Co-funded by the Erasmus+ Programme of the European Union

Training Handbook

Health, Safety and Environment Training Curriculum Development for Joining Technologies

11/20/2018

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HSE JOINING

Health, Safety and Environment Training Curriculum Development for Joining Technologies

KA2 – Cooperation for Innovation and the Exchange of Good Practices

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Intellectual Output 2 – Educational Materials

http://www.hse-joining.eu

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Foreword

HSE-Joining: Health, Safety and Environment training curriculum development for joining technologies, is an ERASMUS+ project, implemented between December 2016 and November 2018.

The project is being conducted by a consortium of six partners from four European countries. All partners have technical expertise to achieve the project objectives and a wide experience of participation and management of national and European projects.

The overall aim of the HSE joining project is to offer VET provider organisations a training curriculum for Environmental and Health and Safety management in manufacturing companies, taking into account the hazards of the workplace for staff (fume, radiation, noise, vibration), factors with potential high risk on the health and safety of welders and also the significant impact on the environment.

Index

General Overview

The present training handbook features "Health and Safety" module, which is divided in 15 topics. The topics are, in order of appearance, fumes, hazards of electricity, electromagnetic fields, cutting risks, hot material and spatter, arc radiation, noise, vibration, gas cylinder handling, welding in confined spaces, ergonomics, pickling of stainless steel, waste management, storage of material and brazing and soldering.

The contents structure in each topic corresponding to recognising the health, safety and environmental risks; organising a safe workplace (for the welder, the group, the supervisor and general workplace checking); proper use and maintenance of equipment (individual equipment, workshop installations and Personal Protection Equipment); and European recommendations and European and national regulations.

Module 1 – Health, Safety and Environment in Welding

1. Fumes

1.1. Recognising Risks

1.1.1. Health (personal risks)

Welding fumes are a complex mixture of metallic particles. Welding fumes are formed when a metal is heated above its boiling point and its vapours condense into very fine, particles (solid particles). Generally, they contain particles from the electrode and the material being welded. Fumes are considered as Hazardous substances.

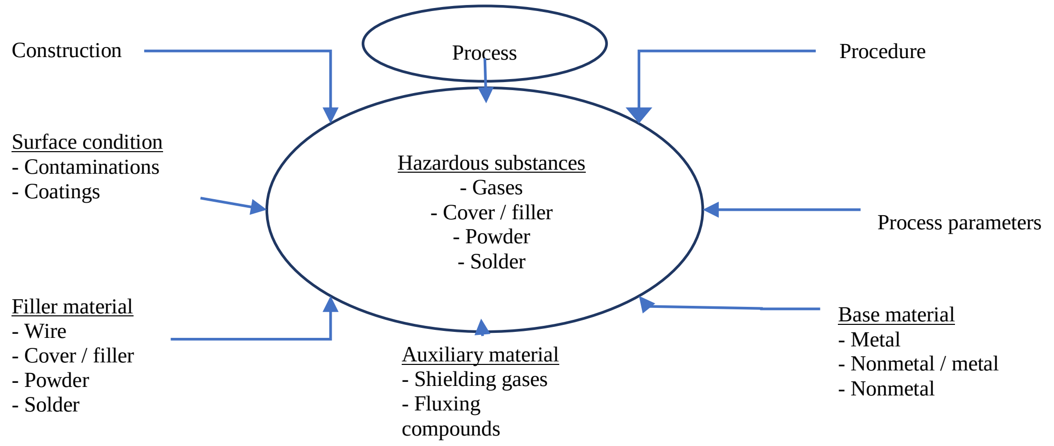


Figure 1 – Hazardous substances. Source: Doc. IIW VIII 2085-2009, excerpt from BGI 593

Two Types of Health Effects:

Acute: Short-Term effects on body. (immediate or shortly after exposure).

Chronic: Long-Term effects on body (from repeated low level exposures).

Symptoms develop over a period of time.

Examples:

Drunkenness =acute effect from overindulgence in alcohol.

Liver & brain damage = chronic effect.

Smoking: Acute = Wheezing, Shortness of Breath

Chronic = Lung Cancer, Emphysema

1.1.2. Safety (workplace risks)

Two main types:

- PEL: Permissible Exposure Limits (exposed up to 8 hours a day, 40 hours/week, without experiencing adverse health effects).
- TLV: Threshold Limit Values. Recommended Exposure Limits. PELs take precedent over TLVs.
- Both types usually expressed as maximum concentration or mass per unit volume (ug/m^3).

TLVs and PELs have STELs - 15 minute values (Short Term Exposure Limits)

Toxic Effects

- Corrosive: Liquid or solid that causes visible destruction or irreversible alterations in human tissue.

- *Examples: Acids, Flux, Caustics, Hydroxides, Ammonia*

- Irritant: Inflammatory response of eye, skin or respiratory system

- *Examples: Smoke, Dusts, Almost all Chemical Vapors*

- Sensitizer: Can become sensitized after just one exposure if you are susceptible. Skin sensitization is most common form.

- *Examples: Isocyanates used in Plastics and Resins*

- Neurotoxin: Able to cause neurological damage to the central nervous system, (usually after long-term over exposures).

- *Examples: Solvents*

Classification of particulate hazardous substances in welding and allied processes according to particle size

Inhalable dust
Fumes and dusts generated during thermal spraying
Fumes generated during thermal cutting
Fumes generated during welding
Fumes generated during soldering and brazing
Ultrafine particles (UFP)

Table 1 – Fume classification acc. to particle size acc. EN 481

1.1.3. Environment

Ventilation - 1st option. Hazards are also related to the confined space. This means additional checks. The air volume intake in a safe location has always to be checked and documented. One of the main question here is: Is it a continuous ventilation? Retesting of confined space before entry is a must.	 Figure 2 - Improper welding conditions. Source: www.lincolnelectric.com/en-us/support/welding-solutions/Pages/Five-potential-welding-safety-hazards.aspx?utm_referrer=https%3A%2F%2Fww

1.2. Organising a safe workplace

If samples show < Action Level

- May discontinue monitoring

If samples show ≥ Action Level

- Periodic monitoring every six months

If samples show ≥ Permissible Exposure Level

- Periodic monitoring every three months

Additional monitoring if changing process.

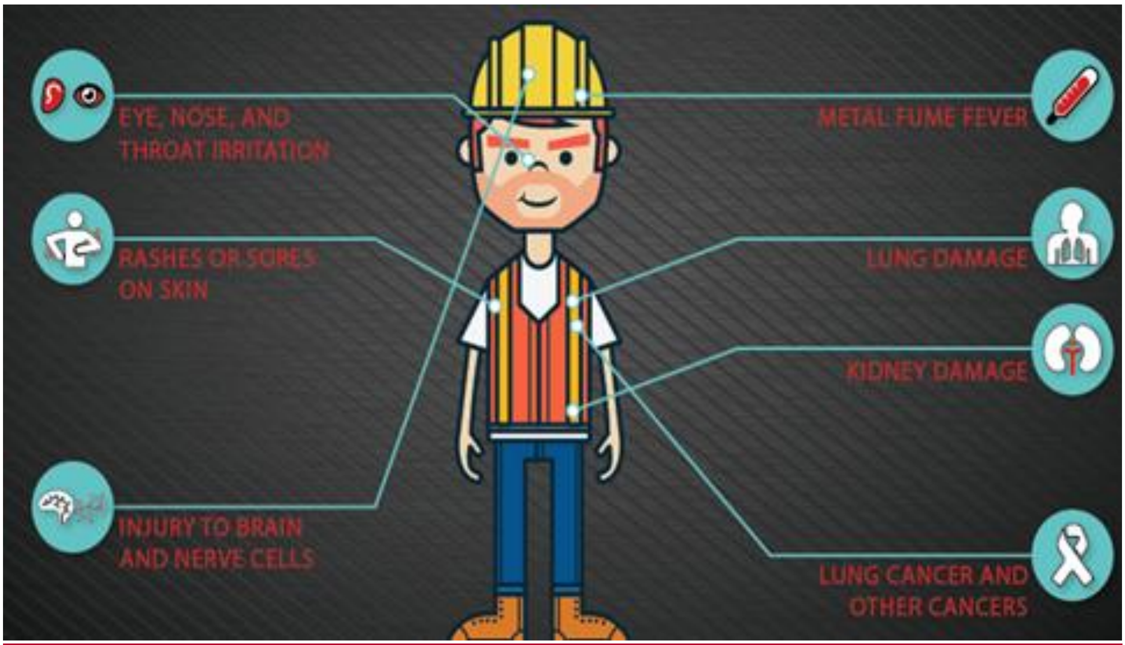


Figure 3 –Health risks of plasma cutting and welding fumes. Source: www.isystemsweb.com/wp-content/uploads/2016/09/Plasma-cutting-and-Welding-fume_paper-1.pdf

https://www.isystemsweb.com/wp-content/uploads/2016/09/Plasma-cutting-and-Welding-fume_paper-1.pdf

Exposure Determination

Fumes:

- Small solid particles.
- Generated by condensation of metals volatilized to gaseous state.
  - VERY small particles (90% less than 1 micron in size).
  - Not always visible to the unaided eye.
- Small particles are HIGHLY respirable meaning they can get deep into the lung.
- Vary considerably in their toxicity.
- Sources
  - Consumable or filler metal
  - Base metal
  - Coatings or surface treatments

Factors Affecting Fume Formation & Exposure

- Type of consumable (composition, coating/flux type)
- Amperage (current)/Polarity
- Wire feed rate
- Type of filler material
- Amount of arc time
- Metal transfer mode (GMAW)
- Welding position
- Ventilation

Metal Fumes

Iron

- Usually the majority of the metal in welding on ferrous alloys
- Prolonged exposure can cause siderosis

Copper Fume/Dust

- Found in non-ferrous alloys such as brass, bronze, Monel
- May also be present in electrodes in especially arc gouging

Zinc Oxide

- Sources
  - Alloys containing zinc
  - Surface coatings such as zinc covered surfaces

Manganese

- In many consumables used for steel welding
- Associated with Parkinson's-like disorders
- PEL is out-of-date-control to the TLV (0.2 mg/m^3)

Other metals

- Aluminum
- Molybdenum
- Nickel
- Tin
- Titanium

Metal Fumes-Lead

Sources:

- Surface coatings:
  - Galvaneal/galvanized metals
  - Paints or other surface coatings
  - Terne plate
- Alloys:
  - Brass/bronze leaded alloys
  - Solders
- Lead burning for tanks and vessels

Problem in welding, cutting and grinding.

Health Effects

- Anemia
- Gastrointestinal
- Reproductive
- Neurological

Chromium

Routes of exposure:

- Skin contact;

- Inhalation;
- Ingestion;

Trivalent form:

- Irritant;

Hexavalent form:

- Cancer;
    - Evidence is primarily from chrome plating; less compelling for welding.
- Soluble forms:
    - Perforation of nasal septum
    - Nasal irritation
    - Nasal ulcerations
    - Asthma
    - Bronchitis
    - Allergic skin reactions

Welding and Cr^{+6}

Exposures can vary greatly.

Generated during welding or cutting of stainless steel or metal structures coated with chromate paint.

Electroplating (chrome plating)

Affected industries:

- Food processing;
- Chemical processing;
- Foundries;
- Metal fabricators;
- Equipment/repair operations;
- Tank/truck manufacturers;
- Shipbuilding;
- Electric utilities;
- Demolition & repair;

Factors Affecting Cr+6 Formation

- SMAW, MIG, FCAW. Higher risk than TIG or SAW.
- Arc gouging & plasma cutting;

- Hard facing/surfacing;
- Amount of arc time;
- High amperages;
- Chromium content of the consumable and base metal;
- Breathing zone close to the arc;

Figure 4 – “Chrome hole” on finger. Source: https://www.cdc.gov/niosh/topics/skin/occderm-slides/ocderm8.html

Respiratory Protection

Required when exposures exceed the PEL and:

- Waiting for feasible engineering or work practice controls to be installed;
- Where controls not feasible (i.e. maintenance, repair activities);
- Controls cannot get <PEL;
- The exposures take place <30 days/year;
- During emergencies;

Compliance with norms, when respirators are used.

Figure 5 –Proper use of respirators. Source: www.allsafetyproducts.com/msa-pressure-demand-supplied-air-respirators-p-22150.html

1.3. Proper use and maintenance of equipment

When the potential hazard cannot be removed, replaced, or enclosed, the next best approach is a barrier to exposure or, local exhaust ventilation to remove the fumes and/or air contaminant from the workplace.

What else?

- Change welding procedure;
    - Stick to MIG or even better TIG
- Use welding wires/rods designed for lower fume generation;
- Change power source;
- Change shielding gas;
- Fume removal / extraction.

Figure 6 – Fume extraction torch. Source: https://www.westermans.com/sifgun-fume-extraction-torch.aspx

Fume Removal / Extraction

Low Vacuum (High Volume)

- remove large amount of air at low velocity and low vacuum pressure;
- Articulated “arms”, 30 to 45cm from the welding arc;
- These arms typically draw between 100 and 200 CM per arm.
- If access to the joint prevents the use of fume guns or suction heads, low vacuum may be the better solution.
- If weldment smokes after welding due to die oils or paint, fume guns will not work since they are removed after welding.

Low Vacuum (High Volume)

Portable Fan:

- For hard to reach areas, exhaust the fume;
- 5m long hose set with magnet mounted hood exhaust or extension hose set;

- Does not provide filtration;

Figure 7 – Portable low vacuum Extractor. Source: https://uedata.amazon.com/Mobiflex-100-NF-Portable-Vacuum-Single/dp/B001TG703E

Low Vacuum (High Volume)

Base Unit - Mobile Welding Fume Extractor;

- A portable, disposable system designed for intermittent or continuous extraction and filtration of welding fumes.
- On-board internal extraction fan and is designed specifically for weld applications.
- Particles are collected inside the cartridge, minimizing exposure during filter maintenance and disposal.

Figure 8 – Low vacuum base Unit. Source: https://www.lincolnelectric.com/en-gb/equipment/weld-fume-control/Pages/stationary-units.aspx

Fume Removal / Extraction

High Vacuum (Low Volume)

- capture fume as close as possible to the arc, using integrated fume extraction guns or heads, about 10 to 15cm from welding arc;
- Fume is captured before it reaches the operators breathing zone;
- Using fume guns, eliminates the need of repositioning with low vacuum arms;

- (only a small volume of air is processed)

High Vacuum (Low Volume)

Portable Welding Fume Extractor:

- Specifically designed for the removal and filtration of welding fumes;
- Can be completely disassembled in minutes for cleaning and maintenance;
- With an automatic start/stop function, the unit automatically turns on and off during welding;
- Can be used in confined spaces and locations that are not accessible with other welding fume extractors;

Figure 9 – High vacuum base Unit. Source: from https://www.lincolnelectric.com/en-us/equipment/weld-fume-control/Pages/portable-units.aspx

Criteria for the selection of ventilation

More intensive ventilation for:	Less intensive ventilation for:
- high gas flow rates; - high current intensities; - contamination of workpiece surface; - unfavorable spatial conditions (e.g. confined spaces etc.)	- low gas flow rates; - low current intensities; - contamination of workpiece surface; - favorable spatial conditions (e.g. high halls etc.); - coatings that generate low quantities of hazardous substances;

Table 2 – Criteria for the selection of ventilation. Source: ISIM

Personal Protective Equipment

When exposure to hazards cannot be engineered completely out of normal operations or maintenance work, and when safe work practices cannot provide sufficient additional protection, use protective clothing or equipment.

It includes face shields, steel-toed shoes, hard hats, respirators, hearing protection, gloves and safety glasses.

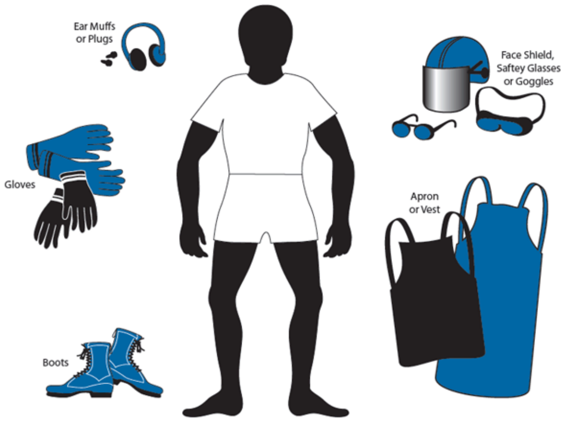


Figure 10 – PPE. Source: https://steelhub.files.wordpress.com/2015/03/welding-ppe.gif

Respiratory Protection Program

Written respiratory protection program with worksite-specific procedures and elements for required respirator use including:

- Procedures for selecting respirators (in workplace);
- Medical evaluations of employees required to use respirators;
- Testing procedures for tight-fitting respirators;
- Procedures for proper use of respirators (in routine and reasonably foreseeable emergency situations);

Figure 11 – Respirator. Source: www.cromweld.com/best-welding-respirators

Types of Respiratory Protective Equipment

Dust, Fume and Mist Respirators:

- Mechanical filter respirators: protection against airborne matter (dusts, mists, metal fumes and smoke);
- Mechanical filter respirators do not provide protection against gases, vapors, or oxygen deficiency;

Figure 12 – Mechanical filter respirators. Source: www.totaltools.com.au/safety/respiratory-protection/32055-prochoice-respirator-dust-mist-mask-with-valve-12-pack-pc321

Types of Respiratory Protective Equipment

Chemical Cartridge Respirators:

- Protection against concentrations of acid gases and organic vapors using chemical agents to purify inhaled air. Not be used in oxygen deficient atmospheres;
- Chemical Cartridge Respirators (1/2 mask) shall not be used for protection against:
    - Gaseous material extremely toxic in small concentrations;
    - Harmful gaseous substances which cannot be detected by odor (carbon monoxide);
    - Gaseous material which are highly irritating to the eyes;

Types of Respiratory Protective Equipment

Air Supplied Hood:

- Used where user requires protection against levels of material or requires an air flow for cooling purposes.
- Not to be used in situations where user would be endangered.

Airline Respirator:

- Full face mask supplied with breathing air by a compressor.
- Care to prevent damage to the hose and regulator while in use.

Types of Respiratory Protective Equipment

Cylinder Type Self-Contained Breathing Apparatus:

- Compressed breathing air will provide protection in any atmosphere.
- Provides breathing air for approximately 30 minutes (caution or emotional strain may reduce time).
- Equipment users shall begin exiting the hazardous atmosphere when the low pressure alarm sounds.

