Welding Fumes: An Occupational Health Perspective

Speaker:

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Occupational Hygienist

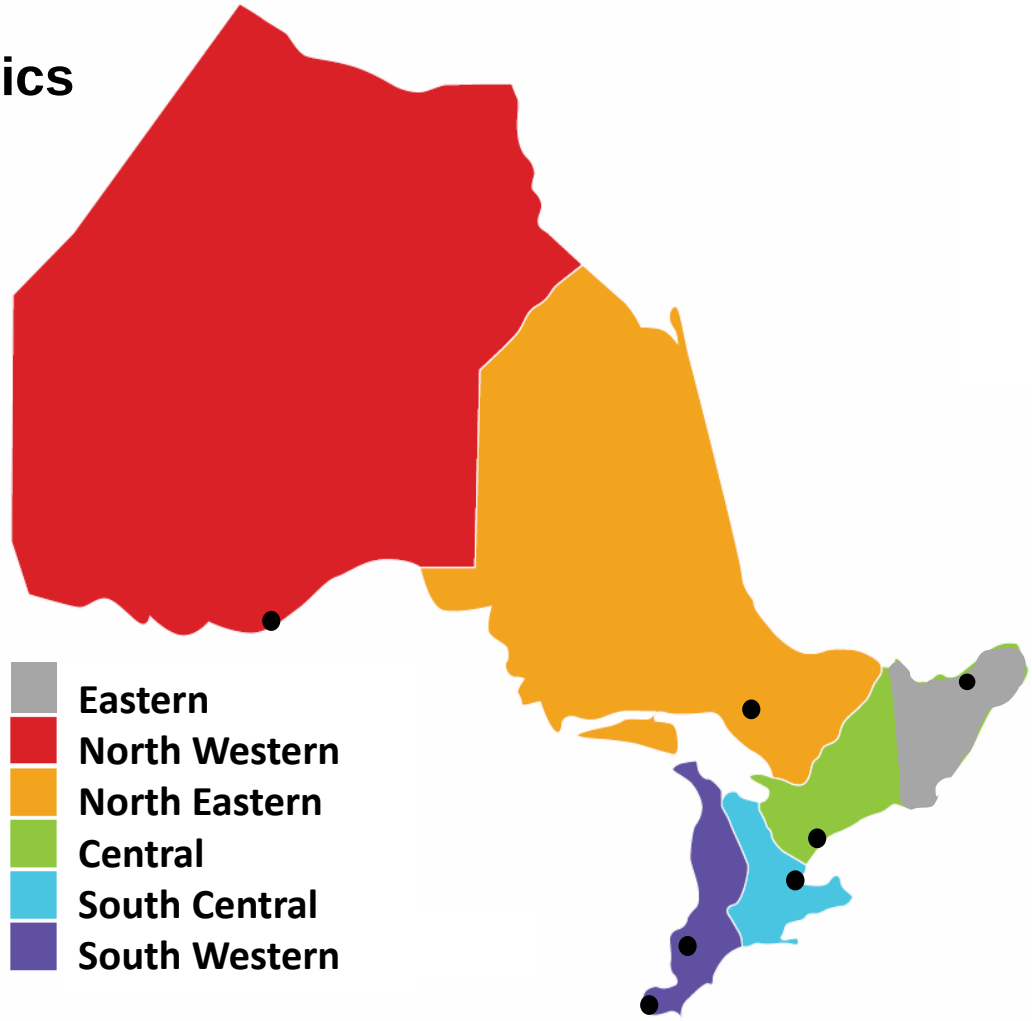
Outline

- Introduction to OHCOW
- Overview of the workforce
- Basics of welding and welding Fume
- Size fraction of the Particulate Matter
- Health hazards and medical surveillance
  - Adverse health effects of welding exposure
    - Manganese
    - Hexavalent Chromium
    - Nickel
    - Iron
    - Beryllium
- Welding Fume Exposure Prevention Strategies

Occupational Health Clinics for Ontario Workers (OHCOW)

7 Clinics

Hamilton, 1989
Toronto, 1989
Windsor, 1991
Sudbury, 1992
Sarnia, 1999, 2004
Thunder Bay, 2010
Ottawa, 2016



Occupational Health Clinics for Ontario Workers

Multi-disciplinary Occupational health team:

- Client Service Coordinators
- Occupational medicine physicians
- Occupational health nurses
- Ergonomists
- Occupational hygienists

OHCOW Services

1. Individual client (clinical)
2. Enquiry (Occupational health/illness related)
3. Informational presentations
4. Workplace visits
   - requested by co-chairs of JH&SC
5. Intake Clinic/health investigations
   - medical/hygiene/ergonomic combined
   - research projects

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Welding and the workforce

- Over 11 million workers are directly and 110 million indirectly exposed to welding fumes world-wide.(IARC 2017).
- 754,000 welders in USA (AWS 2021)
- Approximately 1 million welders in North America.

OSHA fact sheet: Controlling Hazardous Fume and Gases During Welding

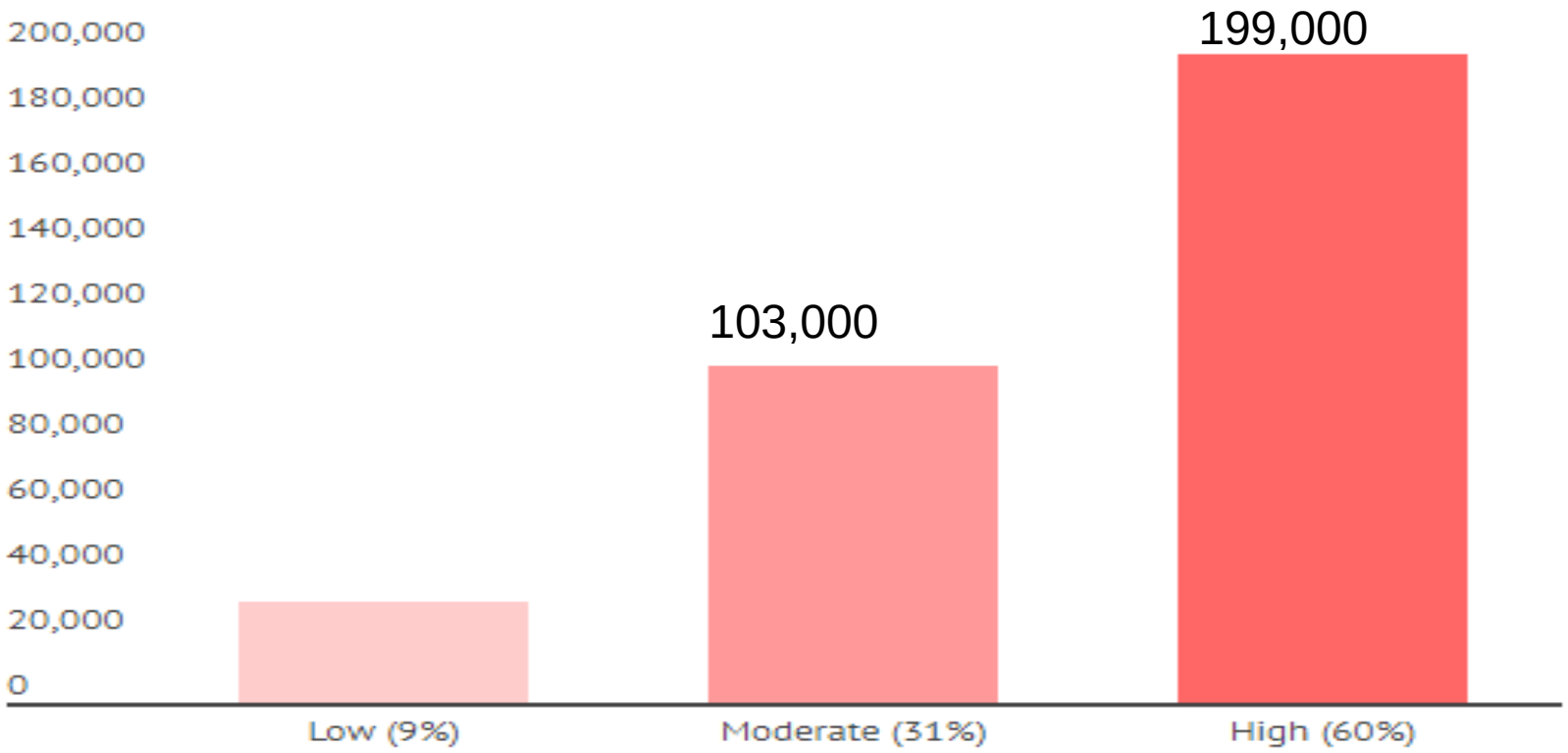
Highly exposed workers

333,000 WORKERS (EST.) > WELDING FUMES EXPOSURE **IN CANADA**

FIVE LARGEST EXPOSURE GROUPS BY INDUSTRY		PROPORTION OF INDUSTRY EXPOSED
Machinery and equipment repair and maintenance*	26,000	45%
Building equipment contractors	25,000	11%
Automotive repair and maintenance	22,000	13%
Motor vehicle parts manufacturing	16,000	15%
Architectural and structural metals manufacturing	15,000	24%

CAREX Canada: [Welding Fumes - Occupational Exposures - CAREX Canada]

