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VENTILATION OF WELDING FUMES IN VOCATIONAL AGRICULTURE LABORATORIES IN MISSOURI

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Arc welding is a skill which is taught to many students in vocational agriculture programs. Many times, being in a welding environment of a vocational agriculture mechanics laboratory will indicate that ventilation is inadequate because of smoke which may cause coughing or watery and irritated eyes. The teacher, students and visitors in the welding environment will also be exposed to fumes and gases. The International Institute of Welding (1963) indicated that exposure of the welder to fumes and gases is dependent on ventilation in the laboratory. Health hazards to teachers, students and visitors in vocational agriculture mechanics laboratories can be minimized by proper ventilation.

Just because there is a ventilation system in operation during welding, it cannot be assumed that the welder is being protected from dangerous fumes and gases. The ventilation system must be designed for the job to be done, properly engineered and periodically maintained. Stellman and Daum (1973) found that ventilation is neglected because it is not related directly to production; therefore, there seems to be no great need to maintain the system. The National Safety Council (1977) suggested a need to check and maintain ventilation systems because of new processes, the use of more toxic substances and increased exposure of workers to smoke and finely divided particles in the work place. The use of adequate ventilation to effectively remove the fumes and gases produced and to supply sufficient clean air to the welder is of utmost importance.

Purpose of the Study

The purpose of this study was to measure the effectiveness of ventilation systems in removing airborne contaminants produced by arc welding in selected vocational agriculture mechanics laboratories in Missouri. More specifically, the following research questions were studied:

1. Do the ventilation systems used in vocational agriculture mechanics laboratories meet or exceed OSHA ventilation standards?

2. Which ventilation system is most effective according to OSHA standards in removal of airborne contaminants produced by arc welding in vocational agriculture mechanics laboratories?

3. What is the level of teacher exposure to fumes while teaching and supervising as compared to student exposure to fumes while welding?

Methodology

After consultation with the National Institute for Occupational Safety and Health (NIOSH), a governmental agency whose purpose is to provide research on safety and health matters in industry, it was determined that iron oxide, carbon monoxide, and ozone were contaminants which might be present in Missouri vocational agriculture mechanics laboratories during arc welding in sufficient amounts to create a health hazard.

Sampling Procedure

A survey was mailed to all schools in Missouri offering vocational agriculture at the secondary level to determine the different ventilation systems in vocational agriculture mechanics laboratories. The five most common ventilation systems in Missouri vocational agriculture mechanics laboratories were chosen for this study. They were wall and ceiling fans, drop curtains, hoods, boot pickups, and precipitators. Five schools per ventilation system were selected by stratified random sampling procedures to participate in the experiment.

Treatment and Data Collection

Six students, who had been instructed in proper welding procedures and safety rules, welded constantly on twelve inch hot-rolled low carbon steel pads with one-eighth inch E6011 Lincoln

Fleetweld 180 electrodes for one hour. All doors and windows were closed during the test. The ventilation system was in operation at the time the welding began. The amperage of each welding machine was set at 100 or 105. Two students were monitored by Mine Safety Appliances (MSA) Portable Personal Sampling Pump Model G. The additional four students were needed to build up a measurable amount of smoke. The purpose of the Portable Personal Sampling Pump, a battery operated air pump, was to collect iron oxide, a hazardous by-product of welding. Two pumps were attached to the belt of each student. Each pump was connected by clear plastic hose to an Aerosol Field Monitor, a plastic cassette, which held a filter. The review of literature indicated that the helmet should diffuse iron oxide away from the breathing zone of the welder. In order to determine the amount of iron oxide diffused away from the breathing zone of the welder by the helmet, one cassette monitor was attached to the welding helmet of the student at the breathing zone, the other was attached to the collar of the student. A mixture of particulates which included iron oxide was collected on the filters. The filters were chemically analyzed to determine the amount of iron oxide on each filter.

Students working in other areas of the laboratory are also exposed to airborne contaminants. To determine the amount of iron oxide to which these individuals would be exposed, the Portable Personal Sampling Pump with an Aerosol Field Monitor was placed in the middle of the laboratory. The teacher is also exposed to airborne contaminants. In order to prevent interruption of this experiment, the investigator was monitored in place of the teacher. The investigator wore a Portable Personal Sampling Pump on the belt with an Aerosol Field Monitor attached to the collar.

Carbon monoxide and ozone, gaseous by-products of welding, were collected with a Mine Safety Appliances Universal Sampling Pump, carbon monoxide detector tubes and ozone detector tubes. The detector tube contained a chemical which is sensitive to low concentrations of a specific gas or vapor. The tube is a sealed glass container. After fifty minutes of welding, the sealed ends of the tube were broken and inserted into the rubber holder of the pump. The pump drew a measured quantity of air through the detector tube. The detector tubes are a length of stain tube, i.e., as the concentration of carbon monoxide or ozone becomes greater, the stain becomes longer. The tubes were held in the welding fumes six inches above the welding table for an amount of time specified by the detector tube directions. Carbon monoxide and ozone results were directly read from the tubes.

