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Assessment of Students' Exposure to Welding Fumes in a Vocational School Welding Shop

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Introduction

U.S. vocational schools can be likened to a group of small job shops where the students are the workers. More than 11 million students attend these schools. Students are often subjected to the same workplace health and safety hazards that exist in the real world. At least 70 vocational programs, out of more than 240 different types offered, can be considered to have physical, chemical, or biological health hazards. To reduce the hazards to students, each vocational school's safety and health program must be adequately funded, and administrators and class instructors must be knowledgeable of safety and health issues. Vocational schools often rely on inspections by outside agencies, particularly state Occupational Safety and Health Administration (OSHA) programs, to help identify potential safety and health problems.

Unfortunately, vocational schools may fall short of adequately protecting their students for a variety of reasons. Often, school administrators are not provided with adequate funding to maintain facilities and equipment properly or to improve their safety and health programs. Outside inspections may be few and far between. Instructors may be unaware of current safety and health hazards or how to control certain problems. Safety rules that are in place may not be strictly enforced. Additionally, because of class time limitations, students may never be taught how safety and health relates to their job.

Recent initiatives within the National Institute for Occupational Safety and Health (NIOSH) have provided the opportunity to conduct hazard assessments within vocational schools to study health and safety risks to teenagers. The efforts are aimed at increasing safety awareness and education within vocational schools to produce informed students capable of recognizing, controlling, and remediating vocational safety and health hazards, applying safe work practices, and consequently becoming safe American workers in the future. During the NIOSH assessments, the industrial trades department was of particular interest. This case study[1] focuses on student exposures in the welding shop of one vocational school located in the midwestern United States. The study was conducted in January 1996. The goals of this study were to gain an understanding of the hazards that existed in the welding shop and to provide the administration with recommendations to improve the health and safety of the students.

Background

The school provides vocational training in a number of different trades for students from surrounding high schools. Students enrolled at the school commute to the facility each day to spend one half day in vocational training in addition to pursuing their academic studies at their regular high school. The vocational school building is approximately 30 years old and the last major capital improvement was the installation of a fire alarm/detection system several years prior to this study.

Two classes were held each day in the welding shop: the first class met from 9 to 11 a.m. and the second class met from 12 to 2 p.m. Each class received one 15-minute break. On average, 15 to 25 students attended each class. On the day of the study, approximately 20 students per class worked in the welding shop.

The welding shop is depicted in Figure 1. The shop measured 30 × 50 ft, with 12-ft high ceilings. The welding area was divided into three rows of individual bays, with 17 total bays. Two rows of bays were along adjacent walls. The third row of bays was situated in the center of the room. Each bay measured approximately 4.5 ft wide × 4.5 ft deep. Bays were separated from each other by cinder block walls. A heavy welding curtain was hung in front of each bay to protect passersby from welder's flash during the welding operations. Usually two students worked together in one bay. Each bay was equipped with a small workstand at which the students would stand and weld.

A local exhaust hood, composed of a rectangular exhaust duct with a 2-ft wide flange, was positioned flat against the back wall of each of the first 13 bays. The duct ended about 7 ft from the floor and was positioned 2.5 to 4 ft away from the workstand. The exhaust hoods from the six welding bays along the south wall were connected to a central duct which exhausted through the roof to the outside. A similar setup was observed for the seven bays along the adjoining wall. The four bays in the center of the room did not have local exhaust hoods. However, a central duct with several exhaust grilles was located above these bays and was apparently being used for general room ventilation.

Students in the welding shop learned a variety of welding techniques. During this study, the majority of students performed shielded metal arc welding or stick welding. This technique requires the use of a manually held, flux-coated consumable electrode of a finite length to produce an arc. One student performed metal inert gas (MIG) welding, a technique that involves a welding gun with a continuously fed, solid-core wire consumable electrode, used in conjunction with a shielding gas to prevent oxidation of the base metal. The shielding gas used by this student was argon based. Stick welding was taught to seniors, while the juniors learned MIG welding techniques. Several students said that MIG welding was less difficult to learn, while stick welding was considered the dirtiest. During the year, students learned to weld stainless steel and aluminum; however, only mild steel welding was performed during the study. In addition to welding,