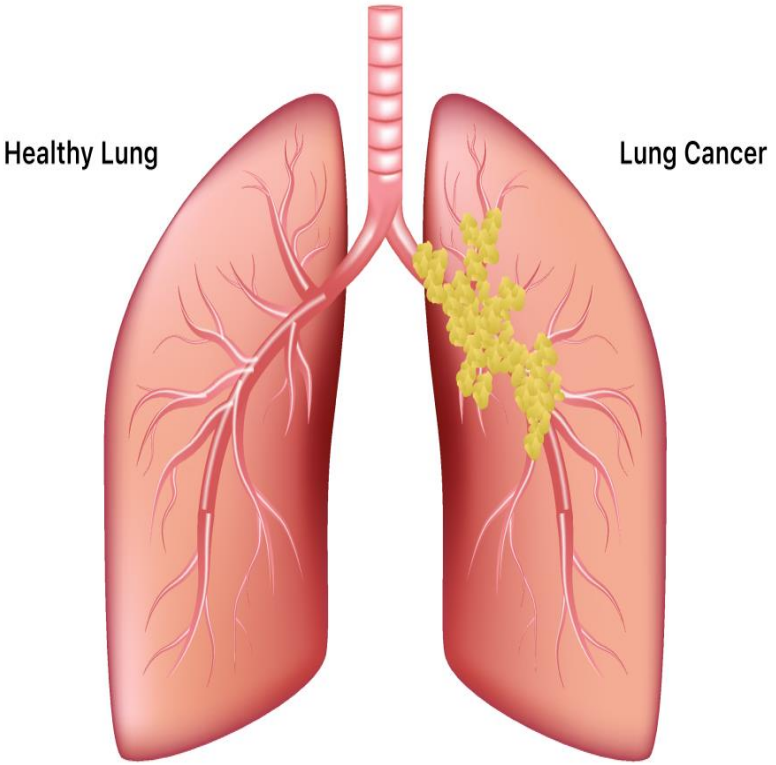
Intensity of exposure



CAREX Canada: [Welding Fumes - Occupational Exposures - CAREX Canada]

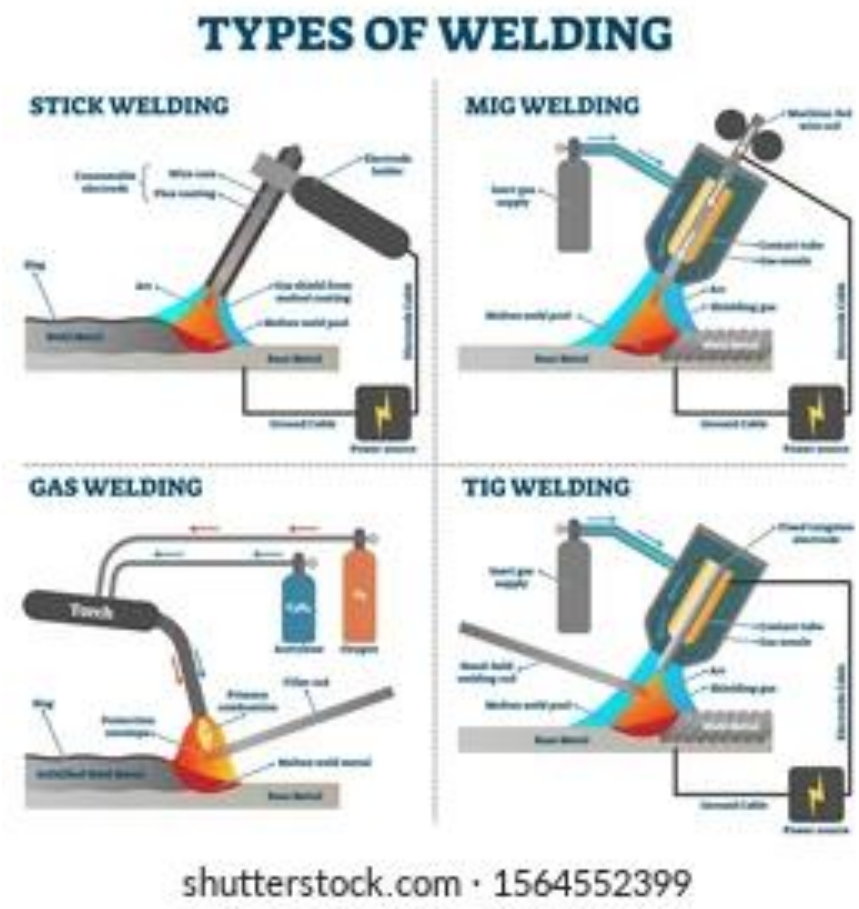
Burden of occupational cancer

- 310 lung cancer and 15 ocular melanoma from past exposures between 1961-2001.
- 1.3% of lung cancer cases and 5.4% ocular melanomas diagnosed annually.
- Work related lung cancers from welding fumes costed $308 million in 2011.

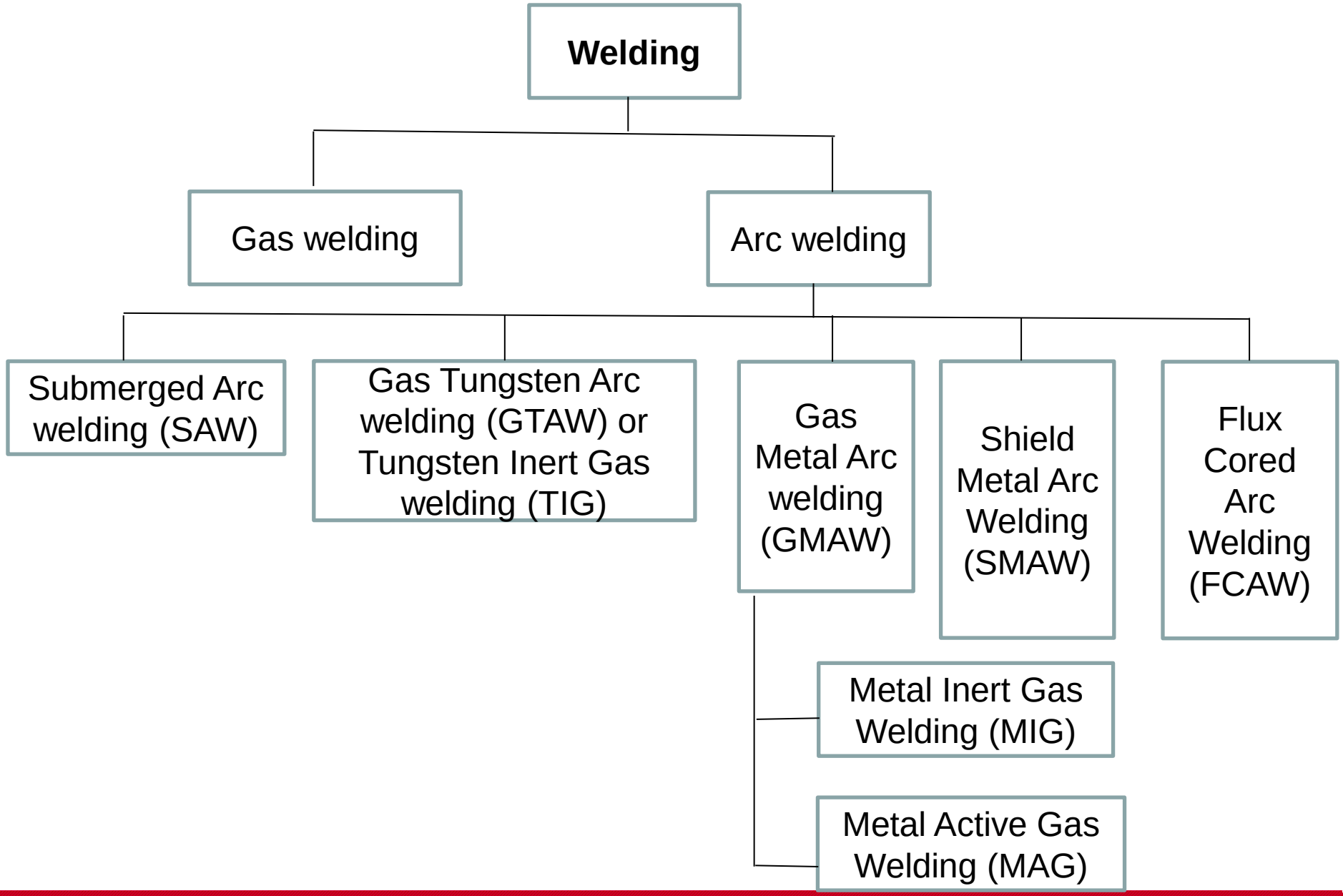


Lung Cancer | Symptoms, Causes, Treatment and Survival Rates (drugwatch.com)

Welding Basics



- Welding = process that uses heat generated by electricity (arc welding) or fuel gases (oxyfuel welding) to fuse metal materials.
- Based on the source of heat, welding is broadly classified into Arc welding and gas welding


Welding
Gas welding
Arc welding
Submerged Arc welding (SAW)
Gas Tungsten Arc welding (GTAW) or Tungsten Inert Gas welding (TIG)
Gas Metal Arc welding (GMAW)
Shield Metal Arc Welding (SMAW)
Flux Cored Arc Welding (FCAW)
Metal Inert Gas Welding (MIG)
Metal Active Gas Welding (MAG)

