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Labour

A Guide to Health Hazards and Hazard Control Measures with Respect to Welding and Allied Processes

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A Guide to Health Hazards and Hazard Control Measures with Respect to Welding and Allied Processes

The purpose of this guide is to assist an Occupational Health and Safety Officer in recognizing health hazards associated with welding and thermal cutting operations and verifying whether the control measures are in place.

This guide is intended for those Officers who specialize in Part II of the *Canada Labour Code* and the pursuant regulations. It can also be used to assist the employers in federally regulated work places in developing and implementing a hazard prevention program.

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Chapter 1

Introduction

Welding is defined as a materials joining process used in making welds. Welding and cutting operations present certain potential hazards to welders that can result in temporary or permanent physical injury, short- or long-term adverse health effects, discomfort and even death. The potential health hazards associated with welding and allied processes include exposure to fumes and gases, heat, noise, radiation, as well as, musculoskeletal injuries (MSI's), such as strains and sprains.

Chapter 2

Fumes & gases

Fume produced during welding is comprised of solid particles, usually less than 1.0 μm in size, formed by condensation and oxidation of the vaporized metal. These particles are capable of being deposited in the gas-exchange region of the lungs. The chemical composition of the welding fumes and gases depends on the welded material, the process and the electrodes used. However, the potential health hazards from exposure to welding fumes are dependent not only on the welded metal, the process and the composition of the welding electrode, but also on the work environment, including the location (indoor vs. outdoor), the type and quality of natural and mechanical exhaust ventilation, degree of enclosure of the work station, length of exposure, and personal protection equipment.

Prolonged exposure to welding fumes and gases at high concentrations can cause:

- siderosis (iron oxide)
- metal fume fever (zinc oxide, magnesium oxide, copper, aluminum)

- nervous system disorders (manganese)
- irritation of respiratory system
- eye, nose and throat irritation
- chest pain
- kidney damage (cadmium oxide, fluorides)
- cancer (cadmium oxide, nickel, chromium (VI))
- fluid in the lungs (cadmium oxide, fluorides, ozone, nitrogen oxide)
- haemorrhage (ozone)
- dermatitis, eczema (nickel, chromium (VI))
- bone and joint problems (fluorides)
- headaches and dizziness

Usually, a welding operation is associated with the generation of two or more hazardous substances into the working atmosphere. Therefore, the hazard should be evaluated by measurement of each constituent and, if the constituents have similar toxicological effects, or there is no information to the contrary, their synergistic (combined) effect should be given primary consideration. Attention should also be paid to synergism with non-occupational risk factors, such as cigarette smoking. Smoking may enhance the adverse health effects of respiratory hazards related to welding.

The following table shows the most common metal fumes and gases that may be generated during different types of welding and thermal cutting, as well as, their sources and potential health effects.

Table I – Welding fumes and gases and their potential health effects

Fumes	Source	Health effects & symptoms
Cadmium oxide	Stainless steel containing cadmium, plating	Pulmonary edema, nose irritation and ulceration; chronic effects include kidney damage and emphysema, cancer (prostate, lung), pulmonary fibrosis
Chromium (VI)	Stainless steel, plating, chromium pigment manufacturing, electrode	Skin irritation, respiratory tract irritation, effects on nose, eyes and ears; chronic effects include lung cancer, kidney and liver damage
Copper	Coating on filler wire, sheaths on air carbon arc gouging electrodes, nonferrous alloys	Metal fume fever, eyes, nose and throat irritation
Iron oxide	All iron or steel welding processes	Acute effects are nose and lung irritation; siderosis (pulmonary deposition of iron dust)
Magnesium oxide	Magnesium or aluminum alloys	Eyes and nose irritation, metal fume fever
Manganese	Most welding processes, high-tensile steel	Chemical pneumonitis; chronic effects include nervous system disorders
Nickel	Stainless steel, nickel-clad steel, plating	Dermatitis, asthma-like lung disease; chronic effects include cancer (nose, larynx, lung), respiratory tract irritation, renal dysfunction
Zinc oxide	Galvanized and painted metals	Metal fume fever

