Guidance for National Labour Inspectors on addressing health risks from Welding Fume

Senior Labour Inspectors' Committee (SLIC)
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Employment, Social Affairs and Inclusion

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PART 1

1.1 Introduction & Background

The Senior Labour Inspectors' Committee (SLIC) recognised the need to redress the imbalance between **Occupational Safety** and **Health** and agreed in spring 2014 to support work on Respirable Crystalline Silica (RCS). This resulted in guidance for inspectors being published in 2016. (https://osha.europa.eu/en/guidance-national-labour-inspectors-on-addressing-risks-from-worker-exposure-to-respirable-crystalline-silica.)

The second topic prioritised was Welding Fume which is widely encountered in workplaces in EU countries, across a number of industry sectors, and is known to have serious health risks, mostly developing over many years.

National Labour Inspectorates (NLIs) were asked to express interest in this work in 2014, when the RCS work commenced and representatives of several NLIs formed the Long Latency Sub-Working Group (LLSWG) of CHEMEX WG. NLIs currently represented are listed in Appendix 1. The guidance produced has a focus on the levers available to NLIs and a primary objective of sharing good practice.

Comments, or suggestions, on the guidance should be directed to CHEMEX WG, via national KSS focal points.

Purpose and structure of the guidance
This guidance document was developed for NLIs, with the aim of increasing inspectors' confidence in addressing and regulating health risks from welding activities and exposure to welding fume, thereby enhancing the effectiveness of NLI interventions principally in **manufacturing and other sectors such as construction**. Workers' health is just as important as their safety. The key ambition of the SLIC CHEMEX WG is to provide guidance which will support NLIs in tackling the risks to workers' health associated with welding activities in Europe's workplaces, as skilfully as they would tackle the safety risks.

Welding activities and exposure to welding fume are the focus of this guidance because:

- **There are approximately 2.000.000 welders in the EU, according to the European Welders Association.**
- Other workers may also undertake limited welding activities as part of their regular work, e.g. maintenance, construction - significantly increasing the number of workers exposed to welding fume;
- These activities are widespread across Member States (MS); and
- There is a high potential for exposure to hazardous substances associated with welding activities.

Taken from EU Welding Institute
http://european-welding.org/welding-in-europe/importance-welding-europe/

This guidance is divided into 2 parts:

Part 1 provides the background information including: health risks, types of welding, the legal framework for regulation, typical control measures, health surveillance and key information summary.

Scope of guidance

In addition to the activities described as 'welding' there are a number of associated processes that can produce fume similar to that from true welding. The following processes are included in the scope of this guidance and are those which can give rise to fume exposures which have the potential to cause ill-health (in no particular order):

- Shielded Metal Arc Welding (SMAW), also known as Manual Metal Arc (MMA) welding
- Gas Tungsten Arc Welding (GTAW), also known as Tungsten Inert Gas (TIG) welding
- Gas Metal Arc Welding (GMAW) also known as Metal Inert gas (MIG) and Metal Active Gas (MAG) welding
- Flux-Cored Arc Welding (FCAW)
- Plasma cutting
- Laser cutting
- Flame cutting
- Arc-air gouging

Part 2 principally focuses on 9 Welding Fume Task Sheets, specific to different welding activities. These have been developed to provide basic guidance on each activity; approaches to control welding fume exposure; illustrative photographs where available; and, suggested actions for NLIs.

Important Note: National arrangements.
The NLI will always have discretion on the level of action considered appropriate to the workplace circumstances, as it is fully recognised that methods of enforcement vary from one country to another, sometimes going beyond EU Directive minimum requirements described in this guidance. The choice of enforcement regime depends on the legal/cultural background of each country.

In addition, Part 2 contains a section on Inspector personal safety, and summary information about other health and safety hazards from welding activities, in addition to welding fume.

1.2 Health effects associated with Welding Fume

The primary impact on individuals from exposure to welding fume relates to ill-health effects on the respiratory system (see also section 1.3). There are generally two categories of such ill-health effects resulting from welding fume – acute (short-term) and chronic (long-term) health effects.[1,2]

Acute respiratory health effects:

- Irritation to Upper Respiratory Tract i.e. throat and larger airways to the lung. Extreme exposure to ozone can also cause pulmonary oedema (fluid on the lungs).
- Acute Irritant Induced Asthma; although not common, very high levels of exposure to inhaled irritants can ***cause*** asthma to develop. This is termed acute irritant induced asthma and was formerly called reactive airways dysfunction syndrome.
- Temporary reduction in lung function i.e. overall lung capacity and the ease of breathing out (peak flow) can be affected by exposure to welding fume. This is normally seen in the context of Occupational Asthma (see below).
- Metal fume fever ('flu-like symptoms). Onset is a few hours after exposure begins and persists for a period after exposure ends. This is associated with specific metals, e.g. zinc.
- Other acute health effects (sometimes fatal) can result from exposure to welding gases, including:
    - Acute pneumonia: welders are known to be at an increased risk of developing pneumococcal pneumonia. It is not known exactly why this is the case but may be due to the ***effects*** of metal(s) being inhaled. Pneumococcal vaccination is suggested by many as a sensible ***preventive*** approach for current welders.
    - headache, dizziness and nausea: due to overexposure to carbon monoxide which impairs the oxygen carrying capacity of the blood by the formation of carboxyhaemoglobin;
    - Asphyxiation (suffocation from lack of oxygen): may result from accumulation of shielding gases (such as argon, helium and nitrogen, or argon-based mixtures containing carbon dioxide, oxygen or both) in confined and enclosed spaces.