Welding type	Primary exposures encountered	Common industrial uses	Most common base metals welded	References
Oxyfuel	NO_2	Repair/maintenance	MS[a], AS	Weman (2003), Moniz & Miller (2010)
MMA	Metals, silicates, fluoride, asbestos[b], UV radiation, ELF-EMF	Steel fabrication, construction	MS[a], SS, AS	Burgess (1995), Weman (2003)
GMA	Metals, O_3, NO_2, CO, chlorinated HC, UV radiation, ELF-EMF	Various metal fabrication	MS[a], SS, AS, Al	Burgess (1995), Weman & Lindén (2006)
FCA	Metals, CO_2, UV radiation, ELF-EMF	Equipment repair, shipbuilding	MS[a], SS, AS	Spiegel-Ciobanu (2010)
GTA	O_3, NO, NO_2, metals, chlorinated HC, UV radiation, ELF-EMF	Aerospace, bicycle manufacturing, various metal fabrication	MS, SS[a], AS, Al	Burgess (1995), Weman (2003)
SA	Fluorides, UV radiation, ELF-EMF	Steel fabrication, shipbuilding	MS[a], SS, AS	Burgess (1995), Weman (2003)
ER	Metals, UV radiation, ELF-EMF	Aerospace, automobile, shipbuilding	MS, SS, AS, Al	Weman (2003), Moniz & Miller (2010)
Brazing/soldering	Metals, UV radiation	Metal arts, plumbing, electric components	All metals/steels	Moniz & Miller (2010)
Cutting/gouging	Metals, O_3, NO_2, UV radiation	Fabrication, construction, shipbuilding	All metals/steels	Weman (2003), Moniz & Miller (2010)

[a] Most common type welded

[b] Used historically as an insulating material in ships, to insulate covered rod electrodes, in cylinders holding acetylene gas, and in heat-protective equipment of welders and the weld Metals include but are not limited to: Fe, Mn, Al, Ni, Cr, K, Ba, Ca, F, Ti, Co, Zn, Mo, Pb, Mg, and As. These will vary by composition of base metal

Al, aluminium alloys; AS, alloyed steel; CO, carbon monoxide; CO_2, carbon dioxide; ELF-EMF, extremely low-frequency electromagnetic fields; ER, electric resistance; FCA, flux cored arc; GMA, gas metal arc; GTA, gas tungsten arc; HC, hydrocarbon; MMA, manual metal arc; MS, mild steel; NO, nitric oxide; NO_2, nitrogen dioxide; O_3, ozone; SA, submerged arc; SS, stainless steel; UV, ultraviolet

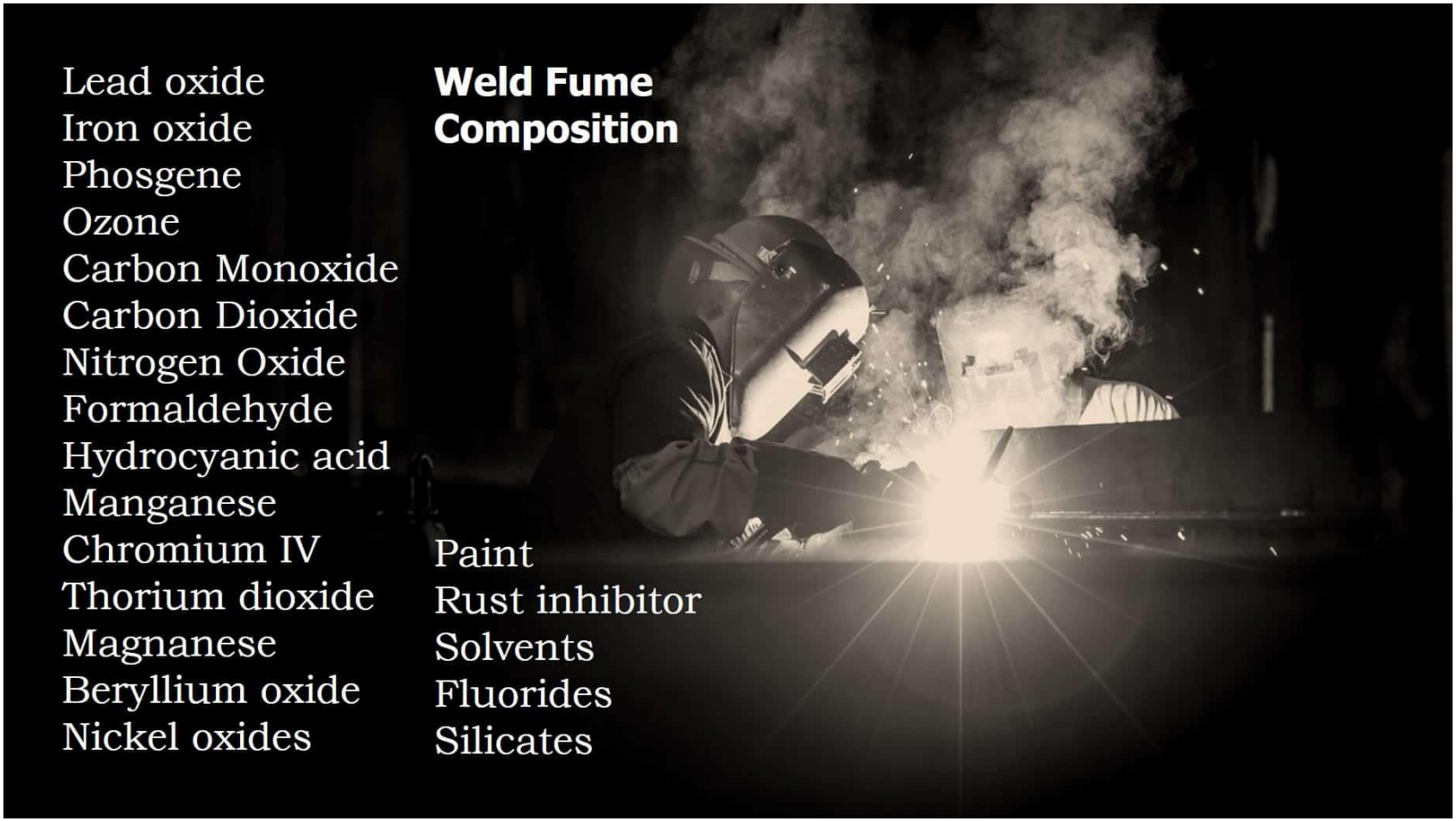
Welding Fume Composition

The composition and the amount of welding fume generated depends on the type of gas used for welding, welding rod materials, base material, metallic or paint coatings, welding process, and ventilation effectiveness.

Welding Fume Composition

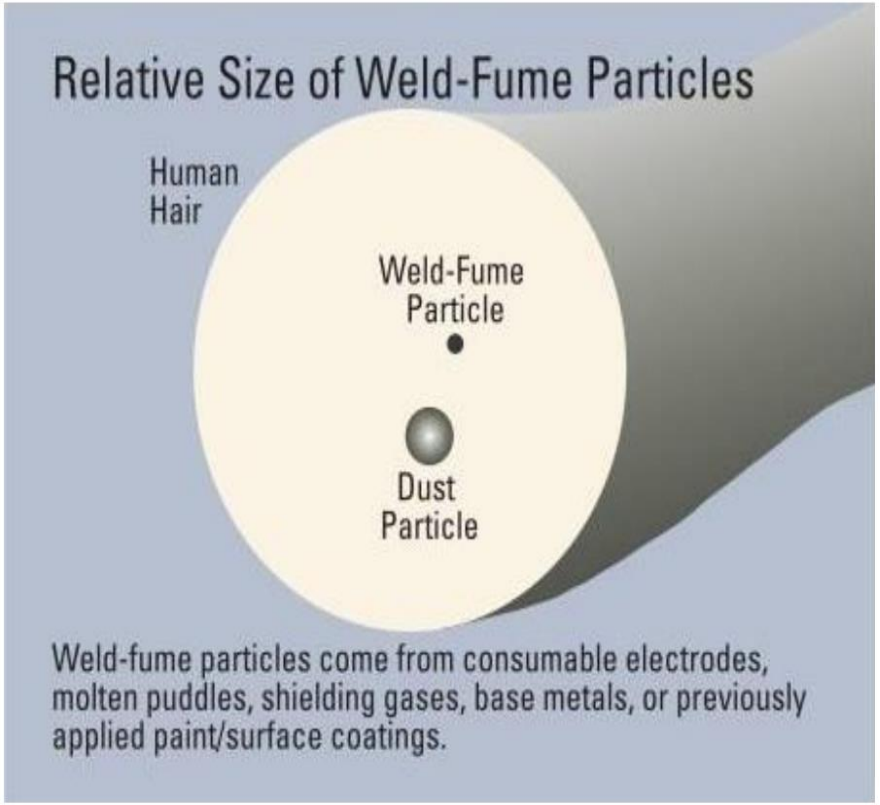
- **Particulate matter**: Aluminium, antimony, Arsenic, Beryllium, Cadmium, Chromium, Cobalt, Copper, Iron, Lead, Manganese, Molybdenum, Nickel, Silver, Tin, Titanium, Vanadium, Zinc, Silicates, Fluorides.
- **Gases:** Shielding gases (Argon, Helium, nitrogen, Carbon Dioxide), Process gases (Nitric Oxide, Nitrogen dioxide, Carbon monoxide, Ozone, Phosgene, Hydrogen Fluoride, Carbon Dioxide.

