Introduction:

This standard outlines the many inherent physical hazards as well as the potential to produce toxic fumes and gases while welding. It also outlines the hazards to be observed and the protective equipment to be used.

Standard:

As for any industrial process, welding and cutting operations present certain potential hazards to welding personnel that can result in temporary or permanent physical injury, short- or long-term health effects, discomfort, and, in severe circumstances, death. A thorough understanding of the process hazards is necessary to develop adequate controls to prevent accidents and eliminate adverse health effects.

1. COMMON WELDING PROCESSES

1.1 Thermo-Chemical

(a) Thermit Welding
(b) Atomic Hydrogen Welding
(c) Gas Welding
(d) Plasma Arc Welding: I - Non-transferred
II - Transferred or Constricted

1.2 Electric Arc

(a) Metal Arc Welding: I - Flux Cored Arc Welding - F.C.A.W. (Flux-Shielded Arc Welding)
II - Gas Metal Arc Welding - G.M.A.W. [Inert-Gas Metal-Arc Welding (M.I.G.)]
(b) Gas Tungsten Arc Welding - G.T.A.W. [Inert-Gas Tungsten-Arc Welding (T.I.G.)]
(c) Submerged Arc Welding (S.A.W.)
(d) Electro-Slag Welding (E.S.W.)

2. HAZARDS

For a better understanding, we have divided welding hazards into two categories - Physical Hazards and Health Hazards.

2.1 Physical Hazards

These are hazards which are directly associated with the various welding processes.

(a) Fuel Hazards: The major concern is the handling of the fuel gases which could involve fire and explosion.

Acetylene: The explosive range for acetylene is from 2.5% to 80% by volume in air. Acetylene, 3.0% to 93% in oxygen is flammable and under

some circumstances also explosive. Copper or alloys containing more than 67% copper form violently explosive compounds in the presence of acetylene and therefore are prohibited for acetylene service. It is regarded as a simple asphyxiant when present in concentrations of 40% or greater. Acetylene is not considered to be a medical hazard.

Propane:

Hydrogen: The explosive range for hydrogen is from 4.1% to 71% by volume in air. It has no toxic medical effects and is considered mainly as a fire and explosion hazard.

Oxygen: Non-combustible, but actively supports combustion. Oxygen enriched atmospheres present a severe fire risk. Compressed air or oxygen should never be used for cleaning purposes.

Natural Gas: The explosive range for natural gas is from 3.8% to 17% in air. Generally contains a high percentage of methane (85%) with varying amounts of ethane (10%) and inerts (carbon dioxide, nitrogen, and helium). It is regarded as a simple asphyxiant with the exception of natural gas containing nitrogen (risk of nitrous fumes). It is a flammable gas and can form explosive mixtures with air or oxygen.

Coal Gas: The explosive range for coal gas is from 5.3% to 32% in air. Contains methane and hydrogen with lesser amounts of nitrogen, oxygen, carbon dioxide and carbon monoxide. It is regarded as a chemical asphyxiant. This gas is also flammable and can form explosive mixtures with air or oxygen.

NOTE: The concentration of oxygen in the ambient atmosphere should never be reduced below the level necessary to sustain life by the presence of other gases.

(b) **Electric Shock** - may occur from improper grounding, and/or contact with electric current by moist gloves or clothing, damp floors or humid surroundings. It must be noted, that if the shock itself was not fatal, the jolt may dislodge the worker from his working position and cause serious injuries or death. Should an operator receive a severe shock or burn, a doctor should be summoned without delay. Never under any circumstances touch a person who is in contact with an electrical power line. The power will be transmitted and injury will result.

(c) **Burns** - the major cause of burns is the employee's failure to wear protective clothing or to wear it properly (e.g., sleeves rolled up). It must also be emphasized that burns may occur from the rays emitted from the arc as well as contact with hot metal. Metal that has been welded must be marked "Hot" to warn employees who may have to handle it.