Chronic respiratory health effects:

- Chronic Obstructive Pulmonary Disease (COPD) has been associated with welding fume exposure, although the evidence from studies is varied. Normally seen in those who smoke tobacco, lung function can decline more quickly than expected, and fume can potentially contribute to this decline. Established COPD causes progressive shortness of breath, chest tightness and wheeze. Fatigue may also be a feature. If the disease progresses then workers, can become very severely incapacitated.
- Welder's Lung is normally a term used to describe metal deposition in the lung from previous exposure to welding fume. It is thought to be a benign type of pneumoconiosis. On its own, the welder may not complain of any

particular health problems. If COPD also exists, then there may be additional respiratory complaints as detailed above.

- Occupational Asthma is associated with exposure to specific metals e.g. chromium, nickel, cobalt resulting in symptoms including episodes of severe shortness of breath, wheezing, coughing and chest tightness. It typically involves a latency period, of a few months to a few years, between first exposure to a respiratory sensitiser in the workplace, and the onset of symptoms
- Lung Cancer is associated with exposure to specific metals e.g. chromium, nickel. Welding fumes are produced when metals heated above their melting point vaporise and condense to fine particles. Many studies report increased risks of lung cancer in welders or other workers exposed to welding fumes. The International Agency for Research on Cancer (IARC) has classified welding fumes as Group 1 carcinogenic substances.

In addition to these effects, exposure to welding fumes can induce chronic inflammation and impairment of the immunological response; for this reason, the risk of other bronchial and pulmonary conditions such as pneumonia may be increased in welders. Certain chronic lung conditions such as COPD and lung cancer are also adversely influenced by tobacco smoking.

Welding activities on surfaces with coatings, debris and residual degreasing agents will generate other hazardous substances with a range of health effects, e.g. phosgene, aldehydes, amines, isocyanates (allergens).

Other health effects

Exposure to welding fume may also cause:

- Neurological effects: exposure to manganese can lead to neurological symptoms similar to Parkinson's disease. These symptoms include speech and balance disorders;
- Ototoxic effects: Some studies have shown that workers exposed to both manganese and noise seemed to have accelerated hearing impairment compared with those exposed to manganese alone.[3]
- Reprotoxic effects, e.g. manganese
- Depression; and
- Sexual dysfunction.

Skin effects may arise from contact with consumables e.g. allergic contact dermatitis caused by dermal exposure to nickel or chromium.

1.3 Why should NLIs address Welding Fume?

Exposure to welding fume can lead to very debilitating health conditions and these can have a profound effect on the individual's ability to perform everyday tasks, such as walking, climbing stairs or showering, impacting adversely on the quality of their life, and affecting their family, for instance not being able to play with their children.[4]

The following link is to a case study http://www.hse.gov.uk/mvr/resources/videos/video8.htm

It is clear from the video that this former welder has been profoundly affected by having developed Occupational Asthma.

Welders are exposed to harmful substances causing cancer, asthma, brain damage and other serious respiratory conditions

What is Welding Fume?
It is a complex and variable mixture of gases and particulates of varying sizes. The composition, rate of generation and particle size of the fume will depend on the:

- Composition of the consumable electrode and the materials being welded;
- Welding process parameters (current, shielding gas and technique);
- Surface coatings, contamination and 'flash rust';
- Local environmental conditions (e.g. outdoors, indoors, enclosed.); and
- Control measures and their effectiveness (general ventilation, extraction at source e.g. on tool extraction, local exhaust ventilation, automation etc.)

A number of other processes associated with welding also generate dust e.g. grinding and polishing.

Each work situation is different. The particulate fume is re-condensed aggregates of vaporised metal and their compounds, originating, predominantly, from the consumable (rod, wire & flux material).

The composition of the fume is consistent with the component metals within the alloy being welded.

Further information on the principal components and typical key components of commonly encountered welding fumes can be found in Table 1[5]

Table 1. Welding processes, consumables and components in Welding Fume

Process	Consumables	Principal Components	Other components	Typical key components
MMA/SMAW	Mild steel	Fe, Mn, Cu,	F	Mn
	Stainless & high chromium steels*	Fe, Mn, Cr, Cr(VI),Ni, Co	V, F	Cr(VI), Ni
	Cast iron	Fe, Mn, Cu, Ni		Ni or Cu
	Nickel-based alloys	Ni, Cr(VI)	Fe	Ni, Cr(VI)
	Copper-based alloys	Cu, Ni		Cu or Ni
MIG/MAG/GMAW	Mild steel	Fe, Mn, Cu,		Mn
	Stainless & high chromium steels*	Fe, Mn, Cr, Cr(VI),Ni, Co		Cr, Cr(VI), Ni
	Aluminium alloys	Al, Mg, Mn, Zn		Mn
	Nickel-based alloys	Ni, Cr, Cr(VI)	Fe	Ni or Cr
	Copper-based alloys	Cu, Ni		Ni or Cu
FCW	Mild steel	Fe, Mn, Cu	Ba, F	Mn
	Stainless & high chromium steels*	Fe, Mn, Cr, Cr(VI),Ni, Al	V	Cr(VI), Ni

* high chromium steels, include alloys such as Duplex, armour-plating, Austenitic steels.
Technical data for specific consumables should be used when available

Based on data from *Table E-1 of Annex E of EN ISO 15011-4:2006+A1:2008 Health and Safety in Welding +allied processes – Laboratory method for sampling fume and gases Part 4.*

In Table 1 the symbols were used in accordance with the periodic table.

