Workplace Health and Safety
Bulletin

Welder's Guide to the Hazards of Welding Gases and Fumes

Welding gases and fumes can be hazardous to your health. This Safety Bulletin provides basic information to help you reduce the health risks associated with welding gases and fumes.

The health risks and effects associated with welding gases and fumes are determined by:

- the length of time that you are exposed to them
- the type of welding you do
- the work environment
- the protection you use.

What are gases and fumes?

Gases

All welding processes produce hazardous gases. Gases are invisible to the eye, and may or may not have an odour. The heat in both the flame and the arc, and the ultraviolet radiation from the arc, produce gases such as carbon monoxide, carbon dioxide, oxides of nitrogen and ozone. Other gases and vapours may be produced as by-products from the breakdown of solvents or coatings on the metal. Gases used for arc shielding, or as a fuel, are also given off during welding.

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Fumes

Welding also produces fumes. Fumes are formed when hot metal vapours cool and condense into very small particles that stay suspended in the vapour or the gas. The particles may be metal or metal compounds, and are often smaller than one micrometre (one-fiftieths) the width of a human hair). Fumes may be visible or not. Welding "smoke" is an example of a visible fume. But even if the fume can't be seen, its particles are still present.

How do gases, vapours and fumes affect health?

Gases, vapours and fumes enter the body through the air we breathe. Different gases and fumes affect us in various ways. A healthy body can rid itself of some gases and fumes without lasting effects. Gases such as carbon dioxide and argon, for example, are relatively non-toxic unless inhaled in large quantities. However, gases such as carbon monoxide, nitrogen oxides and ozone are extremely toxic.

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The health effects of inhaling fumes depend on the type of fume inhaled. Iron oxides, which are produced during most manual welding processes, are relatively non-toxic. The effects, as currently known, are not permanent unless tobacco smoke or other substances, such as silica and asbestos, have already affected your lungs. Effects such as breathing problems tend to disappear over time — once exposure is reduced or stopped. Fumes such as those produced during the welding of stainless steel may produce serious and long-lasting problems. These can include chronic breathing difficulty and cancer, in the case of exposure to chromium.

Table 1 — Health Effects of Fumes, Gases and Organic Vapours During Welding, lists examples of the health effects of exposure to materials present during common welding situations. In the table, "acute effects" refers to effects that occur immediately or quickly, while "chronic effects" refers to those that take a long time to appear. Metal fume fever is an example of a common acute effect of exposure to several types of welding fumes. This reaction consists of flu-like symptoms, including alternating chills and high fever. Symptoms usually last one or two days and then subside, although their onset may be delayed. It is possible to experience both acute and chronic effects from a brief exposure to large quantities of a substance, or from repeated exposures to smaller quantities of a substance.

Table 1 Health Effects of Fumes, Gases and Organic Vapours Produced During Welding

	Source	Effects and Symptoms
FUMES		
Aluminum	Aluminum component of some alloys, e.g., Inconels, copper, zinc, steel, magnesium, brass and filler materials.	Respiratory irritant.
Beryllium	Hardening agent found in copper, magnesium, aluminum alloys and electrical contacts.	"Metal Fume Fever." A carcinogen. Other chronic effects include damage to the respiratory tract.
Cadmium Oxides	Stainless steel containing cadmium or plated materials, zinc alloy.	Irritation of respiratory system, sore and dry throat, chest pain and breathing difficulty. Chronic effects include kidney damage and emphysema. Suspected carcinogen.
Chromium	Most stainless-steel and high-alloy materials, welding rods. Also used as plating material.	Increased risk of lung cancer. Some individuals may develop skin irritation. Some forms are carcinogens (hexavalent chromium).
Copper	Alloys such as Monel, brass, bronze. Also some welding rods.	Acute effects include irritation of the eyes, nose and throat, nausea and "Metal Fume Fever."
Fluorides	Common electrode coating and flux material for both low- and high-alloy steels.	Acute effect is irritation of the eyes, nose and throat. Long-term exposures may result in bone and joint problems. Chronic effects also include excess fluid in the lungs.
Iron Oxide	The major contaminant in all iron or steel welding processes.	Siderosis – a benign form of lung disease caused by particles deposited in the lungs. Acute symptoms include irritation of the nose and lungs. Tends to clear up when exposure stops.
Lead	Solder, brass and bronze alloys, primer/coating on steels.	Chronic effects to nervous system, kidneys, digestive system and mental capacity. Can cause lead poisoning.

