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Welding Health and Safety

A Field Guide for OEHS Professionals

2nd Edition

Learn to communicate more effectively with welding shop and plant personnel with this practical guide.

By Michael K. Harris, PhD, CIH and Michael R. Phibbs, CIH, ROH

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American Welding Society

AIHA and the author express their appreciation to the American Welding Society for granting permission to use numerous figures from their *Welding Handbook* in this edition. Their figures have added greatly to the usefulness and appearance of this field guide.

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1
Introduction to Welding Health and Safety

1. Introduction to Welding and Thermal Cutting

This chapter is designed to acquaint the occupational and environmental health and safety (OEHS) Professional with basics of welding and thermal cutting, investigation procedures, regulations, and resource materials related to welding health and safety. Information presented in Chapter 2 of this book is intended to provide sufficient understanding of the details of the work to allow the OEHS Professional to communicate with shop and plant personnel and understand the jargon used by welders. However, no attempt has been made to offer an encyclopedic discussion of the numerous nuances of welding. The American Welding Society (AWS) produces a wide variety of welding publications that may be consulted for a comprehensive treatment of welding. The AWS may be contacted at 8669 NW 36 Street, #130 Miami, FL 33166 (800-443-9353) or www.aws.org.

Many hazards such as noise, thermal burns, and crushing/pinch point injuries are generally self-evident during a walk-through. Other hazards, such as those associated with inhalation exposures to a variety of metal fumes, products of flux decomposition, products of cleaning solvent decomposition, handling of compressed gases, working with high-amperage electrical equipment, and the unique hazards associated with work in confined spaces, may be less obvious.

Welding has often been regarded by our profession as a "task," not unlike abrasive blasting or painting. It is more appropriate to regard welding and thermal cutting as an industry that is interdigitated with fabrication and repair processes. Welding is similar to painting and blasting tasks in that the worker is seldom more than an arm's length from the source of the airborne contaminant(s). There, however, the similarity ends. In the case of blasting or painting, a relatively limited number of abrasives and coatings are found common use, constraining the number of airborne contaminants. By comparison, the AWS lists well over 30 welding and thermal

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cutting processes, each with its own suite of health and safety hazards. Moreover, hundreds of ferrous and nonferrous alloys (each with its own distinct chemical composition) are subjected to the violence of electricity during construction, fabrication, and repair tasks. In addition to the variety of welding and thermal cutting processes, base metals, filler metals, and tasks, there is another source of variability that has proven to be a frequent cause of frustration when parsing out the sources of exposure data variability: the work environment. The size, configuration, dimensions, and ventilation (natural or mechanically assisted) of the work environment have a profound effect on the dispersion, or lack thereof, of the welding fume. Finally, individual variations in body position, eyesight, and personal habit can have a notable effect on exposure potential between workers performing essentially the same work.

Several challenges are faced by welding engineers and welders as they develop processes and techniques for joining metal. Some are mechanical, such as controlling distortion caused by the cooling of the weld metal. Think about that for moment. Welding has been defined as "A joining process that produces coalescence of materials by heating them to the welding temperature, with or without the application of pressure alone and with or without the use of filler metal."[1] In the case of the most common manual welding processes, filler metal is added to the pool of molten metal to create weld. As this metal solidifies and cools, it contracts, and in doing so creates stresses in the welded assembly or "weldment." These stresses due to contraction result in warpage or distortion of the weldment. This can be counteracted by preheating, postheating, joint design, and use of fixtures to limit component movement as it cools. That's the easy part.

The hard part is protecting the molten metal from exposure to atmospheric oxygen and nitrogen. Exposure of the molten pool of metal to the atmosphere can easily result in weakening of the weld due to voids in the weld ("Swiss cheesing") and compromised metallurgical properties that may cause outright failures of the weld. When one considers that the weldment may be the hull of a ship, the chassis of a piece of earthmoving equipment, the housing of a jet engine, the body of a railroad passenger car, or the body of the car you drove to work, the need for ensuring weld quality by excluding the atmosphere from the weld pool is evident.[a]

[a] Not all welding processes create a pool of molten metal subject to exposure to the atmosphere. Exceptions include resistance welding, explosion welding, and stud welding.

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A number of methods are used to exclude the atmosphere during the welding process. The shielding techniques for each process are described in Chapter 2. The shielding methods used for the various processes affect the quantity and makeup of the fume emitted by the processes.

