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HEALTH HAZARDS IN A SMALL AUTOMOTIVE BODY REPAIR SHOP

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Abstract—Significant numbers of occupationally exposed workers are engaged in small operations which are not covered by governmental or other occupational health services. The neighbourhood automotive body repair shop is one such activity. Workers there are regularly exposed, with few effective controls, to solvents, metal pigments and paints, polyester plastic fumes and dusts, noise and vibration. A study at a typical owner–operator shop throughout a 1-yr period revealed high, short-term exposures (relative to available TLV-STEL values) to solvent vapours and occasionally lead and chromium pigments. Conditions were exacerbated by the workers' disinclination to use protective equipment or exhaust ventilation, particularly during cold weather. Although noise and nuisance dust levels were sporadically high, they did not appear to pose a health problem. The possible causation of a Raynaud's syndrome by the use of pneumatic tools and the undefined toxic implications of an aliphatic isocyanate exposure from an enamel curing agent are discussed.

INTRODUCTION

ACCORDING to the United States Bureau of Labor Statistics (1981), there were an estimated 179 000 small automotive body repair workers in 1980 in the United States, most of whom work in one- to four-man operations. Their work typically involves exposures to solvents, paint and chemical vapours, metal pigments and dust, polyester plastic dusts, isocyanates and proprietary chemicals, noise and vibration, frequently in restricted spaces and often with inadequate or ineffective controls. These workers have little or no training, or interest, in health and safety hazards and their controls; rather, because their operations are highly competitive, they have less inclination to be concerned with either unproved hazards or impediments to getting their work done. Furthermore, in common with very small industrial and commercial operations, they are not provided with any governmental or other occupational health services.

A literature search revealed a paucity of published industrial hygiene studies of automotive body repair activities. There are recommendations for safe work practices in the NIOSH series of Good Practices for Employees with reference to auto body repair shops (1977) and spray painting (1976) and in the NIOSH Health and Safety Guide for Auto Repair and Body Shops (1975). However, these publications provide little information on actual conditions that may be encountered. An experimental inhalation study by SCHEPERS *et al.* (1958) of the biological activity of the type of plastic dust generated by the sanding of automotive fibreglass is relevant to the problem. Therefore, it seemed productive to undertake a comprehensive survey at a typical neighbourhood auto body repair shop. The primary purpose was to define and evaluate the occupational health hazards and controls and to recommend improvements or areas for further study.

OUTLINE OF STUDY

A representative two-man jointly owned shop, limited to autobody and frame repair, was selected (Fig. 1) and judged to be typical of the small one- to four-man 'bump and paint' garages operating along the east coast of the U.S.

At this shop one worker/partner does most of the painting; however, since actual painting takes relatively little time, he also gets involved with all other operations. Both men experience occasional solvent intoxication and both sporadically have symptoms of what appears to be Raynaud's phenomenon (possibly from pneumatic hand tools). Neither shows nor reports any other apparent chronic health effects that can be readily related to their exposures. Some years ago one partner experienced chest pain which he suspected was related to his exposure to enamel paint. He began using a particulate/organic vapour respirator and reports no recurrence of the symptoms.

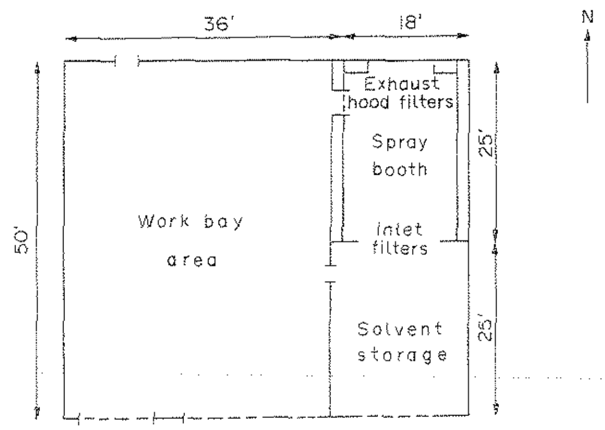

FIG. 1. Floor plan autobody repair shop. ----- designates a door. 11 ft high ceiling in work bay, 10 ft in storage area and 9 ft in spraybooth.

Upon request, the two manufacturers which supply most of the paint, solvents and associated products used, provided Material Safety Data Sheets (MSDS) and other product information. The ACGIH Threshold Limit Values (1982) were referred to for permissible exposure limits. The following exposures were evaluated:

Spray painting:
—solvent vapours;
—pigments (lead, chromium and cadmium);
—isocyanate.