Weld Fume Composition Ex.



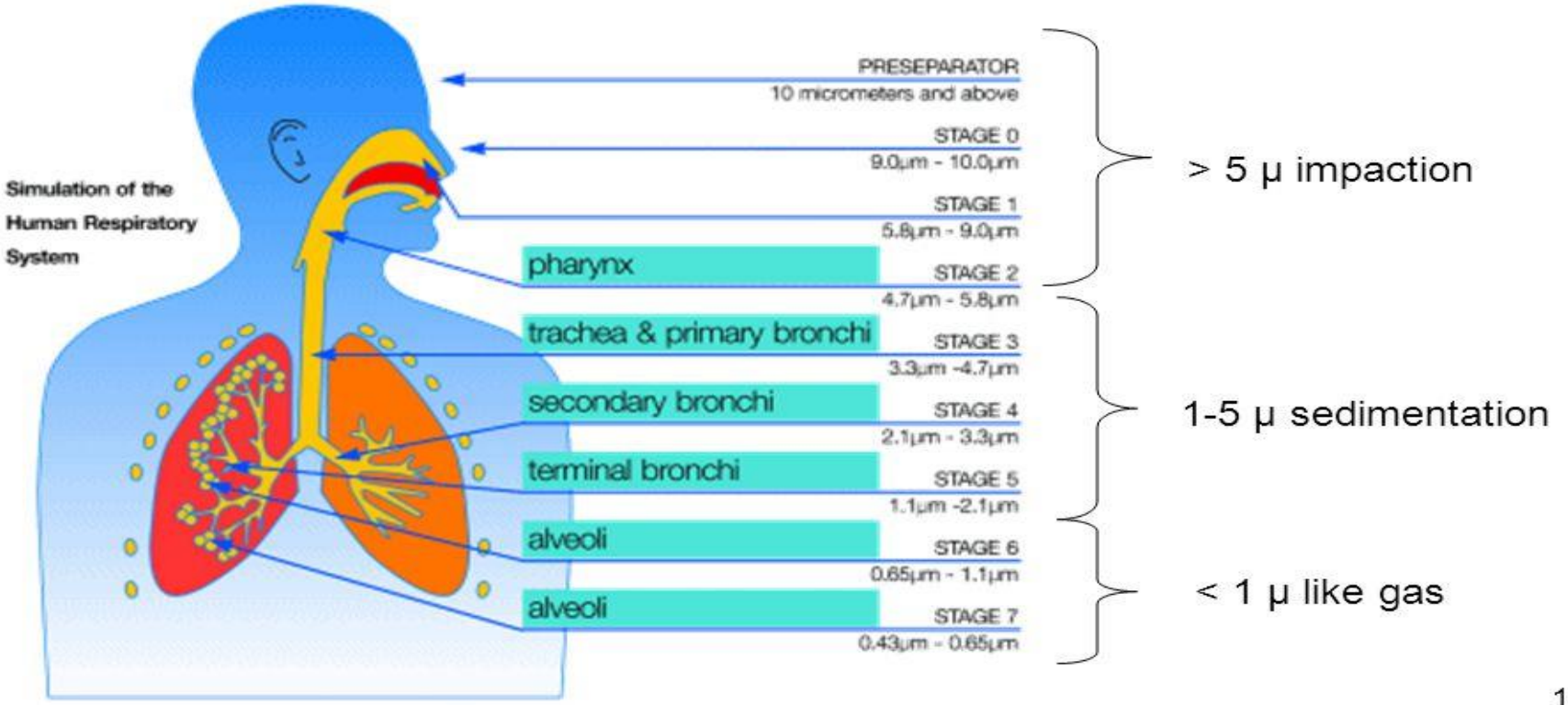
What are welding fumes?

Produced when metals are heated above their melting point, vaporize, and condense into fumes



www.aws.org

Deposition of particles



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Factors Affecting Exposure

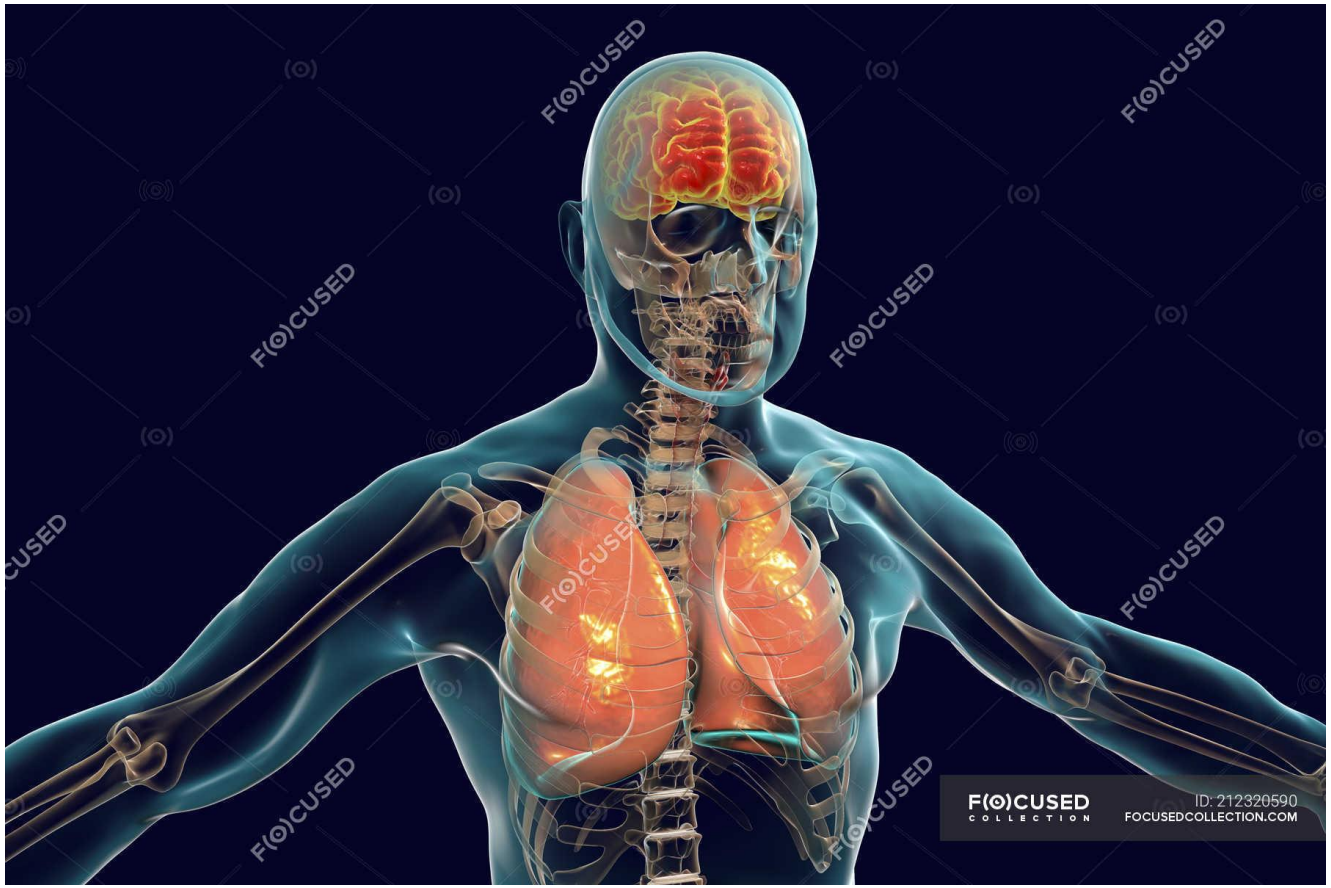
- Type of welding process
- Base metal and filler metals used
- Welding rod composition
- Shielding gas ratio
- Use of ventilation controls
- Degree of enclosure
- Air movement
- Current and voltage

Factors Affecting Exposure

- The work practices of a welder
  - Use of proper Personal Protective Equipment (PPE)
  - Position of the welder
  - Surface cleaning
  - Working upwind when welding outdoors

Welding Fume Exposure and Health Effects

- Fumes
- Gases
- Vapours



Welding exposure – Health Effects

- Acute effects
  - Eye, nose and throat irritation, dizziness and nausea
- Chronic Effects (welding fumes and UV radiation)
  - Cataracts
  - COPD, Occupational asthma, Pneumonia
  - Parkinson, Metal Fume fever
  - IARC classified as group 1 carcinogen
    - Type of cancer depends on material and type of process
      - Lung cancer, kidney cancer, eye melanoma

Medical Surveillance

- Surveillance for Cr/Ni/Cd/Be/Mn is not mandated (they are not designated substances) in Ontario and BC
- Spirometry and symptom assessment
- Blood and urine testing not recommended as results are difficult to interpret in individuals unless they are compared with BEIs
- Biological testing could be considered when checking control methods in a group of workers (e.g., to verify that control methods are working)

