioxide</td>
<td>0.2 mg/m(^3)</td>
<td>10 mg/m(^3)</td>
<td>10 mg/m(^3)</td>
</tr>
<tr>
<td>Toluene</td>
<td>100 ppm (200 ppm Ceiling)</td>
<td>100 ppm</td>
<td>100 ppm</td>
</tr>
<tr>
<td>Trimehtyl Benzene</td>
<td>25 ppm</td>
<td>25 ppm</td>
<td>25 ppm</td>
</tr>
<tr>
<td>Xylene</td>
<td>100 ppm (200 ppm Ceiling)</td>
<td>100 ppm</td>
<td>100 ppm</td>
</tr>
</tbody>
</table>

Note: In July 1992, the 11th Circuit Court of Appeals vacated revisions to the OSHA PELs listed in 29 CFR 1910 1000. The OSHA PELs listed in Table 1 were the PELs which were enforced at the time of the study and present PELs may be different.

* TWA - Time-Weighted Average based upon a 10-hour day, 40-hour workweek for a NIOSH Recommended Exposure Limit

\(^{13}\) TWA - 8-hour Time-Weighted Average

\(^{15}\) STEL - Short-Term Exposure Limit
Generally, spray painters are exposed to multiple solvents. To evaluate whether the total solvent exposure is excessive, a combined exposure, $C_e$, is computed

$$C_e = \frac{C_1}{L_1} + \frac{C_2}{L_2} + \ldots + \frac{C_n}{L_n}$$  \hspace{1cm} (1)

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

If the value of $C_e$ is less than 1, the combined exposure is believed to be acceptable.

EXPOSURE LIMITS FOR PREPOLYMERIZED DIISOCYANATES

Although health effects are attributed to prepolymerized diisocyanates, OSHA, NIOSH, and ACGIH have not developed exposure limit values for these substances. 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. 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. In contrast, Sweden has a 5-minute, short-term exposure limit of 0.2 mg/m$^3$ for occupational exposure to hexamethylene diisocyanate biuret.

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

1. An 8-hour time-weighted average of 20 μg/m$^3$, and
2. A 10-minute ceiling limit of 70 μg/m$^3$.

During spray painting operations, occupational exposure to isocyanates frequently exceed these control limits.

EVALUATION PROCEDURES

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

AIR CONTAMINANT EXPOSURE MONITORING

The total dust concentrations were measured using NIOSH Method 0500. In this method, a known volume of air is drawn through a preweighed PVC filter. In the spray painting booth, an air sampling flow rate of 5 liters per minute using a personal sampling pump (Aircheck Sampler, Model 224 -- PCKR7, SKC Inc, Eighty Four, Pennsylvania). During sanding operations, an air sampling flow rate of 13 liters per minute was obtained by using a vacuum pump to maintain an absolute pressure less than 15 inches of mercury downstream of a critical flow orifice. The weight gain of the filter is used to compute the milligrams of particulate per cubic meter of air. After weighing, the filters were analyzed for lead, cadmium, chromium, and titanium. The metals on each filter were solubilized using a modification of NIOSH Method 7300. Each filter was placed in a 125-mL beaker and then 1 mL of perchloric acid and 4 mL of nitric acid were added. The beakers were placed on a hot plate and heated to approximately 150°C and the sample volume was reduced to nearly 0.5 mL. The samples were quantitatively transferred to a 10-mL volumetric flask, diluted to 10 mL, and then were analyzed by a simultaneous-scanning, inductively coupled plasma emission spectrometer.

Material safety data sheets were used to identify the major organic solvents which may be present during spray painting. Concentration measurements were made for methyl ethyl ketone, toluene, xylene, and n-butyl acetate. The measurements were made by placing charcoal tubes (SKC Lot 120) in a charcoal tube holder and mounting the charcoal tube holder on the worker. Tubing connected the outlet of the charcoal tube holder to a personal sampler pump (Model 200, DuPont Inc) that draws air through the charcoal tube at 200 cm³/min. The collected solvents were desorbed from the charcoal using carbon disulfide and the solvents were quantitated using a gas chromatograph equipped with a flame ionization detector. NIOSH Method 1401 was used for the analysis with the following modifications:

<table>
<thead>
<tr>
<th>Desorption Process</th>
<th>Thirty minutes in 10 mL of carbon disulfide with 0.5 µL ethyl benzene/mL CS₂ as an internal standard and 1 percent n-propyl alcohol as a desorbing aid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Chromatograph</td>
<td>Hewlett-Packard Model 5890 equipped with a flame ionization detector</td>
</tr>
<tr>
<td>Column</td>
<td>30 m x 0.32 mm fused silica capillary coated, internally with 0.5 µm of DB-WAX</td>
</tr>
<tr>
<td>Oven Conditions</td>
<td>Temperature programming from 40°C to 120°C at a rate of 4°C/minute</td>
</tr>
</tbody>
</table>

During spray painting operations involving the use of isocyanate hardeners, the concentrations of hexamethylene disiocyanate and its isocyanurate trimer were measured by using NIOSH Method 5521. In this method, air samples are...
bubbled through an impinger at a sampling rate of 1 liter per minute. The impinger contains a solution of 1-(2-methoxyphenyl)piperazine, which reacts with the isocyanate to form ureas, in toluene. The concentration of this solution is 43 mg/L. The ureas are quantitated by high pressure liquid chromatography operated with a UV or electrochemical detector. Because analytical standards are not available for trimers of diisocyanate monomers, this method extrapolates the calibration curve for the hexamethylene diisocyanate monomer to the prepolymer which, according to the material safety data sheet, is the isocyanurate trimer of HDI (CAS NO 28182-81-2). The results of NIOSH Method 5521 are reported in terms of mass of isocyanate group per unit volume (μg NCO/μm³).