	Source	Effects and Symptoms
Manganese	Most welding processes, especially high-tensile steels.	"Metal Fume Fever." Chronic effects may include central nervous system problems.
Molybdenum	Steel alloys, iron, stainless steel, nickel alloys.	Acute effects are eye, nose and throat irritation, and shortness of breath.
Nickel	Stainless steel, Inconel, Monel, Hastelloy and other high-alloy materials, welding rods and plated steel.	Acute effect is irritation of the eyes, nose and throat. Increased cancer risk has been noted in occupations other than welding. Also associated with dermatitis and lung problems.
Vanadium	Some steel alloys, iron, stainless steel, nickel alloys.	Acute effect is irritation of the eyes, skin and respiratory tract. Chronic effects include bronchitis, retinitis, fluid in the lungs and pneumonia.
Zinc Oxides	Galvanized and painted metal.	"Metal Fume Fever." .
GASES		
Carbon Monoxide	Formed in the arc.	Absorbed readily into the bloodstream, causing headaches, dizziness or muscular weakness. High concentrations may result in unconsciousness and death.
Hydrogen Fluoride	Decomposition of rod coatings.	Irritating to the eyes and respiratory tract. Overexposure can cause lung, kidney, bone and liver damage. Chronic exposure can result in chronic irritation of the nose, throat and bronchi.
Nitrogen Oxide	Formed in the arc.	Eye, nose and throat irritation in low concentrations. Abnormal fluid in the lung and other serious effects at higher concentrations. Chronic effects include lung problems such as emphysema.
Oxygen Deficiency	Welding in confined spaces, and air displacement by shielding gas.	Dizziness, mental confusion, asphyxiation and death.
Ozone	Formed in the welding arc, especially during plasma-arc, MIG and TIG processes.	Acute effects include fluid in the lungs and hemorrhaging. Very low concentrations (e.g., one part per million) cause headaches and dryness of the eyes. Chronic effects include significant changes in lung function.

	Source	Effects and Symptoms
ORGANIC VAPOURS		
Aldehydes (such as formaldehyde)	Metal coating with binders and pigments. Degreasing solvents.	Irritant to eyes and respiratory tract.
Di-isocyanates	Metal with polyurethane paint.	Eye, nose and throat irritation. High possibility of sensitization, producing asthmatic or other allergic symptoms, even at very low exposures.
Phosgene	Metal with residual degreasing solvents. (Phosgene is formed by reaction of the solvent and welding radiation.)	Severe irritant to eyes, nose and respiratory system. Symptoms may be delayed.
Phosphine	Metal coated with rust inhibitors. (Phosphine is formed by reaction of the rust inhibitor with welding radiation.)	Irritant to eyes and respiratory system, can damage kidneys and other organs.

How do you recognize the symptoms of harmful exposure?

The early symptoms of harmful exposure to most substances produced during welding are similar. These may consist of irritation of the eyes, nose, respiratory system and sometimes the skin (such as “nickel itch,” caused by exposure to nickel fumes). Coughing, a tight chest or chest pains, headaches, nausea, vomiting and fatigue may also be some persistent symptoms. Since these symptoms are common to many other illnesses, it is important to determine whether or not they are related to work.

If you experience these symptoms, report them to your doctor and explain what you do for a living.

For more information

http://employment.alberta.ca/documents/WHS/WHS-PUB_gh006.pdf
What Your Doctor Needs to Know About Your Job – GHOO6

What are Occupational Exposure Limits?

Occupational Exposure Limits (OELs) are the maximum permissible concentrations of a hazardous substance that most healthy adults may be repeatedly exposed to without suffering adverse health effects. Remember, these limits assume the individual exposed to the substance is a *healthy* adult. There maybe increased risk, for example, for a smoker, a person with pre-existing health problems or individuals who suffer from allergies.

OELs are often assigned three values. **One value** is based on normal working conditions of 8 hours per day, over an average lifetime of exposure. If more than 8 hours are worked (for example, in a 12-hour shift), this value must be adjusted.