Medical Surveillance

- Checking for lung cancer can be difficult:
  - Chest x-ray
    - Pros: simple, inexpensive, little radiation
    - Cons: may miss cancers, ? frequency
  - CT scan
    - Pros: good at detecting early cancer
    - Cons: expensive, lots of radiation (50x CXR)
- The best approach depends on each person's circumstance, e.g., other risk factors, risk tolerance

Biomonitoring

- Biomonitoring can be done for specific metals in the welding fumes which has a BEI
- Commonly used biomedia are blood and urine
- One has to consider the timing between exposure and sample

It should be noted that the presence of a metal or its metabolite in the blood or urine only confirms the exposure

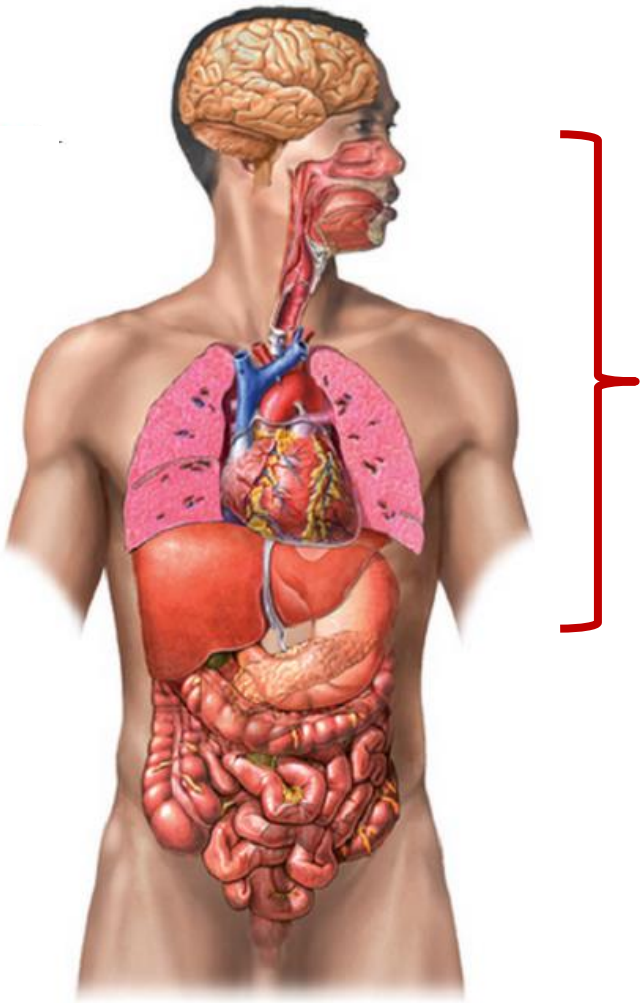
Major metals and their health effects

- Chromium
- Manganese
- Nickel
- Iron
- Beryllium

Chromium exposure

- Chromium is naturally occurring in rocks, plants and soil
  - 3 main forms of chromium
    - Chromium(0)
    - Chromium(III)
    - **Chromium(IV)**
- How does it enter the body
  - Inhalation (main route)
  - Ingestion and skin (small amounts)

Chromium – Health Effects

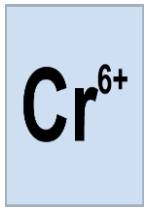


- Irritation to respiratory tract
  - Runny nose, shortness of breath, coughing, wheezing (acute)
  - Nasal perforation and ulceration
  - Bronchitis, decreased pulmonary function (chronic)
- Asthma sensitizer (CrIII,CrVI)
- Lung cancer (CrVI)

- Skin sensitizer/allergy(CrIII,CrVI)
  - rashes

- Animal studies: stomach irritation, anemia, stomach and intestinal tumours, sperm damage

Hexavalent Chromium in the Body



- Most Cr is either absorbed by the lung or Gastrointestinal tract, with some skin absorption
- Inside the cell Cr(VI) is reduced to **Cr (III)**
- Once absorbed, its excretion is usually rapid via urine (half-life = 15 to 41h) but certain exposures may lead to much longer duration
- 3 compartments: may have half-life of years

Biological Tests

- Blood Analysis ($30 **plasma blood** , NOT covered by OHIP)
  - Plasma, whole blood, erythrocytes
  - Can distinguish Cr(VI) vs. other forms of Cr by measuring red blood cells (erythrocytes) vs. plasma
- Urine Analysis ($60, not covered by OHIP)
  - Measures TOTAL Chromium (CrVI and CrIII)
  - Two ways of measuring:
    - End of shift at end of workweek
    - Before shift and at the end of shift (to check increase in total Cr)

ACGIH 2022

What can affect chromium levels (blood and urine)

- Physical activity
- Dietary Supplements
- Foods
- Smoking

What is a normal Cr level?

- If you are occupationally exposed, you will likely have higher levels than what the lab reports: they give “normal” values for non-exposed populations
- BEI for total Chromium is 0.7 µg/L (ACGIH 2022)
- Treatment of elevated Cr levels = **TIME** and possibly avoidance of exposure

Should we test for Cr in the body?

- The best method is urine Cr (end of week, or change across shift)
- ***Measuring chromium in our bodies does not tell us about potential health effects***
- Can be helpful to determine how much exposure/absorption someone has
  - e.g. Is the respirator effective? Are the control programs effective?

Manganese

Neurological and neurobehavioral deficits from low exposure include changes in mood and short-term memory, altered reaction time, and reduced hand-eye coordination.

Male workers also have a higher risk of fertility problems.

There is no BEI for manganese since the corelation between manganese airborne and urine concentration is weak.

Manganese

- Manganese is an essential nutrient.
- Inhaled manganese by passes the metabolism and accumulates in the body.
- The accumulation causes damage to lungs, liver, kidney, and central nervous system.
- Chronic high exposure (>0.1 mg/m3 - TLV) may lead to parkinsonian syndrome or Manganism.
- Parkinson like symptoms may include tremors, slowness of movement, muscle rigidity, and poor balance.

Nickel (Ni)- Health effects

- The adverse health effects depends on the solubility or bioavailability of the nickel compounds.
- The health effects from nickel exposure are mainly chronic irritation, inflammation, and cancer of the respiratory system and allergic contact dermatitis.

Nickel solubility

- Soluble Ni compounds are Ni salts such as chloride, carbonate, sulfate, carboxylate and hydroxide. These compounds are commonly used in the electroplating industries and the manufacture of Ni-cadmium batteries.
- Poorly soluble Ni compounds include oxides which is commonly found in Ni refineries and in welding fumes (Ni +2 and +3)
- Ni (sub)sulfides and Ni oxides can not be strictly categorized as soluble or poorly soluble.

Nickel fate in the body

- Inhalation
- Ingestion
- Skin absorption
- Distribution
- Elimination

Nickel - BEI

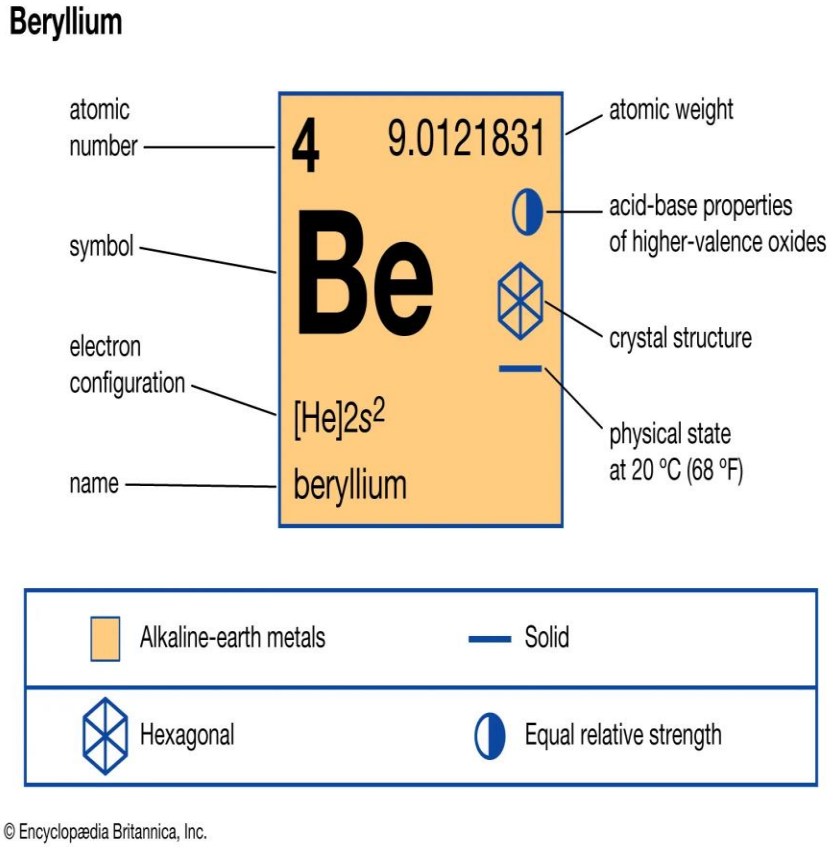
- Biological Exposure Indices (BEI) is the association between airborne exposure to nickel and its compounds and its excretion in the urine.
- BEI for elemental nickel and poorly soluble nickel is 5 µg/L (ACGIH 2022).
- BEI for soluble nickel compounds is 30 µg/L (ACGIH 2022).
- BEI is for a urine sample collected post shift at the end of work week.

Iron Oxides

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.