Figure 13 – Cylinder Type Self-Contained Breathing Apparatus. Source: www.alibaba.com/product-detail/wholesale-5L-portable-oxygen-breathing-apparatus_60622407245.html

An Activity Hazard Analysis (AHA) requires a proactive attitude to identify and quantify all anticipated possible hazards and also to mitigate/control the findings, to environmentally manage all possible/existing risks.

Identify and Evaluate Potential Hazards

Surveillance audits/measurements to be conducted periodically (conformity and risk-free environment).

Appropriate Personal Protective Equipment (hot work permits) to be worn and regularly checked.

1.4. European, National Regulations and Recommendations

In this section, a list of the main European H&S standards and codes of practice related to fumes are presented:

EN ISO 15011-4: Health and safety in welding and allied processes. Laboratory method for sampling fume and gases. Fume data sheets

EN ISO 15012-1, -2 & -4: Health and safety in welding and allied processes -- Equipment for capture and separation of welding fume - Part 1: Requirements for testing and marking of separation efficiency

EN ISO 21904-3:2018: Health and safety in welding and allied processes. Requirements, testing and marking of equipment for air filtration. Determination of the capture efficiency of on-torch welding fume extraction devices

EN ISO 10882-1: Health and safety in welding and allied processes. Sampling of airborne particles and gases in the operator's breathing zone. Sampling of airborne particles

EN ISO 17652-4: Welding. Test for shop primers in relation to welding and allied processes. Emission of fumes and gases.

2. Hazards of Electricity

2.1. Recognising risks

Any person or equipment may be subjected to harm when exposed to “live electrical parts”. Impairment might occur when parts are touched directly or indirectly by means of some conducting object/material. The resistance to electrical flow offered by the part, human or other, along with the level of voltage to which it is exposed, determine the impact of the hazard.

2.1.1. Health (personal risks)

Although it is not usually referred, it is common knowledge that electricity might cause death. In 2015, around 80 178 work accidents due to electricity issues were reported in the EU, 254 lead to death [1]. Everyone at work should be aware of the risks related to working with electrical equipment.

The arc welding process, as well as other adjacent processes that require the use of electrical tools, requires an equipment connected to a live electrical circuit. This means that all arc welders using hand held equipment will be at risk of electric shock and electrical burns. Electrical circuits include the sources that provide power to the equipment, the machine itself, whether it is a welding apparatus or otherwise (e.g. torches, nippers, mass clip), and also the cables that connect the power source to it. The harmful effects of electricity on the human body can be subdivided into two categories previously mentioned:

- Burns – Whether it is a superficial burn or a deep skin tissue one, the impact on the human body is relatively clear.

- Electrical shocks – The threshold of the human perception of an electrical shock remains between 0.5 mA and 6 mA. Prolonged exposure between 30 mA to 60 mA might be fatal. This occurrence also comprises severe effects in a person's body. From these effects, the most relevant ones to highlight seem to be:
  - Muscular contraction
  - Asphyxia
  - Respiratory Arrest
  - Ventricular Fibrillation

The harm induced by electricity to the human body is more influenced by the current than the voltage, although higher voltage allows for higher and more dangerous currents. Depending on the time of contact, usually a voltage over 50V AC or 90V DC (according to IEC 479-1: considering 200ms contact duration; 40mA for AC and 65mA for DC – current values where no organic damage is expected), can induce dangerous shock currents, but lower voltages can also be dangerous by startling the victim and causing it to step back and contact something far dangerous.

The passage of current in the body may lead to *tetanus*, condition in which muscles unwillingly contract due to the passage of external electric current. Direct current (DC) is more likely to cause *tetanus* over alternating current (AC), making DC more likely to "freeze" a person. AC's alternating nature has a greater tendency to throw the heart's pacemaker neurons into a condition of fibrillation, whereas DC tends to just make the heart stand still. Once the shock current is halted, a "frozen" heart has a better chance of regaining a normal beat pattern than a fibrillating heart thus the higher voltage limit for DC.

So, when working with electricity it's always safer to increase your resistance through the use of insulated tools, gloves, boots and other gear, as resistance opposes current.

2.1.2. Safety (workplace risks)

Since there are so many electrical hazards derived from welding and complementing technologies, the workplace risks along with measures to minimize them should also be pointed out. Those risks might involve the full interruption of the production chain, temporary/permanent equipment damage or even the loss of the production facility. There are circumstances where the working needs comprise an increased risk of electrical accidents such as welding in damp or wet conditions, positioning the welder inside a metallic structure or even in direct contact with the workpiece. The avoidance of workplace accidents depends greatly on the prevention rather than solving an already existent flaw. Some important preventive measures that should take place when welding with arc processes include:

The used welding equipment should always conform to the appropriate national or international standard;

The installation of any electric apparatus should always be carried out by qualified personnel and connected according to manufacturer recommendations;

All the electrical connectors and leads should be clean, undamaged and always correctly rated for the current required;

Always use welding equipment with undamaged insulations (either cables, plugs, clamps or electrode holders);

Another important measure that might reduce the risks associated to electricity is the earthing of the system. Earthing prevents conductive components from becoming "live" during faults.

2.2. Organising a safe workplace

In order to have a workplace completely safe from electrical hazards, a strong effort should be made by every worker at the company, from the welder to the company manager, without excluding engineers and supervisors.

2.2.1. Start to work for the welder (individual)

This section will rely on individual procedures that turn the welder's work into harm free duties when speaking about electrical issues. Welders should wear clean, dry welding gloves and overalls. Using an overall greatly minimises the amount of "naked skin" that might contact electrically live parts.

2.2.2. Safe work for the group (including signs)

To have a safe work environment for the whole team, it is important to ensure all the precaution/danger signs are correctly distributed in the workshop. There should be an organized, published, approved and taught safety plan. The manager should always require safety training on all equipment before it can be used. Some examples of the most common signs that describe an electrically hazardous environment are given below in Figure 15.

Figure 14 – Signalization related to electrical hazards. Source: https://www.panduit.com/en/products/signs-labels-identification/signs-accessories/pre-printed-write-on-safety-signs.html

2.2.2.3. Supervisor checking his workshop

As previously mentioned, minimising the risks associated to electricity involves the effort of every person in the company. The supervisor of a workshop is responsible for ensuring all the maintenance, operations and repair work of the equipment is performed correctly and by qualified personnel. The supervisor must also provide the necessary replacements of equipment/accessories as soon as possible after receiving the information that it might be damaged. It should also be ensured that all the equipment is installed and grounded in accordance with national and local codes.

2.2.4. Checking the workplace

The checking of the workplace is a subject of upmost importance regarding health and safety hazards associated to electricity. Every worker should perform regular checks to all the equipment used and respective PPE. Ensuring that there are no live cables is one of the checks that can be performed in the workplace. Also, work tools, like the welding torch or mass clips, should be monitored for wear to ensure its safe handling. Electrically live objects, like welding cables or cutting tools, might cause serious damage to an individual's health and, in extreme cases, they can cause death. Thus, checking the workplace should be implemented as an important daily task.

2.2.5. Stray welding currents

Stray welding currents are the electrical currents that go back to the welding system by different paths than the welding return cable. This type of electrical currents can be considerably high when compared to the welding current. Such possibility results in risks associated to electric shocks, burns and damage to property. Stray currents are more likely to happen if the welding return is clamped on a rusty surface, for example.

Some older MMA equipment, commonly used in the shipbuilding and ship repair industry, has an earth return cable that is shared between several welding sets. The current return path in these situations should be as short as possible, to minimize risks.

2.2.6. Three-phase electrical supplies

When a welder is using three-phase welding circuits, the welding positions connected to the different phases should be segmented by distance or partitions. This measure greatly reduces the risks of electric shock.

2.3. Proper use and maintenance of equipment

All electrical equipment is prone to flaws and imperfections. Thus, when welding with electrical equipment, additional care should be taken to prevent major accidents. The welder should regularly check his/her individual equipment. The workshop supervisor should frequently check the installations he/she is responsible for. Every worker, including the previously mentioned ones, should follow every standard related to personal protection equipment (PPE).

2.3.1. Individual Equipment

The welder should be responsible for daily checks of all the welding equipment and reporting of defects to superiors. Some measures that should be taken to avoid personal risks when working with electricity are listed below:

- Read all instructions, labels and installation manuals before installing, operating, or servicing the equipment;
- Do not touch live electrical parts;
- Do not work alone where there are electrically hazardous conditions;
- Do not touch an energized electrode while you are in contact with the work circuit;
- Do not wrap cables carrying electrical current around any part of your body;
- Never touch the electrode with bare hands;

- Use fully insulated electrode holders. Never dip the holder into water to cool it or lay it on conductive surfaces or the work surface;

2.3.2. Workshop Installations

When working with arc welding equipment, some precautions should be taken to avoid major accidents. All workstations that demand the use of electricity, e.g. automated and robotized systems, should have their own earthing, ensuring electrical safeness. When welding on large structures and pipework installations, clamping the welding return cable to handrails, pipes or the frame of the structure should be avoided unless they form part of the workpiece itself. Also, rusty surfaces should be avoided to prevent stray currents. This type of welding set up should only be used with equipment devised to be handled this way. The current return path should be as short as possible and may need to be carefully planned to ensure risk is minimized.

Earthing the equipment is another technique that should always be applied, since it prevents conducting parts of the equipment from becoming live during faults. A right and a wrong earthing situation are depicted in the figure below. There should be no potential difference between the hand rail and the casing.

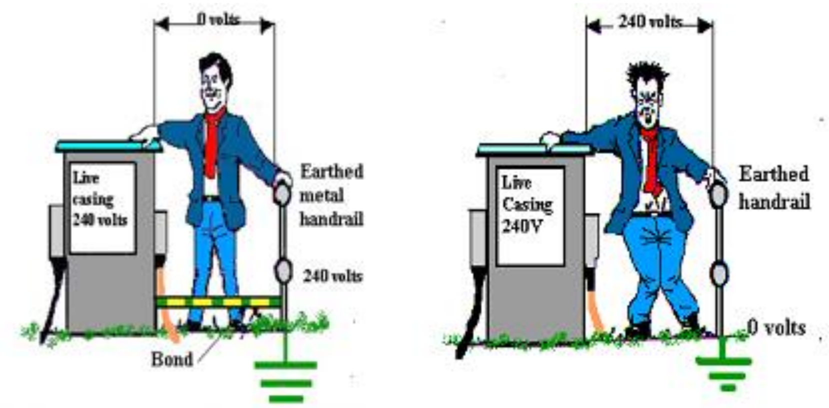


Figure 15 – Consequences in terms of potential difference when the whole circuit is connected. Source: https://slideplayer.com/slide/8690671/

2.3.2. Personal Protection Equipment

Like other jobs or careers, welders must wear suitable protective equipment. In general, PPE must protect against hazards such as burns, sparks, spatter, electric shock, and radiation. The use of PPE is a good safe practice and may be required by regulatory agencies. For example, OSHA requires the use of PPE when engineering and administrative controls are not feasible or effective. Safe practice guidelines related to this topic are listed below.

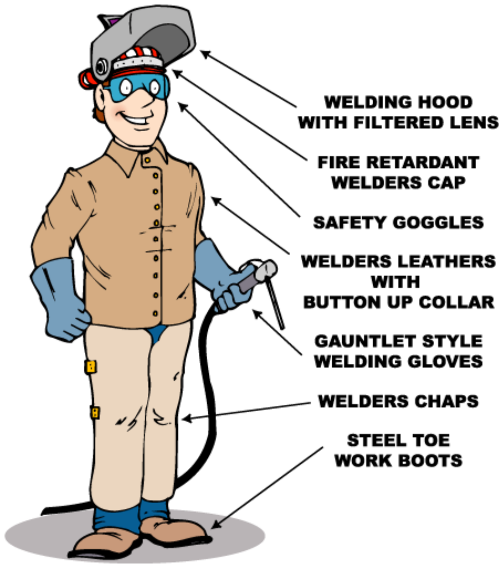


Figure 16 – Welder with recommended PPE. Source: https://www.canstockphoto.pt/welder2-cofre-5369759.html

The regular welding PPE are not specially designed to prevent electrical shocks. Thus, it does not offer the necessary protection when working in electrical hazardous environments. This fact highlights the importance of taking the necessary precautions in terms of PPEs. The following paragraphs describe these special precautions.

Head and ear protection:

• Helmet shell should insulate from electricity...

Hand and foot protection

• Always wear dry, hole-free, insulated welding gloves in good condition. They will help protect your hands from electric shocks. Leather is a good insulator when maintained dry.

• Always wear dry insulated protective boots in good condition. They will help protect your body from electric shocks.

Body protection

• Keep clothing dry. Change it when you feel it's wet (this reduces the possibility of electric shock).

• Wear leather aprons, leggings, capes and sleeves as needed for the application. Leather protects better than most materials.

Although welding PPE is able to give some protection, clothes that are damp or contaminated see their electrical resistance greatly diminished. In the case of manual metal arc welding (MMA), the best prevention measure is to use an equipment with an open circuit voltage limiting device. These devices reduce the risk of electrocution due to inadvertent contact with the electrode.

2.4. European, National Regulations and Recommendations:

2.4.1 European Recommendations

EU legislation in the electrical sector is important to ensure Europe-wide harmonisation of a set of essential health and safety requirements for products placed on the market. The Low Voltage Directive (LVD) 2014/35/EU ensures that electrical equipment within certain voltage limits provides a high level of protection for European citizens, and benefits fully from the Single Market. All health and safety risks of electrical equipment operating with a voltage between 50 and 1000 V for AC and between 75 and 1500 V for DC is covered by the LVD. These voltage ratings refer to the voltage of the electrical input or output, not to voltages that may appear inside the equipment.

2.4.2. European and national regulations

In this section, a list of the main European H&S standards and codes of practice related to electricity are presented:

ISO 45001:2018 - Occupational health and safety management systems

ISO/TR 18786:2014 - Health and safety in welding - Guidelines for risk assessment of welding fabrication activities

IEC 60364-4-41:2005+AMD1:2017 CSV - Low voltage electrical installations - Part 4-41: Protection for safety - Protection against electric shock

IEC 60364-5-54:2011 - Low-voltage electrical installations - Part 5-54: Selection and erection of electrical equipment - Earthing arrangements and protective conductors

IEC 61140:2016 RLV - Protection against electric shock - Common aspects for installation and equipment

IEC TS 60479-2:2017 RLV - Effects of current on human beings and livestock - Part 2: Special aspects

IEC 60974-1:2017 - Arc welding equipment - Part 1: Welding power sources

IEC GUIDE 116:2010 - Guidelines for safety related risk assessment and risk reduction for low voltage equipment

EN 61439 – Low voltage switchgear and control gear assemblies

BS 5424 Parts 2 and 3 – Specification for low voltage control gear.EN 60422 – Monitoring and maintenance guide for mineral insulating oils in electrical equipment.

EN 60079-30-2 – Electrical surface heating.

BS 6423 – Code of practice for maintenance of electrical switchgear and control gear for voltages up to and including 1 kV.

BS 6626 – Code of practice for maintenance of electrical switchgear and control gear for voltages above 1kV and up to and including 36 kV.

BS 7375 – Code of practice for distribution of electricity on construction and building sites.

BS 7430 – Code of practice for earthing.

BS 7671 – Requirements for electrical installations. IEE Wiring Regulations. Seventeenth edition.

EN 50110 Parts 1 and 2 – Operation of electrical installations.

EN 60529 – Specification for degrees of protection provided by enclosures (IP code).

EN 60947 Parts 1 to 8 – Specification for low voltage switch gear and control gear

3. Electromagnetic fields

3.1. Recognising risks:

3.1.1. Health (personal risks)

Electromagnetic fields (EMFs) arise whenever electrical energy is used. So, for example, EMFs arise everywhere there is an electric system, like in a large electric generator, power saws, drills or power supply or electric cables of a building. For a long time, it has been known the exposure of people to high levels of EMFs can give rise to acute effects. Although these effects are extremely rare and will not occur in most day-to-day work situations, all electric welding processes create EMFs. In fact, welders are among the work force which is more exposed to magnetic fields [2]. EMFs might be static electric, static magnetic or time varying electric, magnetic and electromagnetic. The effects of EMFs on the human body will depend on the frequency of the radiation. For low frequencies, the main effects will be felt on the central nervous system. When it comes to higher frequencies, the effects lead to heating effects which can rise the body temperature. At frequencies above 100kHz, the energy of an electromagnetic field will be partially absorbed by body tissues, which can lead to dielectric whole-body or local heating effects.

Some additional considerations regarding the exposure of workers with implants to EMFs are presented as it follows:

- The dominating effect on the human body are resulting forces on ferromagnetic elements (e.g. metallic implants) or moving charges (e.g. blood ions).
- Passive and active medical implants like cardiac pacemakers might be susceptible to electromagnetic fields.

3.1.2. Safety (workplace risks)

Welding processes generally involve high currents and relatively low voltages. Thus, the magnetic field is of most importance. The two main welding processes that produce considerable magnetic fields are resistance welding and arc welding. The main EMF sources in resistance welding are the electrodes. In the case of arc welding the relevant emitters are the electrode and the cable. Thus, the level of exposure of a welder will greatly depend on the proximity of the main emitters to the welder’s body. In the case of arc welding, if the operator works with the cables wrapped around his/her body, the exposure will be higher than if he/she did it with the cables far away from him/her. The same principle works for the electrode in both welding processes referred.

3.2. Organizing a safe workplace

3.2.1. Safe to work for the welder (individual)

With the main EMF hazardous effects on the human body previously explained, this section will focus on preventive measures for the welder. These measures are listed below being prone to diminish the exposure of the welder to EMF risks.

- Do not place your body between the welding electrode and work cables;
- Route cables on the same side of your body;
- Route the welding cables close together. Secure them together with tape or cable ties;
- Connect the work cable and clamp to the workpiece as close to the weld zone as practical;
- Do not use current settings higher than necessary;
- Keep welding power source and cables as far away as practical;
- Do not weld with rapidly repeated short spurts—wait about 10 seconds between each weld;
- If you feel sick, stop welding immediately and get medical attention;

3.2.2. Safe work for the group (including signs)

The electromagnetic spectrum comprises the entire range of frequencies of electromagnetic radiation and their respective photon energies and also wavelengths. EMF risks are possibly hazardous for the body. Thus, this section will focus on the signalization usually found in a workshop where the workers might be subjected to EMFs with dicey intensities.

In the case of low frequency EMFs, the most hazardous situation relies on exposure to radio frequency radiation (RFR) which can be classified as non-ionizing radiation. This classification is based on the fact that RFR does not have the necessary energy to dissociate electrons. The most common signs related to this type of radiation are depicted in Error! Reference source not found..