Body work:
—dust from sanding plastic filler;
—dust from compounding and buffing;
—noise.

Significant exposures are defined as those greater than one-third of the short-term exposure limit (TLV-STEL) or half the time weighted average threshold limit value (TLV-TWA)—whichever was smaller.

METHODS AND RESULTS

Organic vapours

Table 1 lists 36 potential contaminant solvent vapours compiled from the suppliers' MSDS forms with their respective TLV-STEL or, if unavailable, the TLV-TWA.

The chosen gas chromatography (GC) set-up was versatile in that there were only three sets of two co-eluting compounds, all of which had relatively high TLVs (≥ 200 ppm) and were present at relatively low levels.

Area and personal air samples for vapours were taken with a Bendix BDX-44 or DuPont P-4000 pump with commercial charcoal tubes (100/50 mg). The front and back sections of the charcoal tubes were desorbed separately with carbon disulphide and analysed with GC in accordance with WHITE *et al.* (1970).

The results obtained for vapours under various work conditions are shown in Tables 2(a) and 2(b).

Only specific contaminant air concentrations $\geq$ 1/10 TLV (based on recovered quantities in nominal 3 l. air samples) are reported. However, 40–50 chromatographically distinct species were identified during lacquer spraying and about 20 from enamel. The total organic vapour concentrations were estimated from total GC detector counts, assuming an average mol. wt of 125 g mole^{-1} and a desorption efficiency of 90%.

Combined exposure rates were derived from the TLV Documentation (ACGIH, 1982) for (a) compounds that are irritants or central nervous system (CNS) depressants and (b) systemically toxic compounds with the blood as the target system. [Details are given in Tables 2(a) and 2(b).]

Most of the spray painting is done in the spray booths; however, some is done in the workbay area when many cars are being handled. Ventilation is provided by opening the door between the workbay area and the spray booth and running the spray booth fan while spraying in the workbay. During the summer, all outside doors are open and two floor fans help dilute the vapours. This results in essentially no difference in exposures between the workbay and spray booths.

Winter workbay spraying with closed external doors results in considerably higher exposure levels than spraying in the spray booth with the booth fan on. In extremely cold weather [less than -7°C (19°F) outside], the exhaust fan can be run for only a few minutes or the shop loses heat rapidly. Although spraying in the workbay without the use of the booth fan is recognized by the workers as an explosion hazard, it is still done on occasion as an expedient.

During extremely cold weather, whole car paint jobs are usually done in the spray booth, in which case the painter sprays with the fan off and turns it on for a few minutes to clear the vapours. This results in some very high short-term exposures; indeed, during one session the painter became visibly intoxicated within the first 5–10 min of painting.

Isocyanate

The enamel paint used has between 4–9 wt% of what is described as an aliphatic polyisocyanate. In view of the known severe health effects of overexposure to monomeric isocyanates (e.g. toluene diisocyanate) (NIOSH, 1973), it was desirable to evaluate potential exposure to this agent: An established colorimetric method for aliphatic monomeric isocyanate (AIHA, 1970) was unsuccessful, since the polyiso-

TABLE 1. SOLVENTS CITED IN THE SHOP'S MATERIAL SAFETY DATA SHEETS

Compound	TLV-STEL (ppm)	Compound	TLV-STEL (ppm)	Compound	TLV-STEL (ppm)
Acetone	1000	Ethyl acetate	400*	Methyl isobutyl ketone	125
Benzene	25	Ethyl benzene	125	Nonane	250
n-Butyl acetate	200	*n*-Hexane	50*	*n*-Octane	375
Butyl cellosolve	75(skin)	2-Hexanone	5*	*n*-Propyl acetate	250
Cellosolve	100(skin)	Iso-hexanes	1000	Propylene dichloride	110
				Toluene	150(skin)
Cellosolve acetate	100(skin)	Iso-octane	375	1,2,3 Trimethyl benzene	35
Cumene	75(skin)	Isopropanol	500(skin)	1,2,4 Trimethyl benzene	35
Cyclohexane	375	Isopropyl acetate	310	1,3,5 Trimethyl benzene	35
cis-Decalin	—	Methyl cellosolve	35(skin)	*o*-Xylene	150
		Methyl cellosolve acetate	35(skin)	*m*-Xylene	150
trans-Decalin	—	Methyl cyclopentane	—	*p*-xylene	150
Dichloromethane	500	Methyl cyclohexane	500		
Ethanol	1000*	Methyl ethyl ketone	300		

* TLV-TWA (No TLV-STEL listed).