Table 2 gives the full name of metals commonly encountered in welding fume and possible adverse health effects of metals as denoted by the required Hazard Statements:

Table 2. Metals commonly encountered in Welding Fume and possible adverse health effects[7]

Symbol	Full name	Health effect of compounds containing element *(lower limit of effects)*
Al	Aluminium	May be harmful if inhaled May cause allergy or asthma symptoms or breathing difficulties if inhaled
Ba	Barium	Toxic if inhaled
Co	Cobalt	Suspected of causing cancer
Cr	Chromium	May cause cancer
Cr (VI)	Hexavalent Chromium	May cause cancer
Cu	Copper	Toxic if inhaled
F	Fluorine	Toxic if inhaled
Fe	Iron	May be harmful if inhaled May cause allergy or asthma symptoms or breathing difficulties if inhaled
Mg	Magnesium	May be harmful if inhaled May cause allergy or asthma symptoms or breathing difficulties if inhaled
Mn	Manganese	Toxic if inhaled May damage fertility or the unborn child
Ni	Nickel	May cause cancer
V	Vanadium	Toxic if inhaled

[Health effects from: Hazardous substances in welding and allied processes -BGI 593, Spiegel, Ciobanu 2008].

The gaseous fraction of welding fume is predominantly produced by the ultraviolet radiation from the welding arc acting on the molecules of oxygen and nitrogen in the atmosphere, to generate ozone (O_3), nitric oxide (NO) and nitrogen dioxide (NO_2). Carbon within ferrous alloys can result in the generation of carbon monoxide (CO) and carbon dioxide (CO_2).

The exposures from welding fume can be complicated by a variety of factors:

- **Surface coatings – primers containing metallic compounds release metal oxides** e.g. iron oxide, zinc oxide;
- **Surface coatings - resins and organic compounds release gases** due to degradation of the coating by the welding process;
- **Flash rust** – welding of mild steel with any rust generates greater amounts of iron oxide fume;
- **Contaminants** – the more common contaminants are greases and oils, which degrade to carbon soot, organic compounds, including aldehydes, and gases such as CO_2, CO and oxides of nitrogen; and
- **Degreasing agents** – these are often chlorinated solvents, selected for their rapid evaporation at room temperature. In cooler environments they can remain, and heat from the welding process results in the release of the residual solvent and degradation products including: hydrogen chloride (HCl), phosgene ($COCl_2$) and gaseous chlorine (Cl_2).

Any surface coating, flash rust, contaminant or degreasing agent is likely to thermally decompose or degrade due to the high temperature of the welding arc. The distance from the weld that this degradation occurs is determined by the material being welded, and by the type and magnitude of the current used during the welding process.

1.4 Welding

Welding is a fabrication process that joins materials, most usually metals, by causing fusion. It is distinct from lower temperature metal-joining techniques such as brazing and soldering, which do not melt the base metal. In addition to melting the base metal, a filler material is typically added to the joint during welding to form a pool of molten material (the weld pool), that cools to form a joint that is usually stronger than the base material. Pressure may also be used in conjunction with heat, or by itself, to produce a weld. Welding also requires a form of shield to protect the filler metals or melted metals from being contaminated or oxidised.

The most commonly used welding methods (in no particular order) include:

- **Gas tungsten arc welding (GTAW)** – also known as Tungsten, Inert Gas (TIG), uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by an inert shielding gas such as argon or helium.
- **Gas metal arc welding (GMAW)** – commonly termed **Metal Inert Gas (MIG)**, uses a gun that feeds wire at an adjustable speed and with an argon-based shielding gas over the weld pool to protect it from atmospheric contamination. There is a variation where the shield gas contains an active ingredient, e.g. argon + CO_2. This form of GMAW is known as **Metal Active Gas (MAG)** welding.
- **Flux-cored arc welding (FCAW)** – similar to MIG welding except it uses a special tubular wire filled with flux; it can be used with or without shielding gas, depending on the filler.
- **Shielded metal arc welding (SMAW)** – also known as **Manual Metal Arc (MMA)** or "stick welding", uses a rigid electrode (rod) that has flux around it to protect the weld pool. A device known as a 'welding gun' or 'torch' holds the electrode as it melts. The flux protects the weld pool from atmospheric contamination and forms 'slag', which is removed after the weld cools.

Other operations produce fumes similar to those from the welding processes, described above. These include:

- **Plasma cutting –** utilises the principle of a welding arc to cut metal with a clean profile. It uses a high velocity jet of ionised gas such as oxygen, nitrogen, argon, or even workshop air, that is delivered from a constricting orifice. The high velocity ionised gas, i.e. the plasma, conducts electricity from the torch of the plasma cutter to the workpiece. The plasma heats the workpiece, melting the material with temperatures reaching up to 22204 °C, quickly piercing through the work piece and blowing away the molten material. The high velocity stream of ionised gas mechanically blows the molten metal away, severing the material. The majority of plasma cutting is pre-programmed computer numerical control (CNC) with the operator at a distance from the fume source.
- **Laser cutting** – utilises a focussed laser beam, usually with an annular gas jet to create a fine cut, with minimal loss of material and a quality profile. Most of

industrial sheet metal laser cutting is carried out using two types of lasers: CO_2 and fibre. The CO_2 laser (carbon dioxide laser) is generated in a gas mixture, which mostly consists of CO_2, helium and nitrogen. A fibre laser beam is generated by a series of laser diodes. The laser beam is then transmitted through an optical fibre where it gets amplified. The majority of laser cutting is pre-programmed (CNC) with the operator at a distance from the fume source.