Figure 17 – Colour code for RFR warning signs. Source: https://blink.ucsd.edu/safety/radiation/radfreq.html

There are also typical signs used in workshops to warn the presence of high intensity magnetic fields. This signalization is shown in Figure . Strong magnetic fields might be critical to persons with pacemakers or other metallic implants since those fields cause strong attractive forces.

Figure 18– Typical warning sign of an area subjected to strong magnetic fields. Source: https://www.safetysign.com/products/4991/danger-restricted-access-sign?s=st1ztfjkzsk15m9zppj7pzbp14x

Figure 19 - Standard prohibition signs often displayed in relation to EMF: No access for people with active implanted cardiac devices (left) and No access for people with metallic implants (right). Source: https://en.wikipedia.org/wiki/ISO_7010

3.2.3. Supervisor checking his workshop

Preventing EMF hazards in the workshop is part of the responsibilities of a factory supervisor. Thus, the need to perform reliable measurements of the EMF intensity and frequency arises. Hence, the person in charge of these duties should check that the results of those tests are in accordance with the implemented safety standards on this issue and act in case of an unacceptable working environment. The European Directive 2013/35/EU presents guidelines for the exposure limits of workers to EMFs.

3.2.4. Checking the workplace

It is of upmost importance to have staff that knows every process and the scope of EMFs produced by each equipment in detail. This staff should also be aware of the usage of EMF measuring equipment.

Considerations shall be taken regarding the action level (AL) and the exposure limit value (ELV), since there is a wide range of equipment that produces EMFs that are not hazardous for a person and a wide range of equipment that do so. ELVs are the legal limitations on the exposure of employees to EMFs and relate to the levels of exposure to EMFs within the body. These are often impossible or difficult and expensive to measure directly, so a separate set of values, known as ALs, have been produced relating to quantities which can be measured more easily. If the AL is not exceeded, exposure cannot exceed the corresponding ELV, however in case the AL is exceeded it is required to assess if the corresponding ELV may have been exceeded, as it can be below the limit value. Some ALs are not tied to a particular ELV but serve as guidelines to indirect effects that may take place and harm the operator, i.e. interference with pacemakers or risking that metal objects become projectiles due to strong magnetic field.

3.3. Proper use and maintenance of equipment

3.3.1. Individual Equipment

In most workplaces electromagnetic fields are expected to be so weak that there is no risk, although employers are required to assess if workers are at risk following guides listing work activities, equipment and workplaces more susceptible to EMFs. Although, workers with implanted medical devices (which may contain metal) or that are pregnant are considered to be at particular risk. These individuals must receive appropriate advice from the medical practitioner responsible for their care and this should assist the employer to establish whether the individual is at risk in the workplace.

In case the assessment by the employer dictates that a measurement must be made to assess if the worker is at risk, an EMF meter can be used. This type of equipment allows the control of the intensity of an EMF produced by any individual welding equipment. Every equipment tested should comply with the MPE allowed by the European directive on this subject.

3.3.2. Workshop Installations

As for individual equipment, the workshop installations should also be tested. The devices used in this task should be similar to the previously mentioned EMF meters. Considerations should be taken regarding the position of the measurement as well as the equipment that operates at higher current values in the facility.

3.3.3. Personal Protection Equipment

Every supervisor should be responsible for their workers' safety at the workplace. Thus, it is part of the supervisor's function assuring every worker that might be subjected to EMF related risks have their own PPE. This equipment should be free of damage and compliant with European and national safety standards. It is also part of the supervisor's job to provide the correct maintenance of the PPE according to those standards. Some of the protective actions concerning PPE which both the workshop supervisor and the worker should be responsible for are listed below:

- Provide face shields, coveralls and gloves;

- Provide other protection devices such as screens/curtains/restricted access;
- Provide information and training;
- Display appropriate warning signs;
- Monitor and enforce the use of control measures;
- If any workers are over-exposed, provide medical examination and consider whether follow-up health surveillance is appropriate;

3.4. European, National Regulations and Recommendations

3.4.1. European Recommendations

- Directive 2013/35/EU

4 Cutting Risks

4.1. Recognising risks

A cut is a break or an opening in the skin of a person. A cut can be deep, jagged or smooth. Depending on the depth, a cut could damage nerves, muscles and even bones.

There are 4 types of open wounds:

- An abrasion:
  Skin is rubbed or scraped against rough/hard surface;
- A cut (laceration):
  An opening in the skin due to a sharp object;
- A puncture:
  Small hole caused by a long pointy object;
- An avulsion:
  Partial or complete tearing away of the skin;

If these wounds are not treated in the correct way, an infection could occur. Most common infections from cuts are tetanus or gangrene. These infections are deadly and develop fast. Don't hesitate to contact medical help if the injury looks severe.

Cuts are usually caused by sharp objects. For welders, and other staff that work in the metal industry, these sharp objects are mostly materials and tools. For instance, handling thin plates with sharp edges, knifes or grinders. Although a lot of cuts are caused by the person itself, the organisational factor must be kept in mind. Sharp objects sticking out of a rack or lying on the floor for example.

People who had cuts were often not concentrated during their work or didn't use common sense. Even when wearing all the proper protective equipment, working with sharp objects requires focus.

As mentioned before, there's a big variation in consequences. Most injuries caused by sharp objects are not very serious and can be cured simply by disinfecting the wound and stopping the bleeding by using a Band-Aid. Other cases may require medical attention. The latter could have a serious impact on the welder's life. A permanent disability could occur when not treated correctly.

Usually the contaminants in the wound make these injuries very severe. A cut caused by a sharp steel plate or a grinding device will contaminate the wound with iron dust, rust, particles, or else. Cleaning these wounds is very important.

Another factor is the mental health of the injured. People left with scars or amputated limbs have the chance of developing depression and anxiety. For all involved parties, a huge financial blow can be expected.

Welders often work with grinders. These tools are very common but dangerous as well. When getting cut by a grinder, the wound is a combination of a cut and a burn. These wounds are often contaminated with iron dust, particles, etc. increasing the chance of an infection. The disc spins at such high speeds that the wound gets scorched in a way. These nasty wounds heal slowly and can be very painful.

4.2. Organising a safe workplace

Before a welder starts to work, he should be critical about the state of his work space. He should make sure that no materials, tools or equipment are lying on the ground, over which he can trip and fall. It's not always possible to keep the ground clear of all objects, so make sure they are not in your way.

Make sure that no sharp objects are exposed to yourself or others. Store them in a safe place where accidental contact is impossible. When using sharp tools, never put them in your pocket without an appropriate casing. If you're holding sharp objects do not run or climb, it could penetrate or hurt you when falling.

If for example you're responsible for changing the sawblade of the band saw, leave the protective plastic on during installation. Be careful with unpacking the sawblade for it's basically a wound-up spring. These are just some examples of situations in which the staff is vulnerable to cuts.

When using tools such as a band saw or grinder, make sure a protective cap is installed. If not, the machine is not safe to work with and should be shut down until it meets the security measurements. It's important to hold your grinder with 2 hands at all times. After you've finished grinding, make sure the grinder has come to a complete stop before you lay it down.

Sharp objects like thin metal plates can cause serious cuts when slipping through your hands. Deburring these plates, if possible, could decrease the chance of someone getting cut. Protective tape or rubber to put over the sharp edges makes handling it a lot safer.

4.3. Proper use and maintenance of equipment

If we want to avoid getting cut and we tried to eliminate the risks of coming in contact with sharp objects, we must protect ourselves. In the case of cutting risks, the first thing we think about are gloves. The most important property of these gloves should be their resistance against sharp object penetrating, cutting or slicing. We call these risks: "mechanical risks".

Gloves that protect us against these risks are labelled with a 'hammer' symbol. Underneath this symbol are 4 digits. Each digit represents a mechanical risk. The lower the digit, the lower the protection against that particular risk. The digits go from 1 to 4, except for the second digit which can go up to 5.

Table 1 — Levels of performance

Test	Level 1	Level 2	Level 3	Level 4	Level 5
6.1 Abrasion resistance (number of rubs)	100	500	2 000	8 000	-
6.2 Coupe test: Blade cut resistance (index)	1,2	2,5	5,0	10,0	20,0
6.4 Tear resistance (N)	10	25	50	75	-
6.5 Puncture resistance (N)	20	60	100	150	-

Figure 20 & Table 3- Numbers on Gloves. Source: EN 12477

It speaks for itself that we should try to wear gloves with as high a digit as possible. But that's not always possible, we need to keep in mind the comfort and manoeuvrability of the welder wearing them.

There's also the possibility to purchase gloves with both a 'fire' symbol and a 'hammer' one. These gloves are suited for grinding, which produces heat and a risk of getting burns.

We've been talking about cuts in hands, but what about legs or other body parts? Workwear is very important when it comes to cuts. Make sure to wear long trousers and long sleeves to protect your arms and legs. The fabric of the workwear should be a heavy duty cotton or a technical fabric with resistance to cuts. Doing this will reduce the chance of getting hurt when running into sharp objects.

Last but not least, when grinding make sure to wear eye protection and earplugs or headphones. These things might not be required when working with other tools. Check the signs or ask supervisors what is recommended.

4.4. European, National Regulations and Recommendations

Standard used in the presentation and for the handbook:

- EN 388
- EN 407
- EN 12477

5 Hot Material and Spatter

5.1. Recognising risks

When do we consider an object to be hot? That is not an easy question to be answered because people's resistance to heat varies from one another. You could say that an object is considered hot when it has a higher temperature than the human body. For this subject it might be more correct to state that something is hot when you're not able to maintain contact without getting burned.

Watch out with aluminium, it doesn't change colour when it's hot. This can be deceitful when handling aluminium.

When a burn occurs, even when the contact was brief, it will continue to cause injury unless it is stopped. This means that after you got burned, you should slow down and stop the burn by rinsing with lukewarm water.

There are four degrees listed when it comes to burns. They represent the severity of the burn. First degree being the least severe (a sunburn for example), and fourth the degree, the most severe (when charring appears).

Depending on the degree, a burn can leave scars and has a slow healing process. Making it a mentally tough injury to deal with.

Spatter is unwanted molten metal that flies around because of a disturbance in the weldpool. Especially gas metal arc welding (GMAW) causes a lot of spatter. Although these droplets are usually very small, they can cause quite a lot of damage. If a droplet manages to find its way into your shoes, gloves, or overalls, burns could occur.

It is better to take off any jewellery like rings and braces. Gold and silver are very good conductors, if a spatter comes in contact with it, the heat will spread around you finger or wrist very fast and burn it.

Sparks occur when grinding, they consist of hot, burned pieces of metal and grinding disc particles. If these sparks come in contact with your skin, irritation and burns could occur.

Contact with hot materials and spatters can cause severe burns. Touching hot objects or getting hit by molten spatters are the most common injuries for welders. Permanent damage and scars are only a few of the consequences from contact with hot objects. A mental aspect of such an event should be kept in mind. A serious depression due to scars and mutilation could occur. The welder might be unable to proceed his job or develop a justified fear of working in an environment with hot objects.

When working with hot materials, one could easily injure co-workers or people surrounding you. Causing a fire is another example of endangering others. Therefore working with these object affects everybody surrounding you as well.

Be aware of the fact that when a fire occurs, toxic gasses are released which possibly could be harmful. A cloud of toxic gasses can easily affect an area of several square kilometres.

5.2. Organising a safe workplace

Before a welder starts to work, he should be critical about the state of his work space. He should make sure that no materials, tools or equipment are lying on the ground, over which he can trip and fall. It's not always possible to keep the ground clear of all objects, so make sure they are not in your way.

As for the equipment regarding hot materials and spatter, like welding equipment. Have a look at the state of the cables, hoses, etc. When in doubt about something, don't hesitate to inform or ask your supervisor. Make sure all your tools are present and the correct safety measurements can be taken.

All the machines and equipment in the workshop should be safe to work with, if not inform everybody that the machine is (temporarily) out of use. Do this by hanging signs on the machine and lock it so nobody is able to use it.

When a machine is functional and safe, inform the staff on how to use it correctly. Training your staff is the best way to do so. As a reminder, hang safety signs and if necessary a procedure.

With regard to hot materials and spatter, signs warning the welders that objects are hot, have a risk of exploding and wearing heat protection are the most common. Keep flammable or explosive products stored in the correct way. Label these items as well. Things like paper, cardboard or degreaser do not belong anywhere near an open flame or sparks produced by welding processes and grinding.

Checking the workplace is something that not only supervisors should do. Everybody can look for dangerous situations and if necessary report or eliminate them. If you see someone work in an unsafe environment, do not hesitate to warn them.

Like mentioned before, tubes and cables have to be in mint condition to prevent a fire or an explosion. Make sure when welding that there are no flammable object nearby. This is a fulltime job, it is not enough to do this before you start your work, always be aware of what is happening around you. Someone could accidentally have put a rag with flammable product nearby where you're welding, grinding, cutting, etc.

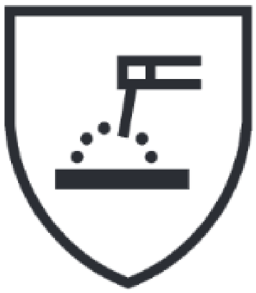


Figure 21 – Suitable for welding and numbers on gloves. Source: VCL & ISO 11611

5.6. Personal Protective Equipment

A very important thing for welders is heat resistant personal protective equipment. The welder's skin from neck to toe should be covered with this equipment. Any fabric increasing the risk of burns (like nylon, polyester, etc.) is out of the question. Leather or heavy cotton workwear is always a safe option. Modern welding overalls are made of flame-retardant materials. These overalls contain a 'suitable for welding' symbol like shown on the right.

Gloves are very important for protecting the hands against contact with hot objects and spatters produced during the welding process. A glove suited for working with hot materials will contain a 'fire' symbol. Underneath this symbol 6 digits will be printed. These digits tell us what the level of protection against a specific kind of contact with heat is. Sometimes these welding gloves limit your manoeuvrability, in that case you should choose a glove of type A. For example, when TIG welding these gloves are easier to use.

Welding helmets are not only for protecting your eyes against radiation but they cover your face against spatters. Depending on the process these helmets can be equipped with extra caps and fabric to cover your neck and head.

Safety shoes for welders have a slight variation in comparison to your average work boots. Instead of the laces being uncovered, there's a leather piece over them to prevent molten metal coming into your shoes.

There are a lot of different tools to make a welder's life more comfortable. Almost every part of the human body can be protected by an extra PPE. For instance, leather sleeves, aprons, etc. For TIG welding something called a TIG-finger is available. You slide it over your finger which makes it possible to maintain contact with the workpiece if you want more balance.

Figure 22- TIG finger. Source: http://www.weldingtipsandtricks.com/aluminum-welding-training.html

5.4. European, National Regulations and Recommendations

Standard used in the presentation and for the handbook:

- EN12477: 'Protective Gloves for Welders'
- EN407: 'Protective Gloves against Thermal Risks (Heat and/or Fire)
- EN388: 'Protective Gloves against Mechanical Risks'
- EN ISO 14116: 'Protective Clothing - Protection against Flames – Limited Flame Spread Materials, Material Assemblies and Clothing'
- EN ISO 11611: 'Protective Clothes for use in Welding and Allied Processes'

6. Arc Radiation

6.1. Recognising risks

The welding process involves heating materials to high temperatures, and materials emit radiation as a function of temperature. Measurements of the light emitted by welding processes in the infrared, visible and ultraviolet wave-lengths are of relevance to safety. In this way measures can be established for the protection of the involved personnel from arc radiation.

Figure 23 – Arc radiation. Source: https://slideplayer.com/slide/10464580

Electromagnetic Spectrum

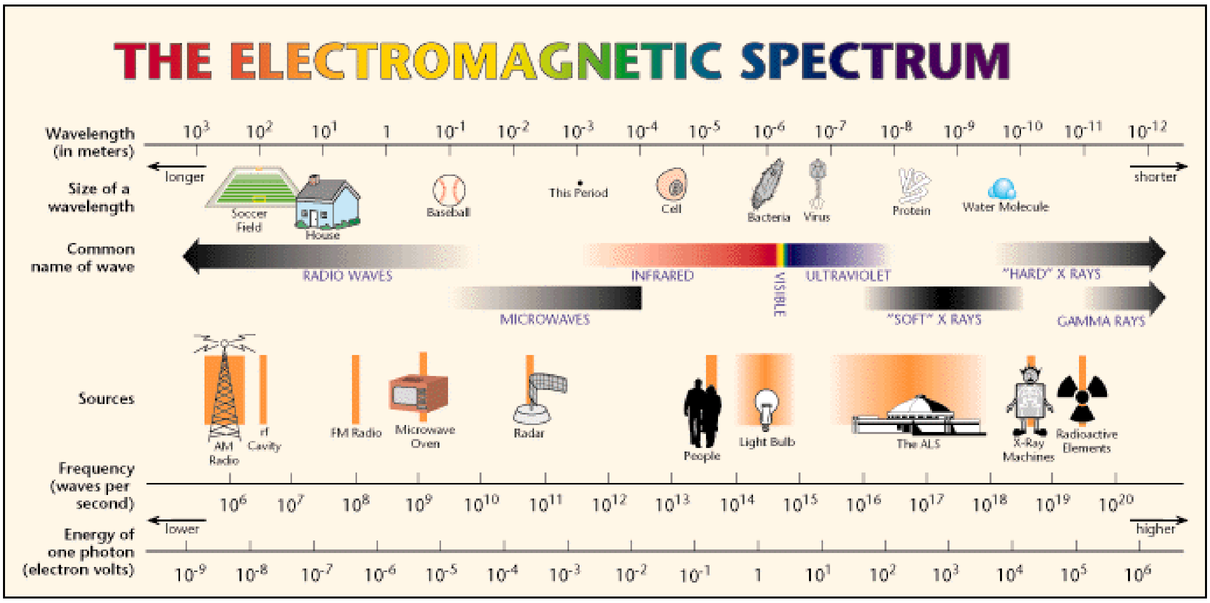


Table 4 – Electromagnetic spectrum. Source: https://marine.rutgers.edu/cool/education/class/josh/em_spec.html

Radiation

Types	Sources	Main Effects on Health
Ionizing	X-rays Gamma rays	Cancer, congenital defects, death
Non-ionizing	Ultraviolet Infrared Laser	Skin problems (ageing, cancer etc.) Corneal and conjunctival burns, retinal injury,

		cataract Eye problems

Table 5 – Main Effects on health related to the type of radiation. Source: ISIM

Ionizing Radiation

- Produced by the electron beam welding process.
- Controlled within acceptable limits by using suitable shielding around the electron beam welding area.
- Produced during grinding (pointing) of thoriated tungsten electrodes for TIG process (grinding dust is radioactive).