(d) **Radiant Energy** - in welding and cutting operation, the radiant energy falls into four classifications:

Visible Light Rays: These rays reflect off walls or other objects and may cause eye problems to anyone nearby who is not wearing good eye protection with appropriate lenses. Intense visible light rays may cause eye strain and, possibly, temporary blindness. The laser beam when used in welding, may cause severe eye damage or blindness if eyes are in the direct path of the beam for any length of time. Special procedures, safety precautions, and regulations are required for laser beam equipment.

Infrared Rays (Invisible): Also known as ultrared, may cause cumulative effects that may lead to cataracts. These rays are regarded as heat rays and may cause temperature increases on the unprotected skin.

Ultraviolet Rays (Invisible): Ultraviolet rays in arc welding processes are a hazard to bare skin and unprotected eyes. Ultraviolet rays may cause skin burning, tanning and a condition known as "arc eyes" or "flash". The main symptoms of arc eyes or flash are: sensitivity to light, excess tearing and a feeling of sand in the eyes. Ultraviolet rays are also responsible for certain chemical changes in the welding area such as the formation of ozone from atmospheric oxygen, and the formation of oxides of nitrogen from atmospheric nitrogen. Greater quantities of these gases result from ionization by electric discharge through air in the welding arc. (See Table IV).

X-Rays (Invisible): X-rays are produced during electron beam welding (E.B.W.) procedures. If the shielding of the welding chamber is sufficient and complete, the x-rays will be confined to the chamber resulting in NO radiation hazard to the operator.

(e) **Noise** - Plasma Arc Processes - the intense temperatures and speed with which the plasma jet is ejected through the torch nozzle creates excessive high frequency noise levels. Ear protection must be worn when involved in this process.

Resistance Welding machines also warrant operators to wear ear protection due to excessive noise levels (e.g., flash butt welding).

2.2 Health Hazards

Health hazards are associated with the fumes, dusts, and toxic gases which are produced during welding operations. The origin of these fumes and gases may be found in:

- the base metal and filler metal
- the electrode coating or shielding gas
- the base metal protective coating, if present

- the reaction that may occur during the welding process (e.g., the formation of phosgene from the decomposition of chlorinated hydrocarbon cleaning agents). (See Tables I, II, III, IV)

(a) **Welding Fumes and Welding Dusts:** These are microscopic particles which gain easy access into the respiratory tract and lungs. The deposition of particulate matter in the lung is termed pneumoconiosis. Metal Fume Fever is one of the most common hazards in welding. It is caused by freshly formed oxides of various metals (e.g., zinc oxide). It is best known to welders of galvanized metal. The flu-like symptoms develop a few hours after exposure, when the victim becomes ill. It has been suggested that fine calcium fluoride (C_aF_2) particles resulting from the very common basic coated (lime-fluoride or low-hydrogen) electrodes could be dangerous. Although normally insoluble and inert, in very fine form it becomes more active, hydrolyzing with atmospheric moisture, giving rise to hydrofluoric acid (HF), which is toxic. (See Table III)

(b) **Gases:** Exposure to the various gases may produce one or more of the following effects:

- inflammation of the lung (chemical pneumonitis)
- pulmonary edema (swelling and accumulation of fluid)
- emphysema (loss of elasticity of the lung)
- chronic bronchitis
- asphyxiation

The primary potential toxic gases associated with welding are carbon monoxide, ozone, and oxides of nitrogen (nitric oxide and nitrogen dioxide). These substances are highly toxic and must be carefully monitored. Phosgene and phosphine may also be present as the result of thermal decomposition of chlorinated hydrocarbon cleaning agents and phosphate metal coatings. It should be noted that the recommended occupational exposure level (e.g., Threshold Limit Value - A.C.G.I.H.) should be enforced to prevent the possibility of asphyxiation and/or death. (See Table IV)

3. PRECAUTIONS

The simplest approach to the control of toxic materials would be to eliminate the source. However, this is not practical in most cases. Welding hazards are controlled by adequate ventilation principles, and proper work practices.

3.1 General Precautions

Depending on the welding process used and the airborne by-products involved (toxicity), the air flow figures should increase if the fumes and gases are more toxic than normal. Flash barriers should be used to protect other workers from ultra-violet rays (e.g., arc welding) in the work area and to prevent reactions

with ozone and oxides of nitrogen in the surrounding atmosphere. Keep barriers mounted approximately 2 feet above the floor.