Table I – Welding fumes and gases and their potential health effects *(Cont'd)*

Fumes	Source	Health effects & symptoms
Fluorides	Electrode coating, flux material	Eye, nose and throat irritation, gastro-intestinal symptoms; chronic effects include bone and joint problems, fluid in the lungs, kidney dysfunction
Ozone	Formed in the welding arc	Acute effects include fluid in the lungs and haemorrhage; chronic effects include changes in lung function
Nitrogen oxide	Formed in the welding arc	Pneumonitis, pulmonary edema; chronic bronchitis, emphysema; pulmonary fibrosis
Carbon monoxide	Carbon dioxide shielded metal-arc welding, electrode coatings	Headache, nausea, dizziness, collapse, death; chronnic cardiovascular effects

The concentration of welding fumes to which welders are exposed depends on the type of welding process, work area, existing ventilation, personal protective equipment, as well as, a welder's position and posture.

The following are the most common types of welding processes:

- shielded metal arc welding (SMAW)
- gas metal arc welding (GMAW)
- flux-cored arc welding (FCAW)
- gas tungsten arc welding (GTAW)
- plasma arc gouging (PAG)

- plasma arc welding (PAW)
- plasma arc cutting (PAC)
- submerged arc welding (SAW)
- air carbon arc gouging
- metal-cored arc welding (MCAW)

The type of process including the shielding gas, electrode size and type, manual or mechanized welding, current/voltage and arc time significantly influences the amount of fumes produced and affects the exposure of workers to contaminants. For example, open arc processes that use a flux, higher current and larger electrodes will produce more fumes than gas tungsten arc welding (GTAW) or submerged arc welding (SAW) processes.

Hot environments

Hot environmental conditions include air temperature, radiant heat, humidity and air movement. Welding and cutting operations, and in particular plasma arc cutting, are known to produce heat, the exposure to which in combination with the internal body heat due to physical activity and clothing requirements may lead to some health disorders or even heat-related illnesses. The most common signs and symptoms of the body response to heat include:

Sweating

Discontinued sweating

Increased heart rate

Increased body temperature

Urinating less frequently than normal

Small volume of dark-colored urine

Irritability

Lack of coordination

Lack of judgement

Excessive and prolonged exposure to hot work environment can cause heat-related illnesses such as:

Heat rush

Heat edema

Heat cramp

Heat exhaustion

Heat syncope (fainting)

Heat stroke

Signs and symptoms of heat illnesses include:

Excessive sweating

Rapid breathing

Weaknesses or fainting

Tiredness

Headache

Confusion

Noise

Air carbon arc cutting, gouging and plasma arc processes generate significantly high noise levels. Excessive exposure to noise among welders can cause noise-induced hearing losses.

Radiation

The plasma arc emits intense ultraviolet, visible light and infrared radiation. Laser beam and electron beam welding and cutting processes also produce visible and/or invisible radiation. In addition, whenever the high voltage is on, an electron beam system is capable of generating X-rays.

Musculoskeletal injuries

Musculoskeletal injuries, such as strains and sprains, can occur when a welder is welding in a static awkward or horizontal position with a heavy face shield. The extra weight of the shield can cause strain on the welder's neck. Neck problems are also associated with prolonged use of a combination of a hard hat and a welding helmet. In addition, long and repetitive duration of exposure and high force generation may have cumulative effects that contribute to the increased risk of injury.

Welding and allied processes including hazard identification are outlined in the CSA Standard W117.2 *Safety in Welding, Cutting, and Allied Processes*.

Chapter 3

Material Safety Data Sheet

While investigating potential health hazards with respect to welding, it is important to consider the material safety data sheet (MSDS) for each controlled product that is used in the welding operation. MSDSs define which health hazards are associated with the use of these products. These documents also provide recommendations regarding preventive measures such as engineering controls and personal protective equipment (PPE).