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

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

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

2. On the side of the spray painting booth, and

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

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

VIDEO EXPOSURE MONITORING

Video exposure monitoring was used to study in greater detail how specific tasks affect the workers' exposure to air contaminants. Worker exposures were monitored with a direct-reading instrument, and its analog output was recorded with a data logger. Workplace activities were simultaneously recorded on videotape. The analog output of the real-time instruments was connected to a data logger (Rustrak Ranger, Gulton, Inc., East Greenwich, Rhode Island). When the data collection was completed, the data
logger was downloaded to a portable computer (Compaq Portable III, Compaq
Computer Corporation, Houston, Texas) for analysis.

During sanding operations, the Hand-held Aerosol Monitor (HAM, PPM Inc,
Knoxville, Kentucky) was used to measure relative air contaminant
concentrations. The aerosol scatters the light emitted from a light-emitting
diode. The scattered light is detected by a photomultiplier tube. The analog
output of the HAM is proportional to the quantity of the scattered light
detected by a photomultiplier tube. Because the calibration of the HAM varies
with aerosol properties such as refractive index and particle size, the analog
output of the HAM is viewed as a measure of relative concentration. A
personal sampling pump (Aircheck, SEK Inc, Eighty Four, Pennsylvania) was
used to draw air through the HAM's sensing chamber at a rate of 3.5 lpm.

During spray painting, a Photovac TIP II (PROTOVAC Inc, Thornhill, Ontario)
was used to monitor worker solvent concentrations on the worker. The analog
output of the Microtip is proportional to the concentration of ionizable
compounds in the air. Because the instrument's response varies with the
composition of the organic solvents in the air, this instrument also is used
as a measure of relative concentration. Because of fire safety
considerations, this instrument was located outside of the spray painting
booth. Teflon® tubing (0.125-inch inside diameter, 45 feet long, Alltech
Associates, Deerfield, Illinois) was attached to the worker in his breathing
zone. A personal sampler pump drew air through this tubing at 3.5 liters per
minute and exhausted the sampled air into a glass tee. The Photovac then
sampled the air in this glass tee.

VENTILATION MEASUREMENTS

The exhaust flow rates from the ventilated sanders were measured in the
apparatus illustrated in Figure 3. The exhaust flow rate was measured when
the sanders were off, when they were on (but not sanding), and when they were
sanding metal located on the floor of the apparatus. The air velocity in the
exhaust duct was measured using a hot wire anemometer (Model 1040 Digital Air
Velocity Meter, Kurs, Carmel Valley, California). The exhaust flow rate was
calculated as the product of the duct's cross-sectional area and the average
velocity in the exhaust duct.

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

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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 649394, St. Paul, Minnesota 55164) was utilized to test all respirators. The Portacount™ is based on a miniature, continuous-flow condensation nucleus counter (CNC). A CNC takes particles that are too small to be easily detected, grows them to a larger, easily detectable size, and then counts them. 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. 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:

\[
\text{Overall FF} = 6/\left(1/\text{NB1}_n + 1/\text{DB}_n + 1/\text{SS}_n + 1/\text{UD}_n + 1/\text{TK}_n + 1/\text{NB2}_n\right)
\]

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

RESULTS

VENTILATION MEASUREMENTS

Table 2 lists the exhaust flow rates measured for the ventilated sanders. Because the compressed air used to drive these sanders is exhausted through the sander's exhaust port, net exhaust ventilation rates decrease somewhat when the sanders are in use.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Dynaorbita Circular (6-hole)</th>
<th>Hutchins In-Line (18-hole)</th>
<th>Hutchins Circular (6-hole)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sander running without touching bottom of box</td>
<td>14</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>Light sanding</td>
<td>13</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>Heavy sanding</td>
<td>15</td>
<td>19</td>
<td>14</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Location of Exhaust Volume Measurement</th>
<th>Instrument</th>
<th>Exhaust Volume (cfm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air intake on roof</td>
<td>anemometer</td>
<td>8125</td>
</tr>
<tr>
<td>Airflow from filters in ceiling</td>
<td>balometer</td>
<td>6780</td>
</tr>
<tr>
<td>Airflow exhausted through filters in floor</td>
<td>anemometer</td>
<td>6700</td>
</tr>
</tbody>
</table>
Figure 4 contains the airflow measurements through the filters in the ceiling of the spray painting booth. These measurements indicated that the flow through the filters in the ceiling was uniform. In the balometer, the flow contracts from a 6-square-foot area to a 14- by 14-inch area. This restriction in the flow may cause some of the air to flow around the balometer, resulting in a low measurement of the total exhaust volume.

![Diagram of airflow through filters in ceiling of spray painting booth]

**Figure 4** Airflow through filters in ceiling of spray painting booth

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

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

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

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

Table 4  Summary of total dust concentrations during spray painting

<table>
<thead>
<tr>
<th>Location</th>
<th>Number of Samples</th>
<th>Geometric Mean (GM) (mg/m³)</th>
<th>Geometric Standard Deviation (GSD)</th>
<th>Range (mg/m³)</th>
<th>Grouping*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Painter</td>
<td>6</td>
<td>6.2</td>
<td>2.0</td>
<td>2.3 - 17</td>
<td>B</td>
</tr>
<tr>
<td>Under car**</td>
<td>5</td>
<td>45</td>
<td>2.6</td>
<td>13 - 200</td>
<td>A</td>
</tr>
<tr>
<td>Wall</td>
<td>5</td>
<td>12</td>
<td>3.1</td>
<td>2.8 - 47</td>
<td>AB</td>
</tr>
</tbody>
</table>