Solvents such as trichloroethane, trichloroethylene and carbon tetrachloride, yield poisonous fumes upon being heated. All traces of these solvents must be removed before welding, cutting or heating. Do not weld at a distance less than 50 feet from degreasing agents containing chlorinated solvents.

Where chlorinated solvents are being used, care must be taken to prevent the vapours produced from being exposed to ultraviolet radiation. Exposure will decompose such vapours, releasing poisonous phosgene. These solvents must, therefore, be stored and used in a separate room from welding operations. It is recommended most strongly that these solvents not be used on components to be welded. Positively no lubricant or compound of any description should be used for making connections of oxygen or acetylene equipment. Connections in oxy-acetylene apparatus are designed so they can be made tight without the aid of any compound or lubricant.

When using oxygen, open the cylinder valve slightly at first, then all the way.

When using acetylene, open the cylinder valve slightly at first, then to the required pressure.

CAUTION: Always stand to one side of and away from the gauge faces and in front of the regulator when opening the cylinder valve.

Be sure that shielding-gas cylinders are never grounded. Remove empty cylinders from the work area.

A metal block (preferably copper) should be used when checking or cleaning an electrode. Never strike an arc on a cylinder. Be careful of where and how the work is grounded. Make sure all electrical wiring is in good condition, not frayed or exposed.

3.2 Ventilation

When considering the specific type of ventilation system to be used in a welding process consideration must be given to the following factors:

(a) dimensions of the welding space (especially ceiling height)
(b) the number of welders
(c) and possible evolution of hazardous fumes or dust according to the metals, fluxes and other materials involved

Other factors such as weather (e.g., precipitation), heat generation, presence of volatile solvents, must be considered.

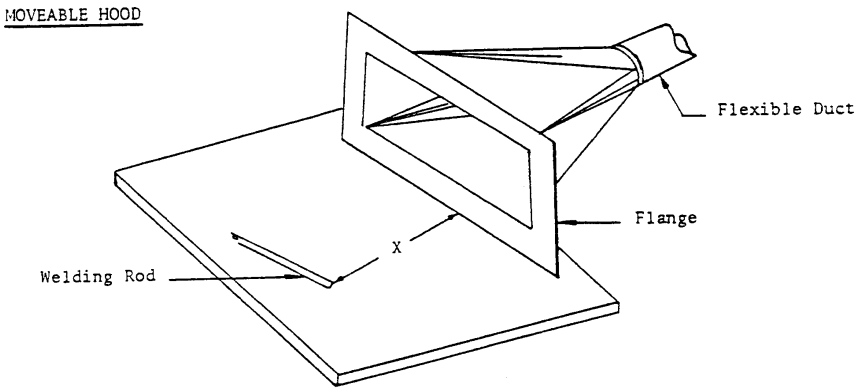
Flash barriers should be positioned so as not to restrict ventilation. Local exhaust ventilation should be used for all welding operations. Where this is not feasible general exhaust ventilation may be helpful. The use of respiratory protection may be necessary where effective local exhaust ventilation cannot be provided.

Integral fume extractors mounted on the welding gun is an effective means of controlling the fume and the gases produced at the weld.

Fixed Enclosure - must develop an air flow of 100-200 feet per minute away from the welder at the arc.

Movable Hood Type - must develop an air flow of 100-200 feet per minute in the welding zone (see "X" in Figure 1).

FIGURE I



In the case of general ventilation the fumes and gases involved may be diluted. For example:

Rod Diameter	CU.FT./MIN./Welder
5/32 inches	1000
3/16 inches	1500
1/4 inches	3500
3/8 inches	4500

Ventilation shall be provided for hazardous situations and processes in conformance with the National Building code of Canada.