Beryllium



Hardening agent found in copper, magnesium, aluminum alloys and electrical contacts.

"Metal Fume Fever." A carcinogen.

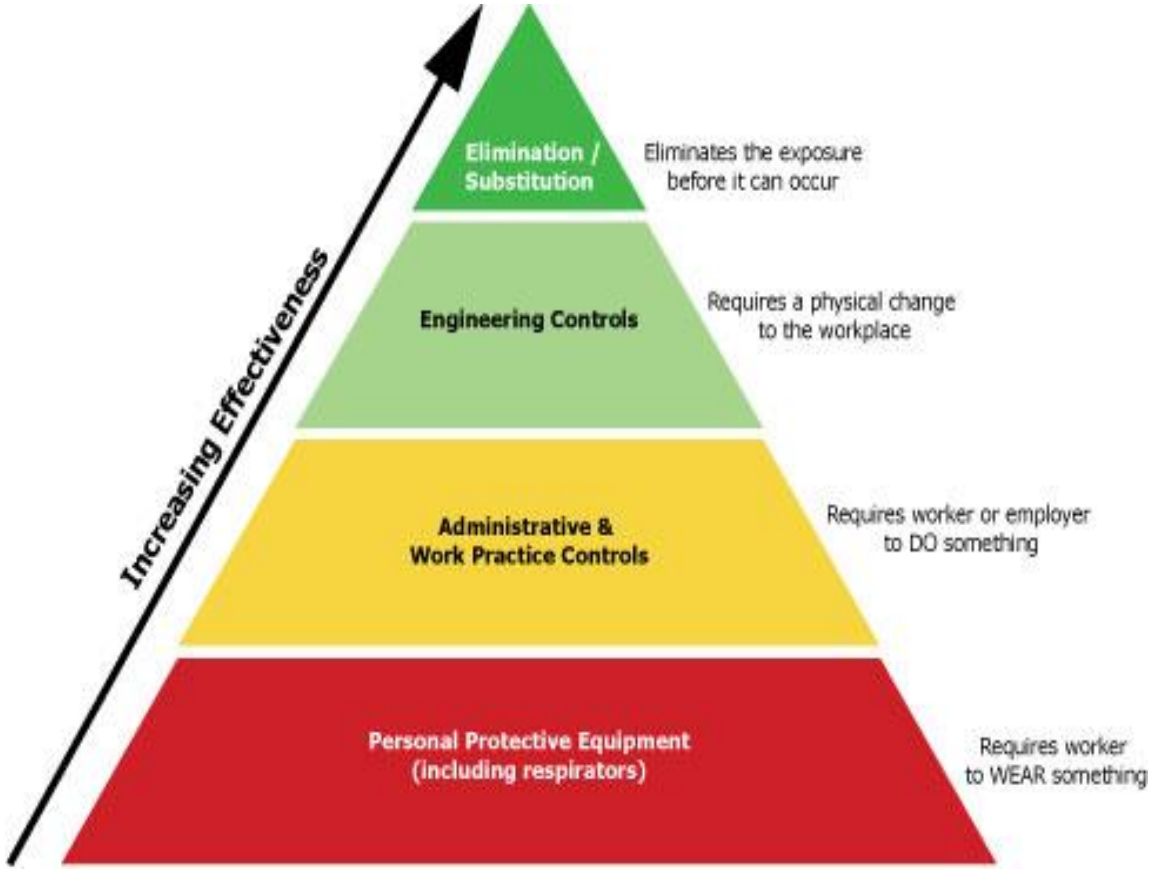
Other chronic effects include damage to the respiratory tract; respiratory sensitizer

WELDING EXPOSURE PREVENTION STRATEGIES

PREVENTION PROGRAM

- Substitution
- Engineering controls
- PPE
- Medical Surveillance

Prevention



https://www.osha.gov/SLTC/hazardoustoxicsubstances/control.html

Welding Fume Generation

Flux Core Arc Welding (FCAW) filler metal electrode; flux shield

Shielded Metal Arc (SMAW) electrode provides both flux and filler material

Gas Metal Arc (GMAW or MIG) widely used; consumable electrode for filler metal, external gas shield

Tungsten Inert Gas (GTAW or TIG) superior finish; non-consumable electrode; externally-supplied inert gas shield

Exposure limits

	Hexavalent Chromium (mg/m^3)	Manganese (mg/m^3)	Nickel (mg/m3)	Iron (mg/m3)	Beryllium (mg/m3)	Welding fumes (mg/m3)
MLTSD OEL	0.01	0.2	1 (I)	5 (R)	0.00005 (I)	-
ACGIH - TLV	0.0002 (I)	0.1 (I) 0.02 (R)	1.5 (I)	5 (R)	0.00005 (I)	5 (withdrawn)
OSHA - PEL	0.005	5 0.2 (OSHA-Cal)	1	10 (fume)	0.002	-
NIOSH – REL	0.0002	1	0.015	5 (dust and fume)		-
GESTIS						5

I= Inhalable
R= Respirable

OHCOW recommended 0.1 mg/m3 as total welding fumes to protect against carcinogenic effect of welding fumes

Occupational Exposure Banding at a Glance

Occupational exposure banding is a tool that can provide guidance for making risk management decisions when an authoritative OEL is not available. Occupational exposure bands not only provide a range of air concentrations expected to protect worker health but also can be used to identify potential health effects and target organs, identify health risks that necessitate health communication, inform implementation of control interventions and preparedness plans, inform medical surveillance decisions, and provide critical chemical toxicity information quickly.

Occupational exposure banding uses easily accessible qualitative and quantitative hazard information on selected health effect endpoints to identify potential inhalation-based exposure ranges or categories for guiding occupational risk assessment and risk management. The occupational exposure banding process provides a series of concrete steps to guide users through the evaluation of health hazard information and identification of the appropriate occupational exposure band from among five categories based on the severity of health outcomes (bands A to E; band A is highest air concentrations, and band E is lowest air concentrations) (Figure 0-1

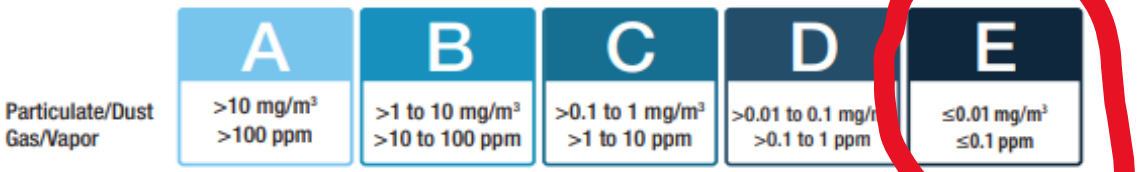


Figure 0-1. Occupational exposure bands [McKernan et al. 2016].

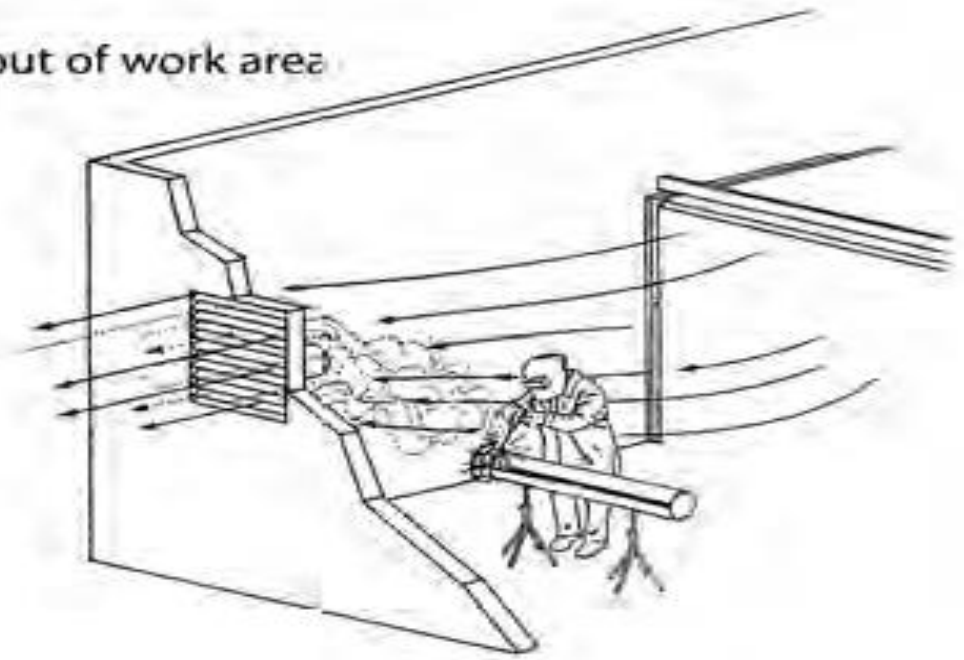
Note: When OSHA and other regulatory bodies limit occupational exposure to chemical substances, users should defer to those regulations, rather than an estimated occupational exposure band. For example, Particulates Not Otherwise Regulated (PNOR) have OSHA exposure limits of 15 mg/m³ for total dust and 5 mg/m³ for respirable fraction [29 CFR 1910.1000 Table Z-1] [OSHA 2012].

The banding process uses a three-tier approach (Figure 0-2). Selection of the most appropriate tier for a specific banding situation depends on the quantity and quality of the available data and the training and expertise of the user.