VAPOUR EXPOSURES DURING LACQUER SPRAY PAINTING

Condition	n	ppm found by volume in air (TLV-STEL) Xylene	Toluene	Benzene	Other	Estimated total hydrocarbon	Combined exposure ratio $\sum \frac{C_i}{(\text{TLV-STEL})_i}$ Irritants and CNS depressants*	Compounds with blood as target organ†
With spraybooth fan off								
Spraybooth in winter (external doors closed)	1	10 (150)	590 (150)	0.9 (25)	11 cellosolve acetate (100) > 337 acetone (1000) 50 methyl isobutyl ketone (75)	> 990	4.7	0.1
Workbay in winter	1	11 (150)	397 (150)	1.0 (25)	9.9 cellosolve acetate (100) 270 acetone (1000) 90 *n*-hexane (50‡)	1010	2.9	0.1
With spraybooth fan on								
Spraybooth in summer (external doors open)	1	12 (150)	56 (150)	ND*	ND	160	0.4	ND
Workbay in summer	1	ND	30 (150)	ND	ND	100	0.2	ND
Workbay in winter (external doors closed)	1	3.1	174	1.1	3.7 cellosolve acetate (100) 62 acetone (1000) 20 *n*-hexane (50) 10 methyl isobutyl ketone (75)	420	1.3	< 0.1

ND Indicates compound not detected at 1/10 TLV-TWA (3 l. samples).
* Includes mylene, toluene, acetone, n-butyl, acetate, ethyl benzene, trimethyl benzene and methyl isobutyl ketone.
† Includes benzene, cellosolve acetate, cellosolve, and methyl cellosolve acetate.
‡ TLV-TWA; No TLV-STEL listed.

TABLE 2(b). PERSONAL VAPOUR EXPOSURES DURING ENAMEL SPRAY PAINTING

Condition	n	(ppm found by volume in air) (TLV-STEL) Xylene	Toluene	Benzene	Other	Estimated total hydrocarbon	Combined exposure ratio $\sum \frac{C_i}{(\text{TLV-STEL})_i}$ Irritants and CNS depressants*	Compounds with blood as target organ†
With spraybooth fan off								
Spraybooth in winter (external doors closed)	2	100–230 (150)	82–86 (150)	7.9–11 (25§)	30–45 methyl cellosolve acetate (35) 3.8–16 trimethyl benzene (35) 23–51 ethyl benzene (125) ND–42 cellosolve (100) 12–26 cellosolve acetate (100) ND–20 *n*-butyl acetate (200) ND–31 methyl isobutyl ketone (75)	710–1400	1.5–3.3	1.3–2.4

With spraybooth fan on								
Spraybooth in summer (external doors open)	3	20–28 (150)	ND–19 (150)	ND–2.0 (25)	12–17 methyl cellosolve acetate (35)	110–200	0.1–0.3	0.3–0.5
Workbay in summer	3	16–44	ND–17	ND–3.7	10–21 methyl cellosolve acetate (35) ND–3.5 trimethyl benzene (35) ND–10 ethyl benzene (125)	80–330	0.1–0.6	0.3–0.7
Spraybooth in winter (external doors closed)	4	15–20 (150)	ND–28 (150)	ND–2.3 (25§)	6.5–11 methyl cellosolve acetate (35) ND–9.0 ethyl benzene (125) ND–4.3 cellosolve acetate (100) ND–12 *n*-butyl acetate (200)	120–170	0.1–0.4	0.2–0.4
Workbay in winter	1	77	37	4.7	26 methyl cellosolve acetate (35) 18 ethyl benzene (125)	450	0.9	0.9

Sampling and painting duration ranged from 10 to 30 min.
* ND indicates compound not detected at 1/10 TLV–TWA (3 l. samples).
† Includes xylene, toluene, acetone, *n*-butyl, acetate, ethyl benzene, trimethyl benzene and methyl isobutyl ketone.
‡ Includes benzene, cellosolve acetate, cellosolve and methyl cellosolve acetate.
§ TLV–TWA; no TLV–STEL listed.

cyanate was insoluble in the absorbing/reacting solution. Although soluble in tetrahydrofuran, the compound failed to produce any measurable colour by this technique, even when applied directly at high levels (250 μg/15 ml in a 4 cm absorption cell). Thus, the isocyanate exposure, which could be the most significant chemical exposure, was not evaluated in our study.