Non-Ionizing Radiation

- Intensity and wavelength of energy produced depend on the process, welding parameters, electrode and base metal composition, fluxes, and any coatings or plating on the base material.
- Ultraviolet radiation increases approximately as the square of the welding current.
- Visible brightness (luminance) of the arc increases at a much lower rate.
- Processes using argon produce larger amounts of ultraviolet radiation than those using most other shielding gases.

Figure 24 - Non-ionizing shield mark. Source: ISIM

Arc welding electrical energy is converted into heat and light. Both of them can have serious health consequences on the operator.

Light radiation can be classified, according to Romanian regulation:

Type	Wavelength, [nm]
Infra red (heat)	>700
Visible	400-700
Ultra violet	<400

Table 6 –Light radiation wavelength. Source: https://en.wikipedia.org/wiki/Light

Ultra violet radiation (UV)

All arc welding processes generate UV and excess exposure may lead to skin inflammation and eye irritation, or, in severe cases, skin cancer or permanent eye damage.

UV-radiation is divided into three ranges:

	UV-A	UV-B	UV-C
Wavelength	315 to 400 nm (also known as black light)	280 to 315 nm	100 to 280 nm
Pathway of the light	passes through cornea and is absorbed in the lens of the eye	absorbed in the cornea of the eye	

Table 7 –UV radiation wavelength. Source: https://en.wikipedia.org/wiki/Ultraviolet

The main risk for welders and Inspectors is related to inflammation of the cornea and conjunctiva (arc eye or flash). Arc eye (caused by UV radiation) damages the outmost protective layer of cells in the cornea. The damaged cells die and gradually fall off the cornea. This causes an intense pain, generally described as "sand in the eye". The pain becomes even more acute if the eye is then exposed to bright light. It develops hours after exposure and usually lasts for 12-24 hours (longer in severe cases).

Treatment in case of arc eye: rest in a dark room. Soothing anaesthetic eye drops can be administered, but only by qualified persons or hospital personnel.

Long-term exposure to UV light can produce cataracts for some persons.

Wearing welding helmets considerably reduces such risks. Also, the use of safety glasses with side shields reduces the associated risks.

Note: The arc can reflect off surrounding materials and nearby co-workers and bystanders. About half of welder's flash injuries affect co-workers who weren't welding.

Figure 25 – Non-conform welding conditions. Source: www.thetoolreport.com/highest-paying-welding-jobs/

The UV from arc welding processes results in reddening and irritation caused by changes in the surface of the blood vessels. The reddened skin may die and flake off in few days. Prolonged or frequent exposure to intensive UV light can develop skin cancer.

Minimizing the level of arc radiation is not possible. This leads to the need of minimizing exposure by proper using of PPE.

Ultraviolet rays at welding can react with chlorinated hydrocarbon solvents (trichloroethylene etc.) to form phosgene gas. Even a very small amount of phosgene may be deadly, although early symptoms of exposure dizziness, chills, and cough. Usually it takes 5 or 6 hours to appear.

Visible light

Light that is visible to the human eye has wavelengths between 400nm (blue) and 760nm (red). The visible spectrum does not contain all the colours that the human eyes and brain can distinguish. Unsaturated colours as pink, or purple can only be made from a mix of multiple wavelengths. Colours containing only one wavelength are called pure colours.

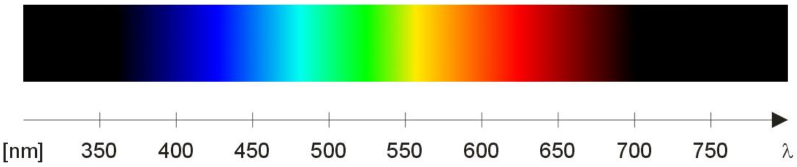


Figure 26 – Visible spectrum. Source: www.giangrandi.ch/optics/spectrum/visible-a.png

The welding processes visible light is very bright and can overwhelm the ability of the iris of the eye to close sufficiently and rapidly enough to limit the brightness reaching the retina. The result is that the light is temporarily blinding and fatiguing the eye.

Intense visible light passing through the cornea can in extreme cases, can damage the optically sensitive nerves on the retina. Effect depends on duration and intensity of exposure and the individual's natural reflex action to close the eye and exclude the incident light. Normally this dazzling effect doesn't last long.

High intensities of blue light (400 to 500nm), have been shown to cause lesions on the retina. "Blue light hazard" is the temporary or permanent scarring of the retina.

Infra-red radiation

Infrared radiation is characterized by longer wavelength than the visible light and is generally invisible to the human eye (is can be often perceived as heat). Infra-red has wavelength from 700nm (red) to 1000 nm. The arc welding infrared radiation causes damage only within a short distance from the arc. An immediate burning sensation in the skin surrounding the eyes can be felt if they are exposed to the arc heat and the natural human reaction is to move or cover up to prevent the skin heating, which also reduces eye exposure to this radiation. Years of prolonged exposure to infra-red radiation can cause a gradual and irreversible opacity of the eyes' lens.EN 169 specifies a range of permanent filter shades which limit exposure to radiation emitted by different processes at different currents. Keep in mind that those shade numbers are only for guidance.

Overexposure to Arc Radiation

Overexposure to arc radiation presents certain symptoms that signalize potential damages.

Potential Symptoms	Potential Damage
Ultraviolet • Itchy, Tearing; "Sand in the Eyes";	**Ultraviolet** • May happen in milliseconds; • Usually to cornea (may lead to cataract);
Visible • Blood Shot; • Headache;	**Visible** • Seconds to hours; • Damage can be immediate or accumulative; • Usually to macular and retina (always permanent);
Infrared • Dry, Tearing, Itchy, Headache;	**Infrared** • Happens usually in years (damage is accumulative); • Usually to the lens of the eye (cataract);

Table 8- Potencial Symptoms and Damage. Source: ISIM

6.2. Organizing a safe workplace

Protection of eyes and skin must be done by using appropriate PPE.

In this respect, one of the main PPE are related to the welding helmet and welding filters.

Welding filters have to conform to the requirements of EN 169.

Welding helmets have to conform to the requirements of EN 175.

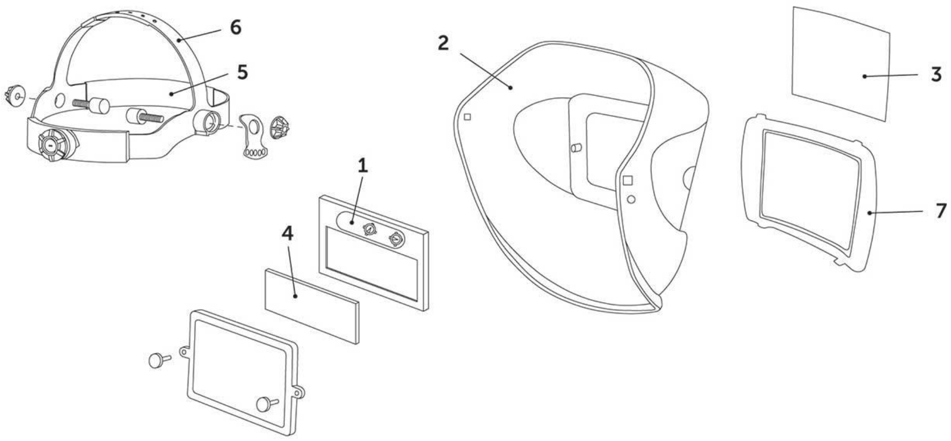


Figure 27 – Element of the welding filter. Source: www.jackson-safety.com/wh40-30-element.html

For arc welding, arc gouging, and plasma jet cutting, the current value is determinant to make an accurate choice of the appropriate filter. Also, the type of arc and parent metal (steel or Al) have to be taken into consideration for the proper choice of the filter.

Other parameters which have a significant influence, but difficult to evaluate their effect, encompass:

- The position of the operator in relation to the flame or the arc;
- local lighting;
- the human factor (hereditary context);

Recommended use of arc welding filter type:

- MMA EW 9 to 14
- MIG/MAG/FCAW EW 10 to 14
- TIG EW 9 to 14

Nearby to the proper use of welding helmets and filters, the welding area should be surrounded with protective curtains to protect also the bystanders.

6.3. Proper use and maintenance of equipment

The protection against ionising radiation is related to the exposure time, distance from source, and the shielding used.

Few measures to protect against ionizing radiation are presented below:

- Follow recommended procedures/regulations;
- When grinding (pointing) thoriated tungsten electrodes, always use local exhaust and, if necessary, respiratory protection to prevent inhalation of dust;

- External radiation from thoriated tungsten electrodes during storage, welding, or disposal of residues is negligible under normal conditions;
- How to protect against non-ionizing radiation;

Few measures to protect against non-ionizing radiation are presented below:

- Use welding helmet, with correct shade of filter plate, according to EN 169;
  Note: Transparent welding curtains are only to protect passers-by from incidental exposure;
- Protect exposed skin with adequate gloves and clothing;
- Be aware of reflections from welding arc, protect all persons from intense reflections due to the welding process;

Measures to be taken for skin protection from arc radiation

Few measures to be taken for skin protection from arc radiation are presented below:

- Wear tightly woven work-weight fabrics to keep UV radiation from reaching your skin;
- Button up your shirt to protect the skin on the throat and neck;
- Wear long sleeves and pant legs;
- Cover your head with a fabric cap to protect the scalp from UV radiation;
- Protect the back of your head by using a hood;
- Protect your face from UV radiation by wearing a welder's helmet;

6.4. European, National Regulations and Recommendations

In this section, a list of the main European H&S standards and codes of practice related to gas cylinder handling are presented:

EN 169: Personal eye-protection. Filters for welding and related techniques. Transmittance requirements and recommended use

EN 170: Personal eye-protection. Ultraviolet filters. Transmittance requirements and recommended use

EN 171: Personal eye-protection. Infrared filters. Transmittance requirements and recommended use

EN 175: Personal protection. Equipment for eye and face protection during welding and allied processes

EN 379: Personal eye-protection. Automatic welding filters

EN 1598: Health and safety in welding and allied processes. Transparent welding curtains, strips and screens for arc welding processes.

7. Noise

Noise is, undesirable sound, and is believable to be the most commonly experienced industrial hazard. Loud noise, whether uninterrupted or occasional, can cause permanent damage to the ear and result in hearing loss.

The human ear is sensitive and fragile and can identify very small changes in sound pressure.

Electric arc welding generates harmful levels of noise, with the exception of TIG. Not only is The process of is noisy as it is other tasks that a welder must perform, usually in a noisy environment. As so, noise levels may vary depending on the process carried.

Typical noise levels for different types of welding:

Process	Typical noise levels
TIG	Up to 75 dB(A)
MMA	85-95 dB(A)
MIG	95-102 dB(A)
Plasma cutting (hand-held up to 100A, cutting up to 25mm thickness only)	98-105 dB(A)
Flame gouging	95 dB(A)
Flame Cutting	Up to 100 dB(A) (typically above 90 dB(A) when cutting thickness above 40 mm)
Air arc gouging	100-115 dB(A)
“Deslagging”/chipping	105 dB(A)
Grinding	95-105 dB(A)

Table 9 – Typical noise levels. Source: http://www.hse.gov.uk/welding/noise-vibration.htm

Variation of noise levels may vary depending on several factors:

- The higher the consumable diameter and current the higher the noise;
- Type of metal also affects noise levels with stainless steel tending to produce the higher noise levels;
- Cutting thicker materials produces higher levels of noise then thinner materials;
- When performing plasma cutting and air arc gouging the prevalent source of noise is the high-pressure compressed air. The noise can be minimize depending on the design of air nozzle with some companies offering "reduced noise" equipment;

Figure 28 – Ear Muffs. Source: https://www.arco.co.uk/103/content/downloads/expert-guide/arco-hearing_conservation-expert-guide.pdf

7.1. Recognising risks

Noise exposure can permanently damage welders' hearing. Noise also causes stress, increased blood pressure and may contribute to heart disease. Working in a noisy environment for long periods of time can make workers tired, nervous, and irritable. If you work in a noisy area, the OSHA Noise Standard requires your employer to test for noise levels to determine your exposure. If your noise exposure exceeds 85 decibels averaged over 8 hours, your employer must provide you with free hearing protection and annual hearing tests.

7.2. Organising a safe workplace

Regular noise exposure depends both on the level of noise (the dB(A) value) and the time of exposure during a working day. To access potential noise exposure, take in consideration:

- welding and hot cutting processes - noise is only generated when an arc is struck or flame lit;

- Amount of time exposed to noise, as a production welder's 'arcing' time may be as much as 80% of the shift, a fabricator welder may spend most of the day setting the job up before starting any welding;

European parliament directive no. 2003/10/EC of 6 February 2003 on the minimum health and safety requirements, regarding the exposure of workers to the risks arising from physical agents (noise) applies to all activities of the private sector, cooperative and social, central, regional and local public administration, public institutes and other legal persons governed by public law, as well as self-employed persons.

This decree stipulates that personal or daily personal exposure of workers at or above 87 dB (A) or at peak values at or above 140 dB (C) are defined as the Limit of Exposure (VLE) to noise, in determination should be considered the attenuation of the hearing protectors**.**

7.3. Proper use and maintenance of equipment

To protect ears from noise, wear hearing protection if working in an area with high noise levels. Doing so will protect your hearing from damage, as well prevent metal and other debris from entering the ear canal. Choose ear plugs or ear muffs to protect the ears.

Hearing protection criteria:

- ability to reduce the noise exposure;
- compatibility with other items of PPE (welding masks, safety helmets, etc.);
- comfort, and suitability for the working environment and activity;

Figure 29 – Ear Pluggs. Source: https://www.dhport.com/trade/hot-sell-disposable-ear-plug-en_1320583623.html

7.4. European, National Regulations and Recommendations

For hearing protection issues exist some specific standards:

EN 352 distinguishes between different types of hearing protectors and each type has to comply with the respective requirements that have been drawn up. The different types can be identified using the extension following EN 352, for example EN 352-2. Six different types are identified in total:

- EN 352-1 applies to ear muffs
- EN 352-2 applies to earplugs and otoplasties
- EN 352-3 is intended for variants, for example ear muffs that are attached to a helmet
- EN 352-4 lists the requirements for level dependent ear muffs
- EN 352-5 relates to active noise reduction ear muffs
- EN 352-6 is restricted to hearing protectors with an electrical audio input

8. Vibration

8.1 Recognising the risks

Vibration is a mechanical phenomenon whereby oscillations occur about an equilibrium point. The word comes from Latin *vibrationem* ("shaking, brandishing"). The oscillations may be periodic, such as the motion of a pendulum—or random, such as the movement of a tire on a gravel road.

Vibration during machining is obviously vibration of low intensity and so there is no negative influence on the cutting process. On the other hand, vibration of high intensity could negatively affect some aspects of cutting process:

- formation of waviness on the machined surface and low precision of machined parts, sometimes high surface roughness;
- more intensive process of tool wear;
- negatively affects the machine life and intensive sound;

There are 2 types of vibration in grinding operations: forced and self – excited. Eccentricity and non – alignment of grinding wheel are the main reason for generation of forced vibration. Regenerative effect takes responsibility for formation of self – excited vibration. Rotary movement of grinding wheel and workpiece generates the waviness on the surface of grinding wheel and so influences formation of waviness on the ground surface. This kind of vibration is given by high dynamic stiffness of grinding wheel.

Grinding: basic

Grinding is a material removal and surface generation process used to shape and finish components made of metals and other materials. The precision and surface finish obtained through grinding can be up to ten times better than with either turning or milling.

Grinding employs an abrasive product, usually a rotating wheel brought into controlled contact with a work surface. The grinding wheel is composed of abrasive grains held together in a binder. These abrasive grains act as cutting tools, removing tiny chips of material from the work. As these abrasive grains wear and become dull, the added resistance leads to fracture of the grains or weakening of their bond. The dull pieces break away, revealing sharp new grains that continue cutting. The requirements for efficient grinding include:

• abrasive components which are harder than the work;
• shock- and heat-resistant abrasive wheels;
• abrasives that are friable. That is, they are capable of controlled fracturing;

Types of grinding

There are many forms of grinding, but the four major industrial grinding processes are:

• cylindrical grinding;
• internal grinding;
• centerless grinding;
• surface grinding;

Figure 30 – Grinding. Source: www. en.wikipedia.org/wiki/Grinding_(abrasive_cutting)

In welding and joined allied process the grinding is a very important step in the joint preparation and in the joint cleaning. Grinding may be used to remove mill scale or rust. Grinders can be manually guided or mounted on the welding machine.

(Protective glasses must be worn at all times and it is a safety essential that the proper type of grinding wheel be selected for the speed at which the wheel is to operate).

Hand-arm vibration

Hand-arm vibration is vibration transmitted into workers' hands and arms. This can come from use of hand-held power tools (such as grinders or road breakers), hand- guided equipment (such as powered lawnmowers or pedestrian controlled floor saws) or by holding materials being worked by hand-fed machines (such as pedestal grinders or forge hammers).

Why is hand-arm vibration an issue?

Regular and frequent exposure to hand-arm vibration can lead to two forms of permanent ill health known as:

1) hand-arm vibration syndrome (HAVS);

2) carpal tunnel syndrome (CTS);

Symptoms and effects of HAVS include:

- Tingling and numbness in the fingers which can result in an inability to do fine work (for example, assembling small components) or everyday tasks (for example, fastening buttons);
- Loss of strength in the hands which might affect the ability to do work safely;
- The fingers going white (blanching) and becoming red and painful on recovery, reducing ability to work in cold or damp conditions, e.g. Outdoors;

Symptoms and effects of CTS can also occur and include:

- Tingling, numbness, pain and weakness in the hand which can interfere with work and everyday tasks and might affect the ability to do work safely;
- Symptoms of both may come and go, but with continued exposure to vibration they may become prolonged or permanent and cause pain, distress and sleep disturbance;

This can happen after only a few months of exposure, but in most cases, it will happen over a few years.

What the law says

The Vibration Regulations, (Control of Vibration at Work Regulations 2005) require you to:

- make sure that risks from vibration are controlled;
- provide information, instruction and training to employees on the risk and the actions being taken to control risk; and provide suitable health surveillance;

The Vibration Regulations include an exposure action value (EAV) and an exposure limit value (ELV) based on a combination of the vibration at the grip point(s) on the equipment or work-piece and the time spent gripping it. The exposure action and limit values are:

- a daily EAV of 2.5 m/s A(8) that represents a clear risk requiring management;

and

- a daily ELV of 5 m/s A(8) that represents a high risk above which employees should not be exposed;

8.1. Organising a safe workplace

The duties are to reduce the risks from vibration to the lowest level reasonably practicable and to reduce exposure to as low as is reasonably practicable if it is above the EAV. It must not allow exposures to exceed the ELV.