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

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

Table 5  Summary of isocyanate concentrations

<table>
<thead>
<tr>
<th>Sample Location</th>
<th>Hardener Concentration Based Upon Bulk Sample of BASF 923-73</th>
<th>Total Isocyanate Concentration via NIOSH Method 5521</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GM mg/m³          GSD  Range</td>
<td>n  CM μg NCO/m³ GSD  Range μg NCO/m³</td>
</tr>
<tr>
<td>Personal</td>
<td>3  1.5             4.0  0.8-7.89</td>
<td>3  690  1.5  330-910</td>
</tr>
<tr>
<td>Under Car</td>
<td>4  29              1.9  9.0-40</td>
<td>4  1200  1.3  890-1500</td>
</tr>
<tr>
<td>Outside Booth</td>
<td>1  38              -</td>
<td>1  4400  -</td>
</tr>
</tbody>
</table>

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Table 6  Summary of personal solvent exposures

<table>
<thead>
<tr>
<th>Description of Activities During Personal Sampling</th>
<th>Date</th>
<th>Sample Start Time</th>
<th>Sample Stop Time</th>
<th>C&lt;sub&gt;t&lt;/sub&gt;*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Painting side of car on well-ventilated side of spray painting booth using a gravity feed gun</td>
<td>1/28/92</td>
<td>12 55</td>
<td>13 12</td>
<td>0.01</td>
</tr>
<tr>
<td>Painting side of car on well-ventilated side of spray painting booth using a gravity feed gun</td>
<td>1/28/92</td>
<td>14 13</td>
<td>14 52</td>
<td>0.07</td>
</tr>
<tr>
<td>Painting hood of car at front of booth with a gravity feed spray painting gun</td>
<td>1/31/92</td>
<td>7 32</td>
<td>8 04</td>
<td>0.09</td>
</tr>
<tr>
<td>Painting two front fenders, hood, and a bumper with a siphon cup spray painting gun</td>
<td>2/4/92</td>
<td>11 40</td>
<td>12 08</td>
<td>0.09</td>
</tr>
<tr>
<td>Painting both sides of car, hood, and parts which were not attached to the car with a siphon cup spray painting gun</td>
<td>1/31/92</td>
<td>10 20</td>
<td>11 50</td>
<td>0.38</td>
</tr>
<tr>
<td>Painting two front fenders, hood, and a bumper with a siphon cup spray painting gun</td>
<td>2/4/92</td>
<td>12 39</td>
<td>13 13</td>
<td>0.03</td>
</tr>
</tbody>
</table>

* See Equation 1, Page 10

Total Dust Concentrations

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

The statistical analysis, summarized in Appendix B, showed that sampling location and type of spray painting gun affected the total dust concentration in the spray painting booth. The column labelled "Grouping" in Table 4 presents the results of a multiple comparison test which evaluates all the possible differences between the sampling locations. During spray painting, the worker actually stands between the car and wall in a space which has stagnant airflow (see Figure 6). Since the geometric mean for the concentration measured on the worker and the geometric mean for the area sample collected next to the wall did not differ significantly, at least some of the overspray accumulates in the area where the worker stands. The fact that the concentration under the car was much higher than these other two measurements indicates that much of the air overspray leaves the spray painting booth without contaminating the worker's breathing zone.
The statistical analysis also indicated that the type of spray painting gun had an effect upon total dust concentrations. As illustrated in Figure 7, the use of the gravity feed spray painting gun was associated with mean concentrations which were nearly a factor of four lower than the concentrations measured when the siphon cup spray painting guns were used. Whether this difference in concentration is solely attributable to the change in spray painting guns is unclear. The guns were used by two different workers. Furthermore, the worker who used the gravity feed spray painting gun painted only on the side of the booth which had a greater airflow. Thus, the effects of spray painting gun, worker, and side of the booth are confounded.

Isocyanates

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

![Figure 7](image-url)  
Figure 7  Effect of spray painting gun and location upon geometric mean particulate concentrations
field samples. The source and identities of other peaks are unknown. Inspection of the material safety data sheets for the clear coat and the hardener suggested that other organic compounds could have caused the UV detector response. Organic solvents used as diluents for the hardener are also used as diluents in the clear coat. Possibly, the diluents used in the clear coat interfered with the analysis for the hardener.

Solvent Concentrations

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

Metals

Metal concentrations are listed in Table A1 of Appendix A. Lead and cadmium were not detected on any of the samples. The detection limits for lead and cadmium were 1 and 0.1 micrograms (μg) per filter, respectively. Chromium was detected on some of the samples at levels at or just above the detection limit of 0.3 μg. The maximum amount of chromium detected on a filter was 0.4 μg. The limit of detection for titanium was 0.2 μg.

As described in Table 1, exposure limits for chromium vary with its valence. Information from the material safety data sheets indicated that only chromium (III) should be present during painting operations. The chromium compounds listed in the material safety data sheets were chrome oxide green (CAS No. 1308-38-9) and a chrome-antimony-titanium buff-rutile (CAS No. 68186-90-3). The latter substance is described by the American Chemical Society (ACS) as an inorganic pigment that is the reaction product of a high temperature calcination in which titanium oxide, chromium (III) oxide, and antimony oxide are homogeneously and ionically interdiffused to form a crystalline structure of rutile. This suggests that during painting operations, the chromium concentrations measured on the worker were below NIOSH RELs. During sanding operations, a chromium concentration of 0.4 μg/m³ was measured on the worker (Appendix A, Table A1). The valence of this chromium is unknown. However, the concentration is below the NIOSH recommended exposure limit of 1 μg/m³ for chromium (VI) compounds. The chromium concentrations measured on the worker appeared to be below NIOSH recommended exposure limits.