Iron oxide, carbon monoxide and ozone data were compared to a specified standard developed by the Occupational Safety and Health Administration (OSHA) in order to determine which ventilation system was most effective in removal of airborne contaminants produced by arc welding in vocational agriculture mechanics laboratories.

During the experiment, data about the facility and ventilation were collected. The square feet and ceiling height of the laboratory were measured and recorded. Ventilation data recorded included type of ventilation system, measurements of each ventilation system and the velocity of the ventilation system in feet per minute. Data about the facility and ventilation systems were collected in order to determine if the ventilation system in each school met the OSHA ventilation standard.

Data Analysis

A Cochran's approximation t-test was used to study the significance between iron oxide samples taken at the helmet and collar of students, significance among iron oxide exposure of the teacher and students and significance between the effectiveness of the boot pickup on the table in removing iron oxide, carbon monoxide and ozone in a vocational agriculture mechanics laboratory. The research questions were formulated and tested at an alpha level of .05.

Results of Ventilation Testing

Data for analyzing the ventilation in the laboratory consisted of the square footage and ceiling height of the laboratory, dimensions of the ventilation system and the velocity of the ventilation system in feet per minute. The data are presented in Table 1.

OSHA (1977:62845A-62846) reported the following standards as requirements for ventilation for general welding and cutting:

(a) In a space of less than 10,000 cubic feet per welder.

(b) In a room having a ceiling height of less than 16 feet.

(c) In confined spaces or where the welding space contains partitions, balconies, or other structural barriers to the extent that they significantly obstruct ventilation.

(ii) Minimum rate. Such ventilation shall be at the minimum rate of 2,000 cubic feet per welder except where local exhaust hood and booths . . . for such purposes are provided.

Table 1

VENTILATION SYSTEM MEANS AND OSHA VENTILATION STANDARDS

Ventilation System	N	Mean Shop Dimension	Mean Cubic Feet of Shop	Mean Airflow of Ventilation System in Cubic Feet per Minute
Fan	5	50 x 70 x 14	49,000	1853**
Drop curtain	5	40 x 72 x 14	40,320	3463**
Hood	5	46 x 81 x 15	55,890	691**
Boot pickup				
On the table	5	37 x 57 x 15	31,635	244*
Above the table	4	36 x 56 x 15	32,256	226**
Precipitator	5	48 x 89 x 16	68,352	2627**

*Meets OSHA standards for general welding and cutting.

**Does not meet OSHA standards for general welding and cutting.

Three ventilation systems, fans, drop curtains, and precipitators, used in this study fall under these OSHA standards. Fans, drop curtains, and precipitators did not meet the OSHA ventilation standards for general welding and cutting. A minimum airflow of 12,000 cubic feet per minute was required for the six welders used in this study.

OSHA (1977:62846) reported that local exhaust hoods, booths and pickups must meet the following OSHA standards.

(i) Hoods. Freely movable hoods intended to be placed by the welder as near as practicable to the work being welded and provided with a rate of airflow sufficient to maintain a velocity in the direction of the hood of 100 linear feet per minute in the zone of welding when the hood is at its most remote distances from point of welding. The rates of ventilation required to accomplish this control velocity using a 3-inch wide flanged suction opening are shown in the table:

Welding Zone	Minimum Airflow Cubic Feet Per Minute (CFM)	Duct Diameter Inches
4 to 6 inches from arc	150	--
6 to 8 inches from arc	275	3½
8 to 10 inches from arc	425	4½
10 to 12 inches from arc	600	5½

(ii) Fixed enclosure. A fixed enclosure with a top of not less than two sides which surround the welding and cutting operations and with a rate of airflow sufficient to maintain a velocity away from the welder of not less than 100 linear feet per minute.

The mean of the distance from the boot pickup on the table to the welding arc was 5 inches. OSHA standards require 150 cfm when the boot pickup is 4 to 6 inches from the welding zone. The mean airflow of the boot pickups on the table tested in this study was 244 cfm. The mean of the duct diameter was 9 inches. Therefore, the boot pickup on the table did meet the OSHA standards for ventilation for general welding and cutting.

The mean distance of the boot pickup above the table was 29 inches from the arc. The greatest distance from the boot pickup to the arc on the OSHA standard table is 10 to 12 inches. The airflow at this distance should be 600 cfm. The mean airflow of the boot pickups above the table tested in this study was 226 cfm. The mean of the duct diameter was 10 inches. Therefore, the boot pickup above the table did not meet OSHA standards for general welding and cutting.