Paint pigments

Our observation showed highly visible levels of aerosol during the spraying with the fan off. ACKLEY (1980) measured the particle size of standard lacquer and enamel aerosols as having mass-mean aerodynamic diameters (MMAD) of 6.4 and 5.7 μm with geometric standard deviations of 3.4 and 2.0 respectively. LIPPMANN (1977) shows that these particles would be deposited throughout the respiratory tract including the alveolar region.

It is likely that the short term unventilated painting sessions were associated with high (>20 mg m^{-3}) total aerosol concentrations; however, the greater concern is possible exposure to lead, chromium or cadmium from the paint pigment systems. Eight breathing zone samples were taken during these short term painting exposures with and without ventilation (cf. standard method of analysis, e.g. NIOSH procedure). The samples were acid digested and analysed for lead, cadmium and chromium in accordance with standard NIOSH procedures employing atomic absorption.

The results are given in Table 3. Only one session showed significant levels of lead or chromium. This occurred with the exhaust fan switched on. Since relatively little organic vapour exposure was measured, these toxic metals probably represent the most serious exposure.

Dust

During the sanding or grinding of plastic body filler, the suspended dust covers the worker's hair and clothing and rapidly coats the nasal passages. A sampling rate and

TABLE 3. AIRBORNE METAL PIGMENT LEVELS DURING SPRAY PAINTING

Paint formula	Litres sampled	Metal concentration (mg m^{-3}) Cr	Cd	Pb
E-2953 Light blue	13.9	<0.11	<0.11	*
E-1633 White	20.8	<0.48	<0.48	<0.60
E-2730 Dark blue	41.6	<0.24	<0.24	<0.30
E-45690 Silver	31.3	<0.38	<0.38	<0.48
E-2851 White	43.8	<0.23	<0.23	<0.28
A-8690 Light green	86.2	<0.13	<0.13	<0.16
E-2774 R Red	43.7	0.49	<0.25	0.21
E-2424 Green	49.8	<0.26	<0.26	<0.64

* Sample accidentally dropped and lost.

TABLE 4. AIRBORNE DUST LEVELS DURING BODY TREATMENT

Sample location/type, operation	Sample duration (min)	Dust concentration, (mg m^{-3})
Sanding plastic		
Simultaneous personal		
Total dust*	55	39.8
Respirable dust†	55	1.2
Area 5½ ft above floor in middle of workbay		
Respirable dust	165	0.38
Compounding and buffing		
Respirable dust	168	1.1
Sanding plastic		
Simultaneous personal		
Total dust	197	5.1
Respirable dust	197	0.33
Area 5½ ft above floor in middle of workbay		
Respirable dust	180	0.67

* 37 mm Millipore PVC-5 filter, closed face cassette at 2.3 l. min^{-1}.
† 37 mm Millipore PVC-5 filter in Bendix BDX99 10 mm lapel cyclone sampler at 1.7 l. min^{-1}.

'closed face' cassette mode were selected for measuring the total dust to simulate the capture velocity of air at the human nostril. If nostrils are assumed to be circular with a 5 mm radius and average human respiration during light–moderate work is 20–40 l. min^{-1} through the nose, then there is a reasonable air velocity match at 2.3 l. min^{-1}.

The sampling results are presented in Table 4. Variable total dust levels were found for the same operation, sometimes reaching high levels.

In a study of the biological action of dust released from the sanding of fibrous glass reinforced automotive polyester body parts, SCHEPERS *et al.* (1958) found negligible toxicity. No deaths among 144 test animals (guinea pigs, rats and rabbits) could be ascribed to the dust which averaged 162 mg m^{-3} over a 25-month exposure period. Thus, it appears reasonable to classify the dust as a nuisance particulate. However, short-term exposure to total dust at the shop is certainly high and on some days probably exceeds the nuisance dust TLV of 10 mg m^{-3}. The operators probably ingest considerable amounts of this dust, but the health significance is unknown.

Noise and vibration

The source and levels of noise are listed in Table 5. A 10-day noise dosimetry study showed doses as high as 160% (8 h/90 dBA Standard—5 dBA doubling rate) of the allowable limit.