3.3 Fire Prevention

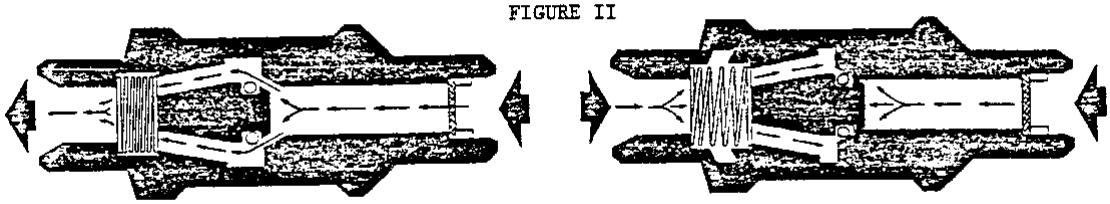
- Maintain a clean and safe workplace free from flammable and explosive material.
- Provide fire barriers in the form of metal sheets or asbestos blankets.
- Cracks or crevices in floors should be filled to prevent sparks or slag from travelling elsewhere.
- Always provide fire extinguishing equipment suitable for the probable types of fire and provide instruction in the proper use of such equipment.
- Provide a fire watcher if felt necessary.
- A carbon tetrachloride fire extinguisher shall not be used.
- Welding operations must conform with the National Fire Code of Canada - Sections 5.1, 5.6 and 5.17, the Canadian Electrical Code, Part 1, and local fire codes.

All cutting torches should be equipped with reverse flow check valves to prevent flash back and possible explosion (see Figure II).

These valves may be placed either at the regulator or at the torch.

REVERSE FLOW CHECK VALVE

FIGURE II



NORMAL OPERATING CONDITION

REVERSE FLOW CONDITION

3.4 Protective Clothing and Equipment

1. Flameproofed gauntlets of leather must be worn.

2. Protective equipment must be worn as work hazards required, such as:

   (a) aprons of leather or asbestos
   (b) flame-proofed long sleeve protection for arms
   (c) fire resistant leggings
   (d) capes or shoulder covers of flame-proofed material
   (e) ear protection
   (f) leather skull caps (flame-proof material)

3. High shoes should be worn, however, if low shoes are worn, ankles should be protected by leggings.

4. Welding hoods or helmets must be worn to protect the eyes from harmful rays. Flip fronts allow for close inspection of work piece once welding has ceased.

5. When arc welding operations are not performed in an enclosed or isolated area, all persons other than welders operating within 75 feet of the arc, must wear anti-flash goggles.

6. Where continuous electric arc welding is performed inside a building, the walls of the bays are often painted flat black or non-reflecting color. Many shops now have individual ventilated booths made from fire resistant material. These booths protect the welder and persons passing or working adjacent to the arc and should be used, if provided. Flash shields must be carried on portable welding carts as standard equipment and should be used. Portable welding carts should be provided with a type ABC fire extinguisher at all times.

7. Electric shock from welding can, and does, kill. Therefore, insulating mats of sufficient size for the operator must be used when welding is being done on steel work or plate upon which the operator is required to sit while doing the welding. Rubber gloves must be worn under welding gloves when work is being done in wet or damp locations or where the welder is perspiring excessively. All cables should be coiled when not in use, and should be maintained as short as possible. The floor area (and bench tops) should be kept tidy and uncluttered at all times.

For welding or cutting metals that include or are coated with lead, cadmium, mercury, or beryllium, supplied air-type respirators or (for limited exposure) respirators designed specifically for use as protection against the appropriate metal fume must be worn.

4. TRAINING AND SUPERVISION

Operators must be adequately trained in their particular process. They must be advised of the hazards involved and the precautions to take. Good housekeeping is an essential practice when welding. No one but a qualified electrician shall make adjustments or repairs to the power source of a welding machine.

5. FIRST AID

Treatment for eye burn (arc eye or flash) should be carried out by a nurse or physician.