If it is complied with the Vibration Regulations, it will prevent disability from HAVS and vibration-related CTS. Some people will develop early signs and symptoms of HAVS or CTS even at low exposures (for example, if they are susceptible to vibration injury and are regularly exposed to vibration at around the exposure action value, usually for some years). The health surveillance should identify any harm early on, so appropriate action by the people at this point will prevent disability.

It's very important that the trade union safety representative or employee representative on the proposals controls risk and provides health surveillance.

Duties of manufacturers and suppliers

When it is bought the work equipment it's should expected by the supplier to provide the following:

- warning of any vibration-related risks from using the equipment;
- information on safe use and, where necessary, training requirements;
- information on how to maintain the equipment;
- information on the vibration emission of the equipment;

Which jobs are most likely to crate a risk?

Jobs involving regular and frequent exposure to vibration above the EAV are found in a wide range of industries, for example:

- construction and civil work;
- engineering;
- forestry;
- foundries;
- motor vehicle manufacture and repair;
- maintenance of parks, gardens, verges, grounds etc.;
- shipbuilding and ship repair;
- utilities (e.g. gas, water, telecommunications).

Which tools are most likely to create a risk?

Users of the types of equipment listed below and similar equipment will often be exposed above the EAV:

- chainsaws;
- grinders (all types and sizes, e.g. angle, die, straight, vertical etc.);
- hand-fed equipment, e.g. pedestal linishers, grinders, mops;
- impact drills;
- scaling hammers including needle scalers;
- pedestrian controlled equipment including mowers, floor saws, floor polishers;
- powered hammers for chipping, demolition, road breaking etc.;
- sanders and polishers;
- hand-held saws for concrete, metal, ground clearance etc.;

Damaged and very old models of equipment may be hazardous even when used for very short periods. Most types of hand-held, hand-guided or hand-fed powered equipment can cause ill health from vibration if used incorrectly.

For powered hand-tools, regular and frequent use of modern, well-designed, well-maintained tools is likely to result in exposure at or above the EAV after:

- the use of a hammer action tool for about 15 minutes;
- the use of non-hammer action tools for about one hour;

The exposure limit value is likely to be reached after:

- use of a hammer action tool for about one hour;
- use of non-hammer action tools for about four hours;

How it is possible to control the risks from HAVS?

It is possible to reduce vibration exposure by reducing one or both of:

- the vibration transmitted to the hand;
- the time spent holding vibrating equipment or work-pieces;

8.3. Proper use and maintenance of equipment

Gloves marketed as 'anti-vibration', which aim to isolate the wearer's hands from the effects if vibration, are available commercially. There are several different types, but many are only suitable for certain tasks, they are not particularly effective at reducing the frequency-weighted vibration associated with risk of HAVS and they can increase the vibration at some frequencies. It is not usually possible to assess the vibration reduction provided in use by anti-vibration gloves, so it should not generally rely on them to provide protection from vibration. However, gloves and other warm clothing can be useful to protect vibration-exposed workers from cold, helping to maintain circulation.

Low hand or body temperature increases the risk of finger blanching because of the reduced blood circulation. It is important therefore to make sure employees working outdoors in cold weather have adequate protection. The temperature in an indoor workplace should provide reasonable comfort without the need for special clothing and should normally be at least 16 °C. If this is not reasonably practicable, it should be provided warm clothing and gloves. (More than one set may be required for each employee if the gloves or clothing are likely to become wet.) Gloves and other clothing should be assessed for good fit and for effectiveness in keeping the hands and body warm and dry in the working environment. It should also be ensured that gloves or other clothing provided do not stop employees working safely and do not present a risk of entanglement with moving parts of machinery.

Figure 31– Grinding operations. Source: www.safeguardtraining.com

8.4. European, National Regulations and Recommendations

In this section, a list of the main European H&S standards and codes of practice related to vibration are presented:

- Vibration Regulations - Control of Vibration at Work Regulations 2005.
- ISO 16089:2015 - Machine tools — Safety — Stationary grinding machines.
- BS EN 388:2016 -Protective gloves against mechanical risks
- ISO 1985:2015 Machine tools - Test conditions for surface grinding machines with vertical grinding wheel spindle and reciprocating table -- Testing of the accuracy.

9 Gas cylinders handling

9.1. Recognising risks

Compressed gases present a unique risk threat. Depending on the gas, there is a potential for simultaneous exposure to both mechanical and chemical hazards.

Gases may be:

- Flammable or combustible;
- Explosive;
- Corrosive;
- Poisonous/toxic;
- Inert;
- Cryogenic;
- Pyrophoric (burns on contact with air);

Combination of hazards

Compressed gases - main causes of accidents:

- Inadequate training and supervision;
- Poor installation;
- Poor maintenance;
- Faulty equipment and/or design (e.g. badly fitting valves or regulators);
- Poor handling;
- Poor storage;
- Inadequately ventilated working conditions;

If the gas is flammable, flash points lower than room temperature compounded by high rates of diffusion present a danger of fire or explosion.

Additional hazards of reactivity and toxicity of the gas, as well as asphyxiation, can be caused by high concentrations of even "harmless" gases such as nitrogen.

Since the gases are contained in heavy, highly pressurized metal containers, the large amount of potential energy resulting from compression of the gas makes the cylinder a potential rocket or fragmentation bomb.

9.2. Organising a safe workplace

Identification and Properties

Read the label and double check if the cylinder/gas is right for the intended use.

If the labelling on a cylinder becomes unclear or attached tag is defaced so as it cannot be identified, the cylinder should be marked "contents unknown" and returned directly to the manufacturer.

Never rely on the colour of the cylinder for identification. Cylinder colours may vary with the supplier.

If mismatch between the colour and the label of a cylinder. Do not use, contact supplier immediately.

Know the properties of the gas (read the Material Safety Data Sheets).

The cylinder's content and status should be identified at all times.

Cylinders should be inspected daily, and prior to each use, for corrosion, leaks, cracks, etc.

Inspection should include the cylinder, piping, safety relief devices, valves, protection caps and stems.

Leaking regulators, cylinder valves or other equipment should be taken out of service.

Figure 32 – Always read the label! Source: www.boconline.co.uk/en/legacy/attachment?files=tcm:5410-116814,tcm:410-116814,tcm:10-116814

9.3. Proper use and maintenance of equipment

Careful procedures are necessary for handling the various compressed gases, the cylinders containing the compressed gases, regulators or valves used to control gas flow, and the piping used to confine gases during flow.

Flashback Arrestors

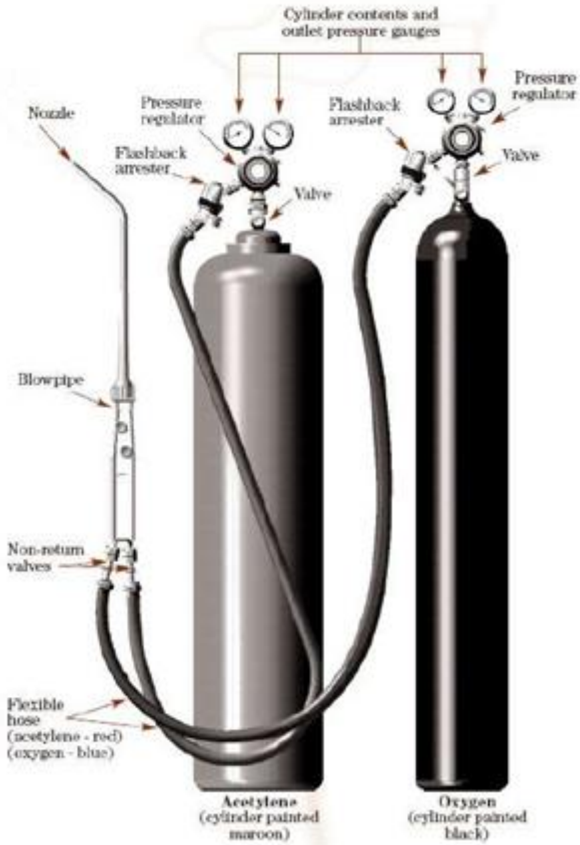


Figure 33 - Oxy-acetylene welding unit with flashback arrestors. Source: /www.metals4u.co.uk/how-to-oxy-acetylene-weld.asp

Flashback = mixture of fuel gas and oxygen burning within the hose, flame travels and burns its way towards the gas source at great speed, can result in force of explosion in either cylinder.

Flashback arrestors must be fitted on both oxygen and fuel gas regulators.

If flashback arrestor is dropped/damaged replace immediately.

Flashback arrestors should only be used with the gas they are labelled for and the pressure they are designed for.

Reasons for flashback: incorrect purging of hose/torch prior to use, incorrect gas pressure, incorrect nozzle, damaged torch valves, gas passages blocked within the torch, kinked or trapped hose.

Hoses

- Pressure rating, length and colour coding are essential for safety;
- Never use equipment whit hoses wrapped around the cylinders or trolley;
- Length of hose should be suitable for the task;
- Keep hoses in good condition;

- Examine hose for cracks, deterioration, damage (test for leaks before use);
- Do not repair hoses;
- Purge hose thoroughly before lighting torch;
- Do not use copper piping with acetylene hoses (potentially explosive);
- Protect hosing from heat, oil, grease or mechanical damage;

Piping

- Distribution lines and their outlets shall be clearly labelled as to the type of gas contained;
- Piping systems should be inspected for leaks on a regular basis;
- Special attention should be given to fittings as well as possible cracks that may have developed;

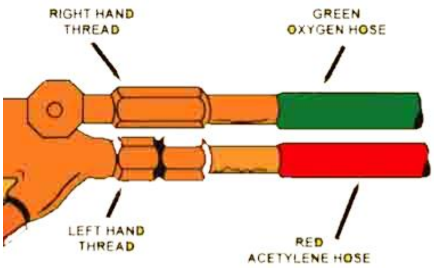


Figure 34 - Typical unit and hose form. Source: https://weldguru.com/bottle-oxygen/

Compressed gases

Never rely only on the colour of the cylinder for identification. Colour coding is not reliable because cylinder colours may vary with the supplier. Additionally, labels on caps have little value because caps are interchangeable.

Always read the label!

All gas lines leading from a compressed gas supply should be clearly labelled to identify the gas, the laboratory or area served, and the relevant emergency telephone numbers.

The labels should be colour coded to distinguish hazardous gases (such as flammable, toxic, or corrosive substances) (e.g., a yellow background and black letters).

Signs should be conspicuously posted in areas where flammable compressed gases are stored, identifying the substances and appropriate precautions (e.g., HYDROGEN - FLAMMABLE GAS - NO SMOKING - NO OPEN FLAMES).

Compressed gases – Handling & Use

Gas cylinders must be secured at all times.

Cylinders may be attached to a bench top, individually to the wall, placed in a holding cage, or have a non-tip base attached. Chains or straps shall be used to secure them.

If a leaking cylinder is discovered, move it to a safe place (if it is safe to do so) and inform the Environmental Health & Safety Department. You should also call the supplier as soon as possible.

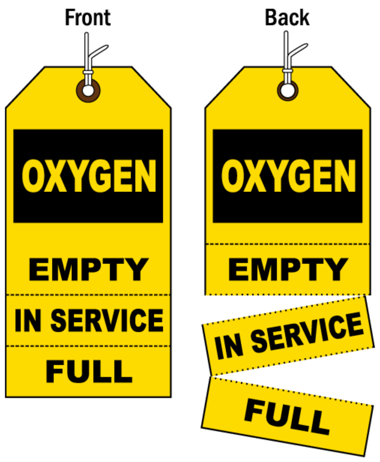


Figure 35 - Labels to caution regarding the storage of cyminders. Source: www.safetysign.com/products/5173/3-part-oxygen-cylinder-status-tag

Under no circumstances should any attempt be made to repair a cylinder or valve.

Cylinders should be placed with the valve accessible at all times. The main cylinder valve should be closed as soon as it is no longer necessary that it be open (i.e., it should never be left open when the equipment is unattended or not operating).

This is necessary not only for safety when the cylinder is under pressure, but also to prevent the corrosion and contamination resulting from diffusion of air and moisture into the cylinder after it has been emptied.

Cylinders are equipped with either a hand wheel or stem valve. For cylinders equipped with a stem valve, the valve spindle key should remain on the stem while the cylinder is in service.

Only wrenches or tools provided by the cylinder supplier should be used to open or close a valve. At no time should pliers be used to open a cylinder valve.

Some valves may require washers; this should be checked before the regulator is fitted.

Cylinder valves should be opened slowly.

Oxygen cylinder valves should be opened <u>*all the way*</u>.

Open up the oxygen cylinder valve stem just a crack. Once the needle on the high-pressure gauge has stopped, open up the valve all the way. This back-seats the valve.

Oxygen cylinders must have the valve opened up all the way because of the high pressure in the cylinder.

When opening the valve on a cylinder containing an irritating or toxic gas, the user should position the cylinder with the valve pointing away from them and warn those working nearby.

Cylinders containing flammable gases such as hydrogen or acetylene must not be stored in close proximity to open flames, areas where electrical sparks are generated, or where other sources of ignition may be present.

Figure 36 -Label for explosive gases. Source: https://www.fivevalleylabels.co.uk/product-page/explosive-gases-i001

Cylinders containing acetylene shall never be stored on their side.

Oxygen cylinders (full or empty) shall not be stored in the vicinity of flammable gases.

The proper storage for oxygen cylinders requires that a minimum of 7 meters be maintained between flammable gas cylinders and oxygen cylinders or the storage areas be separated, at a minimum, by a fire wall 1.524 meters high with a fire rating of 0.5 hours.

Greasy and oily materials shall never be stored around oxygen; nor should oil or grease be applied to fittings.

Regulators are gas specific and not necessarily interchangeable!

Always make sure that the regulator and valve fittings are compatible.

Figure 37 - Gas bottle with regulators. Source: www.rentfreegas.com.au/shop/nitrogen-kit-includes-cylinder-gas-regulator-pressure-rated-hose/

After the regulator is attached, the cylinder valve should be opened just enough to indicate pressure on the regulator gauge (no more than one full turn) and all the connections checked with a soap solution for leaks.

Never use oil or grease on the regulator of a cylinder valve.

If there are questions regarding the suitability of a regulator for a particular gas, call your vendor for advice.

The following rules should always be followed in regard to piping:

- Do not use cast iron pipe for chlorine or plastic piping for high pressure systems;
- Do not conceal distribution lines where a high concentration of a leaking hazardous gas can build up and cause an accident;
- Copper piping shall not be used for acetylene;
- Distribution lines and their outlets should be clearly labelled as to the type of gas contained;
- Piping systems should be inspected for leaks on a regular basis;
- Special attention should be given to fittings and to possible cracks;

When the cylinder needs to be removed or is empty, all valves shall be closed, the system bled, and the regulator removed.

The valve cap shall be replaced, the cylinder clearly marked as "empty," and returned to a storage area for pickup by the supplier.

Empty and full cylinders should be stored in separate areas.

Always use safety glasses (preferably with a face shield) when handling and using compressed gases, especially when connecting and disconnecting compressed gas regulators and lines.

All compressed gas cylinders, including lecture-size cylinders, must be returned to the supplier when empty or no longer in use.

Compressed gases -Transportation

The cylinders that contain compressed gases are primarily shipping containers and should not be subjected to rough handling or abuse.

Such misuse can seriously weaken the cylinder and render it unfit for further use or transform it into a rocket having sufficient thrust to drive it through masonry walls.

Figure 38 -Gas bottle with broken ventile. Source: https://twitter.com/MichaKobs/status/997427383387992065

To protect the valve during transportation, the cover cap should be screwed on hand tight and remain on until the cylinder is in place and ready for use.

Cylinders should never be rolled or dragged.

When moving large cylinders, they should be strapped to a properly designed wheeled cart to ensure stability.

Only one cylinder should be handled (moved) at a time.

Figure 39 -Safely transporting gas bottles. Source: https://weldguru.com/bottle-oxygen/

Handling Gas Cylinders

- Wear PPE: gloves, protective footwear, eye protection;
- Correct way to move cylinders is to: keep upright, secure and with valves uppermost;
- Use suitable clamps or other effective means when lifting;
- On short distances or even ground manually moving cylinders can be used only by trained personnel;
- Never roll cylinders along the ground;

- Never transport cylinder with valve and pressure regulator attached or with valve open;
- Never attempt to catch a falling cylinder;
- Never lift a cylinder by its cap or valve;

Remember: A cylinder is never empty!!!

9.4. European, National Regulations and Recommendations

In this section, a list of the main European standards and codes of practice related to gas cylinder handling are presented:

EN ISO 13769: Gas cylinders. Stamp marking

EN 1439: LPG equipment and accessories. Procedure for checking transportable refillable LPG cylinders before, during and after filling

EN ISO 24431: Gas cylinders. Seamless, welded and composite cylinders for compressed and liquefied gases (excluding acetylene). Inspection at time of filling

EN 16728: LPG equipment and accessories. Transportable refillable LPG cylinders other than traditional welded and brazed steel cylinders. Periodic inspection

EN 1440: LPG equipment and accessories. Transportable refillable traditional welded and brazed steel LPG cylinders. Periodic inspection

ISO 11513: Gas cylinders. Refillable welded steel cylinders containing materials for sub atmospheric gas packaging (excluding acetylene). Design, construction, testing, use and periodic inspection

10. Welding in Confined Spaces

Welding

Welding is a complex technology, used in a variety of applications and applied with a significant amount of different processes and procedures. As a consequence, personnel involved in welding operations may be subject to risks for their health and safety.

The working environment can even strongly influence the risk of involved personnel, either due to other operations carried and due to limitation in ventilation, heat exchange and other climatic effects.

The latter is a typical situation occurring in the so-called confined spaces.

Definition and references

Despite several definitions of Confined Spaces can be found (particularly in the national legislations), for the scope of this document, the definition is based on document "WELDING ADDS HAZARDS TO WORK IN CONFINED SPACES" (Doc. IIW 1416-98, published in Welding in the World, 1999-3, pp14-17 as "*a work space, which by its size, site or configuration, has inadequate natural ventilation and/or limited room for welders to work. Access or egress may be difficult*". It is important to consider that the definition does not consider the special circumstances of underwater welding. Examples of confined work spaces include storage tanks, tunnels, pipelines, sewers, shafts, boilers, containers, chemical vessels, coffer dams, windowless cellars, between deck spaces and double bottoms of ship.