Mechanical/general Ventilation

- Air forced into and out of work area
- Roof exhaust fans
- Wall fans

NOTE: Air volume should deflect fume out of welders breathing zone.



IHSA Tools and Techniques: Welding and Cutting chapter 41

Local Exhaust ventilation (LEV)

FILTAIR® Capture 5 208/230 V, 10 ft. Arm (millerwelds.com)

Welding fume extraction | Fume Eliminator 24/7| Nederman

Fume Extraction for CNC Plasma Cutting machines (cityplasma.co.uk)

Welding and Grinding table (nederman.com)

Correct use of LEV

- Distance from the arc
- Capture velocity
- Design of the exhaust hood
- Level of enclosure
- Equipment maintenance
- Training

OSHA welding factsheet

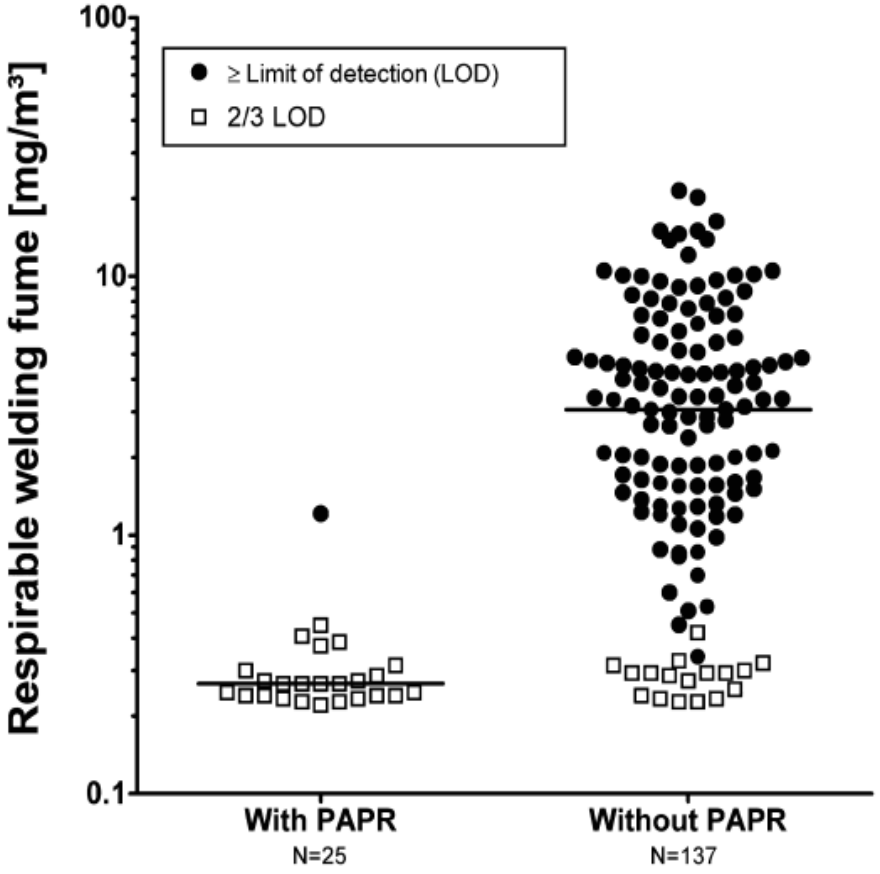
Personal Protective Equipment

https://golocall.com/abhijeetenterprises/offering-you-a-complete-choice-of-products-which-include-welding-safety-accessories-and-welding-glass-welding-safety-acc/gl5682/

PAPR with T94-R™ (millerwelds.com)

Personal Protective Equipment

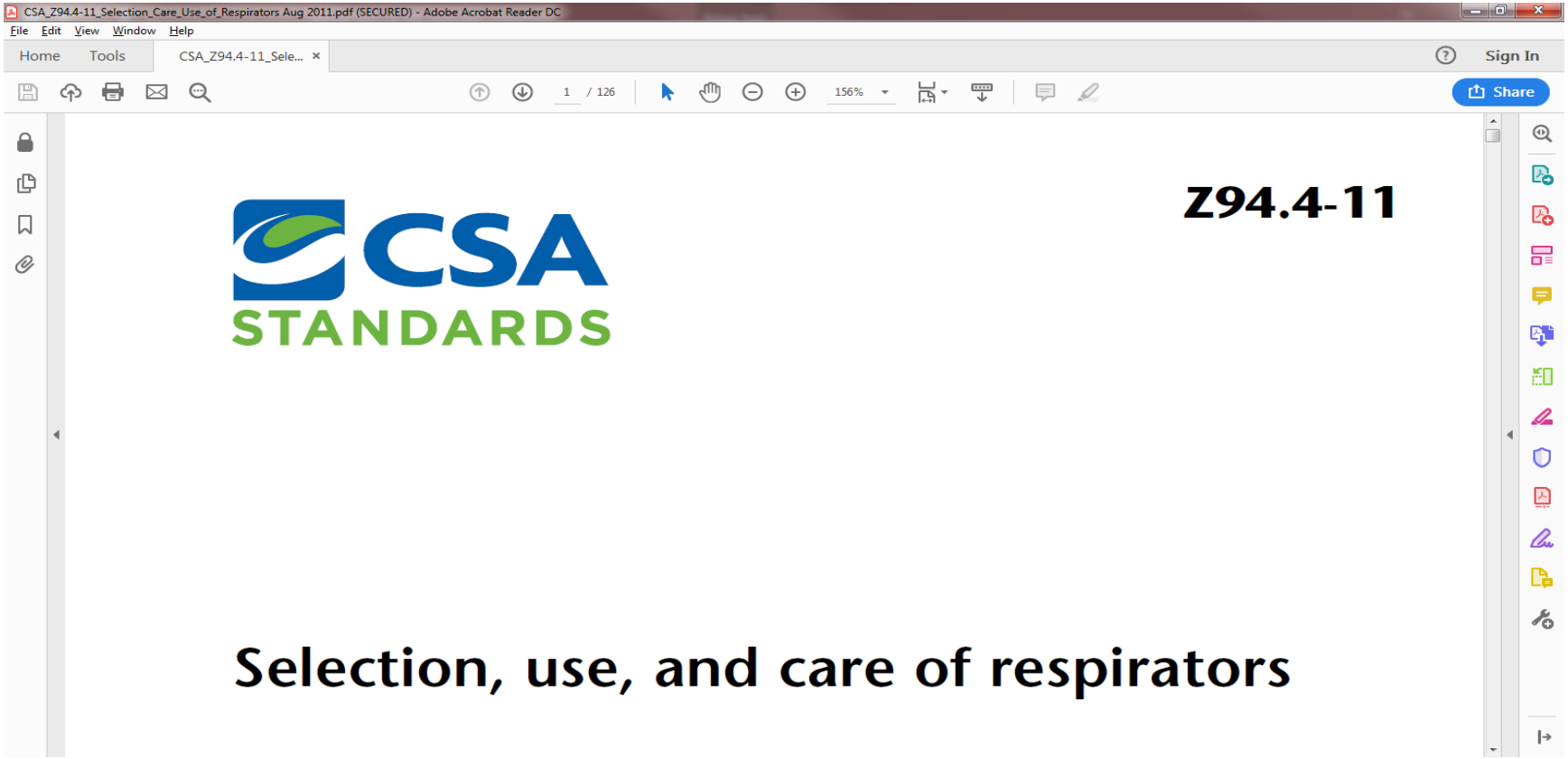
Powered Air Purifying respirators and N95 (provided proper fit) can be very effective in reducing the welding fume exposure, however, they can be difficult to use in confined spaces.



Personal Protective Equipment

Recent studies have shown only marginal reduction of welding fumes from welding helmet and the reduction factors varied due to different factors such as level of exposure, position of the welder, type of welding etc.

Respitory Protection Program



Assigned Protection Factor (APF)

Respiratory mask	APF	Fit testing
Half mask/Dust mask	10	Needed
Half mask (elastomeric)	10	Needed
Full facepiece (Elastomeric)	50	Needed
Loose-fitting Powered Air-Purifying Respirator (PAPR)	25	Not needed
Hood Powered Air-Purifying Respirator (PAPR)	25	Not needed
Full Facepiece Supplied-Air Respirator (SAR	1000 10,000 if used in escape mode	Needed
Full Facepiece Abrasive Blasting Continuous flow	1000	Needed
Full Facepiece Self-Contained Breathing Apparatus (SCBA)	10,000	Needed

OSHA APF 2009

Assigned Protection Factor (APF)

$$\text{Required APF} = \frac{Exposure\ concenration}{Occupational\ Exposure\ Limit}$$

$$\text{Maximum Exposure Limit} = Exposure\ Limit \times APF$$

$$= 0.01 \times 10 = 0.1$$

OSHA respiratory selection eTool

Home | Respirator Change Schedules | Respirator Selection | Expert Systems | Respirator Basics

This eTool® provides instruction on the proper selection of respiratory protection and the development of change schedules for gas/vapor cartridges as well as helps you comply with the OSHA respirator standard. Respirators should be used for protection only when engineering controls have been shown to be infeasible for the control of the hazard or during the interim period when engineering controls are being installed. (Refer to Exposure Control Priority).