- **Flame cutting** - also known as torch or oxygen-gas cutting, is a chemical reaction between pure oxygen and steel to form iron oxide. It can be described as rapid, controlled rusting. Preheat flames are used to raise the surface or edge of the steel to approximately 982 ^{o}C (bright-red colour). Pure oxygen is then directed toward the heated area in a fine, high pressure stream. As the steel is oxidised and blown away to form a cavity, the preheat and oxygen stream are moved at constant speed to form a continuous cut. Only metals whose oxides have a lower melting point than the base metal itself can be cut with this process. Otherwise as soon as the metal oxidises it terminates the oxidation by forming a protective crust. Only low carbon steel and some low alloys meet the above condition and can be cut effectively with the oxy-fuel process.
- **Arc-air gouging** - is an arc cutting process in which metals to be cut are melted by the heat of a carbon arc. The molten metal is removed by a high velocity blast of compressed air. The air jet is external to the consumable carbon-graphite electrode. It strikes the molten metal immediately behind the arc. The most common metals cut with the process includes cast irons, copper alloys and stainless steel.

The industrial sectors, in which welding activities are commonly found, are shown in the box below:

Sectors where welding activities/ users are commonly found

- Fabrication of infrastructure and construction (buildings, bridges, metallic construction, earth moving equipment etc.)
- Fabrication for transport- Shipyards, Rail, Automotive industry, Aeronautic
- Fabrication & construction for energy sector- Petrochemical industry, Energy production
- Fabrication of equipment for the food, chemical & pharmaceutical industry
- Fabrication of military equipment
- Fabrication of equipment for treatment of wastes
- Maintenance activities
- Craftsmen, plumbers,
- Vocational education (e.g. technical colleges, apprenticeships)

Source – EU Welding Institute

1.5 Legal framework

The Framework Directive 89/391/EEC introduces measures to encourage improvements in the safety and health of workers at work. It requires the employer to evaluate all the risks to the safety and health of workers and implement measures which assure an improvement in the level of protection afforded to them. The employer shall, amongst other things:

- take into consideration the worker's capabilities as regards health and safety when he entrusts tasks to workers;
- consult workers on the introduction of new technologies;
- designate worker(s) to carry out activities related to the protection and prevention of occupational risks;
- take the necessary measures for first aid, fire-fighting, evacuation of workers and action required in the event of serious and imminent danger;
- keep a list of occupational accidents and draw up, for the responsible authorities, reports on occupational accidents suffered by their workers;
- inform and consult workers and allow them to take part in discussions on all questions relating to safety and health at work;
- ensure that each worker receives adequate safety and health training; and
- provide health surveillance for workers according to national systems.

Risk elimination is the first general principle for prevention provided for by the Framework Directive 89/391/EEC. Substitution should be encouraged when possible.

The most relevant EU-legislation for this guide is Council Directive 98/24/EC, (Chemical Agents Directive, CAD) and Council directive EU 2004/34 amended via EU 2017/2398 (Carcinogens and Mutagens Directive, CMD).

Hazardous chemical agents are subject to the requirements under CAD and CMD on the protection of the health and safety of workers from the risks related to chemical agents at work. CAD and CMD both state that employers have a duty to determine whether any hazardous chemical agents are present in the workplace, to eliminate the use of these and, where this is not possible, to assess the risks to which they may give rise. This includes hazardous substances that are produced/generated as a by-product of any process.

In welding fume common hazards such as nickel, cobalt, and manganese are regulated by CAD and chromium(vi) which is particularly hazardous is regulated by CMD. The main difference between the two regulations is that for hazards regulated under CMD exposure should be as low as technically possible i.e. economic considerations should not feature. All three directives (Framework Directive, CAD, CMD) require the employer, with or without an exposure assessment, to reduce exposure as low as possible and the employer must continuously work towards reducing the exposure of hazardous chemicals, even if the exposure is below the Occupational Exposure Limit (OEL). OELs included in the CAD/CMD must have a corresponding national OEL.

1.6 Welding Fume controls

Employers should ensure that the risk from welding fumes to the health and safety of workers is eliminated or reduced to a minimum in line with the legal requirements in Section 1.5. There are many different measures that can be implemented to control exposure to welding fumes. Some control measures are more effective than others, so they can be ranked from the highest level of protection to the lowest. This ranking is known as the **hierarchy of control**. As a consequence, the employer should start at the top, considering each option in turn, and deciding whether it is feasible or not. Examples of measures that can be applied to eliminate or reduce the risk from welding fumes are shown in **Table 3**.

Administrative control measures and PPE rely on human behaviour and supervision. If used on their own, they tend to be the least effective in reducing risk. In order to effectively control exposure to welding fumes, a combination of measures from different levels of control may be required. Employers should also ensure that implementing certain control measures does not introduce new hazards.

Workers must know the proper way to perform the job or task in order to minimize their exposure and to maximise the effectiveness of the control measures. As a consequence, welders should be adequately informed or instructed and trained to use these control measures and best work practices e.g. keeping their head out of weld plume, correctly position themselves and the local exhaust ventilation (LEV) to minimise, exposure to welding fume.

When it comes to welding fume, a commonly used term is 'the plume'. The plume is used to mean the visible and invisible emissions during the welding processes. The plume contains the hazardous substances mentioned in section 1.3, and these substances can also be present outside the visible plume.
Although *general ventilation* is not advised as a primary control in the Task Sheets, with the exception of TIG welding, within this guidance there is the assumption that there will be a reasonable level of general ventilation within the workplace.