The document was produced by the Commission VIII of the IIW "Health and safety" as a consensus paper form all the experts involved in the work of the commission. The document is the main reference for this notes.

Figure 40 – Confined spaces. Source: IIS

10.1. Recognising risks

Risk Assessment

In order to properly manage the risk due to welding in confined spaces proper procedures shall be considered.

A first step shall be identifying the hazards and those subject to these.

Any work in confined spaces can be hazardous unless adequate steps are taken to assess and control the risks of harm occurring. In order to correctly evaluate the exposure, hazards shall be properly identified, including:

- General hazards due to welding and allied processes
- Those specifically arising from the particular environment.

It is clear that welders are the most subject to this situation of exposure, but the risk may also be extended to other personnel in the area, such as welding supervisors and inspectors or any other person involved in allied activities, e.g. joint set up, grinding, setting of machines, etc.

Once the first step is performed, risk shall be evaluated according to the appropriate procedures, i.e. taking into account the likelihood and effect of the hazardous event and the exposure levels to evaluate the risk. It has to be underlined that this evaluation does not change that those for the standard working environment (including using of the same exposure levels). This may imply that that for many hazards the associated risk can be significantly higher

As a final step, measure shall be considered to reduce the risk level to maintain appropriate levels of health and safety at work. These measures may be designed for the particular environment and may be different from the generic ones, as the irrelevant implementation may be rendered difficult due to the particular conditions.

The risk assessment must be done by a competent trained person making a written assessment of the health and safety of the workplace and what is to be done. This requires considerable technical knowledge and experience of the process(es).

Working procedures

All workplaces not in the open air or workshop should be assessed by appropriately trained personnel with clearly defined responsibilities for determining which is a "confined space" and the precautions required when work is done in it. This work should be governed by a written Safe System of Work comprising measures for general and process specific (e.g. welding) risk assessment and risk control.

The arrangements should define who is responsible for each of the actions listed in the Safe System of Work. All those involved must be trained appropriately and appreciate the importance of their role.

Modalities and shifts

Before proceeding with any activity, it is necessary to check that all the prescriptions in the Work Permit are applied and, in the case of equipment, all the manholes are accessible and free from any impediment to free access.

Near access to confined sites (reactors, vessels, towers, accumulators, tanks, etc.) must always be present personnel with the task of surveillance, control, signaling and alarm in case of dangerous situations.
The times of possible permanence of the personnel inside the equipment and the relative pauses of work must be congruent with what was established during the meeting of the Plant Operator on the confined spaces. Operators can make a 15-minute break every 2 hours, making sure, in case of removal, that the correct procedures for securing the manhole are performed.

Hazards

Even in the case of welding in confined spaces, hazards may be chemical or physical. The following is a non-exhaustive list of these.

Oxygen

Oxygen is essential to life and is available in the breathing air in concentrations of about 20%.
Higher concentrations in the work space can result in fire and explosion with loss of life. The risk begins to climb with even small increases over the normal concentration of oxygen in air (21 %). This situation of oxygen enrichment can arise accidentally through leaking torches, hoses, pipelines and cylinders or through the wholly irresponsible use of oxygen to "freshen" the air in the confined space or blow dirt or moisture from the workpiece.
Lower concentration of oxygen may increase strain and fatigue, up to faint. Low concentrations of oxygen may be caused in the short term, even during the welding task, through its combustion or its displacement by the accumulation of inert or other relatively heavy gases used for shielding gases or maintaining an anticorrosive environment within pipes. The chemistry of rusting of plates in unventilated spaces such as double bottoms can deplete oxygen levels, posing a serious threat to the unwary who enter without due care.

Fumes and gases

As ventilation in confined spaces is limited by definition, fume and gas emissions form the welding processes and workpiece may accumulate to reach harmful levels.
In the case of oxy-fuel cutting and oxyacetylene welding, nitrogen oxides from oxyfuel processes can be a special risk. In addition, accumulated fuel gases also increase the risk of fire and explosion.

Figure 41 – Welding fumes and aspiration system. Source: https://www.nederman.com/en-au/industry_solutions/welding_and_cutting

Electricity and Electro-magnetic-fields

The risk of electric shock or electrocution associated with any electric welding process may be increased in a confined space because of the enforced proximity of positive and negative parts of metal structures to the welder; damp walls, floors or work materials; and reduced electrical resistance of wet or sweaty skin and work clothes due to raised heat and humidity in space.

Fields of electromagnetic radiation may be generated by electric welding power sources and cables. The dose received by the workers may be increased by their proximity to the equipment and by working within loops of cable.

The majority of sources of EMF found in the workplace produces extremely low levels of exposure. The extent and magnitude of EMFs produced will depend on the voltages, currents and frequencies at which the equipment operates or generates, along with the design of the equipment.

Radiations

Hot metal and infrared (IR) radiation may be induced not only by the welding parts, but also form welding related operation (e.g. pre- and post- heating) in the nearby. These may induce the risk of burns and increase the risk of dehydration and heat strain.

Ultraviolet (UV) radiation introduces the risk of arc eye and skin bums which may be increased through reflection of the radiation and/or the inability to wear appropriate protective clothing due to the cramped conditions.

Ergonomy and postural diseases

The particular working environment may require the welder and the welding related personnel do work in cramped or distorted awkward postures; they may induce or aggravate musculoskeletal injury or disease.

Welding positions are generally reported with reference to a specific standard; ISO 6947 “Welding and allied processes - Welding positions” is the applicable International standard. The welder should be respecting the welding position indicated in the WPS and in a confined spaces (especially in a narrow spaces, as a nozzle about 24” inches of diameter) this could produce temporary and permanent physical and psychological suffering.

Noise

High noise levels produced by some welding and related processes may be amplified by reverberation in the space. The hazard is associated with the risk of noise induced hearing loss and mental stress.

Noise within a confined space can be amplified because of the design and acoustic properties of the space. Excessive noise cannot only damage hearing, but also affect communication, such as causing a shouted warning to go unheard.

Evaluating the risk

The risk evaluation is based on experience, reference data and, when available and necessary, measurements (in laboratory or in the work space). The evaluation is also based on reference levels, defined as technical or as legislative levels. This operation requires competent specialists.

10.2. Organising a safe workplace

Start to work for the welder

This section will comprise possible measures to minimize ergonomics risks for the individual. These actions are described below:

The first and foremost important action is training of all the involved personnel. Personnel should be selected and trained to ensure that those who are to work in a confined space are fit for the work and will work with due regard to their own safety and the safety of others.

Training should include an appreciation of the hazards of the work and the contribution the worker must make to risk control to ensure adequate health and safety. Refresher training may be given at appropriate intervals.

As refers to the welding related actions, these include:

- Selection of Welding process, components and equipment to ensure lowest and least hazardous fume and gas emission, low risk of oxygen enrichment, low risk of explosion (e.g. from accumulated acetylene in coffer dams);
- selection of the procedure to reduce the risk of electrocution (e.g. using DC rather than AC, use of circuit breakers and apparatus with low open circuit voltage);
- Selection and provision of personal protective equipment to ensure provision of overalls which protect against flame, fire and hot metal; gauntlets, eye/face shield, foot wear with electrical insulating soles and, where conditions dictate, electrical insulating mats, heat shields ear defenders or self-contained/pipeline breathing apparatus;
- ventilation equipment may be used to reduce the concentration of harmful airborne emissions and products of the welding process to within acceptable limits and is of appropriate construction to permit its use to ventilate a confined space (the noise levels which can be introduced by ventilation equipment must be considered when siting it);
- maintenance of all equipment to be carried out, including checks of safety precautions to ensure that these comply with all related specifications;
- Comparison among the welding positions and the working time;
- Safety checks of equipment should be made before each use;

Other actions are site safety precautions specific to, such as:

- Removing explosive and combustible materials;
- Providing adequate ventilation of the space or, if this is not practically achievable, appropriate air fed personal respirators;
- Keeping compressed gas cylinders out of the space to avoid risk of leaks and their exposure to heat;
- The vessel should be insulated from any further hazard substances;
- Keeping power sources and, as far as possible, cables, out of the confined space to reduce the risk of electric shock and exposure to electromagnetic fields;

- Removing surface coatings from the required distance from any area on which hot work is to be done so that fume emission is minimized;
- Cleaning and welding a vessel that has held unknown substances should not be done, since this practice involves unknown risks;
- Insulating possible electrical contacts, especially those which aren't far enough (e.g 2 meters);
- Provision should be made to prevent pressure build up in to the vessels during the welding operations;
- Using an effective extractor for the exhausted gases and other gases produced during the welding operations;

In situations when actions on the processes, procedures and working environment are not enough effective to reduce the risk, the working procedures shall consider provision of cooling periods appropriate to the heat load and their use without financial disadvantage to the welder.

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 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 thumboften used is that if the visible fume clears within 30 seconds after the welding stops, ventilation is probably adequate.

10.2.3 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.

10.3. Proper use and maintenance of equipment

In selecting PPE it is important to ensure that the chosen item of PPE will provide the necessary protection under the conditions of use. For example, respiratory protective equipment (RPE) designed to protect from welding fume only, will not provide protection against asphyxiation in welding where shielding gases are used.

Adequate protection will only be offered when:

(1) the right items or combinations of PPE are worn;

(2) the PPE being used is suitable for the welding environment;

(3) the PPE fits each worker properly without causing undue discomfort;

(4) the worker is given information and training in the use of PPE; and

(5) the PPE in use is maintained regularly.

Due to the varied nature of work in welding and allied processes, the type of PPE required is determined not only by the type of welding and materials being used but also by the immediate environment in which the work is being carried out.

Hazard	Risk	PPE REQUIREMENTS						
		Optical Filter	Safety Eyewear	Faceshield	Ear Protectors	RPE	Gloves	Other Clothes
Welding radiation	Skin and eye radiation burns	x	x	x	x	x		
Electricity	Electrical shock and burns	x	x		x	x		
Gases	Inhalation and asphyxiation	x	x		x	x		
Particles	Inhalation and asphyxiation	x		x	x		x	x
Noise	Hearing loss	x	x	x		x	x	x
Sparks ans spatter	Burns and physical injury	x				x		

Table 10 – Hazards, risks and PPE requirements

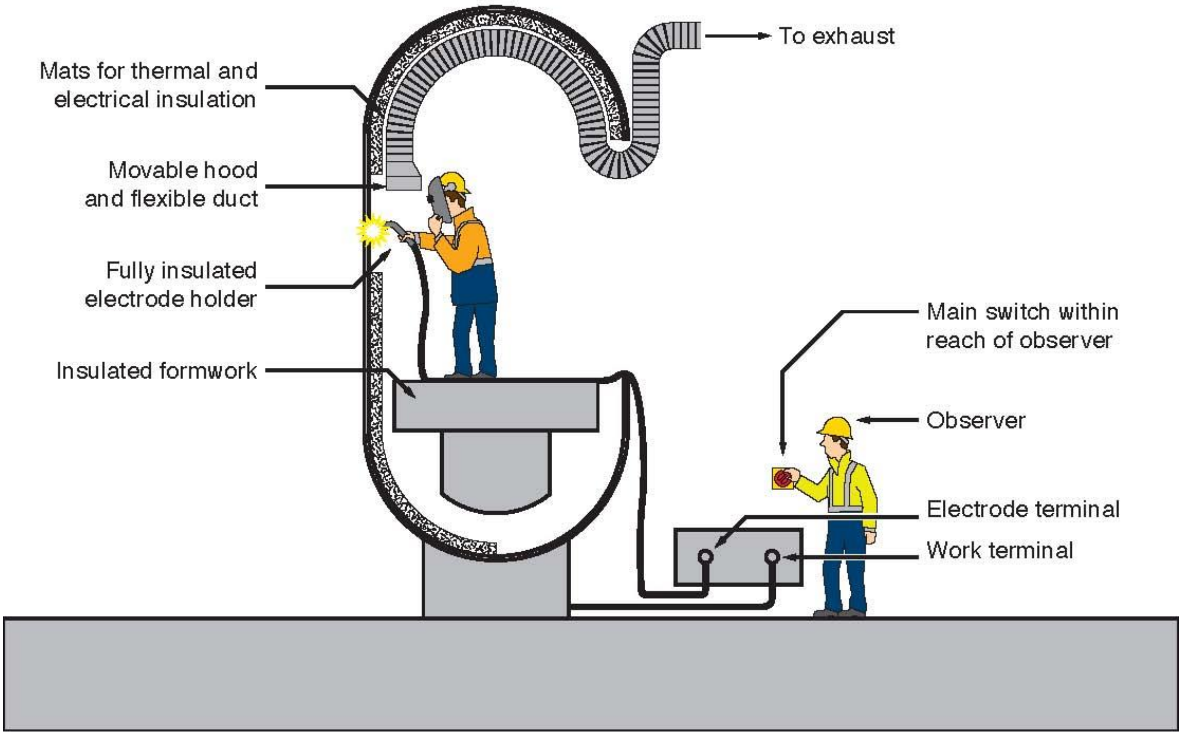
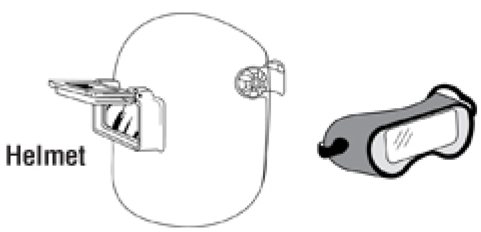
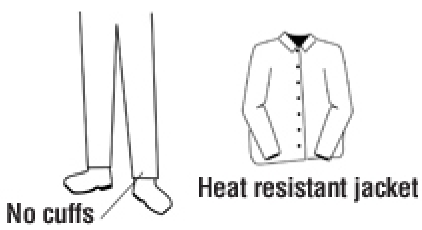


Figure 42 - Welding operations in a confined with the observer. Source: www.canberra.edu.au

Ventilation for welders in confined spaces is very importance. Local exhaust ventilation will be needed. 74

Welding - Personal Protective Equipment			
Body Part	Equipment	Illustration	Reason
Eyes and face	Welding helmet, hand shield, or goggles		Protects from: • radiation • flying particles, debris • hot slag, sparks • intense light

			• irritation and chemical burns Wear fire resistant head coverings under the helmet where appropriate
Lungs (breathing)	Respirators	 	Protects against: • fumes and oxides • lack of Oxygen
Exposed skin (other than feet, hands, and head)	Fire/Flame resistant clothing and aprons		Protects against: • heat, fires • burns • radiation Notes: pants should not have cuffs, shirts should have flaps over pockets or be taped closed

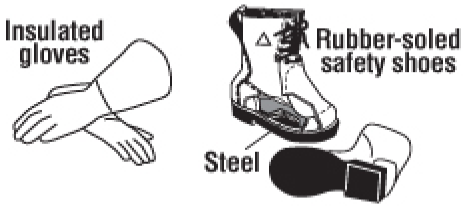
Ears - hearing	Ear muffs, ear plugs		Protects against: • noise Use fire resistant ear muffs where sparks or splatter may enter the ear, rather than plugs.
Feet and hands	Boots, gloves		Protects against: • electric shock • heat • burns • fires

Table 11 – Welding Protective Equipment

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

10.4. European, National Regulations and Recommendations

In this section, a list of the main European H&S standards and codes of practice related to confined spaces are presented:

ANSI/ASSE Z117.1-2016 - Safety Requirements for Entering Confined Spaces

ANSI/ISA 92.04.01 Part I-2007 (R2013) - Requirements for Instruments Used To Detect Oxygen-Deficient/Oxygen-Enriched Atmospheres

ASTM D4276 - 02(2012) - Standard Practice for Confined Area Entry

UNI 7545-32: 2016 – Symbols for Danger Signs – part 32 : Confined spaces.

ASTM F1764 - 97(2012) - Standard Guide for Selection of Hardline Communication Systems for Confined-Space Rescue

CSA Z1006-16 - Z1006-16 - Management of work in confined spaces

EN 529:2006 - Respiratory protective devices - Recommendations for selection, use, care and maintenance - Guidance

11. Ergonomics

Ergonomics is the science of arranging or designing things for efficient use. Ergonomics is also called Human Factors Engineering. It involves making the workplace fit the needs of workers. The concept focuses on the idea of not adjusting the worker to the workplace. When a workplace is designed properly, the worker feels comfortable.

11.1. Recognising risks

Welding introduces many ergonomic challenges. These challenges are starting to be recognised and addressed. Welding often requires awkward body positions. This body position in conjunction with time are key factors in causing injuries. The following subsections will address the main Health and Safety risks associated to ergonomics in welding.

11.1.1. Health (personal risks)

Major health issues might arise from poor or non-existent ergonomics when working with welding and other adjacent technologies. Some personal risk factors associated with a welder's work can be pointed out as lifting heavy loads, static body positioning, using continuous force when working with vibrating equipment and repetitive motions and awkward postures. The health hazards coming from poor ergonomics can be diverse such as back pain, stiff neck, 'trigger fingers' or even cysts in muscular joints.

11.1.2. Safety (workplace risks)

Poor ergonomics might give rise to material/equipment damage. When a welder is working with lack of ergonomics, there are higher possibilities of dropping either the workpiece or the welding equipment. Thus, ergonomics might be described as more hazardous in terms of health than safety. Some factors that should be considered in the workstation design are listed below:

- Position of the work;
- Design and weight of the tools;
- Body mechanics of the operation;
- Workspace size, lighting, temperature, noise and vibration;
- Physical requirements of the job (lifting, turning, reaching);
- Mental requirements (motivation, alertness, concentration);
- Strength and size of the workers;

11.2. Organising a safe workplace:

11.2.1. Start to work for the welder (individual)

This section will comprise possible measures to minimize ergonomics risks for the individual. These actions are described below:

- Workers should be involved
  - Since the worker will be the main beneficiary from the ergonomics situation in the company, it is of utmost importance that the worker provides inputs on the structure and organization of his own workstation.
- The worker should always address problems in a timely manner.
- Recognise that Repetitive Motion Injury is mistakenly felt as a type of short-term weakness or fatigue. In fact, it might be the start of more serious injuries.
- Use gravity as much as possible when moving heavy objects instead of using muscular strength
  - This helps to prevent unnecessary material handling;
- Respect ergonomics warning signalization.
- Avoid fixed work positions
  - These positions reduce blood supply to the muscles.
- Avoid positions where arms are raised above shoulder level
- Suspend tools;
- Support your elbows;
- Use appropriate jigs and fixtures to the performed work;
  - The type of work and the positions in which it will be performed should always be accounted.
- Perform regular checks and maintenance to the used equipment;

11.2.2. Safe work for the group (including signs)

When speaking of ergonomics, the hazards that are present for the group are nearly the same that exist for the individual. Thus, this section will focus on warning signalization that should be available in companies where ergonomics is an issue.