Respirator Change Schedules

Respirator Selection

The OSHA respirator standard applies to all occupational airborne exposures to contaminated air where the employee is:

- Exposed to a hazardous level of an airborne contaminant; or
- Required by the employer to wear respirators; or
- Permitted to wear respirators.

Four major duties are imposed by each of these standards. These duties are:

- Use engineering controls where feasible to control the hazard.
- Provide an appropriate respirator.
- Ensure the use of an appropriate respirator.
- Institute a respiratory protection program that complies with the rest of the standard.

Applicable OSHA Standards:

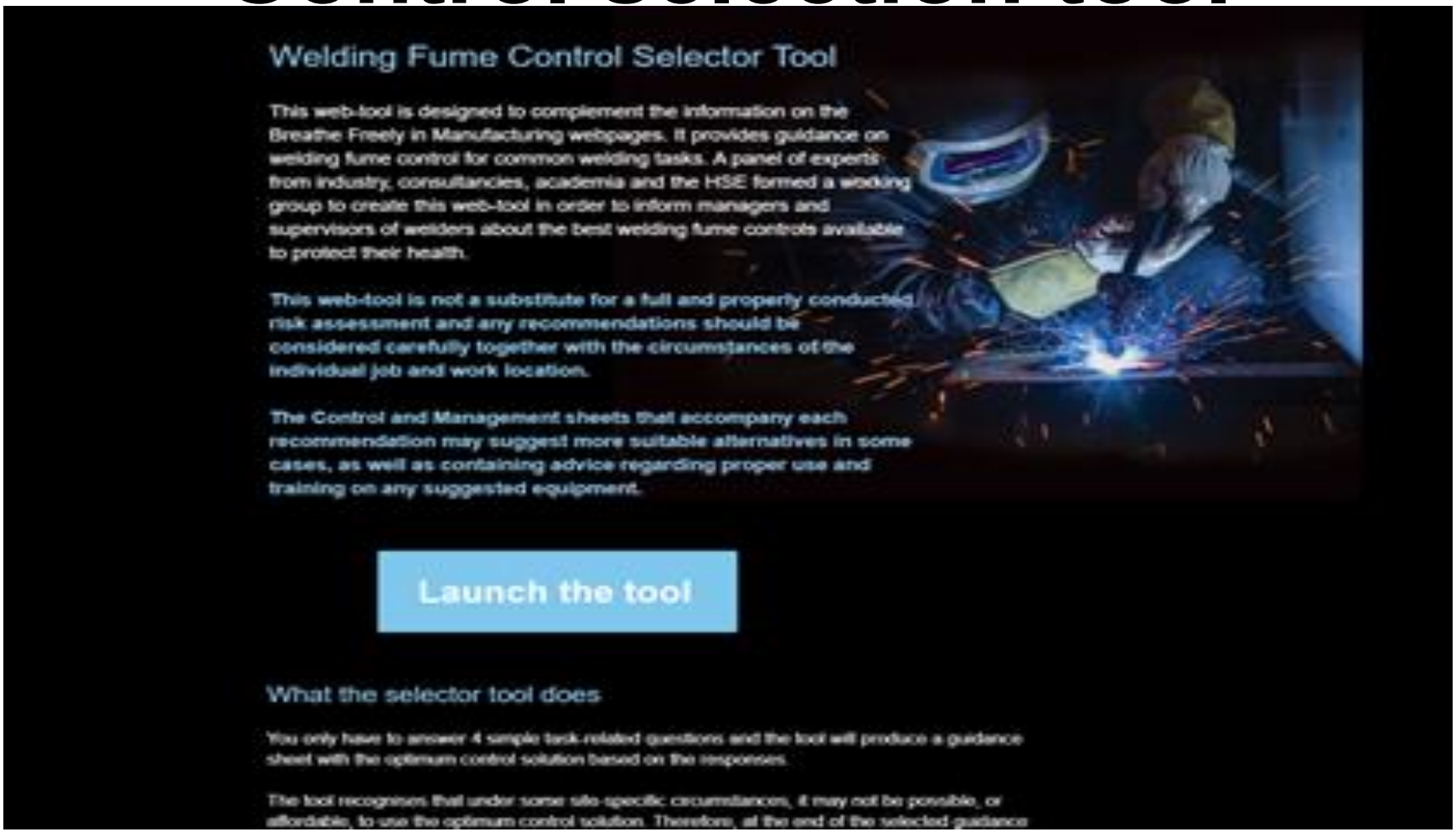
- 29 CFR 1910 Subpart I, Personal protective equipment. OSHA Standard.
  - 1910.134, Respiratory protection
    - 1910.134(a), Permissible practice

Keep In Mind

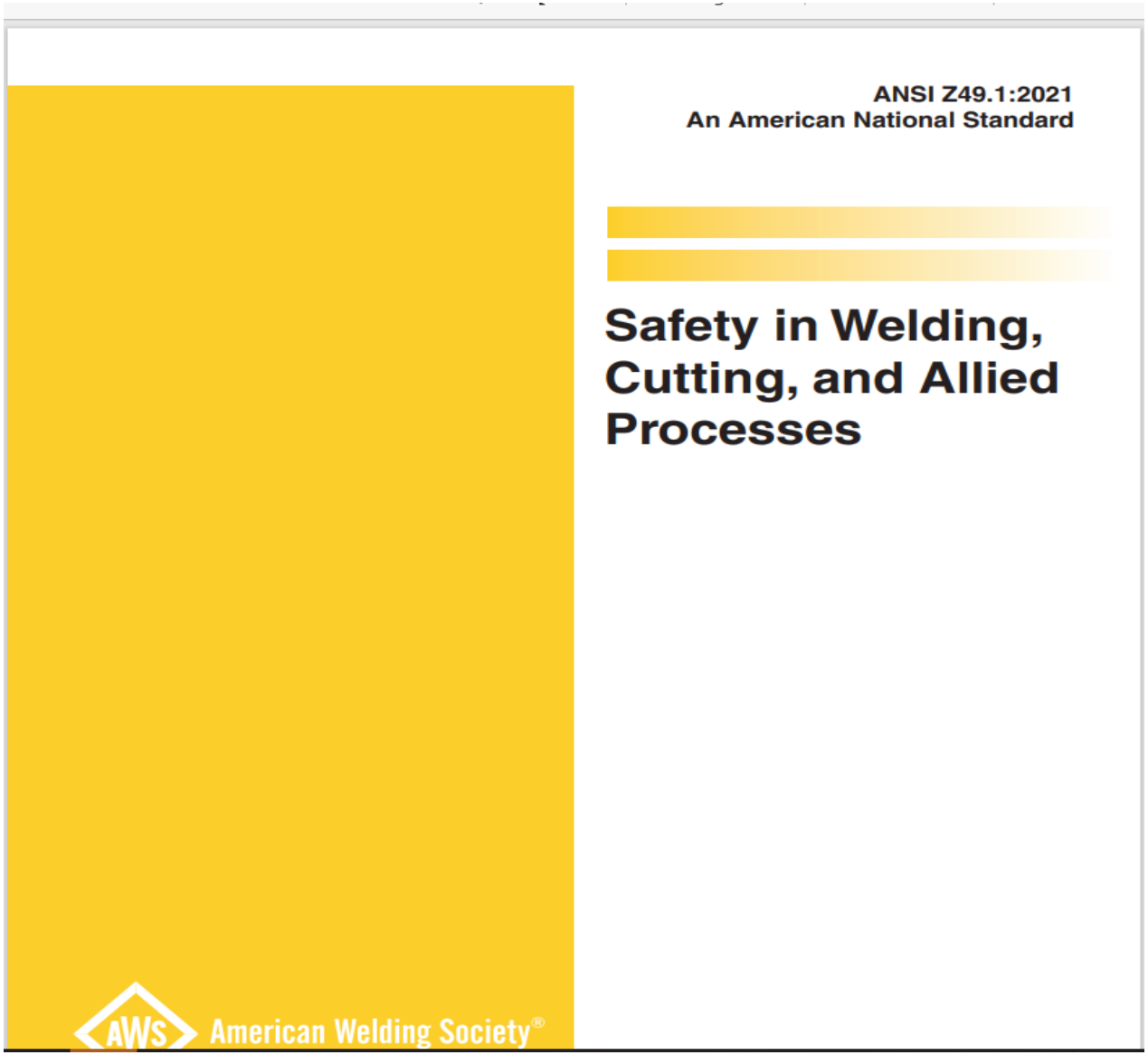
The display or use of particular products in this advisor is for illustrative purposes only and does not constitute an endorsement by the U.S. Department of Labor.

eTool : Respiratory Protection - Respirator Selection - The Advisor Genius -Selecting an Appropriate Respirator | Occupational Safety and Health Administration (osha.gov)

Control selection tool



Welcome to the Breathe Freely Welding Fume Control Selector Tool



ANSI Z49.1:2021 (aws.org)

Thank You

Questions?

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OH-PODS: Occupational Health Podcasts

This is a podcast series by the Occupational Health Clinics for Ontario Workers (OHCOW), where we discuss the challenges of current and emerging trends in occupational health and offer effective prevention strategies to empower workers.

Visit our website to listen/subscribe using Apple Podcasts, Spotify, and more!

https://www.ohcow.on.ca/OH-PODS-Podcasts.html