HealthHazard Evaluation Program

Evaluation of Metals Exposure in an Architectural Metal Fabrication Shop

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Centers for Disease Control and Prevention
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Disclaimer

The Health Hazard Evaluation Program investigates possible health hazards in the workplace under the authority of the Occupational Safety and Health Act of 1970 [29 USC 669a(6)]. The Health Hazard Evaluation Program also provides, upon request, technical assistance to federal, state, and local agencies to investigate occupational health hazards and to prevent occupational disease or injury. Regulations guiding the Program can be found in Title 42, Code of Federal Regulations, Part 85; Requests for Health Hazard Evaluations [42 CFR Part 85].

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Introduction

Request

The National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation from the owner of an architectural metal fabrication shop in Austin, Texas. The request concerned potential exposure to metals during welding, grinding, and plasma cutting activities.

Workplace

The facility consisted of a single-story building with multiple welding and grinding areas and a computerized plasma cutting station. During the site visit, 10 employees did metal inert gas (MIG) welding on mild steel to create metal sculptures, objects, and fixtures. These welders also used pneumatic grinders to clean metal and remove scale and to dress welding beads. One employee operated the plasma cutting table to cut out specialized parts. Portable local exhaust ventilation units were used during welding operations but not during grinding. The plasma cutting table was equipped with a water bath to help capture emissions created when the plasma torch cut metal plate steel.

To learn more about the workplace, go to Section A in the Supporting Technical Information

Our Approach

We completed the following activities during our two-day evaluation:

- Reviewed facility health and safety programs and documents.
- Observed work processes, work practices, and workplace conditions.
- Collected personal air samples for metals during welding and grinding activities.
- Took measurements to estimate the capture air velocity of three portable welding fume extractors used by welders.

To learn more about our methods, go to Section B in the Supporting Technical Information

Our Key Findings

Employees were not overexposed to the metals we sampled

- None of employees' exposures were at or above the occupational exposure limits for the 31 metals we analyzed.

One fume extractor did not provide adequate welding fume capture

- The two Vent Boss Series 100 portable fume extractors in use provided adequate capture of the welding fumes. However, the Miller FiltAir® fume extractor did not have acceptable capture air velocity at the point of welding fume generation.

To learn more about our results, go to Section B in the Supporting Technical Information

Our Recommendations

The Occupational Safety and Health Act requires employers to provide a safe workplace.

Potential Benefits of Improving Workplace Health and Safety:

↑ Improved worker health and well-being	↑ Enhanced image and reputation
↑ Better workplace morale	↑ Superior products, processes, and services
↑ Easier employee recruiting and retention	↑ May increase overall cost savings

The recommendations below are based on the findings of our evaluation. For each recommendation, we list a series of actions you can take to address the issue at your workplace. The actions at the beginning of each list are preferable to the ones listed later. The list order is based on a well-accepted approach called the "hierarchy of controls." The hierarchy of controls groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees. Until such controls are in place, or if they are not effective or practical, administrative measures and personal protective equipment might be needed. Read more about the hierarchy of controls at https://www.cdc.gov/niosh/topics/hierarchy/.

We encourage the company to use a health and safety committee to discuss our recommendations and develop an action plan. Both employee representatives and management representatives should be included on the committee. Helpful guidance can be found in *Recommended Practices for Safety and Health Programs* at https://www.osha.gov/shpguidelines/index.html.

Recommendation 1: Improve the welding fume capture effectiveness of the Miller FiltAir fume extractor

Why? Improving the capture effectiveness of the welding fume extractor will help avoid unnecessary exposure to welding fumes. Even though welders were not overexposed to metals during the site visit, potential for overexposure in the future exists if welding fumes are not effectively controlled.

How? At your workplace, we recommend these specific actions:

Replace the filter on the Miller FiltAir fume extraction unit if it is dirty.

After performing maintenance on the welding fume extractor, measure the air velocity across the hood inlet and at the point of welding smoke generation (approximately 12 inches away from the inlet).

- Replace the unit if it does not maintain a minimum air capture velocity of 100–200 feet per minute at the point of welding fume generation and an average of 2,000–2,500 feet per minute across the hood inlet.

Develop and follow a fume extractor filter check and replacement schedule.

Supporting Technical Information

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Section A: Workplace Information

Building

The facility was part of a complex of buildings within an office park. The office section of the building had approximately 3,000 square feet of floor space. The shop area was considered a "high bay" style of construction with a 25-foot ceiling and approximately 7,000 square feet of floor space dedicated to fabrication activities. Climate control in the shop area was achieved by dilution ventilation. Two rooftop air handlers provided filtered supply air that was either heated or cooled, depending on the season. The air handers used minimum efficiency reporting value (MERV) filters with a rating of 11 to filter the supply air. Air exhausted from the shop through two fans located on the rear exterior wall.

Employee Information

Each of the 10 employees at the shop worked a 10-hour shift, four days per week.