Figure 43 – Examples of signs on ergonomics. Source: https://www.mysafetysign.com/caution-bend-your-knees-not-waist-when-lifting-sign/sku-s-5030

11.2.3. Supervisor checking his workshop

When ergonomics issues are pointed out by the workforce, it is the supervisor's responsibility to solve them or implement measures that might diminish the impact of those issues. Therefore, actions that should be taken by the supervising entities are described below. These measures are somehow complementary and directly related with the previously presented ones for the individual.

- Get employee input;
- Interact with the worker. Discuss possible solutions;
  - The employee should be given ownership of any new plans. The acceptance of solutions proposed by the employee should be promoted.
- Redesign the workstation with employees' help;
  - The employees should feel part of this process.
- Provide adequate warning signalizations when required;
- Provide adequate fixturing equipment to the workforce;

- The type of work and the positions in which it will be performed should always be accounted.

- Recognise that repetitive motion injury is mistakenly felt as a type of short-term weakness or fatigue;
  - This relies on having employee's that address problems in a reasonable timespan. This type of injury should be recognised as hazardous not only by the workers but also by the supervisors.
- Provide regular checks and maintenance to every equipment that might contain ergonomics issues;

11.3. Proper use and maintenance of equipment

11.3.1. Individual Equipment

Considerations shall be taken regarding the availability of equipment in a workshop so that the hazardous situations due to bad ergonomics are avoided. The worker should be aware of the correct use of fixturing devices and supports. This knowledge regarding this type of devices is a measure that greatly decreases the ergonomic risks of a welder.

11.3.2. Workshop Installations

The correct use of the workshop installations is directly related with the previous point of proper use and maintenance of the individual equipment. Most of the times the workshops are equipped with auxiliary devices that helps the worker to place the parts to weld and respective weld seam in the most convenient position to work. Working for extended and continuous time periods in positions where the muscles are being solicited might increase the risk of getting body injuries. Thus, these positioners that hold heavy parts in the most convenient areas greatly decrease the risks associated to ergonomics. This can be explained by the fact that the welder does not experience the need of working in abnormal positions.

11.4. European, National Regulations and Recommendations

11.4.1. European Recommendations

Due to all the risks related to ergonomics the need of having adequate standardization on this topic is a subject of extensive work in the EU. In fact, there is a technical committee that put its efforts in improving the existing standards on the topic. These directives, standards, and regulations are listed in the following section 4.2.

11.4.2. European and national regulations

In 2006 the European Commission published a Machinery Directive (2006/42/EC). This directive contains a section in one of its annexes regarding ergonomics. The family of harmonised standards produced by the technical committee enclosed in this directive are listed below. These standards were further subdivided in categories such as: Operator's variability, work rate, concentration and man/machinery interface.

- EN 1005-1:2001+A1:2008 Safety of machinery - Human physical performance - Part 1: Terms and definitions
- EN 1005-2:2003+A1:2008 Safety of machinery - Human physical performance - Part 2: Manual handling of machinery and component parts of machinery
- EN 1005-3:2002+A1:2008 Safety of machinery - Human physical performance - Part 3: Recommended force limits for machinery operation
- EN 1005-4:2005+A1:2008 Safety of machinery - Human physical performance - Part 4: Evaluation of working postures and movements in relation to machinery
- EN 547-1:1996+A1:2008 Safety of machinery - Human body measurements - Part 1: Principles for determining the dimensions required for openings for whole body access into machinery
- EN 547-2:1996+A1:2008 Safety of machinery - Human body measurements - Part 2: Principles for determining the dimensions required for access openings
- EN 547-3:1996+A1:2008 Safety of machinery - Human body measurements - Part 3: Anthropometric data
- EN 614-1:2006+A1:2009 Safety of machinery - Ergonomic design principles - Part 1: Terminology and general principles
- EN 614-2:2000+A1:2008 Safety of machinery - Ergonomic design principles - Part 2: Interactions between the design of machinery and work tasks
- EN 842:1996+A1:2008 Safety of machinery - Visual danger signals - General requirements, design and testing
- EN 894-1:1997+A1:2008 Safety of machinery - Ergonomics requirements for the design of displays and control actuators - Part 1: General principles for human interactions with displays and control actuators
- EN 894-2:1997+A1:2008 Safety of machinery - Ergonomics requirements for the design of displays and control actuators - Part 2: Displays

- EN 894-3:2000+A1:2008 Safety of machinery - Ergonomics requirements for the design of displays and control actuators - Part 3: Control actuators
- EN 981:1996+A1:2008 Safety of machinery - System of auditory and visual danger and information signals
- EN ISO 13732-1:2008 Ergonomics of the thermal environment - Methods for the assessment of human responses to contact with surfaces - Part 1: Hot surfaces
- EN ISO 13732-3:2008 Ergonomics of the thermal environment - Methods for the assessment of human responses to contact with surfaces - Part 3: Cold surfaces
- EN ISO 14738:2008 Safety of machinery - Anthropometric requirements for the design of workstations at machinery
- EN ISO 15536-1:2008 Ergonomics - Computer manikins and body templates - Part 1: General requirements
- EN ISO 7250:1997 Basic human body measurements for technological design (ISO 7250:1996)
- EN ISO 7731:2008 Ergonomics - Danger signals for public and work areas – Auditory danger signals

12. Pickling of Stainless Steel

12.1. Recognising risks

Stainless Steel gets its properties from a passive, oxide layer. This oxide layer is thin, impervious, invisible and mainly consists of chromium oxide. The oxygen in the atmosphere creates and maintains this oxide layer under normal atmospheric conditions and ambient temperature. It has self-healing properties so to speak. The reason why we perform pickling is because every form of discoloration leads to a decrease in corrosion resistance. If the stainless steel surface layer is damaged, it loses its corrosion properties locally. Therefore, a final chemical process is required to restore this passive oxide layer.

Which post-treatment shall be used depends on different factors:

- Corrosivity of the environment
- Hygiene requirements
- Aesthetics

Defects

Defects that often occur when processing stainless steel are:

A. Heat tint

Due to welding or other high-temperature processes, the oxide layer gets damaged, thus losing its properties. The colour of the stainless steel changes, this is what we call the heat tint.

B. Weld defects

Imperfections with dimensions above certain criteria, like pores, spatter, arc strike, etc.

Iron Contamination

Rust particles corrode and damage the passive layer.

C. Rough surface

Rough surfaces collect deposits more easily, increasing the risk of corrosion and contamination.

D. Organic Contamination

Grease, oil, paint, etc. can cause corrosion.

Cleaning Methods

Chemical cleaning gives us better results than mechanical cleaning. One of those chemical cleaning processes is pickling. Other chemical cleaning methods which will not be discussed in this handbook, are passivation/decontamination and electro polishing.

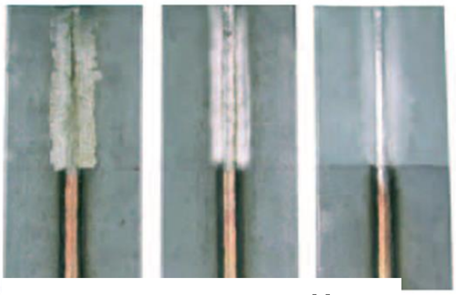


Figure 44 –Comparing pickling. Source: Outokumpu. (2013). Handbook of Stainless Steel, 92.

Pickling

This is the most commonly used method for removing oxides and contamination. Pickling removes the surface layer by controlled corrosion and removes the chromium-depleted zones to restore its corrosion properties. Pickling usually uses strong acids like nitric acid (HNO_3), hydrofluoric acid (HF) and sometimes sulphuric acid (H_2SO_4).

Something to keep in mind when pickling is that not all types of stainless steel are easy to pickle. The ease to which a steel can be pickled is put into 4 group, steel grades.

There are 4 methods to Pickle:

- Immersion pickling;
- Paste or gel pickling;
- Spray pickling;

- Electrochemical cleaning/polishing;

Figure 45 – Pickling of stainless steel. Source: http://www.euroshl.com/project/avesta-pickling-gel-122/; https://polyshop.nl/kunststof-beitsbad-4500-liter; http://www.sofel-sts.be/PDF/NL/PF/INOX_&_METAL_PICKLE_GEL.pdf; http://www.sspicklingandpassivation.com/companyprofile.php

The choice depends on your ability, the size of the object, aesthetics, required corrosion properties, etc. (Voestalpine - Böhler Welding).

When pickling the greatest risk is contact with chemicals. The strong acids used during the process can cause damage to the skin, eyes, intestines, etc., acids that come in contact with the skin can cause severe chemical burns and blindness when in contact with your eyes. Make sure an eye shower is nearby in case of acids coming in contact with your eyes. Rinsing with water is necessary in such cases.

Acids produce toxic fumes that cause damage when they're inhaled. Long-term damage is a dangerous consequence of inhaling the fumes on a regular basis.

Contact with chemicals can cause different types of burns and injuries. Dependant on the chemical to which a person is exposed, the symptoms, severity and treatment may differ. Sometimes there is no visible damage on the outside of the skin but the structures under the skin are damaged.

The skin is an organ just like the liver and the lungs. This means that it will incorporate products to a certain extend and can bring them into our bloodstream. This makes the risk of using chemicals even higher.

There's not only a great risk for the welder but for the environment as well. Chemical waste could endanger the local fauna and flora. The water used to rinse of the products could be contaminated with the strong acids.

12.2. Organising a safe workplace

When working with strong chemicals, some basic rules must be established.

- Only trained and informed personnel are allowed to perform this type of work.
- Eating, smoking and drinking in the pickling area is out of the question.
- Employees handling these chemicals are obliged to wash their hands before eating, using the toilet and after they finish pickling.
- All skin that could be exposed to the chemicals has to be covered.
- A first aid kit with products to treat contact with chemicals should be present.
  - Eye shower and emergency shower
- The pickling area must be ventilated.
- Keep jars and containers closed to avoid unwanted evaporation of the products.
- Pickling residues should be neutralized and disposed of according to the local regulations.
  - When pickling small work pieces, a dip tray could be a handy solution to dispose your contaminated water in a safe way.
- After pickling make sure all remaining products are stored in the correct way. Do not leave those products lying around.

12.3. Proper use and maintenance of equipment

It goes without saying that we need to protect ourselves against these risks. And for pickling we will need PPE's to ensure our safety.

First of all, the gloves used during pickling have to be chemically resistant. There's a big difference between waterproof and chemically resistant. By looking at the symbol on the gloves, you can differentiate the two types. Look at the next symbols to see the difference.

Function	Symbol
Waterproof and low chemical protection	
Waterproof and chemically resistant	

Table 12 – Symbols on gloves. Source: EN374

The letters under the symbol tell us on what chemicals the gloves are tested against.

List of test chemicals

CODE LETTER	CHEMICAL	CAS NUMBER	CLASS
A	Methanol	67-56-1	Primary alcohol
B	Acetone	67-64-1	Ketone
C	Acetonitrile	75-05-8	Nitrile compound
D	Dichloromethane	75-09-2	Chlorinated paraffin
E	Carbon disulphide	75-15-0	Sulphur containing organic compound
F	Toluene	108-88-3	Aromatic hydrocarbon
G	Diethylamine	109-89-7	Amine
H	Tetrahydrofurane	109-99-9	Heterocyclic and ether compound
I	Ethyl acetate	141-78-6	Ester
J	n-Heptane	142-85-5	Saturated hydrocarbon
K	Sodium hydroxide 40%	1310-73-2	Inorganic base
L	Sulphuric acid 96%	7664-93-9	Inorganic mineral acid

Figure 46 & Table 13 – Code on gloves. Source: EN 374

Look for letters which indicate a resistance against acids.

A second important PPE are safety goggles or grinding helmets to protect your face and your eyes. Splashes of acid during immersion pickling or a mist of acid with spray pickling could easily come in contact with your eyes when they're not protected.

If your workwear has acid splashes on it, take them off and wash them. If washing them is not an option, dispose of them in the correct way. An alternative could be disposable coveralls.

Lastly, we will need something to protect us against the fumes generated during pickling. Ideally a fume extraction system should be present otherwise we will need respiratory protection. Even with a fume extraction system, respiratory protection couldn't hurt. When working with pickling baths, make sure that the fume extraction is directly above the bath. Do not work bent over the pickling bath, only if absolutely necessary. In that case you should definitely use respiratory protection.

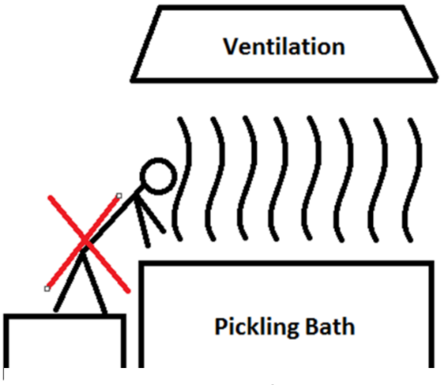


Figure 47 – Use of respiratory devices. Source: VCL

12.4. European, National Regulations and Recommendations

Always check the local regulations when performing activities such as pickling.

Standards used in the presentation and handbook:

- EN 374
- Voestalpine - Böhler Welding. (s.d.). Pickling Handbook. Malmö, Sweden.

13. Waste management

Waste can be either solid, liquid, or gas, and each have different methods of disposal and management. Waste management or waste disposal are the activities and actions required to manage waste from its inception to its final disposal. This includes amongst other things collection, transport, treatment and disposal of waste together with monitoring and regulation. It also encompasses the legal and regulatory framework that relates to waste management encompassing guidance on recycling. Waste management normally deals with all types of waste whether it was created in forms that are industrial, biological, household, or special cases where it may pose a threat to human health.

The waste hierarchy refers to the "3 Rs" reduce, reuse and recycle, which classify waste management strategies according to their desirability in terms of waste minimisation. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste.

Waste disposal methods can be:

- Preventing or reducing waste generation;
- Recycling;
- Incineration;
- Composting;
- Sanitary Landfill;

Safe disposal of waste it's one of the most important health and safety issues associated with welding and related activities.

13.1. Recognising risks

The consumables used in welding industry manufactures a large quantity of products that are utilized as welding or coating material on metallic materials, generating big quantities of waste rich in toxic metals that causes negative environmental impacts when disposed incorrectly. At present, these wastes are disposed in industrial landfills or they are co-processed in cement ovens.

Waste/unusable weld rods shall be disposed of in a red skip tub or other container identified for scrap metal recycling. Waste solvent and solvent soaked rags or tools must be disposed of properly in a hazardous waste drum.

13.1.1. Health (personal risks)

Common waste management health risks:

- muscular-skeletal;
- diarrhea;
- viral hepatitis;
- higher incidents of obstructive and restrictive disorders;

The risks associated with solid waste management in the enterprises can thus be divided into the following categories: occupational accidents, physical risks, chemical risks, ergonomic risks, psychological risks, and biological risks. The health risks either to the worker directly involved or to the enterprise operators and nearby residents are caused by many factors that include the following: the nature of raw waste, its composition (e.g., toxic, allergic, and infectious substances), and its components (e.g., gases, dusts, leachates, and sharps); the handling of waste (e.g., shoveling, lifting, equipment vibrations, and accidents).

13.1.2. Safety (workplace risks)

Common mechanical hazards:

- Cuts from sharp items (saw blades, cutting disks, and metal pieces);
- Tetanus (rusty wires and scrap metals);
- Traumatic injuries (metal scrap sharp objects from welding issues);

Ergonomic hazards result from:

- carrying or lifting heavy loads;
- repetitive movement and work (e.g. shoveling);
- muscular-skeletal disorders resulting from handling heavy containers;
- Manual sorting tasks often require reaching, lifting, and twisting and this can cause workers pain, soreness, general fatigue, tendonitis, and musculoskeletal injuries of the feet, arms, shoulders, hands, wrists, and lower and upper back.

Hazardous wastes

Are wastes or combinations of waste that pose a substantial present or potential hazard to humans or other living organisms because such wastes are nonbiodegradable or persistent in nature (Jerie, 2016).

Hazardous wastes can be:

- Poisonous;
- Corrosive;
- Noxious;
- Explosive;
- Inflammable;
- Radioactive;
- Toxic;
- harmful to the environment.

And can contain:

- Arsenic;
- Cadmium;
- Chromium;
- Lead;
- Mercury;

Hazardous waste management health risks:

- Neurotoxic diseases;
- Cancer, etc.

13.1.3. Environment

Waste is not something that should be discarded or disposed of with no regard for future use. It can be a valuable resource if addressed correctly, through policy and practice. With rational and consistent waste management practices, there is an opportunity to reap a range of benefits, specifically in the Environmental field, as it's possible to reduce or eliminate adverse impacts on the environment through reducing, reusing and recycling, and minimizing resource extraction can provide improved air and water quality and help in the reduction of greenhouse gas emissions.

Welding shops generate waste materials, mostly scrap metal which can be easily recycled. This recycling operation is good for the environment and consists also in a source of revenue.

13.2. Organising a Safe Workplace

Briefly we can point out the major "Waste handling process steps", namely in order:

- distinguish material as waste;
- wear Protective Personal Equipment (PPE);
- containerize waste;
- label waste with date;
- store waste;
- submit waste disposal form.

Beware of areas used for storage and disposal of solid wastes as they can be infested with vermin and/or insects which serve as potential disease vectors.

13.3. Proper use and maintenance of equipment

Every welding consumable and some welding accessories (where applicable) should be provided with its own Material Safety Data Sheet (MSDS). After welding consumables purchase, we must always consult and read the MSDS that comes with the welding consumable, either in form of welding rod, wire/tubular wire, covered electrode or flux, or with some accessories used in welding operations, like Release Agents for anti-spatter formation.

The MSDS provides basic information on a material or chemical product. It contains information on the properties and potential hazards of the material, how to use it safely, and what to do if there is an emergency. MSDSs are written for several audiences other than welding coordination personal, and welders using the material.

The MSDS is an essential starting point for the development of a complete health and safety program for the material, including “Disposal Considerations”, as we can see in Example 1 of Section 13 of an MSDS. This section of the MSDS is intended mainly for environmental professionals.

The MSDS does not usually contain all the steps and precautions necessary for adequate hazardous waste disposal. As well, the MSDS often does not give the federal, provincial, or local regulations which must be followed. The appropriate authorities for your area should be contacted for this information.

Below we have a MSDS from a welding consumable in form of covered electrode, were its possible to see the disposal considerations, including waste treatment methods and legislation, related to this consumable.