The material safety data sheets for the base coats used in this autobody shop list titanium dioxide as a component. Thus, the titanium found on the samples is assumed to be titanium dioxide. One titanium concentration measured on the worker was 300 μg/m³. Based upon the ratio of the molecular weights of titanium dioxide to the atomic weight of titanium, this concentration measurement corresponds to a titanium dioxide concentration of 0.5 mg/m³. The other concentration measurements made on the worker resulted in titanium dioxide concentrations which were less than 37 μg/m³ of titanium, which corresponds to a titanium dioxide concentration of 0.076 mg/m³ of titanium dioxide. Because these concentrations are based upon short-term samples, the worker's 8-hour time-weighted average exposure to titanium dioxide would be less than 0.2 mg/m³, which is specified by the NIOSH recommended exposure limit for titanium dioxide.
Spray Painting Outside of the Spray Painting Booth

When spray painting was conducted outside of the spray painting booth, a short-term dust concentration of over 30 mg/m² was measured on the worker. The material safety data sheet indicates that the hardener is 60 to 70 percent volatile organic compounds and about 25 to 35 percent isocyanurate of HDI. The material safety data sheet indicated that the clear had a volatility of 60 to 70 percent. The ratio of clear to hardener was 2:1. From this information, the exposure to isocyanurate of HDI was estimated to be about 10 mg/m³. Because of random air currents in the body shop, the overspray, which contains isocyanates, may be dispersed throughout the shop. Thus, all workers in this shop have a potential exposure to isocyanates when spray painting is done outside of a spray painting booth. Thus, spray painting outside of a spray painting booth with isocyanates should not be tolerated.

VIDEO EXPOSURE MONITORING IN SPRAY PAINTING BOOTH

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

Video Exposure Monitoring During Sanding

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

RESPIRATOR EVALUATION

The results of the respirator fit tests are presented in Table 7. In this shop, the workers used half- or full-facepiece air-purifying respirators with paint mist filters and organic vapor cartridges. Four out of six original
Figure 8  Summary of relative exposures during two different time periods

Figure 9  Response of HAM to aerosol concentration while sanding with a Dynasorbital sander on the side and roof of a car
Table 7  Comparison of fit factors with old and new full- and half-facepiece air-purifying respirators

<table>
<thead>
<tr>
<th>Worker Tested</th>
<th>Fit Factor Obtained With Worker's Original Respirator</th>
<th>Fit Factor With New Respirator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worker #1</td>
<td>5*</td>
<td>4125*</td>
</tr>
<tr>
<td>Worker #2</td>
<td>37</td>
<td>9916</td>
</tr>
<tr>
<td>Worker #3</td>
<td>93</td>
<td>3575</td>
</tr>
<tr>
<td>Worker #4</td>
<td>638</td>
<td>9632</td>
</tr>
<tr>
<td>Worker #5</td>
<td>144</td>
<td>32811</td>
</tr>
<tr>
<td>Worker #6</td>
<td>74</td>
<td>5431</td>
</tr>
</tbody>
</table>

* Full-facepiece, others are half-facepiece respirators

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

Table 8  Summary of observed defects in the six inspected respirators

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

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DISCUSSION AND RECOMMENDATIONS

The ventilated orbital sanders appear to provide dust control during sanding operations. The dust concentrations measured on the workers, reported in Appendix A, indicate that dust exposures during the two sanding operations were 1.25 and 0.18 mg/m³, which is below the OSHA PEL of 15 mg/m³ for total dust. The first dust measurement involved hand sanding, the use of an in-line Hutchinson sander, and the use of compressed air to blow dust off of the car. The second measurement was taken when a Dynabrade sander was used to sand a replacement door prior to painting. The measurements taken with the HAM indicate that the ventilated sander does reduce the total dust concentration measured near the worker’s lapel during sanding. However, because the ventilated sanders are used very infrequently, the results from all of the field evaluations of ventilated sanders will need to be combined to generate conclusive recommendations for controlling dust generated during sanding operations.

Total dust concentrations measured on the painters in this spray painting booth are somewhat higher than measurements made in other facilities in this study. Some of the isocyanate concentrations measured near the worker’s lapel during spray painting operations are estimated to have exceeded 1.0 mg/m³ (the ceiling limit enforced in Oregon). Thus, worker exposure to paint overspray and isocyanate exposure needs to be minimized through the proper use of the spray painting booth and respirators. Spray painting involving isocyanates should not be permitted outside of a spray painting booth. There is simply too much risk of inadvertently exposing others to a relatively high concentration of isocyanate prepolymers.

SPRAY PAINTING BOOTH VENTILATION

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

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

Generally, airflow recommendations for controlling occupational exposure to air contaminants can be obtained by reviewing the ACGIH publication on ventilation manual and OSHA standards. Unfortunately, OSHA and ACGIH airflow recommendations for spray painting booths address only crossdraft spray painting booths. The OSHA recommendation is contained in an OSHA standard which assumes that the spray painting booth has a crossdraft ventilation at a rate of 100 feet per minute per square foot of cross-sectional area. Although this booth does not comply with this standard, OSHA generally does not enforce this standard unless there is a violation of current OSHA standards for air contaminants. There is a French standard for downdraft spray painting booths which is reported to greatly minimize worker exposure to isocyanates during spray painting in autobody repair shops. This standard has some very specific specifications on the flow of air around a car.