Table 3: Practical considerations for inspectors when assessing implementation of the Hierarchy of Control

← Decreasing effectiveness	Control	Method	Comments
	Elimination	**Is process required?** ✓ Cold cut, e.g. guillotine ✓ Redesign of the job so there is less need to weld	 *No fume* *Less fume, due to use of pre-cast components or extruded shapes*
	Substitution	**Can a cleaner process be used?** ✓ MMA to MIG/MAG; MIG to TIG ✓ Flame cut to plasma cut to laser cut	 *Less fume, reduced post-weld grinding* *Less fume, easier to control, better quality cut*
		Can different consumable be used? ✓ Cleaner rods/wires	 *Less fume*
	Process change	**Can it be automated?** ✓ Robotic Welding, CNC cutting	 *Usually enclosed and distant from worker, lower exposure*
		Can the workpiece be better positioned? ✓ Use of jigs rigs, etc. may require better planning	 *Worker not in fume plume*
		Is the workpiece clean? ✓ Remove grease, flash rust, debris or surface coatings prior to welding	 *Fume only from weld, not other sources*
		Can the process be enclosed? -	 *Associated with automation*
	Ventilation	**Can fume be extracted at source (LEV)?** ✓ On-gun extraction ✓ Extracted benches – rear slots ✓ Flexible or hinged arm ✓ Mobile fume extractors	 *Only applicable to MIG/MAG, requires training of workers to proper use, very effective* *Very effective for smaller components* *Requires maintenance and testing effectiveness* *Requires worker to reposition with weld* *Flexible ducting & capture hoods are prone to damage* *Capture hood design need to be appropriate for weld* *Requires maintenance and testing effectiveness* *As above*
		Can fume be extracted by general ventilation? ✓ Wall or roof fans	 *Not recommended as effectiveness is low and does not remove fume from workers at source. Can result in accumulation in some areas*
	Administrative control & work practices	**Can number of exposed workers be reduced?** ✓ Use dedicated area for welding with restricted access	 *Isolates nearby workers from the welding plume*
		What information, instruction & training is required? ✓ in addition to technical training for the equipment used, workers must receive Health & Safety training	 *Correct use of equipment to minimise fume production & exposure* *Training in the use and maintenance of LEV and RPE*
	Respiratory Protective Equipment (RPE)	**Is this appropriate exposure control?** ✓ If other engineering controls are not adequate	 *Must be appropriate to fume hazards and wearer (fit properly)* *Workers with facial hair must use positive pressure RPE (e.g. battery powered respirator with welding visor or helmet)*

1.7 Exposure assessment and key questions

A Labour Inspector can make a relatively quick assessment of risks from exposure to welding by answering a few simple questions. The questions must be aimed at the factors that influence exposure. These factors are:

1. Welding process: 'dirtier' processes may lead to higher exposure
2. Exposure time: how long is the process performed
3. Consumables: how clean is the welding surface
4. Control measures at the source: visible control measures
5. Control measures in the room
6. Behaviour of welder: head out of the plume, LEV close enough to workpiece, lifting of the welding hood only when plume has dissipated.

Questions for inspectors to ask:

a) What metals are being welded or cut? What is the welding method?

Alloys that contain chromium, nickel, or other metals with higher toxicity would indicate a higher level of health risk, compared with welding of mild steel.

b) Is there any visible fume?

If the predominant welding method is TIG/GTAW, the likelihood of visible fume is very low, unless there is surface contamination of the material being welded. So visible plume with TIG/GTAW is an indication the workpiece has not been prepared properly.

Visible fume is usually evident with other welding techniques, with increasing levels from MIG/GMAW on mild steel to MMA/SMAW on coated or contaminated steels.

c) What is the duration of the process?

The frequency & duration of the welding activity also affects the level of fume produced and hence the rate of dispersal. Spot, tack or stitch welds are of short duration and therefore produce less fume, compared to seam or fillet welds. The greater the frequency and/or duration of weld or 'arc-time', the greater likelihood for fume to build up in the immediate vicinity.

d) Where is the welding being carried out?

Exposure to welding fume is affected by the local environmental conditions, e.g. how enclosed the workplace is, natural air movement. Where the workplace is enclosed, as for example inside a ship, the greater the likelihood of high fume exposure.

Where the working area is outside or a large open factory, natural air movement will reduce the exposure of welding fume to other workers by assisting dispersal of fume.

Good general ventilation is also likely to be a sufficient degree of control for a worker TIG/GTAW welding as the level of fume generated is likely to be low. However, in cases where other welding techniques are used, worker exposure to welding fume may not be significantly reduced and other control measures would be required. The ideal situation would be to have the work segregated

from the worker e.g. in an entirely enclosed process. However, in practice this is not practicable in most cases, unless the process is automated.

e) What visible control measures are in place?

The most effective form of welding fume control is at-source (torch extraction/on gun extraction), followed by local exhaust ventilation (LEV). The effectiveness of LEV is directly related to appropriate design for the task and correct usage by the worker. This can be judged by the proportion of fume that captured. A rule of thumb for LEV is that the distance between the workpiece and the hood of the LEV should be no more than the diameter of the hood.

Where engineering controls are not fully effective or adequate, RPE may also be required. RPE should not be the primary control measure, but it is a supplement to engineering controls. RPE is only fully effective if the correct type of RPE is selected for the task, the working environment and the wearer.

If a filtering device is used, the correct filter should be used and replaced in accordance with manufacturer's instructions. In some Member States, a fit test is required for a tight-fitting mask, to check it matches the wearer's face and seals adequately. Wearers should also be properly instructed, trained and supervised on the correct use, maintenance and storage of the RPE.

f) How is the worker working?

Operator practices are significant in minimising exposure to fume:

- Operator position with respect to the plume of fume - e.g. at what angle is the welder working at? If the work is down-hand, they may be leaning over the workpiece with their head in the plume of fume. Tilting or raising the workpiece slightly can reduce the direct exposure to fume. This can also allow better positioning of an extraction hood;
- Locating LEV correctly, throughout the work;
- Correct use of personal protective equipment (PPE), e.g. not lifting visor during or just after welding; use of a double visor of which the dark part is opened and a clear visor stays closed and;
- Reporting defects or problems with the control measures provided.

