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WELDING AND ALLIED PROCESSES

A guide to health hazards and hazard control measures

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WELDING AND ALLIED PROCESSES

A guide to health hazards and hazard control measures

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This technical guideline is developed by the Labour Program to assist federally regulated work places to identify, manage and reduce exposure hazards from welding and allied processes. The document contains links to the *Canada Occupational Health and Safety Regulations* and relevant technical guidelines and sampling information, description of health effects and control measures. The guideline is to assist Labour Program officials delegated by the Minister in inspecting and verifying compliance; qualified persons in conducting hazard investigations, developing workplace hazard prevention programs or in implementing control measures; and can also be used to generally inform employers and employees. It supports the Labour Program's mandate of fostering healthy and safe work place environments.

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1. Introduction

This guideline provides a summary of the health effects associated with welding processes and the control measures that should be employed at the work place. It also includes links to the relevant Threshold Limit Values (TLVs®) and sections from the ***Canada Occupational Health and Safety Regulations*** **(COHSR)**.

Welding, for the purposes of this guideline, is the industrial process for making welds to join metals. Allied processes also involve metals and are somewhat similar with respect to the hazards created, they include gouging, cutting or grinding metal or otherwise preparing or finishing it.

There are two types of welding: heat or fusion welding, and **pressure welding**. Welding can be perfomed using electric arc, gas or **thermal systems**. These processes often involve the use of multiple metals and chemicals and can lead to employee exposure to chemical agents as fumes and gases. Welding and cutting operations present certain hazards to welders that, if not properly controlled, can result in temporary or permanent physical injury, short- or long-term adverse health effects, discomfort and even death. The health hazards associated with welding and allied processes come from exposure to fumes and gases, heat, noise, radiation, as well as, repetetive stresses that can cause musculoskeletal injuries (MSI's), such as strains and sprains.

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 (ACAG)
- metal-cored arc welding (MCAW)

Aspects within each type of process including the shielding gas; electrode size and type, wheteher it is manual or mechanized welding; current/voltage and arc time can significantly influence the amount of fumes produced and the exposure of employees to contaminants. For example, an open arc process that uses a flux, higher current and larger electrodes will produce more fumes than a gas tungsten arc welding (GTAW) or submerged arc welding (SAW) process.

Details on welding and allied processes, hazard identification, equipment operation/maintanence and hazard prevention strategies are outlined in the CSA Standard W117.2 *Safety in welding, cutting, and allied processes.*[1] Even though the Standard is not referenced in the COHSR, it is still a useful resource to better understand hazards associated with welding operations and allied processes and how to control these hazards.

2. Welding fumes and gases

Fumes produced during welding are solid particles, usually less than 1.0 μm in size, formed by the condensation and oxidation of the metal which had been vapourized by the arc or flame. These particles are capable of being deposited in the gas-exchange region of the lungs. The chemical composition of the welding fumes and gases and therefore the associated health hazards depend on the welded materials, the process and the filler rod or electrodes used. The concentration of welding fumes to which welders are exposed depends on the type of welding process, personal protective equipment, as well as, a welder's position and posture. Importantly, 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 are factors.

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.

3. Sampling for welding fumes

Sampling for welding fumes should be performed by qualified personnel, who possess knowledge, training and experience of sampling techniques, exposure limits and the work place processes. For welding fumes, the ***Occupational chemical agent compliance sampling guideline*** can be used to obtain information on sampling techniques, examples and calculation methods.[2] The ***Thermal Stress in the work place*** guideline is also a useful source for understanding the hazards associated with hot work environments and prevention strategies.[3]

The COHSR should also be referred to by qualified persons when sampling for welding contaminants and other physical hazards associated with welding processes. **Part X, Hazardous Substances**,[4] and **Part VII, Levels of Sound**[5] of the COHSR are helpful resources that must be used when sampling for welding fumes and hazards. These regulations provide the requirements for hazard investigation, employee education and training, exposure limits and exposure measurement.

4. Health effects

Hazards associated with welding processes can also be divided into hazardous chemical agents and physical agents. The chemical hazards include metal and contaminant fumes and gases, and organic vapours that are either used in the welding processes or produced during the processes. The physical agents include noise, radiation and thermal stress. Each of these hazard categories are then associated with specific health concerns in workers.