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

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

**RESPIRATOR USAGE**

The quantitative fit test results (in Table 7) indicate that the respirators, which were used by the workers, did not adequately seal against the worker's face or were poorly maintained. Table 7 shows that fit factors for four of the six respirators tested are below the NIOSH-recommended fit factor for half masks of 100 and 500 for full-face respirators. In addition, OSHA standards for asbestos, benzene, and formaldehyde require that fit factors be a factor of 10 higher than the assigned protection factors. The assigned protection factor for full-facepiece, air-purifying respirators is 100 and for half-facepiece, air-purifying respirators, this factor is 10. When the body shop workers were provided with new respirators of their choice, and were instructed in proper donning techniques, fit factors increased substantially. Inspection of the respirators tested indicated that one of the reasons for these low fit factors was poor respirator maintenance (see Table 8). Lack of training was also a contributing factor.
This autobody shop, like every other autobody shop in this study, did not have a formal respirator program in place. The OSHA respirator standard (29 CFR 1910.134), which is reproduced in Appendix C, requires that

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

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

1. Written standard operating procedures for selection and use of respirators
2. Selection of respirators according to hazard
3. Training in the use and limitations of respirators
4. Respirator cleaning and disinfection
5. Proper selection for respirators
6. Routine inspection and maintenance
7. Workplace exposure monitoring
8. Evaluation of program effectiveness
9. Medical monitoring
10. Use of certified respirators

PROTECTIVE CLOTHING

Material safety data sheets for the polyisocyanates used in this shop indicate that these isocyanates can cause skin irritation and a sensitization reaction. Thus, eye and skin contact should be avoided. Eye and skin protection should be worn when handling isocyanates. A manufacturer of HDI-based polyisocyanates recommends the use of butyl rubber gloves for handling solutions containing these polyisocyanates.