If uncertain or in doubt, contact a Specialist.

A '**Welding Inspection Decision Tool**' is provided in Appendix 1 to assist Labour Inspectors with initial appraisal. This semi-quantitative tool takes the inspector through the steps in order to inform their decision on whether action is needed. Please note that this is not an exposure assessment.

Additional information on welding work can be found in TRGS 528[7]

1.8 Health surveillance

Health surveillance is a system of on-going health checks of workers liable to be exposed to substances hazardous to health, such as welding fume. The approach to health surveillance varies in MS and further referral to national legislation on this matter is advised. The information below is for guidance only and based on the approaches in some MS.

Health surveillance should only be undertaken and interpreted by those who are competent to do so.

The risk assessment, undertaken by the employer should demonstrate when and where there is a need to introduce health surveillance for employees.

For example, a health surveillance programme for workers should be established:

- when there is still a risk to health from exposure, even after the implementation of all reasonable precautions;
- where there is any reliance on RPE/PPE as a control measure;
- in situations where workers are carrying out most of the welding tasks referred to in this guidance, as RPE is also required as a control measure in most cases.

It must be remembered that Health Surveillance does not replace the controls put in place to prevent exposure to welding fume but, is additional and complementary to those controls and provides a means of monitoring the adequacy of them.

The objectives of health surveillance for those workers exposed to welding fume are to:

- detect ill-health effects at an early stage and provide an opinion on fitness to work;
- provide data to help employers evaluate health risks so they can introduce better controls to improve worker protection;
- highlight lapses in workplace control measures, therefore providing invaluable feedback to the risk assessment; and
- give an opportunity for workers to discuss any health concerns relating to welding fume exposure.

Important Note: For the inspector

During a site inspection where health surveillance is an issue, the inspector should consider an appropriate intervention, in line with their national legislation and regulatory framework, if the following is observed:

- No or inadequate health surveillance, where health surveillance would be appropriate.
- No or inadequate action taken by the employer following the report of an adverse health effect.
- No health surveillance undertaken and/or interpreted by a competent provider.

1.9 Key Information Summary for Inspectors

Key information for Inspectors [1,2,4,5,6,7,8]

a) **Welding fume is a complex and variable mixture of fine particles, gases and vapours**

b) **Welding fume is harmful to workers' health** ranging from serious chronic health effects such as occupational asthma, COPD and lung cancer to acute health effects such as irritation of the eyes, throat and airways, which exacerbate asthmatic or other respiratory conditions.

c) **Most of the metal particulate fume – the visible fume - comes from the solid consumable**, i.e. the wire or the rod. nickel, chromium, cobalt and manganese metals and consumables are of the most concern.

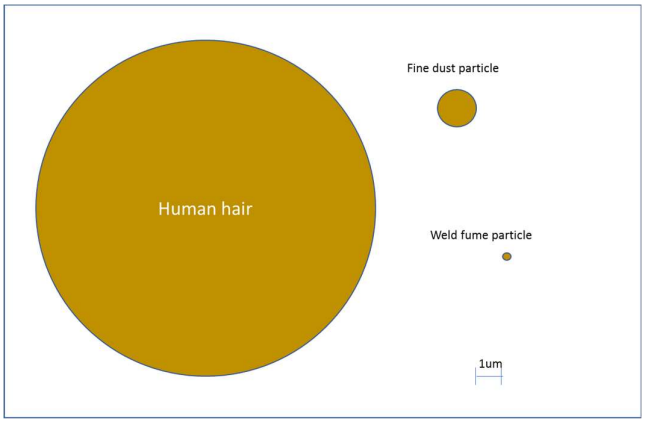
d) **In plasma cutting, laser cutting and flame cutting, the fume is solely from the base metal.**

e) **The cleaner the metal, the less fume is produced** - Surface coatings and/or contaminants such as oils, greases and even degreasing agents, and scale or flash-rust, can also significantly affect the level of fume produced.

f) **A visible plume is an indication that exposures are not adequately controlled**; however, the absence of a visible plume does not indicate a safe level of exposures depending on the metal or consumable involved.

g) **Welding fume particles can remain airborne for significant periods** after the work has been completed (in some cases more than 24 hours).

h) **Welding fume particles are extremely small,** as shown below, **so can penetrate deep into the lungs** where gas exchange takes place, and in most cases are not removed. They can also be in the nanoparticle range i.e. smaller than 100 nanometres (nm).



i) **Health surveillance may be necessary but should only be** undertaken and interpreted by **those who are competent to do so.**

1.10 Further information and resources on welding

References and Links are in English unless otherwise stated.

References

1. Unpublished (November 2016). BOHS occupational lung disease initiative: Breathe Freely Phase 2 – Manufacturing (welding) Summary of available information on the association of welding fume and ill-health – November 2016.

2. Virtual Issue: Welding and Respiratory Disease (Breathe Freely 2017) Annals of Work Exposure Oxford Academic https://academic.oup.com/annweh/pages/welding_and_respiratory_disease

3. Published (2009). Combined exposure to noise and ototoxic substances (EU-OSHA, 2009, page 30 Manganese):**https://osha.europa.eu/en/tools-and-publications/publications/literature_reviews/combined-exposure-to-noise-and-ototoxic-substances**

4. Unpublished (2017). Transcript of Interview with 'Phil the Welder' in 2017.

5. Published (2006). EN ISO 15011-4:2006+A1:2008 [4]Health and Safety in Welding +allied processes – Laboratory method for sampling fume and gases Part 4

6. Published (2008). Hazardous substances in welding and allied processes BGI 593, Spiegel, Ciobanu at https://www.ims-koch.de/wp-content/uploads/lexikon/DGUV_I/209-017.pdf

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8. Published (2013). Down with welding Fume. www.5xbeter.nl.