The nature of the work done in welding processes leads to ergonomic hazards. Processes that do not consider ergonomics can result in employees developing musculoskeletal injuries and disorders. 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 generation of high force from equipment may have cumulative effects that contribute to the increased risk of employee's injury. The ergonomics of all welding processes must be assessed and appropriate controls implemented.

4.1 Chemical agents

Welding and thermal cutting produce multiple types of metal and chemical fumes and gases, and organic vapours that can have specific and additive health effects. Table 1 below summarizes the health effects and the associated sources.[6, 7, 8]

TABLE 1 Summary of health effects as a result of exposure to fumes, gases and vapours released and used during welding processes

Type	Contaminant	Source/Material	Health effects and symptoms
Fumes	Cadmium oxide	Stainless steel containing cadmium, plating	Pulmunory edema and fibrosis, respiratory symptoms, substernal pain, headache, muscle aches, nausea and vomiting, loss of smell, potential carcinogen. Affects respiratory system, kidneys and blood.
Gas	Carbon monoxide	Carbon dioxide shield metal-arc welding, electrode coatings	Headache, nausea, dizziness, confusion, death, cardiovascular symptoms, and carbomonoxyde poisioning.
Fumes	Chromium (VI)	Stainless steel, plating, chromium pigment manufacturing, electrode	Lung and sinonasal cancer. Can irriate and damage ears, eyes, skin, nose, throat and lungs. Asthma. Kidney and liver damage.
Fumes	Copper	Coating on filler wire, sheaths on air carbon arc gouging electrodes, nonferrous alloys	Metal fume fever, irriation in eyes, nose and pharynx. Dermatitis, metallic taste and anemia.
Fumes	Fluorides	Electrode coating, flux material	Bone and joint damage. Eye,nose and throat irritation. Gastro-intestinal symptoms, fluid in lungs and kidney dysfunction.

Type	Contaminant	Source/Material	Health effects and symptoms
Fumes	Iron oxide	All iron or steel welding processes	Pneumoconiosis, nosie and lung irritation, siderosis.
Fumes	Magnesium oxide	Magnesium or aluminum alloys	Metal fume fever, eyes and nose irritation, cough and chest pain.
Fumes	Manganese	Most welding processes, high-tensile steel	Metal fume fever. Central nervous system disorders, chemical pneumonitis, Manganism, kidney damage and insomnia.
Fumes	Nickel	Stainless steel, nickel-clad steel, plating	Dermatitis, pneumoconiosis, lung cancer, asthma-like lung disease, renal dysfunction and respiratory tract irriration.
Gas	Nitrogen oxide	Formed in the welding arc	Pneumonitis, pulmonary edema; chronic bronchitis, emphysema; pulmonary fibrosis.
Gas	Ozone	Formed in the welding arc	Pulmunary function disorders, fluid in lungs, haemorrhage, and lung issues.
Fumes	Zinc oxide	Galvanized and painted metals	Metal fume fever.
Organic vapours and products of incomplete combustion	Aldehydes (such as formaldehyde)	Metal coating with binders and pigments. Degreasing solvents	Eyes and respiratory system irritant.
Organic vapours and products of incomplete combustion	Diisocyanates	Metal with polyurethane paint	Eye, nose and throat irritation. Sensitization, asthma, allergies.
Organic vapours and products of incomplete combustion	Phosgene	Metal with residual degreasing solvents	Eye, nose and respiratory system irritant.
Organic vapours and products of incomplete combustion	Phosphine	Metal coated with rust inhibitors	Eyes and respiratory system irritant; kidney damage.

4.2 Physical agents

1) Hot surfaces and environments

Inadvertent unprotected contact with heated metal will cause local burns to skin or cause clothing to catch fire resulting in burns to more of the body. Welder's gloves and other clothing should be chosen for their ability to insulate from hot surfaces.