CONCLUSIONS

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

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APPENDIX A

LISTINGS OF THE CONCENTRATION MEASUREMENTS
<table>
<thead>
<tr>
<th>Description of Activity</th>
<th>Sample Location</th>
<th>Date</th>
<th>Sample Start Time</th>
<th>Sample Stop Time</th>
<th>Painting Duration (min)</th>
<th>Total dust Conc (mg/m²)</th>
<th>Chromium Conc (µg/m³)</th>
<th>Titanium Conc (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1 Painting side of car on well-ventilated side of spray painting booth using a gravity feed spray painting gun</td>
<td>under car</td>
<td>01/28/92</td>
<td>12 55</td>
<td>13 12</td>
<td>17</td>
<td>0.47</td>
<td>4.71</td>
<td>6.71</td>
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<td>worker</td>
<td>01/28/92</td>
<td>12 55</td>
<td>13 12</td>
<td>17</td>
<td>2.35</td>
<td>&lt; 3.53</td>
<td>2.35</td>
</tr>
<tr>
<td></td>
<td>next to wall</td>
<td>01/28/92</td>
<td>12 55</td>
<td>13 12</td>
<td>17</td>
<td>2.82</td>
<td>3.53</td>
<td>7.06</td>
</tr>
<tr>
<td>P2 Painting side of car on well-ventilated side of spray painting booth using a gravity feed spray painting gun</td>
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<td>01/31/92</td>
<td>14 14</td>
<td>14 53</td>
<td>11</td>
<td>42.3</td>
<td>5.45</td>
<td>&lt; 3.56</td>
</tr>
<tr>
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<td>worker</td>
<td>01/31/92</td>
<td>14 14</td>
<td>14 53</td>
<td>11</td>
<td>4.72</td>
<td>&lt; 5.43</td>
<td>7.27</td>
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<td>P3 Painting hood of car at front of booth with a gravity feed spray painting gun</td>
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<td>01/31/92</td>
<td>07 09</td>
<td>08 20</td>
<td>30</td>
<td>13.5</td>
<td>&lt; 2.00</td>
<td>&lt; 1.33</td>
</tr>
<tr>
<td></td>
<td>worker</td>
<td>01/31/92</td>
<td>07 09</td>
<td>08 20</td>
<td>30</td>
<td>5.53</td>
<td>&lt; 2.00</td>
<td>&lt; 1.33</td>
</tr>
<tr>
<td></td>
<td>next to wall</td>
<td>01/31/92</td>
<td>07 15</td>
<td>08 20</td>
<td>30</td>
<td>7.13</td>
<td>2.00</td>
<td>&lt; 1.33</td>
</tr>
<tr>
<td>P4 Spray painting hood outside of shop with siphon cup gun</td>
<td>worker</td>
<td>01/31/92</td>
<td>08 06</td>
<td>08 12</td>
<td>6</td>
<td>30.67</td>
<td>&lt; 10.00</td>
<td>&lt; 6.87</td>
</tr>
<tr>
<td>P5 Painting both sides of car, hood, and parts which were not attached to the car spray painting done with a siphon spray painting gun</td>
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<td>01/31/92</td>
<td>10 58</td>
<td>12 00</td>
<td>38</td>
<td>37.7</td>
<td>&lt; 1.58</td>
<td>&lt; 1.05</td>
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<td>worker</td>
<td>01/31/92</td>
<td>10 20</td>
<td>11 50</td>
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<td>17.77</td>
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<tr>
<td></td>
<td>next to wall</td>
<td>01/31/92</td>
<td>10 56</td>
<td>11 59</td>
<td>38</td>
<td>33.2</td>
<td>2.11</td>
<td>691.58</td>
</tr>
<tr>
<td>P6 Painting two front fenders, hood, and a bumper with a siphon cup spray painting gun</td>
<td>under car</td>
<td>02/04/92</td>
<td>11 40</td>
<td>12 04</td>
<td>19</td>
<td>46.61</td>
<td>&lt; 3.16</td>
<td>37.83</td>
</tr>
<tr>
<td></td>
<td>worker</td>
<td>02/04/92</td>
<td>11 40</td>
<td>12 04</td>
<td>19</td>
<td>11.03</td>
<td>3.16</td>
<td>7.37</td>
</tr>
<tr>
<td></td>
<td>next to wall</td>
<td>02/04/92</td>
<td>11 40</td>
<td>12 05</td>
<td>19</td>
<td>10.45</td>
<td>&lt; 3.16</td>
<td>4.21</td>
</tr>
<tr>
<td>P7 Painting two front fenders, hood, and a bumper with a siphon cup spray painting gun</td>
<td>under car</td>
<td>02/04/92</td>
<td>12 24</td>
<td>13 14</td>
<td>10</td>
<td>29.2</td>
<td>6.00</td>
<td>&lt; 4.00</td>
</tr>
<tr>
<td></td>
<td>worker</td>
<td>02/04/92</td>
<td>12 24</td>
<td>13 14</td>
<td>10</td>
<td>5.2</td>
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<td>&lt; 4.00</td>
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<tr>
<td></td>
<td>next to wall</td>
<td>02/04/92</td>
<td>12 24</td>
<td>13 14</td>
<td>10</td>
<td>4.74</td>
<td>&lt; 6.00</td>
<td>&lt; 4.00</td>
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<tr>
<td>S1 Sanding body filler with Hutchion in-line sander hand sanding, and using compressed air to blow dust off car</td>
<td>area</td>
<td>12/23/91</td>
<td>19 06</td>
<td>19 15</td>
<td>69</td>
<td>1.163</td>
<td>0.33</td>
<td>2.01</td>
</tr>
<tr>
<td></td>
<td>worker</td>
<td>12/23/91</td>
<td>19 06</td>
<td>19 15</td>
<td>69</td>
<td>1.25</td>
<td>0.56</td>
<td>&lt; 0.22</td>
</tr>
<tr>
<td>S2 Sanding a door panel with a rotating sander (Dynabrade)</td>
<td>area</td>
<td>01/09/92</td>
<td>19 55</td>
<td>19 16</td>
<td>60</td>
<td>0.16</td>
<td>&lt; 0.38</td>
<td>1.03</td>
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<td></td>
<td>worker</td>
<td>01/09/92</td>
<td>19 55</td>
<td>19 16</td>
<td>60</td>
<td>0.18</td>
<td>&lt; 0.39</td>
<td>1.24</td>
</tr>
<tr>
<td>Description of Activity</td>
<td>Sample Location</td>
<td>Date</td>
<td>Sample Start Time</td>
<td>Sample Stop Time</td>
<td>OSHA 929-73 (ug/m³)</td>
<td>HDI Prepolymers Method (μg NCO/m³)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------------------------------------------</td>
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<td>------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Painting side of car on well-ventilated side of spray painting booth using a gravity feed spray painting gun</td>
<td>worker</td>
<td>01/28/92</td>
<td>13 52</td>
<td>14 13</td>
<td>&lt; 0.83</td>
<td>916</td>
<td></td>
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<tr>
<td></td>
<td>under car</td>
<td>01/28/92</td>
<td>13 52</td>
<td>14 13</td>
<td>24 1</td>
<td>1541</td>
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<tr>
<td>Painting hood of car at front of booth with a gravity feed spray painting gun</td>
<td>worker</td>
<td>01/31/92</td>
<td>lost</td>
<td>lost</td>
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</tr>
<tr>
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<td>under car</td>
<td>01/31/92</td>
<td>07 32</td>
<td>08 04</td>
<td>11 25</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Spray painting hood outside of booth with a siphon cup gun</td>
<td>worker</td>
<td>01/31/92</td>
<td>08 06</td>
<td>08 12</td>
<td>38 3</td>
<td>4333</td>
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<tr>
<td>Painting both sides of car, hood, and parts which were not attached to the car</td>
<td>worker</td>
<td>01/31/92</td>
<td>11 11</td>
<td>11 50</td>
<td>7 89</td>
<td>894</td>
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<tr>
<td>Spray painting done with a siphon spray painting gun</td>
<td>under car</td>
<td>01/31/92</td>
<td>11 11</td>
<td>11 50</td>
<td>24 2</td>
<td>894</td>
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<tr>
<td>Painting two front fenders, hood and a bumper with a siphon cup spray painting gun</td>
<td>worker</td>
<td>02/04/92</td>
<td>12 39</td>
<td>13 13</td>
<td>2 25</td>
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<tr>
<td></td>
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<td>02/04/92</td>
<td>12 39</td>
<td>13 13</td>
<td>40 6</td>
<td>1300</td>
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<tr>
<td>Description of Activity</td>
<td>Sample Location</td>
<td>Date</td>
<td>Sample Time (min)</td>
<td>Sample Rate (1/min)</td>
<td>Sampling times</td>
<td>Painting Duration (min)</td>
<td>Solvent Concentration (ppm)</td>
<td>Combined Solvent Exposure (ppm)</td>
</tr>
<tr>
<td>-------------------------</td>
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<td>-------------------------------</td>
</tr>
<tr>
<td>Painting side of car on</td>
<td>Wall</td>
<td>1/28/92</td>
<td>17</td>
<td>0 2</td>
<td>12 55</td>
<td>13 12</td>
<td>16</td>
<td>1          NA             NA</td>
</tr>
<tr>
<td>well-ventilated side of</td>
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<td>17</td>
<td>0 2</td>
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<td>13 12</td>
<td>16</td>
<td>1          NA             NA</td>
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<td>1/28/92</td>
<td>17</td>
<td>0 2</td>
<td>12 55</td>
<td>13 12</td>
<td>16</td>
<td>10         NA             NA</td>
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<td>using a gravity feed</td>
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<td>Painting side of car on</td>
<td>Wall</td>
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<td>34</td>
<td>0 2</td>
<td>13 46</td>
<td>14 20</td>
<td>11</td>
<td>17 0.7     LT 0.8         LT 0.3</td>
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<td>well-ventilated side of</td>
<td>Personal</td>
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<td>34</td>
<td>0 2</td>
<td>13 46</td>
<td>14 20</td>
<td>11</td>
<td>17 0.7     6              LT 0.4</td>
</tr>
<tr>
<td>spray painting booth</td>
<td>Under Car</td>
<td>1/28/92</td>
<td>34</td>
<td>0 2</td>
<td>13 46</td>
<td>14 20</td>
<td>11</td>
<td>15         LT 0.8         33</td>
</tr>
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<td>using a gravity feed</td>
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<td>gun</td>
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<td></td>
<td></td>
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<tr>
<td>Painting hood of car at</td>
<td>Wall</td>
<td>1/31/92</td>
<td>65</td>
<td>0 2</td>
<td>7 13</td>
<td>8 20</td>
<td>30</td>
<td>3          7              3</td>
</tr>
<tr>
<td>front of booth with a</td>
<td>Personal</td>
<td>1/31/92</td>
<td>32</td>
<td>0 2</td>
<td>7 32</td>
<td>8 04</td>
<td>30</td>
<td>2          4              4</td>
</tr>
<tr>
<td>gravity feed spray</td>
<td>Under Car</td>
<td>1/31/92</td>
<td>69</td>
<td>0 2</td>
<td>7 09</td>
<td>8 18</td>
<td>30</td>
<td>20         20             18</td>
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<td>painting gun</td>
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<td></td>
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<tr>
<td>Painting two front</td>
<td>Wall</td>
<td>1/31/92</td>
<td>69</td>
<td>0 2</td>
<td>7 09</td>
<td>8 18</td>
<td>30</td>
<td>10         49             10</td>
</tr>
<tr>
<td>fenders, hood, and a</td>
<td>Under Car</td>
<td>1/31/92</td>
<td>70</td>
<td>0 2</td>
<td>7 09</td>
<td>8 18</td>
<td>30</td>
<td>10         41             10</td>
</tr>
<tr>
<td>bumper with a naphex cup</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>spray painting gun</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