Welding and cutting operations can result in the generation of a hazardous atmosphere, especially in a confined space, even though that space may have been found safe for entry prior to beginning the work. For example, thermal cutting, welding, and arc gouging release metal fumes into the air. In steel fabrication and repair, the most common fume is iron oxide, which in recent literature has been associated with development of neoplastic disease. When hardfacing, corrosion-resistant, or high-strength alloys are subject to welding and cutting, other contaminants of concern such as hexavalent chromium and nickel (among others) are likely to be released. Metal fumes are not the only contaminants of concern. Welding and cutting also generate a number of gaseous contaminants. These include the following:

- Ozone, particularly during aluminum welding.
- Carbon monoxide, particularly during arc gouging.
- Oxides of nitrogen.
- Argon or other inert gases used for gas-shielded arc processes.
- Fluorides that might be released when shielded metal arc welding (SMAW) is used.
- Thermal decomposition of paint coatings might release a wide variety of contaminants, and the material safety data sheet (MSDS) for coated metal should be consulted before commencing welding or cutting operations on those surfaces. Examples include the following:
  - Isocyanates from decomposition of paint coatings that require catalysts (e.g., urethane and polyurethane paints)
  - Aldehydes from decomposition of “weldable paints” and some degreasers.

2. Anticipation and Recognition of Welding and Cutting Health and Safety Hazards

An evaluation of the following three sets of factors will very likely reveal the health and safety hazards associated with nearly all welding and cutting processes:

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1) Materials in use:
   i) Metals being joined or cut
   ii) Filler metals in use (if any)
   iii) Fluxes in use (if any)
   iv) Shielding gases (if any)
   v) Coatings on the metals being joined or cut
   vi) Cleaning or degreasing solvents
2) Heat source for the process under investigation:
   i) Electric arc
   ii) Electrical resistance
   iii) Oxyfuel
   iv) Plasma
   v) Laser beam
   vi) Electron beam
3) Workplace environment:
   i) Open work areas
   ii) Confined spaces
   iii) Restricted spaces
   iv) Wet work areas
   v) Multiple welder worksites

In this context, the answers to a few questions should direct the OEHS Professional's attention to the most likely hazards. The following examples may be of use in this regard:

- "What are you welding?" This question should initiate a discussion of the materials being welded. Generally, the answer will come in the form of some sort of shop shorthand. For example, chrome-molybdenum steel containing 1.25 percent chromium is frequently called "one-and-a-quarter-chrome." Similarly, steel that contains a minimum of alloying ingredients is commonly referred to as "carbon steel" or "mild steel." The process of investigation should now proceed to the facility's *Hazard Communication Manual (HazCom Manual)* for review of the MSDSs to identify probable contaminants of concern.
- A second question might be: "What kind of welding (or cutting) process are you using?" The answer to this question should direct the OEHS Professional to Chapter 2 of this edition. Chapter 2 outlines 25 common welding and thermal cutting processes and briefly describes the health and safety hazards associated with the various processes.

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The majority of Chapter 2 is for reference purposes in the event that the less common processes are in use at your facility. Rather than reading the entire chapter, focus your attention on the commonly used processes. Common high-fume emission processes are:

- Shielded metal arc welding (SMAW), Section 1
- Gas metal arc welding (GMAW), Section 3
- Flux cored arc welding (FCAW), Section 4
- Arc cutting and arc gouging, Section 15

Common low-fume emission processes are:

- Gas tungsten arc welding (GTAW), Section 2
- Submerged arc welding (SAW), Section 5
- Resistance welding (RW), Sections 17 and 18

Welding processes usually (but not always) use filler metal that is melted along with the parts being joined. If the joining process is brazing or soldering rather than welding, it will also be necessary to determine what filler metal is being used. Also, fluxes are in common use for many processes. In either event, it will likely be necessary to revisit the *HazCom Manual* to identify the possible contaminants of concern from filler metal and flux sources.