Hot environmental conditions at the work place can be caused by air temperature, radiant heat, humidity and air movement. Welding and cutting operations, and in particular plasma arc cutting, are known to produce heat. Prolonged exposure to heat along with physical activity and clothing can increase the internal body temperature which may lead to 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

Some general signs and symptoms of heat illnesses include excessive sweating, rapid breathing, weakness, fainting, headache and confusion. Severe heat stress requires immediate medical attention and first aid, as the inability to do so can result in organ damage and/or death. Further details on thermal stress hazard and illness/injuries can be found in the *Thermal stress in the work place guideline* and the infographics on heat stress and cold stress.[3]

2) Noise

Air carbon arc cutting, gouging and plasma arc processes generate significantly high noise levels. General welding processes and physically manipulating metals also produce high noise levels and in some cases, impulse noise. Excessive and long term exposure to noise among welders can cause noise-induced hearing losses, along with other non-auditory health effects such as cardiovascular diseases, stress, lack of sleep etc.[7] COHSR Part VII Levels of Sound must be used as a reference.[5]

3) Radiation

The plasma arc emits intense ultraviolet (UV), visible light and infrared (IR) radiation. Laser beam and electron beam welding and cutting processes also produce visible and/or invisible radiation.Appropriate eye protection is essential in welding. If the welding helmet meets the requirements of CAN/CSA Z94.3 you can be sure that it provides the eyes and face protection from radiation. In addition, whenever the high voltage is on, an electron beam system is capable of generating X-rays. COHSR Part X Hazardous Substances must be used as a reference for details on regulations regarding radiation.[4]

5. Reference exposure limits

5.1 Safety data sheets (SDSs)

While investigating potential health hazards with respect to welding, it is important to consider the safety data sheets (SDSs) for each hazardous substance, metal or other chemical that is used in the welding operation. SDSs define the health hazards associated with the use of these products and provide recommendations on preventive measures such as engineering controls and personal protective equipment (PPE). The SDS also provides the available exposure limits from different regulatory bodies and physical and chemical properties that can be used to control the exposures at the work place.

5.2 Threshold Limit Values (TLVs®)

If an exposure limit is not specified in the COHSR, then the employer must follow the exposure limits as specified in the most recent edition of the American Conference of Governmental Industrial Hygienist (ACGIH®) *Threshold Limit Values (TLVs®) for Chemical Substances and Physical Agents & Biological Exposure Indices (BEIs®)* booklet. The ACGIH® TLVs® and BEIs® booklet is referenced in the *Canada Occupational Health and Safety Regulations* made under Part II of the *Canada Labour Code*. The exposure limits from the booklet must be used in monitoring and controlling exposure at the work place.

A publication entitled *Documentation of the TLVs® and BEIs®* 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. For a detailed explanation of the research and requirements behind the exposure limits, the recent edition of the ACGIH® *Documentation of the TLVs® and BEIs®* must be used.

6. Regulatory requirements

The COHSR, Part X, *Hazardous Substances*, applies to the the chemical and many of the physical aspects of welding processes in the work place. It includes requirements for hazard investigation, storage and handling, employee education and hazard control. The complete Part X must be followed and referred to at the work place. Some examples of subsections include:[4]

- Part X, Subsection 10.17(1) requires that every ventilation system installed on or after January 1, 1997 to control the concentration of an airborne hazardous susbtance shall be so designed, constructed, installed, operated and maintained that:
  a) The concentration of the airborne hazardous substance does not exceed the values and levels prescribed in subsections 10.19(1) and 10.20(1) and (2); and
  b) It meets the standards set out in:
     i) Part 6 of the *National Building Code*;
     ii) the most recent publication of the American Conference of Governmental Industrial Hygienists (ACGIH®) entitled *Industrial Ventilation Recommended Practices for Design*, and its companion entitled *Industrial Ventilation: A Manual of Recommended Practice for Operation and Maintenance*; or
     iii) The most recent edition of ANSI Standard ANSI Z9.2 entitled *Fundamentals Governing the Design and Operation of Local Exhaust Systems.*
- Part X, Paragraph 10.18(3)(a) will ensure that a qualified person carries out each inspection, testing and maintenance of the ventilation system, as specified by the instructions given by the employer.
- Part X, Paragraph 10.19(1)(a) 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 the most recent version of its publication entitled *Threshold Limit Values and Biological Exposure Indices*.