A second value provides a limit for a 15-minute, short-term exposure. This is a value to which a worker may be exposed for 15 minutes, a maximum of 4 times per shift, with at least 1 hour between exposures. In this case, the 8-hour OEL cannot be exceeded.

A third value is the ceiling limit. This limit must never be exceeded. If more than one type of contaminant is present, as in most welding situations, and the effects of exposure to each is similar, an exposure limit for the mixture is calculated. This value is lower than the limits set for exposure to individual contaminants.

OELs permit workers to be exposed to only very small quantities of substances. The amounts are measured in parts-per-million (ppm) or milligrams per cubic metre (mg/m^3). One mg/m^3 is about the same concentration of sugar water that one sugar cube would create if dissolved in a swimming pool 50 metres long, 20 metres wide and 2 metres deep. Such small quantities can only be measured with sophisticated instruments and techniques.

Alberta's health and safety legislation specifies exposure limits for the substances present in welding gases and fumes. OELs represent only minimum standards. Because measurements and workers' susceptibility is expected to vary, the law in Alberta requires that employers keep exposure levels to harmful substances "as low as reasonably practicable." The intent of the law is for employers to reduce exposure to a fraction of the OEL, using ventilation or other control measures. Where it is not possible to reduce levels to below the OEL, workers must use personal protective equipment.

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When do gases and fumes affect your health?

Welding gases and fumes do not normally cause immediate health problems. However, if over the years of working as a welder, you breathe in gases, vapours and fumes in quantities greater than the OELs, it is likely that your health will suffer.

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The seriousness of the hazard depends on:

- the welding process, including the type of metal being welded
- the type of fume generated (not the total number of fume particles). For example, E6010 electrodes used on low-carbon steel generate a large quantity of iron oxide particles. These are relatively non-toxic. However, an E316-15 electrode produces small quantities of highly toxic chromium fumes. The hazard is obviously greater with the E316-15 electrode.

The quantity of gases and fumes generated by welding depend on welding processes and other variables such as:

- type of shielding gas
- current
- voltage
- type of electrode
- polarity.

If the metal is painted or coated, or has a residual solvent on its surface, welding may generate toxic organic vapours.

- Research shows that welding polyurethane-coated steels may expose welders up to 25 times the OELs for di-isocyanates.
- It only takes small amounts of chlorinated solvents, such as trichloroethylene or carbon tetrachloride, used for degreasing, to produce dangerous amounts of phosgene gas.
- Binders and solvents on metal can expose welders to formaldehyde at twice the permitted level. Thus it is essential to allow metals cleaned with chlorinated solvents to dry in a well-ventilated place removed from the welding area. Containers of these fluids must not be stored in the welding area, as welding radiation can react with the vapours.

Welding inside vessels presents additional hazards. Welding may release products that have penetrated the metal. For example, metal from tanks used by the oil and gas industry may be contaminated with sulphur. Welding performed on these tanks may release sulphur fumes.

Ventilation and proximity to work The amount of ventilation and the welder's proximity to the work are two other important variables that influence exposure to a welding gas or fume.

- The amount of available ventilation determines how much of the gases and fumes stay in a welder's breathing area and for how long. Carbon monoxide levels may reach 500 ppm when the ventilation is not adequate, while the 8-hour OEL for carbon monoxide is 25 ppm. In tests performed under poor ventilation, thermal cutting of steel coated with red lead produced a level of exposure to lead 1000 times its OEL.
- The position and posture of the welder's body relative to the job also influences the risk to exposure. For example, if you crouch over your work while welding on pipe racks, your breathing area may be directly above the arc.