- A third question might address the possibility of coatings on the metals being joined or cut. These coatings may include:
  - Process chemical residue, e.g.,
    - Some halogenated cleaning chemicals decompose to form chlorine gas and/or phosgene.
    - Some petrochemical vessels may contain sulfur compounds that form sulfur dioxide (a profound upper respiratory tract irritant) upon heating.
  - Paints
  - Polymers
  - Primers
  - Claddings
  - Plated materials

These possible sources of contaminants are deserving of particular consideration when executing repair and maintenance tasks. Pay attention to the "products of decomposition" section of the MSDS for the coatings. Cadmium, lead, strontium chromate, and isocyanates may evolve or outgas from some of these coatings when heated.

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- A fourth question, or set of questions, should focus on characterizing the work environment. For example:
  - How many welders will be involved in the work?
  - How many helpers will be working with the welders?
  - What other activities are being conducted in the area?
  - Will this work be conducted in a confined space?
  - Will the work be carried out in a fairly open work area?
  - Will the work be executed in a "fabrication tent" at a construction site?

These questions focus on identifying worksite characteristics that may mitigate or exacerbate exposure potentials, not only for the welder, but for other nearby workers as well.

Recognizing that we all have our relative strengths and "growth areas," the industrial hygienist is reminded to consider the potential for physical hazards when working with the high energy levels necessary to melt, weld, cut, and join metals. Similarly, the OEHS Professional is advised to look carefully at the potential for airborne hazards from welding and allied processes. A site-specific checklist for investigating welding and cutting processes may be of real value in this context. A draft or prototype checklist (*Welding Health and Safety: Initial Evaluation Form*) is provided at the end of this chapter. This evaluation form is by no means all-inclusive and very likely will not address all the probable hazards at all facilities. However, it may be useful as a starting place for development of a more appropriate site-specific evaluation form.

3. Regulations

The Occupational Safety and Health General Industry Standards, Subpart Q – Welding, Cutting and Brazing includes the following sections pertinent to welding and other hotwork processes. These standards may be worth reviewing, particularly for OEHS Professionals working in the United States.

- 29 CFR 1910.251: Definitions
- 29 CFR 1910.252: General Requirements
- 29 CFR 1910.253: Oxygen-Fuel Gas Welding and Cutting
- 29 CFR 1910.254: Arc Welding and Cutting
- 29 CFR 1910.255: Resistance Welding

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Applicable OSHA Shipyard standards include:

- 29 CFR 1915.51: Ventilation
- 29 CFR 1915.52: Fire Prevention
- 29 CFR 1915.53: Welding, Cutting and Heating in Way of Preservative Coatings
- 29 CFR 1915.54: Welding, Cutting and Heating in Hollow Metal Structures
- 29 CFR 1915.55: Gas Welding and Cutting
- 29 CFR 1915.56: Arc Welding and Cutting

Construction industry standards promulgated by OSHA with provisions regulating use of welding equipment include:

- 29 CFR 1926.350: Gas Welding and Cutting
- 29 CFR 1926.351: Arc Welding and Cutting
- 29 CFR 1926.352: Fire Prevention
- 29 CFR 1926.353: Ventilation and Protection in Welding, Cutting and Heating
- 29 CFR 1926.354: Welding and Cutting in Way of Preservative Coatings

Other standards pertinent to specific welding and cutting operations are listed and, to some degree annotated, in subsequent chapters of this book.

4. Resource Materials

Several documents have been the source of much of the welding-specific information summarized in this volume. Their use is recommended for those with welding OEHS responsibilities.

- O'Brien A., ed. *Welding Handbook, Ninth Edition, Volume 2: Welding Processes, Part 1*. Miami, FL: American Welding Society, 2004.
- American Welding Society. *Safety in Welding, Cutting and Allied Processes, American National Standard Z49.1:20129*. Miami, FL: American Welding Society, 2012.
- Hitchcock RT, Rockwell RJ. *Laser Radiation: AIHA Nonionizing Radiation Guide Series*. Fairfax, VA: AIHA Press, 1999.
- Hitchcock RT. *Ultraviolet Radiation: Nonionizing Radiation Guide Series*. Fairfax, VA: AIHA Press, 2001.

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5. Welding Health and Safety: Initial Evaluation Form

One must practice great care when using forms, as they rarely exhibit the precise focus one might desire (unless they are site specific). One size does not fit all. The reader is therefore cautioned that this sample welding health and safety evaluation form is neither all-inclusive nor designed to address all worksites. The intended use of this sample form is to offer a starting place for development of a site-specific evaluation form. For instance, many worksites may require additional emphasis and detail regarding fire prevention. Conversely, worksites that do not use compressed gases will have no need to include reference to compressed gas hazards. Cryogenic storage is not addressed here as it is not as common as gaseous state storage. Certainly, if the user has cryogenics on site, those hazards should be addressed in a site-specific evaluation form.