Process Description

A variety of architectural metal structures were custom fabricated in the shop area. Employees created structures using a variety of welding and cutting operations on steel. Most of the welding involved metal inert gas (MIG) welding equipment, although some tungsten inert gas (TIG) welding may be performed if necessary, depending on the material. The safety data sheet (SDS) that accompanied the consumable welding wire indicated that the primary components of the wire were iron, copper, manganese, and carbon. A computer-controlled plasma cutting table equipped with a particle-capturing water bath was used to cut out custom pieces prior to fabrication.

The shop used three portable welding fume extractors to control emissions generated during welding. Each of the portable fume extractors used a 12-conical, tapered bell-mouth inlet hood attached to an 8-inch flexible duct. The duct was attached to an air handler equipped with a MERV 15 filter media and air pressure measuring gauge. The inlet of each extractor was placed approximately 12 inches from the welding arc to capture emissions created during the welding process. Respiratory protection, in the form of an N95 style filtering facepiece respirator, is provided for use on a voluntary basis.

Section B: Methods, Results, and Discussion

We focused on these objectives:

- Evaluate the extent of exposure to metals among welders engaged in welding, grinding, and operating a tabletop plasma cutter.
- Evaluate the local exhaust ventilation systems' performance.

Methods: Exposure Assessment

Air Sampling

We measured full-shift exposures to metals in the personal breathing zone of employees using NIOSH Method 7300 [NIOSH 2019]. Measurements were taken over two 10-hour shifts.

Results: Exposure Assessment

The full-shift personal air sample results for metals are shown in Table C1. None of the welders', grinders', or plasma cutting table operator's exposures to metals were at or above occupational exposure limits (OELs). We analyzed each sample for 31 metals and only detected 7 metals as listed in Table C1.

Methods: Local Exhaust Ventilation Assessment

Each of the portable fume extractors used a 12-inch conical, tapered bell-mouth inlet hood attached to an 8-inch flexible duct. The duct was attached to an air handler equipped with a MERV 15 filter media and an air pressure measuring gauge. Measurement of the capture air velocity for each of the three portable fume extractor units was taken at the working distance from the exhaust hood (approximately 12 inches in front of the inlet hood). The face velocity was determined by a centerline measurement at the inlet hood opening.

Results: Local Exhaust Ventilation Assessment

The face velocities measured at the inlet of two Vent Boss Series 100 exhaust hoods ranged from 1,100–2,200 feet per minute (fpm) while the face velocity at the inlet of the Miller FiltAir Model MWX-D unit was lower (550 fpm). The two Vent Boss Series 100 units provided acceptable capture air velocities ranging 100–135 fpm at the working distance of 12 inches (point of welding smoke generation). However, the Miller FiltAir Model MWX-D only provided a capture air velocity of 70 fpm, which was below the minimum American Conference of Governmental Industrial Hygienists (ACGIH) guideline of 100–200 fpm at the point of welding smoke generation [ACGIH 2019a].

The company had a written respiratory and hearing protection plan within the employee handbook. The company provided N95 filtering facepiece respirators for voluntary use, however, only a few employees engaged in welding and grinding tasks were observed wearing respirators. The written hazard communication program contained details on SDSs, container labeling, and employee training.

Discussion and Conclusions

All welders/grinders and plasma cutters had exposures below OELs for each of the metals detected. We found that one of the portable fume extractors (Miller FiltAir) did not provide the minimum acceptable capture air velocity of 100 fpm at the point of fume generation as recommended by the ACGIH [ACGIH 2019a]. Maintenance on this unit, such as replacing the filter, should be performed to restore proper operation. However, if the performance cannot be improved, the unit should be replaced.

Section C: Tables

Table C1. Full-shift personal air sampling results for metals during welding, grinding, and plasma cutting table operation in milligrams per cubic meter of air (mg/m³)

Day	Sample ID	Aluminum	Chromium	Copper	Iron oxide	Manganese	Potassium	Zinc oxide
Day 1	1	0.007	ND	0.006	1.08	0.022	0.014	0.002
	2	[0.002]*	ND	0.001	0.14	0.006	0.003	0.001
	3	0.012	0.001	0.003	0.45	0.012	0.023	0.004
	4	0.003	ND	0.001	0.10	0.002	0.009	0.001
	5	0.004	ND	0.001	0.20	0.007	0.005	0.001
	6	[0.002]	ND	ND	0.08	0.002	0.003	ND
Day 2	7	0.004	ND	0.003	0.49	0.01	0.009	0.001
	8	[0.002]	ND	0.001	0.14	0.01	0.003	0.001
	9	0.004	0.001	0.002	0.26	0.009	0.004	0.001
	10	[0.002]	ND	0.002	0.28	0.011	0.005	ND
	11 (plasma cutting)	ND	ND	ND	0.04	0.002	0.002	ND
MDC		0.0008	0.0001	0.0001	0.0003	0.0000	0.0004	0.0003
MQC		0.0030	0.0002	0.0004	0.0009	0.0001	0.0013	0.0009
NIOSH REL		10	0.5	1	5	1	N/A	5
OSHA PEL†		15	1	1	10	5§	N/A	5
ACGIH TLV‡		1	0.5	1	5	0.1¶	N/A	2

MDC = Minimum detectable concentration

MQC = Minimum quantifiable concentration

N/A = Not available

ND = Not detected

NIOSH REL = NIOSH recommended exposure limits are time-weighted averages for work shifts of 8 to 10 hours in length.