39
<table>
<thead>
<tr>
<th>Description of Activity</th>
<th>Sample Location</th>
<th>Date</th>
<th>Sample Time (min)</th>
<th>Sample Rate (L/min)</th>
<th>Sampling times</th>
<th>Painting Duration (min)</th>
<th>Solvent Concentration (ppm)</th>
<th>Combined Solvent Exposure (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Painting both sides of car, hood and parts which were not attached to the car. Spray</td>
<td>Wall</td>
<td>1/31/92</td>
<td>93</td>
<td>0.2</td>
<td>10 56</td>
<td>11 59</td>
<td>Xylene: 12, Column: 15, Butyl Acetate: 15, Ethyl Acetate: 24</td>
<td>0.40</td>
</tr>
<tr>
<td>painting done with a siphon cup gun</td>
<td>Personal</td>
<td>1/31/92</td>
<td>90</td>
<td>0.2</td>
<td>10 56</td>
<td>11 59</td>
<td>Xylene: 8, Column: 21, Butyl Acetate: 16, Ethyl Acetate: 17</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>Under Car</td>
<td>1/31/92</td>
<td>93</td>
<td>0.2</td>
<td>10 56</td>
<td>11 59</td>
<td>Xylene: 12, Column: 13, Butyl Acetate: 16, Ethyl Acetate: 22</td>
<td>0.38</td>
</tr>
<tr>
<td>under Car</td>
<td>1/31/92</td>
<td>90</td>
<td>0.2</td>
<td>10 56</td>
<td>11 58</td>
<td>61</td>
<td>Xylene: 12, Column: 15, Butyl Acetate: 17, Ethyl Acetate: 19</td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td>Under Car</td>
<td>1/31/92</td>
<td>93</td>
<td>0.2</td>
<td>10 57</td>
<td>11 57</td>
<td>Xylene: 12, Column: 13, Butyl Acetate: 16, Ethyl Acetate: 21</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td>Under Car</td>
<td>1/31/92</td>
<td>90</td>
<td>0.2</td>
<td>10 57</td>
<td>11 57</td>
<td>Xylene: 13, Column: 17, Butyl Acetate: 18, Ethyl Acetate: 24</td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td>Under Car</td>
<td>1/31/92</td>
<td>90</td>
<td>0.2</td>
<td>10 56</td>
<td>11 56</td>
<td>Xylene: 13, Column: 15, Butyl Acetate: 18, Ethyl Acetate: 24</td>
<td>0.43</td>
</tr>
<tr>
<td>Painting two front fenders, hood, and a bumper with a siphon cup spray painting gun</td>
<td>Wall</td>
<td>2/4/92</td>
<td>50</td>
<td>0.2</td>
<td>12 39</td>
<td>13 29</td>
<td>Xylene: 6, Column: 15, Butyl Acetate: 8, Ethyl Acetate: 10</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>Personal</td>
<td>2/4/92</td>
<td>33</td>
<td>0.2</td>
<td>12 39</td>
<td>13 13</td>
<td>Xylene: 6, Column: 7, Butyl Acetate: 2, Ethyl Acetate: 10</td>
<td>0.03</td>
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<tr>
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<td>Under Car</td>
<td>2/4/92</td>
<td>50</td>
<td>0.2</td>
<td>12 39</td>
<td>13 29</td>
<td>Xylene: 25, Column: 5, Butyl Acetate: 32, Ethyl Acetate: 31</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>Under Car</td>
<td>2/4/92</td>
<td>50</td>
<td>0.2</td>
<td>12 39</td>
<td>13 29</td>
<td>Xylene: 29, Column: 5, Butyl Acetate: 46, Ethyl Acetate: 46</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>Under Car</td>
<td>2/4/92</td>
<td>50</td>
<td>0.2</td>
<td>12 39</td>
<td>13 29</td>
<td>Xylene: 22, Column: 5, Butyl Acetate: 46, Ethyl Acetate: 46</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>Under Car</td>
<td>2/4/92</td>
<td>50</td>
<td>0.2</td>
<td>12 39</td>
<td>13 29</td>
<td>Xylene: 29, Column: 5, Butyl Acetate: 46, Ethyl Acetate: 46</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>Under Car</td>
<td>2/4/92</td>
<td>50</td>
<td>0.2</td>
<td>12 39</td>
<td>13 13</td>
<td>Xylene: 20, Column: 5, Butyl Acetate: 46, Ethyl Acetate: 46</td>
<td>0.42</td>
</tr>
<tr>
<td></td>
<td>Under Car</td>
<td>2/4/92</td>
<td>33</td>
<td>0.2</td>
<td>12 39</td>
<td>13 13</td>
<td>Xylene: 19, Column: 0, Butyl Acetate: 46, Ethyl Acetate: 46</td>
<td>0.41</td>
</tr>
</tbody>
</table>