The pneumatic hand tools cause a considerable amount of segmental vibration to the fingers and hands of the operators. Both workers reported intermittent white and numb fingers suggestive of Raynaud's phenomenon, particularly during the colder months. According to TAYLOR's (1974) clinical classification scheme for assessing the extent of the Raynaud's phenomenon, if confirmed, both owners would be assigned to

TABLE 5. SOUND PRESSURE LEVELS OF THE LOUDEST OPERATIONS IN SHOP

Tool	Operation	dbA*	T† (h)
Pneumatic chisel	Cutting sheet metal	110–115	0.50–0.25
Air hose	Blowing off dust	106–110	0.87–0.50
Pneumatic and electric grinders	Grinding sheet metal	103–105	1.3–1.0
Fileboard sander	Sanding polyester filler	102–104	1.5–1.2
Orbital finishing sander	Sanding polyester filler	95–98	4.0–2.6

* Measured with a GEN-RAD type 1565-B SLM within a 1 ft radius of operator's head.
† Time at indicated sound pressure level that will give 100% of allowable dose re: 90 dbA/8 h.

Stage 2: blanching of one or more fingers with numbness and slight interference with work, home or social activities.

Ventilation

Figure 2 gives representative air velocity measurements inside the spray booth. The prefabricated booth is designed to provide 30.5 m min^{-1} (100 ft min^{-1}) minimal linear hood velocity [as required by OSHA 29 CFR part 1910.107b(5) (spray booths with dry filters)]. Despite the observation of plugged filters, the exhaust output was measured at about 340 m^3 min^{-1} (12000 ft^3 min^{-1}). It is not uncommon for body shop operators to displace the plugged filters to allow the air to flow. This practice causes paint particles to coat the duct and fan blades and introduces a fire hazard. The spray booth fan exhaust of 340 m^3 min^{-1} (12000 ft^3 min^{-1}) can theoretically clear the shop of airborne contaminants in 4–5 min. It would require 1.31×10^8 calories hr^{-1} (518000 BTU h^{-1}) to warm 340 m^3 min^{-1} (12000 ft^3 min^{-1}) of make up air from −7°C (19°F) to 16°C (60°F). The heating system consists of an oil-fired central heater and two kerosene space heaters with a total capacity of about 3.8×10^7 calories hr^{-1} (150000

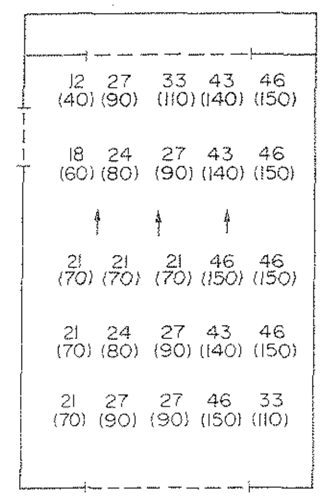

FIG. 2. Flow in spraybooth, m min^{-1} (ft min^{-1}), on 12 December 1980. Air measurement with Alnor Jr. velometer, type 8100. All doors closed. Measurements taken 5 ft from floor with mid-sized car in booth.

BTU h^{-1}). Thus, the design ventilation rate exceeds the capacity of heating system to keep pace with the energy loss. In extremely cold weather, prolonged use of the exhaust fan is impossible, since painting cannot be done below 10°C (50°F). Standard operating procedure during the winter is to paint with the fan off and then run the booth fan for 2–3 min to clear the vapours, producing excessive short-term exposures levels.

CONCLUSIONS AND RECOMMENDATIONS

(1) The small autobody repair shop is a cottage industry in which a large number of workers are overexposed to airborne contaminants by the absence of effective ventilation and failure to wear personal protective equipment or use effective environmental controls.

(2) The observations during the study suggest that the majority of these workers have little or no training or awareness of the potential health hazards in their workplace.

(3) The shop environment is characterized by short-term airborne exposures of relatively high intensity. The full shift TLVs-TWA are rarely exceeded; however, the STELs are often greatly exceeded.

(4) Given the above, selective short-term use of personal protective equipment would effectively reduce worker exposure to airborne contaminants.

Recommendations

(1) The suppliers or possibly the insurance carriers should establish and promote an effective worker education programme which stresses the need and use of personal protective equipment.

(2) Paint manufacturers should specifically identify paints that contain toxic pigments (e.g. lead, cadmium, chromium) with appropriate precautionary labels. This would be an improvement over the generic or 'catch-all' labels currently used.

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