9. Published (1999). Health and safety in engineering workshops Web version can be found at http://www.hse.gov.uk/pubns/priced/hsg129.pdf

10. Published (2010). Cadmium and you - Working with Cadmium: Are you at risk? ISBN 978 0 7176 6397 2. Web version can be found at http://www.hse.gov.uk/pubns/indg391.pdf

11. Published (2011), Beryllium and you - Working with Beryllium: Are you at risk? Web version can be found at www.hse.gov.uk/pubns/indg311.pdf

Useful website links

HSE - Phil the welder (video)	http://www.hse.gov.uk/mvr/resources/videos/video8.htm http://www.hse.gov.uk/mvr/assets/videos/dr-david-fishwick-interviews-phil-Hynes.mp4
BOHS Breath freely initiative on welding	http://breathefreely.org.uk/breathefreelymanufacturing.html
EU Roadmap on Carcinogens	https://roadmaponcarcinogens.eu/
Dust-Free Working – on-tool extraction for welding	http://www.dustfreeworking.tno.nl/innovation/successful-innovations
Swedish trade association/ employee/ experts online tool for welding (Swedish)	http://www.svetsaratt.se/
"Verbetercheck Lasrook (Improvement Check Welding Fume)" – an online tool (Dutch)	https://www.5xbeter.nl/site/nl A Dutch knowledge institute developed the "Welding Fume Assistant" (lasrookassistent): http://www.iras.uu.nl/lasrook/index.php.
HSE Welding health and safety	http://www.hse.gov.uk/welding/index.htm
Pimex	PIMEX (Picture Mixed Exposure) are movies which can be used to give insight into the impact of control measures. The movie 'Welding in a workshop' (in English) shows how you can find the best position for exhaust ventilation in welding processes to give the worker the best possible protection. http://www.pimexservice.de/?page_id=9&lang=en (English)
EU OSHA Dust and aerosols welding fume	OSHwiki welding: https://oshwiki.eu/wiki/Dust_and_aerosols_-_welding_fumes

1.11 Abbreviations

APF: Assigned protection factor

CAD: Chemical Agents Directive

CE Conformité Européane

CIRCA BC: EU Commission collaborative platform, which offers an easy distribution and management of documents

CMD: Carcinogens and Mutagens Directive

COPD: Chronic Obstructive Pulmonary Disease

IARC: The International Agency for Research on Cancer

GDWW, B General Directorate Wellbeing at Work (Belgium)

LEV: Local Exhaust Ventilation

MS: Member States

NLIs: National Labour Inspectors/Inspectorates

OEL: Occupational Exposure Limit

PPE: Personal Protective Equipment

RPE: Respiratory Protective Equipment

SLIC CHEMEX WG: Senior Labour Inspectors' Committee Working Group on Chemicals

SLIC: Senior Labour Inspectors' Committee

URT: Upper Respiratory Tract

Ar - Argon
Be - Beryllium
Cd - Cadmium
Cl - Chlorine
CO - Carbon monoxide
CO_2 - Carbon dioxide
$COCl_2$ - Phosgene
HCl - Hydrogen chloride
NO - Nitrogen monoxide
NO_2 -Nitrogen dioxide

PART 2 Welding Fume Task Sheets

2.1 Essential advice on inspecting using this guidance

The Welding Task Sheets (TS) have been developed for NLIs, to provide basic guidance on various common work activities that give rise to welding fume exposures, with the potential to cause serious ill-health in the workers affected. Note that some photographs have been simulated in order to illustrate particular scenarios.

To obtain the most benefit, inspectors are invited to note the important background information in Part 1. In particular:

1.2 Health effects associated with Welding Fume

1.3 Why should NLIs address Welding Fume?

Both of these provide inspectors with information to underpin the actions they take.

1.4 Welding – explaining what welding processes are and the various types commonly encountered.

1.6 Welding Fume controls - particularly Table 3 which is an aide memoire for assessing the practical implementation of the Hierarchy of Control in the workplace.

1.7 Exposure assessment and key questions – posing questions to ask (linked to the Welding Inspection Decision Tool in Appendix 1).

1.9 Key Information Summary – bringing together key points to note before inspecting.

Any comments on the Task Sheets or proposals for new ones should be directed to CHEMEX WG, via your national KSS focal points.

In addition to the specific task sheets, this part includes sections on Inspector Safety and General Hazards, not specific to the effects of welding fume.

Each task sheet has 6 sections:

i) General comments: Describing the main chemical risks associated with welding fume from task.

ii) Recommended controls for welding fume: These state which controls should be in place, when performing the task under normal circumstances. There are cases when all the recommended controls may not be necessary e.g. very infrequent welding activity, for short periods, and where there is good ventilation. Here it is up to the employer to show that the controls used are adequate, e.g. risk assessment.

Equally there are cases when more stringent controls are required e.g. extensive welding (long periods and/or multiple welders) and poor air circulation. Here the inspector should consider taking further enforcement action.

Always remember that exposure to welding fume should be as low as practicably possible and for Cr(IV) as low as technically possible as it is particularly hazardous (i.e. carcinogenic and/or causing asthma).

iii) Possible actions by National labour inspector:

How to use these task sheets

Possible 'Actions' are recommended for NLIs where they may encounter a potential high, medium or low welding health risk, depending on the extent and level of controls implemented by the employer at the time of inspection.

NLIs should request to see the employer's completed exposure assessment on the level of exposure, whether through modelling or monitoring/measurements, after appropriate controls are implemented, in particular where there has been a medium to high health risk scenario identified.