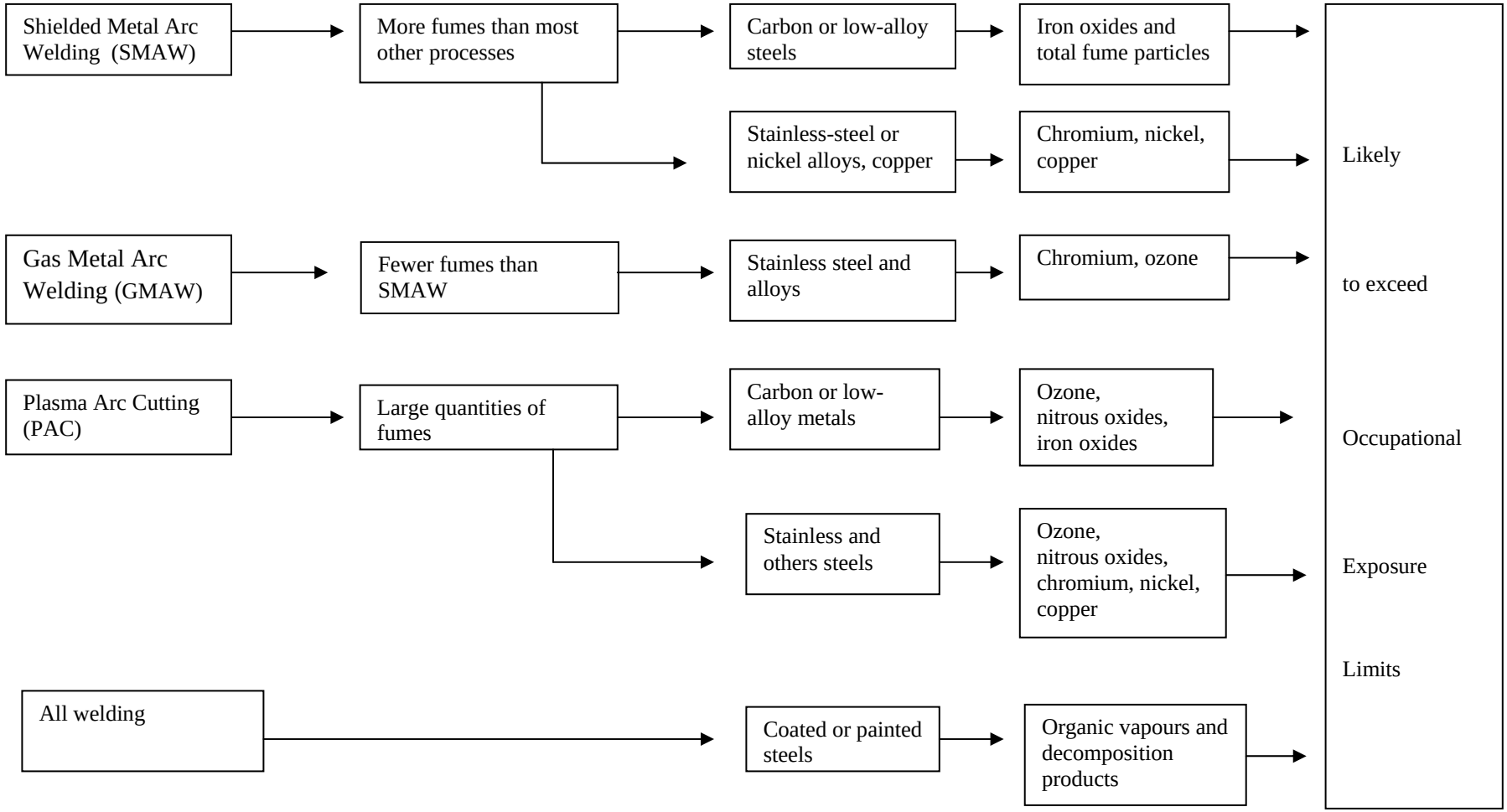
Figure 1, High-Risk Situations, summarizes the most common high-risk situations that a welder will encounter. In these situations, the OELs for the listed substances will likely be exceeded in the welder's breathing zone. OELs may easily be exceeded where work is done in a poorly ventilated work area in a confined space, such as in a vessel indoors with several other welders in the same area, or outdoors on a day without wind.

Reducing exposure

You can reduce exposure to welding fumes and gases by taking these four steps:

(1) substituting less hazardous flux materials
(2) introducing engineering controls, by using enclosures and improving ventilation
(3) developing administrative controls, such as implementing work-rest schedules and safe-work practices
(4) wearing respiratory protection.

Figure 1 High-Risk Situations



How do you know when ventilation is effective?

A welder's work area can be ventilated in several ways. Each method, however, has its limitations.