Threshold Limit Values

In addition to the material safety data sheets, the CSA Standard W117.2, and other documents that might be helpful in the investigation of health hazards associated with welding, it is essential that the following documents be consulted:

- the American Conference of Governmental Industrial Hygienist ACGIH) *Threshold Limit Values (TLVs®) for Chemical Substances and Physical Agents & Biological Exposure Indices (BEIs®)*, and
- the ACGIH *Documentation of the TLVs® and BEIs®*

The TLVs® and BEIs® are developed as guidelines to assist in the control of health hazards, and the *Documentation* is the source publication that provides the critical evaluation of the pertinent scientific information and data with reference to literature sources upon which each TLV® or BEI® is based. The ACGIH publication entitled *Threshold Limit Values and Biological Exposure Indices* is referenced in the *Canada Occupational Health and Safety Regulations* made under Part II of the *Canada Labour Code*.

Chapter 4

Preventive measures

Subsection 10.19 (1)(*a*) of the *Canada Occupational Health and Safety Regulations* (COHSR) requires that an employee shall be kept free from exposure to a concentration of an airborne chemical agent in excess of the value for that chemical agent adopted by the ACGIH, in its publication entitled *Threshold Limit Values and Biological Exposure Indices*.

When concentrations to various constituents present in welding fumes and gases exceed specified TLVs, or when the health of the employee is at risk, the employer is required to reduce exposure below the prescribed limits.

Section 19.5 of Part XIX of the COHSR states that the employer shall, in order to address identified and assessed hazards, take preventive measures that consist first of the elimination of hazards, then the reduction of hazards and finally, the provision of personal protective equipment. As part of the preventive measures, the employer is also required to develop and implement a preventive maintenance program.

Ventilation

Adequate ventilation must be provided for all welding and allied processes. The combination of general dilution ventilation and local exhaust is the most successful method in controlling welding fumes and gases.

Dilution ventilation

Dilution ventilation comprises fans such as roof exhaust fans and wall fans. A dilution ventilation system uses large amounts of air to flush out the whole area and dilute contaminants to the concentrations below prescribed limits. However, it allows the contaminants to enter the welder's breathing zone before the contaminants are removed from the working environment. If used exclusively, dilution ventilation may not be adequate to control the exposure of welders to welding fumes and gases to below the permissible occupational exposure limits.

Local exhaust ventilation

Some welding equipment come equipped with local exhaust ventilation attached to the welding equipment and is designed to remove the fumes and gases close to their point of origin. Other local exhaust ventilation systems are comprised of a hood, fan, duct, and air cleaner. The local exhaust ventilation must be designed and installed in such a way that welding fumes and gases are prevented from entering the welder's breathing zone. For fixed enclosures, local exhaust must be installed such that the fumes and gases are drawn away from the welder's breathing zone.

Local exhaust can be discharged outside the building or re-circulated through an air cleaner.

NOTE

Exhaust air containing carcinogens and/or other toxic contaminants must not be re-circulated.

The employer must ensure that the air cleaning system removes all contaminants, including toxic gases that may be generated during the welding process prior to re-circulating.

There are four types of engineered local exhaust ventilation systems:

- a welding bench with a fixed hood,
- a down-draft bench,
- a portable hood with flexible ducting, and
- a fume extraction gun or gun attachments with flexible ducting.

The effectiveness of local exhaust ventilation depends on:

- the distance of the hood from the source,
- exhaust air velocity, and
- hood placement.

Hoods must be located as close as possible to the welding points so that the welding fumes and gases are captured at the source.

An air velocity of 0.5 m/s (100 ft/min) across the welding site is recommended. In all processes that use shielding gases, air velocities in excess of 0.5 m/s may strip them away. For down-draft benches, it is necessary that an air velocity be great enough to assure that the fumes and gases generated during welding do not rise into the breathing zone of the

welder. In addition, the welder must know that if the work pieces cover too much of the down-draft hood assembly the exhaust effect is lost.

Practical procedures for controlling welding fumes and gases are outlined in the CSA Standard W117.2. These procedures include the installation of ventilation and fume extraction equipment.

Respiratory protection

Respiratory protection should only be used when engineering controls, such as ventilation are not technically and/or economically feasible. In some cases, the combination of both ventilation and respiratory protection may be necessary to reassure that the welders are protected.