Health & Safety Standard

Énergie NB Power

Number: **V-2**

Date Effective: **2013-09-01**

Supercedes 2004-01-26

Title: **Welding**

Reference/Appendix: Table I, Recommended Eye Protection for Welding and Related Operations
Table II, Possible Particulate Matter of Welding Fume - Pneumoconiosis
Table III, Possible Particulate Matter of Welding Fume - Pulmonary Irritants or Toxic Inhalants
Table IV, Possible Gases Evolved in Welding Processes

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Revision Number	Revised Section(s)	Revision Summary	Revised By:	Effective Date:
01		Updated introduction	N. Allen	13-09-01

TABLE I

RECOMMENDED EYE PROTECTION FOR WELDING AND RELATED OPERATIONS

SELECTION OF SHADE NUMBERS
(CSA Standard W117.2 - 1974)

WELDING OPERATION	SHADE NUMBER
Soldering	2
Torch Brazing	3 or 4
Oxygen Cutting:	
Up to 1 inch	3 or 4
1 to 6 inches	4 or 5
6 inches and over	5 or 6
Gas Welding:	
Up to 1/8 to 1/2 inch	4 or 5
1/8 to 1/2 inch	5 or 6
1/2 inch and over	6 or 8
Shielded Metal-Arc Welding:	
1/16, 3/32, 1/8, 5/32 inch Electrodes	10
3/16, 7/32, 1/4 inch Electrodes	12
5/16, 3/8 inch Electrodes	14
Gas Tungsten-Arc Welding:	
Non-Ferrous	11
Ferrous	12
Gas Metal-Arc Welding:	
Non-Ferrous	11
Ferrous	12
Aluminum	12 or 14
Plasma-Arc Welding and Cutting	12
Atomic Hydrogen Welding	10 to 14
Carbon-Arc Welding	14
Air Carbon-Arc Cutting	14

NOTE: In gas welding or oxygen cutting where the torch produces a high yellow light, it is desirable to use a filter or lens that absorbs the yellow or sodium line in the visible light of the operation.

TABLE II
POSSIBLE PARTICULATE MATTER OF WELDING FUME - PNEUMOCONIOSIS

	PARTICULATE	PNEUMOCONIOSIS	1991-92 THRESHOLD LIMIT VALUE	COMMENTS
Insert Pneumoconiosis	1) Carbon	Anthracosis	3.5 mg/m^3	- pneumoconiosis caused by the deposition of carbon particles in the lung.
	2) Tin Oxide	Stannosis	2 mg/m^3	- pneumoconiosis caused by the deposition of tin oxide particles in the lung.
	3) Aluminum Oxide	Aluminosis	10 mg/m^3	- pneumoconiosis caused by the deposition of aluminum oxide particles in the lung.
	4) Iron Oxide	Siderosis	5 mg/m^3	- pneumoconiosis caused by the deposition of iron oxide particles in the lung.
Harmful Pneumoconiosis (Fibrotic)	5) Respirable Crystalline Silica: - cristabalite, tridymite - quartz, tripoli or fused silica		 0.05 mg/m^3 0.1 mg/m^3	- pneumoconiosis caused by the deposition of silicon dioxide (silica) particles in the lung.
	6) Asbestos: - crociodlite - amosite - chrysotile and all other forms		 0.2 fibers/cc 0.5 fibers/cc 2 fibers/cc	- pneumoconiosis caused by the deposition of asbestos in the lung.
Harmful Pneumoconiosis (Non-Fibrotic)	7) Beryllium	Berylliosis	0.002 mg/m^3	- pneumoconiosis caused by the inhalation of beryllium fume.

TABLE III
POSSIBLE PARTICULATE MATTER OF WELDING FUME
Pulmonary Irritants or Toxic Inhalants

PARTICULATE	1991-92 THRESHOLD LIMIT VALUE	SOURCE	SYMPTOMS
1) Cadmium Oxide	0.05 mg/m^3 Ceiling (not to be exceeded at any time)	- metals containing cadmium or cadmium plated metals.	- inhalation of cadmium oxide fumes may cause pulmonary irritation with sore, dry throat and a metallic taste followed be cough, chest pain, and difficulty in breathing.
2) Chromium Trioxide Fume	0.05 mg/m^3	- chromium may be found in the parent metal or electrode - stainless steel metals.	- chromium trioxide fumes react with water vapour to form chromic and dichromic acid. Inhalation of these fumes will produce bronchospasm, edema and hypersecretion, bronchitis and a hyperreaction of the treaches bronchial tree similar to asthma.
3) Copper Oxide Fume	0.02 mg/m^3	- copper and copper alloy parent metals. - copper and copper alloy rods.	- may produce metal fume fever (see item 13, zinc oxide).
4) Fluorides	2.5 mg/m^3	- low hydrogen electrode coating. - flux for submerged arc welding.	- inhalation of fluoride fumes may produce respiratory tract irritation manifested by chills, fever, dyspnea and cough.
5) Lead Oxide	0.15 mg/m^3	- lead coated metals, mainly metals coated with a lead base paint.	- abdominal pain with tenderness, constipation, headache, weakness, muscular aches, loss of appetite, nausea, vomiting, weight loss.