DISPOSAL CONSIDERATIONS
Waste treatment methods Non-contaminated waste from production and welding rods are recyclable. The unused product is not classified as hazardous waste. Dispose in accordance with appropriate government regulations. Any residues of finely divided product (particles, dust, fumes) may be are regarded as Hazardous Waste, depending on local regulations.

EU and Local legislation The recommendations given are considered appropriate for safe disposal. However, local regulations may be more stringent and these must be complied with EURAL CODE: 120113

Table 14 – Section 13 of a Covered Electrode MSDS

Regarding Safe disposal of waste materials, there is legislation governing the proper disposal of waste, ranging from low risk waste through to hazardous waste. These laws are enforced by the Environment Agency and Local Authorities.

When waste is disposed, certain types of waste may require waste tracking notes or may need to be disposed by specialists, particularly if it's hazardous.

13.3.1. Personal Protection Equipment

There are various methods to prevent injuries and these include the use of personal protective equipment (PPE), personal protective clothing (PPC), and safety warnings. Safety related injuries are the major problem in most sections.

Figure 48 – Warning Chemical Waste Sign, Source: Source:: https://www.loudandcleargraphics.co.uk/wp-content/uploads/2015/03/warn_0029_150x200H1.jpg

High levels of dust:

- Dust masks

Figure 49 – Disposable Dust Mask. Source: https://www.walmart.com/ip/ToolBasix-TGE-DM01-Disposable-Dust-Mask-Plastic-White/140989204

- Respirators

Other harmful objects:

- Work-suits;
- Safety Shoes;

13.4. European, National Regulations and Recommendations

14. Storage of Material

Storing materials involves diverse operations, such as hoisting tons of steel with a crane; driving a truck loaded with concrete blocks; carrying bags or materials manually; and stacking palletized bricks or other materials such as drums, barrels, kegs, and lumber.

The efficient handling and storage of materials are vital to industry. In addition to raw materials, these operations provide a continuous flow of parts and assemblies through the workplace and ensure that materials are available when needed. Unfortunately, the improper handling and storage of materials often result in costly injuries.

14.1. Recognising risks

Employers can reduce injuries resulting from storing materials by using some basic safety procedures such as adopting sound ergonomics practices, taking general fire safety precautions, and keeping aisles and passageways clear.

14.2. Organizing a safe workplace

Store materials in a planned and orderly manner that does not endanger employee safety. Ensure stacks, tiers, and piles are stable and stacked to aid safe handling and loading. Store hazardous materials in accordance with the individual requirements.

Store all materials on pallets to discourage rodent infestation. Immediately clean up spills and leaks that create such rodent habitat. Use slings to hoist bagged material, lumber, bricks, masonry blocks, and similar loosely stacked materials only if the slings are fully secured against falling by straps, sideboards, nets, or other suitable devices.

What precautions must workers take to avoid storage hazards?

Stored materials must not create a hazard for employees. Employers should make workers aware of such factors as the materials' height and weight, how accessible the stored materials are to the user, and the condition of the containers where the materials are being stored when stacking and piling materials. To prevent creating hazards when storing materials, employers must do the following:

- Keep storage areas free from accumulated materials that cause tripping, fires, or explosions, or that may contribute to the harboring of rats and other pests;
- Place stored materials inside buildings that are under construction and at least 1,8 m from hoist ways, or inside floor openings and at least 3 m away from exterior walls;
- Separate noncompatible material;
- Equip employees who work on stored grain in silos, hoppers, or tanks, with lifelines and safety belts.

In addition, workers should consider placing bound material on racks, and secure it by stacking, blocking, or interlocking to prevent it from sliding, falling, or collapsing.

Storing Materials in an Open Yard

Putting away materials in an open yard expects consideration regarding combustible materials, acess, powerlines, and fire protection.

Combustible Materials - Stack combustible materials securely. Stacks or piles must be no more than 4,9 m high. Store combustible material at least 3 m away from a building or structure.

Access - Driveways between and around combustible storage piles must be at least 4,5 m wide. Keep them free from accumulations of material or rubbish. Use a map grid system of 15 by 45 m when planning driveways in open-yard combustible material storage areas.

Powerlines - Do not store materials under power lines or where materials may block egress or emergency equipment.

Requirements for Storing Materials Indoors

Storing materials indoors requires attention to access, fire prevention and protection, floor loading, and overhead hazards. Buildings under construction require special precautions.

Access. Place or store materials so they don’t meddle with access ways, entryways, electrical panels, fire extinguishers, or hoistways. Do not obstruct access ways or exits with accumulations of scrap or materials. Aisles must be sufficiently wide to accommodate forklifts or firefighting equipment.

Fire Prevention. When storing, handling, and piling materials, consider the fire characteristics. Store noncompatible materials that may create a fire hazard at least 7,6 m apart or separate them with a barrier having at least a 1-hour fire rating. Pile material to minimize internal fire spread and to provide convenient access for firefighting.

Fire Doors. Maintain about 60 cm clearance around the travel path of fire doors.

Sprinklers. Maintain at least about 45 cm clearance between stored materials and sprinkler heads.

Heating Appliances. Maintain at least a 90 cm clearance between stored materials and unit heaters, radiant space heaters, duct furnaces, and flues or the clearances shown on the approval agency label.

Fire Protection. Emergency fire equipment must be readily accessible and in good working order.

Floor Loading. Conspicuously post load limits in all storage areas, except for floors or slabs on grade.

Requirements for Handling and Storing Reinforcing, Sheet, and Structural Steel

Stack steel to prevent sliding, rolling, spreading, or falling. Use lagging (sleeve) when steel is handled by a crane or forklift to aid safe rigging.

Requirements for Handling and Storing Pipe, Conduit, and Cylindrical Material

Make sure cylindrical materials are stable when storing or handling.

Stacking. Place pipe, conduit bar stock, and other cylindrical materials in racks or stack and block them on a firm, level surface to prevent spreading, rolling, or falling. Use either a pyramided or battened stack. Step back battened stacks at least one unit per tier and securely chock them on both sides of the stack.

Removal. Remove round stock (e.g., wood poles, pipe, and conduit) from a stack from the ends of the stock.

Unloading. Unload carriers so that employees are not exposed to the unsecured load.

Taglines. Use taglines when working with round stock.

Welding consumables: Storage

The duties relating to the storage of welding materials and shielding gases shall be as follows.

All welding materials that can be damaged by moisture (electrodes, wires and fluxes) shall be kept in a dry, well ventilated store. For this purpose storage cabinets or rooms shall be established in the welding material control and issue center(s). The temperature in the cabinets and rooms shall be maintained at least 10°C above ambient in order to keep the relative humidity below 60%.

For the distribution of welding materials to the various areas of consumption on the construction site, a (number of) welding material issue station(s) shall be set up. These will be equipped with holding ovens operating at a temperature of between 130°C and 150°C for storage of low hydrogen electrodes.

In the welding material control and issue center(s), unopened containers shall be warehoused in the storage room clear of direct contact with the ground and stacking of containers shall be such as to avoid damage to the contents.

GTAW filler rod, and GMAW, FCAW and SAW filler wire shall be stored under the same conditions as for covered electrodes and shall be kept in their protective wrappers until ready for use.

14.3. Proper use and maintenance of storing material

Segregation of Materials and Waste. Consider storage segregation precautions for all materials. Use MSDS to determine appropriate storage segregation. Identify and label segregated material containers.

In addition to training and education, applying general safety principles—such as proper work practices, equipment, and controls—can help reduce workplace accidents involving the moving, handling, and storing of materials. Whether moving materials manually or mechanically, your employees should know and understand the potential hazards associated with the task at hand and how to control their workplaces to minimize the danger.

14.4. European, National Regulations and Recommendations:

15. Brazing and Soldering

Brazing and soldering are principally classified according to process temperature.

Brazing

The American Welding Society (AWS), defines brazing as a group of joining processes that produce coalescence of materials by heating them to the brazing temperature and by using a filler metal (solder) having a liquidus above 840°F (450°C), and below the solidus of the base metals.

Soldering

Soldering has the same definition as brazing except for the fact that the filler metal used has a liquidus below 840°F (450°C) and below the solidus of the base metals.

A brazed joint is made in a completely different way from a welded joint.

The first big difference is in temperature. Brazing doesn't melt the base metals. So brazing temperatures are invariably lower than the melting points of the base metals. And, of course, always significantly lower than welding temperatures for the same base metals.

The brazing process joins the base metals by creating a metallurgical bond between the filler metal and the surfaces of the two metals being joined.

The principle by which the filler metal is drawn through the joint to create this bond is capillary action. In a brazing operation, you apply heat broadly to the base metals. The filler metal is then brought into contact with the heated parts. It is melted instantly by the heat in the base metals and drawn by capillary action completely through the joint.

Why Choose Brazing or Soldering

First, a brazed joint is a strong joint. A properly-made brazed joint (like a welded joint) will in many cases be as strong or stronger than the metals being joined. Second, the joint is made at relatively low temperatures. Brazing temperatures generally range from about 1150°F to 1600°F (620°C to 870°C).

Parameter	**Process**		
	Soldering	Brazing	Welding
Joint formed	Mechanical	Metallurgical	Metallurgical
Filler metal melt temperature, °C (°F)	<450 (<840)	>450 (>840)	>450 (>840)
Base metal	Does not melt	Does not melt	
Fluxes used to protect and to assist in wetting of base metal surfaces	Required	Optional	Optional
Typical heat sources	Soldering iron:	Furnace; chemical	Plasma , EB; GTAW

	ultrasonics; resistance; oven	reaction; induction; torch; infared	and SAW, RW; laser
Tendency to warp or burn	Atypical	Atypical	Potential distortion and warpage of base metal likely
Residual stresses			Likely around weld area

Table 15: Comparison of soldering, brazing and welding

15.1. Recognise the risks

Several risk exposures related to soldering and brazing are common with other welding processes, such as:

- Burns
- Working with gas cylinders
- Fumes from fluxes and solder
- Skin contact with fluxes
- Wrong waste disposal.

The following paragraph refers to brazing and soldering fumes, which are significantly different than welding fumes in general.

Grazing and soldering fumes

The emission of fumes is related to the process and the material used. The amount and the chemical composition of possible hazardous substances generated (soldering or brazing fume) depend on the materials used (solder and brazing alloys, flux, binder) and on the process parameters (brazing or soldering temperature, soldering and holding time).

Considering that the base material is not melted, its composition is not expected to influence the composition of the fumes.

Soldering (T < 450 °C)

Soldering is a process in which two or more items (usually metal) are joined together by melting and putting a filler metal (solder) into the joint, the filler metal having a lower melting point than the adjoining metal. Soldering differs from welding in that soldering does not involve melting the work pieces. In brazing, the filler metal melts at a higher temperature, but the work piece metal does not melt.

It is especially useful in electronics and plumbing. Alloys that melt between 180 and 190 °C (360 and 370 °F) are the most commonly used. If alloys with melting points above 450 °C (840 °F) are used, the process is no longer called soldering but brazing.

Solder can contain lead and/or flux, but in many applications, solder is now lead-free.

In the soldering process, heat is applied to the parts to be joined, causing the solder to melt and to bond to the workpieces in an alloying process called wetting. In the soldering of stranded wire, the solder is drawn up into the wire by capillary action in a process called wicking. Capillary action also takes place when the workpieces are touching or very close together. The joint strength is dependent on the filler metal used.

Soldering filler materials are available in many different alloys for differing applications. In electronics assembly, the eutectic alloy of 63% tin and 37% lead (or 60/40, which is almost identical in melting point) has been the alloy of choice. Other alloys are used for plumbing, mechanical assembly, and other applications.

Common solder formulations based on tin and lead are listed below. The fraction represents percentage of tin first, then lead, totalling 100%:

- 63/37: melts at 183 °C (361 °F) (eutectic: the only mixture that melts at a point, instead of over a range)
- 60/40: melts between 183–190 °C (361–374 °F)
- 50/50: melts between 183–215 °C (361–419 °F)

For environmental reasons (and the introduction of regulations such as the European RoHS (Restriction of Hazardous Substances Directive)), lead-free solders are becoming more widely used. Unfortunately, most lead-free solders are not eutectic formulations, melting at around 250 °C (482 °F), making it more difficult to create reliable joints with them.

Brazing (T > 450 °C)

For brazing, filler metals may contain aluminium, copper, zinc, nickel, tin, silver and cadmium additives. The fluxes used contain mixtures of boric acids, single and complex fluorides, oxyfluorides and borax.

Depending on the brazing alloys and flux, brazing may produces hazardous substances such as cadmium oxide, copper oxide, zinc oxide, silver oxide, fluorides, boron oxides, etc.

From the occupational health point of view, cadmium compounds and fluorides in brazing fume are especially important.

15.2. Organising a safe workplace

Flux Residue Treatment

When brazing or soldering is completed then the flux residues are to be removed because without removal the residues may lead to corrosion of assemblies.

Brazing flux residues can be removed by rinsing with hot water followed by drying. If the residue is sticky, then it can be removed by thermal shock i.e. heating and quenching. Sometimes steam jet may be applied followed by wire brushing.

Soldering flux residues of rosin flux can be left on the surface of joint, however, activated rosin flux and other flux residues require proper treatment. If rosin residues removal is required then alcohol, acetone or carbon tetrachloride can be used. Organic flux residues are soluble in hot water so double rising in warm water shall remove it. Residue removal of zinc chloride base fluxes can be achieved by washing first in 2% hydrochloric acid mixed in hot water followed by simple hot water rinsing.

According to the different nature of the fluxes is very import to take into account the requirements listed in the Safety Data Sheets, (especially points 2 -6 and 13). However SDS gave an overview on the all characteristics of the specific product (hazard and precautionary statements).

MIG brazing, laser brazing, plasma brazing (T > 900 °C)

For these processes mostly copper base alloys in the form of wire are used as filler metal with a melting temperature lower than that of the parent metal, e.g. $CuSi_3$ (Si 3%, Mn 1%, rest Cu), AlBz (Al 8,2%, rest Cu). Hence, high amounts of copper oxide are generated from the filler metal.

As previously stated, the base material composition does not affect the exposure; however, during processing of galvanized steels, the fume contains high proportions of zinc oxide generated by vaporization and oxidization of the coating.

The amount of fumes emitted depends on the process; experiments shows that during plasma brazing and laser brazing, the welding fume emission is commonly much lower than during MIG brazing.

15.3. Proper use and maintenance of equipment

The following basic safety precautions on the job should be observed in order to guarantee workers safety when using brazing alloys:

- Wear appropriate clothing and gloves (individual protection devices IDP).
- Wear safety goggles or face masks at all time (for better protection dark ones are recommended).
- Avoid direct exposure of the face with the working area.
- Use at all time an adequate aspiration system to guarantee good ventilation.

- Ventilate confined areas. Use adequate ventilating fans and exhaust hoods to carry all fumes and gases away from work, and air supplied respirators as required.

15.4. European, National Regulations and Recommendations

In this section, a list of the main European H&S standards and codes of practice related to brazing and soldering are presented:

ANSI Z49.1:2012- Safety in Welding, Cutting, and Allied Processes

ISO 857-2:2005 Welding and allied processes -- Vocabulary -- Part 2: Soldering and brazing processes and related terms

ISO 9455-11:2017 Soft soldering fluxes -- Test methods -- Part 11: Solubility of flux residues

References

Ansari, A. (2010). *Radiation threats and your safety*. Cambridge International Science Publishing

API RP 74 1st Ed. Oct. 2001 (R2007). *Recommended Practice for Occupational Safety for Onshore Oil and Gas Production Operation*

AWS (1999). *Soldering handbook.* SHB

Bahadori, A. (2015). *Personnel Protection and Safety Equipment for the Oil and Gas Industries*. Gulf Professional Publishing

Jenney, C. & O'Brien, J. (n.a.). *Welding Handbook.* Miami: American Welding Society

CCOHS (n.a.) *Welding - Storage and Handling of Compressed Gas Cylinders*. Available at: https://www.ccohs.ca/oshanswers/safety_haz/welding/storage.html

Doc. IIW Commision VIII 2080-08. *Comparative studies on the characterisation of ultrafine particles during welding and allied processes*

Doc. IIW Commision VIII 2085- 09. *Welding: Health and Safety Hazards*

Doc. IIW Commision VIII 2023- 11. *Health and Safety risks in welding activities*

Domenech, H. (2017). *Radiation Safety: Management and Programs, Springer International Publishing*

European Commission (2013). *The European Directive 2013/35/EU*. Luxembourg: Official Journal of the European Union. Available at: http://data.europa.eu/eli/dir/2013/35/oj

ESAW (2016). *Accidents at work by sex, age, severity, NACE Rev. 2 activity and contact mode of injury*. Brussels: Eurostat. Available at: https://ec.europa.eu/eurostat/web/products-datasets/product?code=hsw_ph3_09

HSE (n.a.) *Hearing loss and vibration white finger*. Available at: http://www.hse.gov.uk/welding/noise-vibration.htm

Ivanov, L. I. & Yu Platov (2004). *Radiation physics of metals and its applications.* Cambridge International Science Publishing

Jenney, C. & O'Brien, J. (n.a.) *Welding Handbook.* Miami: American Welding Society

Jerie (2016*).* Occupational Risks Associated with Solid Waste Management in the Informal Sector of Gweru. Zimbabwe. *Journal of Environmental and Public Health*. https://doi.org/10.1155/2016/9024160

Lippold; Boellinghaus, T.; Richardson, I. (1999). Doc. IIW 1416-98. *Welding in the World (3).*

NIOSH (2014). *EMFs In The Workplace*. The National Institute for Occupational Safety and Health. Available at https://www.cdc.gov/niosh/docs/96-129/default.html

Olson, L.; Siewert, T.; Liu, S.; Edwards, G. (1993). *ASM Handbook Volume 6: Welding, Brazing, and Soldering.* ASM International.

OSHA (2002). *Materials Handling and Storage*. Available at: https://www.osha.gov/Publications/osha2236.pdf

Pluvinage, G.; Elwany, M. H. (2008). *Safety, Reliability and Risks Associated with Water, Oil and Gas Pipelines*. Netherlands: Springer

Prasad, K. (2012). Radiation injury prevention and mitigation in humans physics. *Cambridge International Science Publishing*

Vervolmakingscentrum voor Lassers vzw. (2018). *Cutting Risks*. Neder-Over-Heembeek, Belgic.

Vervolmakingscentrum voor Lassers vzw. (2018). *Hot materials and spatter*. Neder-Over-Heembeek, Belgic.

Voestalpine – Böhler (n.a.). *Pickling Handbook*.