* Values in brackets are between the MDC and the MQC; more uncertainty is associated with these results.

† Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs), except as noted, are time-weighted-averages based on an 8-hour shift and are not adjusted for longer work shifts.

‡ The ACGIH threshold limit values (TLVs) were adjusted to reflect a 10-hour work shift using the Brief and Scala method [1975].

§ Ceiling value not to be exceeded.

¶ Inhalable fraction

Section D: Occupational Exposure Limits

NIOSH investigators refer to mandatory (legally enforceable) and recommended occupational exposure limits (OELs) for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to prevent adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects.

However, not all employees will be protected if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a preexisting medical condition, or a hypersensitivity (allergy). In addition, some hazardous substances act in combination with other exposures, with the general environment, or with medications or personal habits of the employee to produce adverse health effects. Most OELs address airborne exposures, but some substances can be absorbed directly through the skin and mucous membranes.

Most OELs are expressed as a time-weighted average (TWA) exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended short-term exposure limits (STEL) or ceiling values. Unless otherwise noted, the STEL is a 15-minute TWA exposure. It should not be exceeded at any time during a workday. The ceiling limit should not be exceeded at any time.

In the United States, OELs have been established by federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits; others are recommendations.

- OSHA, an agency of the U.S. Department of Labor, publishes permissible exposure limits [29 CFR 1910 for general industry; 29 CFR 1926 for construction industry; and 29 CFR 1917 for maritime industry] called PELs. These legal limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH recommended exposure limits (RELs) are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. NIOSH RELs are published in the *NIOSH Pocket Guide to Chemical Hazards* [NIOSH 2007]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, PPE, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.
- Another set of OELs commonly used and cited in the United States includes the threshold limit values or TLVs, which are recommended by ACGIH. The ACGIH TLVs are developed by committee members of this professional organization from a review of the published, peer-reviewed literature. TLVs are not consensus standards. They are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH 2019b].

Outside the United States, OELs have been established by various agencies and organizations and include legal and recommended limits. The Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (Institute for Occupational Safety and Health of the German Social Accident Insurance) maintains a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States. The database, available at https://www.dguv.de/ifa/gestis/gestis-stoffdatenbank/index-2.jsp, contains international limits for more than 2,000 hazardous substances and is updated periodically.

OSHA (Public Law 91-596) requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm. This is true in the absence of a specific OEL. It also is important to keep in mind that OELs may not reflect current health-based information.

When multiple OELs exist for a substance or agent, NIOSH investigators generally encourage employers to use the lowest OEL when making risk assessment and risk management decisions.

Health Effects of Welding Fumes

Even though no overexposures occurred during this evaluation, it is important to be aware of the potential health effects of welding fumes. The effect on an individual's health can vary depending on the length and intensity of the exposure and the specific metals involved. Of concern is welding processes involving stainless steel, cadmium or lead-coated steel, and metals, such as manganese, iron, nickel, chrome, zinc, and copper. Fumes from these metals are considerably more toxic than those encountered when welding iron or mild steel. Epidemiologic studies and case reports of employees exposed to welding emissions have shown an excessive incidence of acute and chronic respiratory diseases [NIOSH 1988]. These illnesses include metal fume fever, pneumonitis, pulmonary edema, and lung cancer. Excessive exposure to manganese has been associated with Parkinson-like health effects, such as poor hand-eye coordination, motor slowing, increased tremor, reduced response speed, mood disturbance, and possible memory and intellectual loss [Antonini et al. 2006; Bowler et al. 2006; Lundin et al. 2014; Racette et al. 2012; Welch et al. 2004].

The content of welding fumes depends on the base metal being welded, the welding process, and parameters such as voltage and amperage, the composition of the consumable welding electrode or wire, the shielding gas, and any surface coatings or contaminants on the base metal. The flux coating (or core) of the electrode/wire may contain up to 30 organic and inorganic compounds. In general, welding fume constituents may include minerals, such as silica and fluorides, and metals, such as arsenic, beryllium, cadmium, chromium, cobalt, nickel, copper, iron, lead, magnesium, manganese, molybdenum, tin, vanadium, and zinc [NIOSH 1988; Welding Institute 1976]. OSHA has not established a PEL for total welding fumes; however, PELs have been set for individual welding fume constituents (e.g., iron, manganese) [29 CFR 1910.1000]. NIOSH has concluded that it is not possible to establish an exposure limit for total welding emissions because the composition of welding fumes and gases varies greatly, and the welding constituents may interact to produce adverse health effects. Therefore, NIOSH recommends controlling total welding fume to the lowest feasible concentration and meeting the exposure limit for each welding fume constituent [NIOSH 2007]. In addition to welding fumes, many other potential health hazards exist for welders. Welding operations can produce gaseous emissions, such as carbon monoxide, ozone, nitrogen dioxide, and phosgene (formed from chlorinated solvent decomposition) [NIOSH 1988; Welding Institute 1976]. Welders can also be exposed to hazardous levels of ultraviolet radiation from the welding arc if welding curtains or other precautions are not used.

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