- **Prevailing winds** — In outdoor or semi-outdoor situations, air movement can provide natural ventilation. Its effectiveness, however, depends on whether the day is windy or calm, and whether you are working upwind or downwind. Using welding curtains, spark enclosures or hoardings when working outside prevents exposure to natural air movement and therefore prevents effective ventilation.

- **General ventilation** — In indoor locations and confined spaces, draft fans or air-movers provide general or dilution ventilation. A well-designed and well-maintained ventilation system is usually effective for most situations involving clean, uncoated, mild steels. However, the only means of judging if the system is doing its job is to take regular airflow measurements and to sample for exposure.

  As a guide, the U.S. Occupational Safety and Health Administration (OSHA) requires that a minimum of 65 cubic metres (2000 cubic feet) of air be moved per minute for each welder in a room. These figures will change if, for example, a plasma-arc machine is being used in the room.

  Since welding curtains may interfere with airflow, make sure that they are at least 20 centimetres off the floor. Hoardings should have sufficiently large openings to allow good airflow. A rule of thumb often used is that if the visible fume clears within 30 seconds after the welding stops, ventilation is probably adequate.

- **Local exhaust systems** — Vent hoods or gun-mounted exhausts can provide local exhaust ventilation. Local exhausts are the most effective ventilation systems for all situations that generate fumes containing heavy metals and, particularly, for stainless steel or plasma-arc welding. In field locations portable hoods may be available. The effectiveness of local exhaust ventilation depends on the distance the hood is from the source of gases and fumes, on the air velocity and on the hood placement.

When using local exhaust systems, in general:

- place vent hoods close to the source of the airborne contaminants
- ensure that air moves across the arc at about 0.5 m/s (100 ft./min.). (In processes that use shielding gases, higher air velocities may strip them away.)
- place the hood above and to the side of the arc to capture the contaminants.

Vent hoods often fail to protect welders because they are poorly designed and located. To properly design and locate the vent hood system you must have a good understanding of the types of contaminants being produced, and of the work procedures and characteristics of the work area. Airflow checks must also be done regularly with a measuring instrument. The checks will ensure that the equipment is working as designed. When using vent hoods, make sure that the exhaust discharges outside the room or confined space.

What can you do to protect yourself?

- **Effective ventilation** is the first step to controlling exposure. Ask your employer to check the ventilation system regularly. Before starting work, check that the fan operates properly and the filters are clean. Learn how to use the exhaust system correctly.

- **Know what materials and hazards** you are dealing with. Make sure you read the Material Safety Data Sheet (MSDS) supplied with welding electrodes. It contains information you need to know and understand. Your employer is responsible for having up-to-date MSDSs at the work site and providing you with WHMIS (Workplace Hazardous Materials Information System) training. If you are self-employed, ask your contractor or supplier for a copy of the MSDS. Read the MSDS and take the precautions it describes.

- **Evaluate the work situation**. Are you in a confined space with little or no ventilation? What type of metals are you welding? Are the work pieces clean? Are the work pieces coated, painted or covered with a film of degreasing solvent? Whenever possible, weld on clean metal only. Remove all coatings or paints that are within 5 - 10 centimetres of the weld area.

- Use respiratory equipment when necessary. The risks of exposure to gases and fumes are high for plasma-arc cutting and for arc gouging and cutting. They are also high when welding stainless and high-alloy steel, as well as galvanized, coated and painted steels, even when air-movers and draft fans, or wide-open work areas provide good ventilation. Always use respiratory equipment under such conditions. With poor ventilation and no local exhaust, most jobs, whatever the welding process, will require a respirator.

How do you select respirators?

Respiratory protective equipment (RPE) must be used as required by Alberta's health and safety legislation. According to the law:

- Respirators must be of an approved type.
- Respirators must be suitable for the hazard.
- Respirators must be selected and fit tested according to the CSA Standard Z94.4-03 (R2008), *Selection, Use and Care of Respirators.*
- The employer must establish a Code of Practice for the selection, use and maintenance of respirators at the work site.
- The employer is responsible for providing appropriate equipment.

All respirators are uncomfortable to a degree, especially for the first-time user. Selecting the right type goes a long way toward making wearing it more bearable. You may want to consult with an occupational hygienist or supplier before making your final selection.