PARTICULATE	1991-92 THRESHOLD LIMIT VALUE	SOURCE	SYMPTOMS
6) Manganese Dioxide	1 mg/m^3	- welding of alloy steel and high-strength steels. - used extensively in most steel filler wires.	- fumes from manganese are highly toxic, co-ordination is generally affected; weakness of the legs, difficulty in walking downhill, instability and weakness while doing heavy work.
7) Magnesium Oxide	10 mg/m^3	- parent metal and electrode rods.	- may result in metal fume fever which may result in irritation to mucous membranes.
8) Mercury	aryl and inorganic compounds of mercury 0.1 mg/m^3 alkyl mercury compounds 0.01 mg/m^3 all other forms 0.05 mg/m^3	- parent metal coatings (anti fouling paints).	- may produce abdominal pain, vomiting, diarrhea, gingivitis, pneumonitis, kidney damage and circulatory or respiratory failure.
9) Molybdenum	soluble compounds of molybdenum 5 mg/m^3 insoluble compounds of molybdenum 10 mg/m^3	- molybdenum is found in some steel alloys.	- may produce bronchial and alveolar irritation with moderate fatty changes in the liver and kidneys.
10) Nickel	metal and insoluble compounds of nickel 1.0 mg/m^3 soluble compounds of nickel 0.1 mg/m^3	- nickel is found in some stainless steels. - nickel carbonyl may be generated with nickel fumes where carbon monoxide is present.	- nickel and its compounds are carcinogenic and toxic. (Usually after long exposure period).

PARTICULATE	1991-92 THRESHOLD LIMIT VALUE	SOURCE	SYMPTOMS
11) Titanium Dioxide	10 mg/m^3	- titanium is found in some steel alloys.	- may produce irritation of the respiratory tract.
12) Vanadium Pentoxide - respirable	0.05 mg/m^3	- vanadium is found in some filler wires.	- may produce irritation of the eyes, throat and respiratory tract.
13) Zinc Oxide	5 mg/m^3	- galvanized and painted metals.	- may produce metal fume fever, chills, fever, nausea, vomiting, muscular pain, headache, fatigue.

TABLE IV

POSSIBLE GASES EVOLVED IN WELDING PROCESSES

	GAS	THRESHOLD LIMIT VALUE	SOURCE	SYMPTOMS OF EXPOSURE
Non-Pulmonary	1) Carbon Dioxide	5000 ppm	- used as a shielding gas.	- generally not considered to be a problem in welding.
	2) Carbon Monoxide	50 ppm	- carbon dioxide shielded metal-arc welding. - electrode coatings; cellulose decomposes to form carbon monoxide and hydrogen.	- may produce headaches and dullness typical of carbon monoxide exposures.
Primary Pulmonary	3) Ozone	0.1 ppm * * Ceiling value	- ozone is formed by the action of ultraviolet radiation on atmospheric oxygen.	- may produce headaches, pain in the chest and dryness of the upper respiratory tract.
	4) Nitrogen Dioxide	3 ppm	- oxides of nitrogen are formed by the action of ultraviolet on atmospheric nitrogen and nitrogen shielding (plasma arc). - produced in the greatest quantity when welding aluminum.	- may produce irritation to eyes and mucous membranes, coughing and chest pain, pulmonary edema.
	5) Phosgene	0.1 ppm	- decomposition of chlorinated hydrocarbons such as trichlorethylene.	- inhalation of phosgene may produce pulmonary edema.