A complete respiratory protection training including selection, fit testing, maintenance and inspection, must be provided to all welders who are provided with and wear respirators. Reference should be made to the CSA Standard Z.94.4, *Selection, Use and Care of Respirators*.

According to the Standard, a respiratory protection program must consist of the following components:

- roles and responsibilities,
- hazard assessment,
- selection of the appropriate respirators,
- respirator fit testing,
- training,
- use of respirators,
- cleaning, inspection, maintenance, and storage of respirators,
- health surveillance of respirator users,

- program evaluation, and
- recordkeeping.

A respirator must be of a type approved for its intended use and listed in the National Institute for Occupational Safety and Health (NIOSH) *Certified Equipment List* published by NIOSH. There are three types of respirators classified according to the mode of operation:

- atmosphere-supplying respirators,
- air-purifying respirators, and
- combination atmosphere-supplying and air-purifying respirators.

Atmosphere-supplying respirators provide a breathing air that is independent of atmospheric conditions. For air-purifying respirators, ambient air, prior to being inhaled, is passed through a filter, cartridge, or canister that removes particles and gases. For welding fumes, particulate-removing respirators must be equipped with 99.97%, referred to as 100% efficiency (He) class filters.

Welders using positive-pressure or negative-pressure respirators must be clean-shaven where the face piece seals to the skin.

Where breathing air is provided for the purpose of a respirator, the air must meet the standards set out in the CSA Standard Z180.1 *Compressed Breathing Air and Systems*.

Other protective equipment

For all welding and cutting operations, welders must wear appropriate eye and face protection, and clothing. Hearing protection may also be required depending on the levels of noise to which welders are exposed. In addition, attention must be paid to the use of screens to prevent the welding arc from affecting other workers. The screens of sturdy opaque or translucent materials with at least 50 cm (20 inch) bottom clearance for ventilation are recommended.

Medical surveillance program

Medical surveillance program, when recommended by a qualified person, must be made available to all workers exposed to welding fumes and gases. Particular attention should be paid to the respiratory tract, as well as, each welder's ability to use respiratory protection. As per the CSA Standard Z94.4 requirements, it is necessary that prior to fit testing and respirator use, the program administrator must ensure that documentation is completed to confirm that the individual is free from any physiological or psychological condition which may preclude him or her from being assigned the use of the selected respirator.

Chapter 5

Reference material

Reading and sources for reference:

1. Part II of the *Canada Labour Code*
2. *Occupational Health and Safety Regulations* made under Part II of the *Canada Labour Code*
3. ACGIH *Threshold Limit Values (TLVs®) for Chemical Substances and Physical Agents & Biological Exposure Indices (BEIs®)*. American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio
4. ACGIH *Documentation of the TLVs® and BEIs®*. American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio
5. CSA Standard W117.2 *Safety in Welding, Cutting, and Allied Processes*. Canadian Standard Association, Mississauga, Ontario
6. CSA Standard Z.94.4, *Selection, Use and Care of Respirators*. Canadian Standard Association, Mississauga, Ontario

7. CSA Standard Z180.1 *Compressed Breathing Air and Systems*. Canadian Standard Association, Mississauga, Ontario

8. *Industrial Ventilation. A Manual of Recommended Practice*. American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio

9. Karpinski, E.: *Worker Exposure to Welding Fumes and Gases in Federally Regulated Workplaces*. Human Resources Development Canada – Labour Program

10. *Welding Data Sheet*. Occupational Safety and Health, No. A-1, Canada Safety Council, Ottawa, Ontario

11. *Guide to the Management Hazardous Substances*. Human Resources and Skills Development Canada – Labour Program

12. Godin, C.: *Guide de prévention soudage – coupage*.

Contact

For additional information or technical assistance regarding the health and safety hazards associated with welding operations, or other work-related health and safety issues, contact Eva Karpinski, Industrial Hygiene Engineeer, **Technical Services Unit** of Occupational Health and Safety and Injury Compensation Division, Labour Operations:

165 Hotel de Ville Street
Place du Portage, Phase II, 10th floor
Gatineau, Quebec
K1A 0J2
Tel.: (819) 953-0218

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