The COHSR, Part XIX, *Hazard Prevention Program* (HPP) specifies that a work place must include a HPP which consists of methods and implementation of a HPP, assessing hazards—including ergonomic hazards—implementing preventive measures and educating employees.[9]

- Part XIX Section 19.5 states that the employer shall, in order to address identified and assessed hazards, take preventive measures that consist of 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.

7. Control measures

When exposure to welding fumes and gases, and physical hazards exceed specified TLVs® and noise exposure limits, or when the health of the employee is at risk, the employer is required to reduce and control exposure below the prescribed limits. The controls employed should follow the hierarchy explained in the COHSR and multiple controls can be employed simultaneously.

1) 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.

a) Dilution ventilation

Dilution ventilation comprises of 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 dilutes contaminants to concentrations below exposure 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 is not adequate to control the exposure of welders to welding fumes and gases to below the permissible occupational exposure limits.

b) 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 task-specific design 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 re-circulated through an air cleaner.

It is important to note that exhaust air containing carcinogens and/or other toxic contaminants must not be re-circulated.

The employer must ensure that the air cleaning system removes airborne 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 side-draft hood or a task-specific 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 a local exhaust ventilation system will depend on the distance of the hood from the source, exhaust air velocity and hood placement. The type of hood should follow the specifications as given in the recent edition of the ACGIH® *Industrial Ventilation* publication.[10] 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.

Further 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.

2) 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*.[11] Where breathing air is provided for the purpose of a respirator, the air must meet the standards set out in the recent edition of the CSA Standard Z180.1 *Compressed breathing air and systems*.[12]

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 Certified Equipment List published by National Institute for Occupational Safety and Health (NIOSH).[13] 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 negative-pressure respirators only must be clean-shaven where the face piece seals to the skin. Positive-pressure powered air purifying respirators that do not have a facepiece that seals to the skin do not require the workers to be clean shaven.

3) Other personal protective equipment (PPE)

Apart from respiratory protection, the workers should also use other forms of PPE either in conjunction with other controls or separate, keeping in mind that it is the least effective form of control. As mentioned earlier in this document, 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's UV radiation 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.

4) Administrative controls

Apart from the control measures above, there should also be general preventive strategies and administrative controls in place at the work place. Welders should receive regular training and education on handling equipment, protecting themselves, the hazards associated with welding processes and basic first aid. There should be cleaning and maintenance procedures in place for the welding equipment so that any exposure through that route is reduced. The work stations should also be positioned in such a way that the welding fumes are released away from the worker. Welding must not be performed in confined spaces in the absence of adequate ventilation.

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 may preclude the employee from being assigned the use of the selected respirator. In case of any change to the health of the employee, the employers should be notified immediately.

In addition, the work place should undergo regular monitoring and sampling so that exposure levels can be kept under the exposure limits.

8. Additional resources

1. Work place Health and Safety bulletin – *Welding gases and fumes*
   https://open.alberta.ca/publications/ch032-chemical-hazards
2. OSHA Fact sheet
   https://www.osha.gov/Publications/OSHA_FS-3647_Welding.pdf
3. *Welding and Manganese*
   https://www.cdc.gov/niosh/topics/welding/default.html
4. *Guide to management of hazardous substances*
   https://www.canada.ca/en/employment-social-development/services/health-safety/reports/hazardous-substances.html

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4 *Canadian Occupational Health and Safety Regulations* (COHSR). (2018). Part X – Hazardous Substances. Retrieved from **http://laws.justice.gc.ca/eng/regulations/SOR-86-304/page-22.html#h-110**.

5 *Canadian Occupational Health and Safety Regulations* (COHSR). (2018). Part VII – Levels of Sound. Retrieved from **http://laws-lois.justice.gc.ca/eng/regulations/SOR-86-304/page-12.html#h-70**.

6 Centers for Disease Control and Prevention (CDC). (2016). *NIOSH Pocket Guide to Chemical Hazards*. Retrieved on August 13, 2018 from **https://www.cdc.gov/niosh/npg/**.

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[13] Centers for Disease Control and Prevention (CDC). (2018). *Certified Equipment List Search*. Retrieved from **https://www2a.cdc.gov/drds/cel/cel_form_code.asp**.