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

STATISTICAL ANALYSIS OF TOTAL DUST DATA

Figure B1 lists selected items from the statistical analysis of the total dust concentrations. The data was analyzed using the SAS General Linear Models (GLM) procedure. The analysis was conducted to determine whether the spray painting gun, sampling location, or some combination of these two variables affected exposure. Before data analysis, the logarithm of the concentration data was taken in order to obtain normally distributed residuals. One value of concentration measured under the car on January 28 from 12:55 to 13:12 was excluded from the analysis as an outlier. The concentration value for this measurement was 0.47 mg/m³ and this appears to be a relatively low measurement for being located under the car. Furthermore, when this concentration value was included in the analysis, the residuals were not normally distributed, indicating that there is something different about this measurement.

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

REFERENCES
ITEM 1

Dependent Variable: ln(CONC)

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Type III SS</th>
<th>Mean Square</th>
<th>F Value</th>
<th>Pr &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>GUN</td>
<td>1</td>
<td>615443042</td>
<td>615443042</td>
<td>12.04</td>
<td>0.0060</td>
</tr>
<tr>
<td>LOCATION</td>
<td>2</td>
<td>987595885</td>
<td>49379745</td>
<td>9.65</td>
<td>0.0046</td>
</tr>
<tr>
<td>GUN*LOCATION</td>
<td>2</td>
<td>44163999</td>
<td>22081700</td>
<td>0.43</td>
<td>0.6639</td>
</tr>
</tbody>
</table>

ITEM 2

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

Comparisons significant at the 0.05 level are indicated by ***

<table>
<thead>
<tr>
<th>Comparsion</th>
<th>Lower Limit</th>
<th>Difference Mean</th>
<th>Upper Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>C - W</td>
<td>0.058</td>
<td>1.299</td>
<td>2.537</td>
</tr>
<tr>
<td>C - P</td>
<td>0.817</td>
<td>2.004</td>
<td>3.191</td>
</tr>
<tr>
<td>W - C</td>
<td>-2.537</td>
<td>-1.299</td>
<td>-0.058</td>
</tr>
<tr>
<td>W - P</td>
<td>-0.481</td>
<td>-0.706</td>
<td>-1.893</td>
</tr>
<tr>
<td>P - C</td>
<td>-3.191</td>
<td>-2.004</td>
<td>-0.817</td>
</tr>
<tr>
<td>P - W</td>
<td>-1.893</td>
<td>-0.706</td>
<td>0.481</td>
</tr>
</tbody>
</table>

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

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

RESPIRATORY PROTECTION

(a) Permissible practice (1) In the control of those occupational diseases caused by breathing air contaminated with harmful dusts, fogs, fumes, mists, gases, smoke, sprays, or vapors, the primary objective shall be to prevent atmospheric contamination. This shall be accomplished as far as feasible by accepted engineering control measures (for example, enclosure or confinement of the operation, general and local ventilation, and substitution of less toxic materials). When effective engineering controls are not feasible, or while they are being instituted, appropriate respirators shall be used pursuant to the following requirements.

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

(3) The employee shall use the provided respiratory protection in accordance with instructions and training received.

(b) Requirements for a minimal acceptable program (1) Written standard operating procedures governing the selection and use of respirators shall be established.

1910.134(b)(2)

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

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

(4) [Reserved]

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

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

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

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

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

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

1910.134(b)(11)

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

(c) Selection of respirators

(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 Pharmacopeia 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 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)


(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)

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

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

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

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

1910 134(e)(5)

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

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

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

1910 134(e)(5)(ii)

(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
disinfecting as frequently as
necessary to ensure that proper
protection is provided for the
wearer. Respirators maintained for
emergency use shall be cleaned and
disinfecting 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.

47
<table>
<thead>
<tr>
<th>Atmospheric contaminants to be protected against</th>
<th>Colors assigned(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid gases</td>
<td>White</td>
</tr>
<tr>
<td>Hydrocyanic acid gas</td>
<td>White with 1/2-inch green stripe completely around the canister near the bottom</td>
</tr>
<tr>
<td>Chlorine gas</td>
<td>White with 1/2-inch yellow stripe completely around the canister near the bottom</td>
</tr>
<tr>
<td>Organic vapors</td>
<td>Black</td>
</tr>
<tr>
<td>Ammonia gas</td>
<td>Green</td>
</tr>
<tr>
<td>Acid gases and ammonia gases</td>
<td>Green with 1/2-inch white stripe completely around the canister near the bottom</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>Blue</td>
</tr>
<tr>
<td>Acid gases and organic vapors</td>
<td>Yellow</td>
</tr>
<tr>
<td>Hydrocyanic acid gas and chloropicrin vapor</td>
<td>Yellow with 1/2-inch blue stripe completely around the canister near the bottom</td>
</tr>
<tr>
<td>Acid gases, organic vapors, and ammonia gases</td>
<td>Brown</td>
</tr>
<tr>
<td>Radioactive materials, excepting tritium and noble gases</td>
<td>Purple (Magenta)</td>
</tr>
<tr>
<td>Particulates (dusts, fumes, mists, fogs, or smokes) in combination with any of the above gases or vapors</td>
<td>Red with 1/2-inch gray stripe completely around the canister near the top</td>
</tr>
<tr>
<td>All of the above atmospheric contaminants</td>
<td></td>
</tr>
</tbody>
</table>

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.