This sample evaluation form uses a question-and-answer format. Some of these questions have added syntax to allow a consistent "Yes" answer if conditions meet the desired criteria. This approach merely reflects the author's preference and is not the only way to develop an evaluation form. The layout of the reader's site-specific form is a matter of personal preference, and the reader is encouraged to make his/her form fit his/her workplace and work habits. There is a certain amount of redundancy in the form offered here.

For example, reference to correct filter lenses is made under nonionizing radiation and again under personal protective equipment (PPE). This reflects the dichotomy many of us face when evaluating hazards and PPE in the same breath: does the question go under the hazard itself [ultraviolet (UV) radiation] or under the PPE needed to address the hazard (filter lenses)? This author (M.K. Harris) elects to leave that editorial decision up to the developer of the site-specific evaluation form. Clearly, there is room for more detailed questions than those asked here. However, the following form is believed to be an adequate starting point for developing an initial evaluation form for the site under investigation.

Reference

1. **O'Brien RL, ed.** *Jefferson's Welding Encyclopedia, 18th Edition*. Miami, FL: American Welding Society, 1997.

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Appendix A: Metals Data[1]

1	2	3	4	5	6	7	8
Constituent	**CAS No.**	**Health-Based H-Statements**	**Hazard Group**	**Melting Pt °C**	**Boiling Pt °C**	**2021 ACGIH TLV® – TWA**	**NIOSH Target Organs**
Total Dust – Welding Fume		H350: May cause cancer**	E	NAv	NAv		Eyes, skin respiratory system, central nervous system
Aluminum	1344-28-1	NAp	NAp	660	2327	1 mg/m^3 (R)	Eyes, skin respiratory system
Antimony	7440-36-0	H302: Harmful if swallowed. H332: Harmful if inhaled. H351: Suspected of causing cancer. H373: May cause damage to organs through repeated or prolonged exposure.	D	630	1635	0.5 mg/m^3	Eyes, skin respiratory system, cardiovascular system
Beryllium	7440-41-7	H301: Toxic if swallowed. H315: Causes skin irritation. H317: May cause an allergic skin reaction. H319: Causes serious eye irritation. H330: Fatal if inhaled H335: May cause respiratory irritation. H350: May cause cancer. H372: Causes damage to organs through prolonged or repeated exposure.	E	1287	2468	0.00005 mg/m^3 (I)	Eyes, skin, respiratory system

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Appendix A (continued): Metals Data[1]

1	2	3	4	5	6	7	8
Constituent	**CAS No.**	**Health-Based H-Statements**	**Hazard Group**	**Melting Pt °C**	**Boiling Pt °C**	**2021 ACGIH TLV® – TWA**	**NIOSH Target Organs**
Cadmium	7440-43-9	H330: Fatal if inhaled. H341: Suspected of causing genetic defects. H350 May cause cancer. H361f: Suspected of damaging fertility. H361d: Suspected of damaging the unborn child. H372: Causes damage to organs through prolonged or repeated exposure.	E	321	765	0.01 mg/m^3 0.002 mg/m^3 (R)	Respiratory system, kidneys, prostrate blood
Chromium	7440-47-3	H317: May cause an allergic skin reaction. H319: Causes serious eye irritation. H334: May cause allergy or asthma symptoms or breathing difficulties if inhaled.	E	1907	2642	0.5 mg/m^3 (I) Cr(III) 0.003 mg/m^3 (I)	Eyes, skin, respiratory system
Cobalt	7440-48-4	H317: May cause an allergic skin reaction. H334: May cause allergy or asthma symptoms or breathing difficulties if inhaled.	E	1495	2927	0.02 mg/m^3 (I)	Skin, respiratory system

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Michael R. Phibbs, CIH, ROH

Learn to communicate more effectively with welding shop and plant personnel with this practical guide, written for those who have little actual “hands on” shop experience. Topics include health and safety considerations, welding terminology, equipment, welding and cutting in confined spaces, construction, maintenance, and repair welding, plus the health effects of metals, gases, and other agents commonly encountered in welding processes.

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