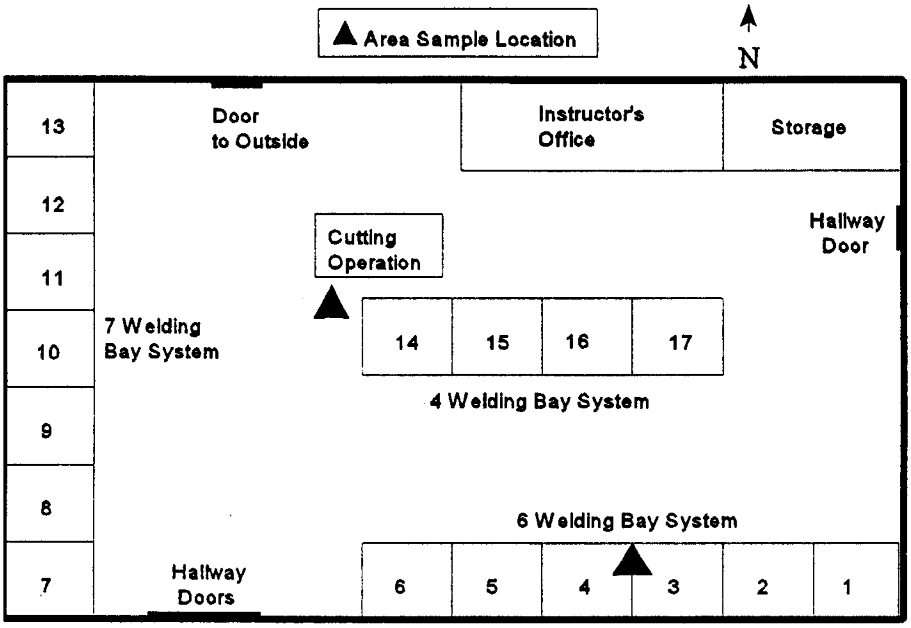

FIGURE 1. Diagram of welding shop.

students performed grinding and cutting operations. Students were equipped with welding gloves, safety glasses, and welding helmets. Steel-toed shoes were not required and none were observed being worn.

The effect of welding fumes on an individual's health can vary depending on such factors as the length and intensity of the exposure and the specific toxic metals involved. Welding processes involving stainless steel, cadmium- or lead-coated steel, or metals such as nickel, chrome, zinc, and copper are particularly hazardous, as the fumes produced are considerably more toxic than those encountered when welding mild steel. NIOSH considers total welding fume and welding fume constituents, such as arsenic, beryllium, cadmium, chromium (VI), and nickel, to be potential occupational carcinogens. Welder respiratory ailments can include occupational asthma, siderosis, emphysema, chronic bronchitis, fibrosis of the lung, and lung cancer.[2] Other cancers associated with welding include leukemia and cancer of the stomach, brain, nasal sinus, and pancreas. A common reaction to overexposure to metal fumes, particularly zinc oxide, is metal fume fever, and symptoms resemble influenza. Additional welding health hazards include vision problems and dermatitis arising from ultraviolet radiation exposures, burns, and musculoskeletal stress from awkward work positions.

Sampling Methodology

To gain a basic understanding of air contaminant hazards in the welding shop, sampling data were collected in the students' breathing zones and in the general welding area. One area sample was positioned in the middle of the welding shop, near the oxy-acetylene torch cutting operations. The second area sample was positioned above welding booths 3 and 4 (see Figure 1). Personal air sampling pumps, operating at 3 L/min, were connected to polyvinylchloride filter cassettes. Sampling durations ranged from 80 to 109 minutes for personal samples. Area samples were collected simultaneously for durations of 264 and 268 minutes. The samples were later analyzed according to NIOSH Analytical Method 0500 for total particulate (total welding fume). The same filters also underwent elemental analysis, according to NIOSH Analytical Method 7300, to determine airborne exposure levels of the various welding fume constituents.

Smoke tubes were used to visualize the air flow patterns in the room and the bays, particularly to observe the capture efficiencies of the ventilation hoods. A hot wire anemometer was used to quantify air capture rates of the local exhaust hoods.

Results

Monitoring results are shown in Table 1. There is no current OSHA permissible exposure limit (PEL) established for welding fume; however, OSHA has set a PEL for total dust at 15 mg/m^3 as an 8-hour time-weighted average (TWA).[3] The American Conference of Governmental Industrial Hygienists (ACGIH) has established a threshold limit value (TLV) of 5 mg/m^3 as a TWA for total welding fume.[4] Levels measured for the personal samples ranged from 3.1 to 10.8 mg/m.[3] Because the exposure time was much shorter than 8 hours, it seems unlikely that any of the students would have experienced total welding fume exposures greater than the PEL. There would be greater exposure

TABLE 1. Total Welding Fume Air Sampling Results

Sample No.	Personal or Area	Class Time	Location	Sample Duration (min)	Concentration (mg/m^3)
1	P	a.m.	Bay near wall	84	7.3
2	P	a.m.	Bay near wall	83	5.5
3	P	a.m.	Bay near wall	83	3.3
4	P	a.m.	Bay near wall	80	7.1
5	P	a.m.	Bay near wall	82	3.1
6	P	p.m.	Bay 4	106	10.8
7	P	p.m.	Bay 5	109	9.1
8	P	p.m.	Bay 2	105	4.8
9	P	p.m.	Bay 7	106	4.9
10	P	p.m.	Bay 7	103	6.1
11	A	a.m./p.m.	Center wall	268	2.7
12	A	a.m./p.m.	Above bay 3	264	3.4

potential for the class instructor, who is in the welding shop for both the morning and afternoon classes. No data were collected on the instructor. On average, the afternoon personal exposures were higher than the morning personal exposures. It is possible that residual fume remaining in the welding shop after the morning class could have led to higher background concentrations in the afternoon, resulting in higher personal concentrations for these students as well.