Here are some suggestions that you and your employer can follow to help you select the most appropriate type of respirator for your circumstances.

- Using the information given earlier in this Safety Bulletin, decide which gases and fumes present the most serious problem for the job you are about to do. Consult with protective equipment manufacturers or suppliers for advice on the most suitable type(s) of respirator.

- Take into consideration any prior medical conditions that may worsen if you use a respirator. Workers who use respiratory protective equipment should have a medical assessment to ensure they are medically fit to use it.

- The respirator you select must protect you from the respiratory hazard. Air-purifying masks will protect you from low levels of metal fumes, welding gases and organic vapours, but only if the correct filtration cartridge is selected. Contact the respirator supplier for help in choosing an appropriate cartridge.

- If you use an air-purifying mask to protect yourself from fumes containing metals such as chromium and cadmium, the cartridges with disposable filters may need to be changed frequently. The mask supplier can provide you with information about how often cartridges need to be changed.

- Supplied-air respirators provide the best all-around protection from gases, fumes and vapours.

- Once you have selected the type of respirator that will properly protect you from the respiratory hazard, select the specific model to meet other needs. Fit, for example, is extremely important. A respirator that fits poorly allows hazardous materials to leak into the air you're breathing. Check that the respirator has a good seal. Is the respirator easy to adjust? Does it come in several sizes? Will it fit different-shaped faces?

- Check that the respirator provides clear and unrestricted views up, down and sideways. Will glasses or goggles fit when the respirator is worn? Does the face shield fog up? Will the respirator fit under a hard hat if necessary? Will it fit under the welding helmet? Some welding helmets are equipped with built-in respiratory equipment.

- Does the respirator provide enough freedom of movement and allow for verbal communication when these are necessary? Is the respirator noisy, as are some supplied-air respirators? Does it interfere with hearing?

- Does the respirator provide a speaking diaphragm or a way to communicate electronically? Can others make out what you are saying when you communicate through these devices? How far away can you be heard? The answers to these questions may be important in situations where you are working in a confined space and away from others.

Other Personal Protective Equipment

You may need to use other types of protective equipment to protect yourself from the numerous other hazards present during welding. Examples of these include:

Eye hazards — All welding jobs present these, either from ultraviolet radiation, flashes, "weld-spatter," or from chipping or grinding.

Burns, from radiation, hot metal spatter, or handling hot tools and equipment.

Electrical shock, caused by inadequate grounding of equipment, worn or damaged cables, lack of proper gloves and working in wet conditions.

Fire and explosion, from welding or cutting close to combustible materials, leakage of welding or cutting gases from poorly fitting and leaky hoses.

Compressed-gas cylinders, hazardous if there's damage to cylinder valves, and because of the risk of explosion or flashback (compressed gas cylinders need to be equipped with reverse flow check valves to prevent flashback).

Heat stress, from wearing protective clothing and being subjected to heat from the welding process.

Dust hazards, from some welding jobs as work is performed.

Overhead hazards, where head protection is required.

Excessive noise levels, where hearing protection is required.

Confined spaces — A Code of Practice is required.

For more information

📖 *Welding Data Sheet*. Occupational Safety and Health, Canada Safety Council. Ottawa, Ontario. www.safety-council.org

📖 *Safety and Health in Welding*. Industrial Accident Prevention Association. Toronto, Ontario. www.iapa.on.ca

📖 *Code for Safety in Welding and Cutting — CSA W117.2-01*. Canadian Standards Association. Rexdale, Ontario. www.csa.ca

📖 *Welders' Health and Safety Guide*. Canadian Centre for Occupational Health and Safety. Hamilton, Ontario. www.ccohs.ca

📖 Occupational Safety and Health Administration, 29 CFR 1910.252. www.osha.gov

💻 http://employment.alberta.ca/documents/WHS/WHS-PUB_ppe001.pdf
Respiratory Protective Equipment – Employers' Guide (PPE001)

💻 http://employment.alberta.ca/documents/WHS/WHS-PUB_ppe004.pdf
Guidelines for the Development of a Code of Practice for Respiratory Protective Equipment (PPE004)

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