The mean distance from the hood to the welding arc was 70 inches. The mean of the duct diameter was 12 inches. Although the OSHA standard table does not give standards for welding zones above 12 inches, one can assume that the hoods tested in this study did not meet OSHA standards for general welding and cutting because for 10 to 12 inches from ventilation system to welding arc, an airflow of 600 cfm is required. The hoods in this study had an airflow of 691 cfm at 70 inches from the welding arc. Judging from the ratio of cubic feet per minute needed for the given distances, the hood did not meet OSHA standards for general welding and cutting.

Results of Iron Oxide, Carbon Monoxide and Ozone Testing

The data for the means of iron oxide, carbon monoxide, and ozone collected in the schools are presented in Table 2. These means were compared to OSHA standards to determine if the ventilation system met or exceeded the OSHA standard.

Table 2

EFFECTIVENESS OF VENTILATION SYSTEMS IN REMOVAL OF IRON OXIDE, CARBON MONOXIDE AND OZONE PRODUCED BY ARC WELDING

Ventilation System	Mean Iron Oxide	Mean Carbon Monoxide	Mean Ozone
Drop curtain	1.83 mg/m^3*	7.40 ppm	0.06 ppm
Boot pickup On the table	8.26 mg/m^3*	4.20 ppm	0.24 ppm*
Hood	10.57 mg/m^3*	4.60 ppm	0.28 ppm*
Boot pickup Above the table	11.22 mg/m^3*	3.50 ppm	0.21 ppm*
Fan	12.60 mg/m^3*	3.50 ppm	0.03 ppm
Precipitator	14.80 mg/m^3*	____[a]	____[a]

*Exceeds specific OSHA standard.

[a]Precipitator is not designed to remove gases such as carbon monoxide or ozone.

All iron oxide means reported were collected at the student's breathing zone in order to report on the amount of iron oxide which is most likely to be inhaled by the students while welding. The maximum OSHA iron oxide standard is 5 mg/m^3. All ventilation systems exceeded the OSHA standard for removal of iron oxide from the laboratory environment.

All ventilation systems were within the OSHA standard (50 ppm) for removal of carbon monoxide from the labroatory environment.

The fan and drop curtain met the OSHA standard (0.1 ppm) for removal of ozone from the laboratory environment. The hood, boot pickup on the table and boot pickup above the table did not meet the OSHA standard.

Results of Teacher and Student Exposure to Iron Oxide Fumes

The results of t-tests which were used to test the significant differences in the amount of exposure to iron oxide fumes between the teacher and students among the five vocational agriculture mechanics laboratory ventilation systems is presented in Table 3. Teacher exposure was significantly less than that of the students when fans, drop curtains, and precipitators were used as ventilation systems.

Table 3

T-TEST FOR IRON OXIDE EXPOSURE
OF THE TEACHER AND STUDENTS

Ventilation System	t'	test t
Fan	2.571	2.262*
Drop curtain	3.121	2.262*
Hood	0.995	2.262
Boot pickup		
On the table	0.948	2.262
Above the table	0.160	2.262
Precipitator	2.884	2.262*

*p = .05.

Findings

The findings of this study are summarized below.

1. The boot pickup on the table was the only ventilation system studied which met the OSHA ventilation standards.

2. All ventilation systems exceeded the OSHA standard for removal of iron oxide from laboratory environment.

3. Carbon monoxide levels were within the OSHA standard.

4. The fan and drop curtain met the OSHA standard for removal of ozone from the laboratory environment. The hood, boot pickup on the table and boot pickup above the table did not meet the OSHA standard for ozone.

5. The students were exposed to a greater amount of iron oxide while welding than the teacher.

6. Teacher and students were exposed to levels of iron oxide which exceeded OSHA standards.

Implications and Recommendations

The following implications and recommendations are suggested, based on the findings and conclusions of this study.

1. All ventilation systems should be designed or expanded to meet OSHA ventilation standards. This study found that only one ventilation system, the boot pickup on the table, met the OSHA ventilation standard. This problem may be more serious than it seems because most schools had more than the six welders used for this study. These schools did not meet the minimum standards for six welders so it is assumed they would not meet minimum qualifications for more than six welders.

2. Missouri schools should provide more adequate ventilation systems for individuals in the welding area in vocational agriculture mechanics laboratories to remove excessive levels of iron oxide.

3. Precipitators used as the only ventilation system must have provision to bring in outside air to dilute the CO_2 and ozone gases in the welding area.

4. While there was a significant difference between teacher exposure to iron oxide and student exposure to iron oxide, allowance must be made for teachers teaching for more than one period. The time the teacher spends teaching welding must be considered when designing the ventilation system.

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