None of the levels for the specific elements in the welding fume were in excess of OSHA regulatory standards. For example, the highest concentration for lead was 6 $\mu g/m^3$ (PEL = 50 $\mu g/m^3$), total chromium = 10 $\mu g/m^3$ (PEL = 1000 $\mu g/m^3$), nickel = 2 $\mu g/m^3$ (PEL = 1000 $\mu g/m^3$), cadmium = 1 $\mu g/m^3$ (PEL = 5 $\mu g/m^3$), and zinc = 790 $\mu g/m^3$ (PEL = 5000 $\mu g/m^3$). However, the levels of manganese for six of the personal samples exceeded ACGIH's TLV of 200 $\mu g/m^3$ as a TWA. One of the samples also contained beryllium at a concentration of 0.48 $\mu g/m^3$. While this is below the OSHA PEL of 2 $\mu g/m^3$ for beryllium, it closely approaches the NIOSH ceiling limit of 0.5 $\mu g/m^3$.[5] This was the only sample in which beryllium was detected, and it was noted that the sample was obtained from the only student who was MIG welding.

In each class, shortly after the students began welding, a visible haze became apparent throughout the welding shop. Interestingly, when the students were asked if they thought the ventilation system in the welding shop was protecting them adequately from the fumes, most stated that they thought the system was doing a good job. However, inspection of the ventilation system confirmed a variety of problems. For the system servicing the six bays along the south wall, minimal capture of smoke released at the hood faces indicated the ventilation was not functioning properly. In fact, in some cases the smoke appeared to be repelled at the hood face rather than exhausted. The velometer showed little air movement at most of the hoods in this system. Stagnant air near the duct system in the center of the shop indicated that this system also was not functioning properly. The ventilation system used by the third row of bays along the west wall did appear to be working adequately; hood face velocities for these seven bays ranged between 50 and 150 ft/min. As a general criterion, ACGIH's Industrial Ventilation: A Manual of Recommended Practice recommends an air velocity between 100 and 200 ft/min to capture and convey welding fumes into the hood.[6]

To determine the cause of the ventilation problems in the welding shop, an inspection of the fan motor units on the roof was made. The inspection revealed that of the three exhaust fans servicing the welding area, the only operational fan was the one responsible for exhausting the row of seven bays (7 through 13). Of the two nonoperational fans, one had a malfunctioning motor and one had a broken fan belt. According to school officials, students in the electrical vocational classes had upgraded these fans the previous year, from 3/4-horsepower (HP) motors to 1-HP motors. Since that time, the exhaust fans had not been serviced. In fact, no formal preventive maintenance plan for the fans was in place at the school.

In addition to the inoperable fans, the positioning of the local exhaust hoods was problematic. The bays were set up so that the distance from the flanged edge of the hood to the workstand ranged between 2.5 and 4 ft, and the hood was often positioned far to the side of the workstand. The effectiveness of the hood in capturing the emissions at the source would be almost negligible at these distances. Because the student was positioned between the hood and the workpiece, fumes that were captured often passed through the student's breathing zone before being exhausted.

Conclusions

Recommendations to the school administration focused on improving the ventilation systems to reduce students' exposures to welding fume. Exhaust fans were in need of service to ensure operability. A preventive maintenance plan for the welding systems should be implemented not only for the exhaust fan motor units, but also for the ductwork; the system was about 30 years old and the ducts had never been cleaned. Air velocities at the face of all the local exhaust hoods should be great enough to capture the welding fume. The bays should be redesigned so that exhaust hoods are positioned closer to the work area for improved fume capture. Additional testing might be required to determine the correct distance and position of each of the hoods for capturing fumes. The hoods also need to be positioned so that the students are not standing between the hood and the workstand.

As a general precaution, instructors should enforce the wearing of personal protective equipment, including hearing protection, steel-toed boots, welding/safety glasses, and, where applicable, respiratory protection. School administrators should ensure that safety and health is part of the curriculum in these classes so that students are aware of hazards associated with welding, can recognize potential problems, and will know what personal protective equipment and work practices can help protect them.

The study at this school emphasized that vocational school students do indeed face health and safety hazards. More emphasis needs to be placed on health and safety issues at these schools, for it is here that many of tomorrow's workers are being trained. If students are not provided with the proper knowledge, they may enter the work world believing it is okay for them to put their health and safety at risk by welding in a smoke-filled room. Ideally, students should be taught not only their craft but also how to work safely with minimal risk to their health.

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EDITORIAL NOTE: Marjorie E. Wallace, John M. Fajen, and John Palassis are with the National Institute for Occupational Safety and Health, and T.J. Lentz is with the Department of Environmental Health, University of Cincinnati. More detailed information on this evaluation is contained in ECTB Pub. No. 005-106, available through NIOSH, 4676 Columbia Parkway, Cincinnati, Ohio 45226; telephone: (800) 35-NIOSH.