- The '**Welding Inspection Decision Tool**' is provided in Appendix 1 to assist with the Inspector's judgement on the adequacy of the workplace, but this is not an exposure assessment. This semi-quantitative tool takes the inspector through the steps to consider and gives an *indication* of the level of NLI Action enforcement that may be required, to be considered alongside the employer's assessment. The value calculated will indicate the following:

Low = <7; Medium = 8 to 20; High >20

Possible Actions by National labour Inspector	**High Health Risk** - Consider **immediate action** when all controls missing/ineffective (e.g. stop work, use of Notices, use of administrative fines etc.)
	Medium Health Risk - Consider **action** in situations where one control is missing/ ineffective (e.g. use of Notices requiring action) or the **Hierarchy of control** has not been followed**,** i.e. RPE without consideration of LEV
	Low Health Risk - No action required where all controls are present and effective

Note: TIG/GTAW have been omitted from the Tool as fume is less visible and the likelihood of requiring engineering control measures is low.

Important Note: National arrangements.
The NLI will always have discretion on the level of action considered appropriate to the workplace circumstances, as it is fully recognised that methods of enforcement vary from one country to another, sometimes going beyond EU Directive minimum requirements described in this guidance. The choice of enforcement regime depends on the legal/cultural background of each country.

iv) Designing out risks: This section details how an employer can eliminate or reduce the risks by changing the process or the materials used.

v) Maintenance of control equipment and respiratory protective equipment: This section details how the inspector could check the implementation of the controls.
vi) Other benefits: Details how controls can benefit worker safety in other areas than exposure to welding fume.

A systematic risk management system is necessary to be able to handle all the risks associated with welding. This is a good place to start any inspection on welding.

2.2 Inspector Safety

On entering industrial premises, where welding and associated processes are being undertaken, it is of major importance that the NLI remains safe. The potential risks for an inspector include:

- Welding flash (Arc eye) – do not look directly at a welding arc! Suitable eye protection must be worn in a metal fabrication area. Normal prescription lens will give a degree of protection. Greater protection can be achieved using appropriate tinted safety glasses. To observe a welding arc directly, you must use an appropriate welding screen meeting relevant standards.
- Burns from hot metal – metal that has been welded or cut by flame or arc will retain heat for a significant period. NEVER touch hot metal.
- Noise – the majority of welding and associated processes generate noise in excess 85dBA and a significant number generate in excess of 90dBA. Always use appropriate ear protection when entering metal fabrication areas.
- Burns from sparks– a number of welding and associated processes generate a significant amount of sparks, which can burn clothes & skin. Wear suitable inflammable clothing. DO NOT approach a welder while welding, but wait till the task is complete.

See also the General hazards Information which follows, also important for the inspector!

2.3 General hazards – Welding

General Comment

General hazards of welding excluding very fine particles (fumes) and gases include impact, heat, light radiation, electrical shock, noise, awkward posture, fire/explosions and use of compressed gas.

Eye injuries have resulted from contact with sparks, hot slag and metal chips. The intense heat of welding and sparks can cause burns. The intense light associated with welding can cause eye damage. Ultraviolet light from an arc can cause "welder's flash" and also skin burns. There is also a danger of electric shock. If combustible or flammable materials are nearby, the heat and sparks produced by welding can cause fires or explosions. Hearing loss can result from working close to noisy welding equipment. The use of compressed gas cylinders poses some unique hazards to the welder. Electric current flowing through any conductor causes localized Electric and Magnetic Fields (EMF).

Hazard	Factors for NLI to consider	Recommended controls
Electric shock	• Wetness in work area • Welder in or on workpiece • Confined space • Electrode holder and cable insulation	• Insulate welder from workpiece and ground using dry insulation. Rubber mat or dry wood • Wear dry, hole-free gloves (change as necessary to keep dry) • Do not touch electrically "hot" parts or electrode with bare skin or wet clothing • If wet area and welder cannot be insulated from workpiece with dry insulation, use a semiautomatic, constant voltage welder or stick welder with voltage reducing device • Keep electrode holder and cable insulation in good condition. Do not use if insulation is damaged or missing • Settings correct for the job • If basic electric shock precautions cannot be followed to insulate welder from work and electrode, use semi-automatic, constant voltage equipment with cold electrode or stick welder with voltage reducing device.
Confined spaces	• Metal enclosure • Wetness • Restricted entry • Heavier than air gas • Welder inside or on workpiece	• Only undertaken with authorised access – assessment by competent person • Carefully evaluate adequacy of ventilation especially where gas may displace breathing air. • Provide welder helper and method of welder retrieval from outside enclosure.
Noise	• All manual welding methods produce noise levels >85dBA • Plasma and gas cutting produce noise levels >85dBA • Pre- and post-welding/cutting tasks, e.g. grinding, produce noise levels >95dBA	• Automate where possible • Select quieter methods • Grinding on noise absorbent surface • Clamp lighter workpieces to reduce secondary noise • Select appropriate ear protection where noise exposure is in excess of 80dBA.

Hazard	Factors for NLI to consider	Recommended controls
Welding sparks can cause fire or explosion	• Containers which have held combustibles • Flammable materials	• Do not heat, cut or weld tanks, drums or containers until the proper steps have been taken to ensure that flammable substances are not present. • Check before welding. • Remove flammable materials from welding area or shield from sparks, heat. • Keep a fire watch in area during and after welding. • Keep a fire extinguisher in the welding area. • Wear fire-retardant clothing and hat. • Avoid welding near hydraulic lines. • Cables should be the right size for your job and any damaged cable insulation is repaired. Cables should be spread out and run neatly to prevent overheating.
Arc rays can burn eyes and skin	• Process: gas-shielded arc most severe	• Select a filter lens which is comfortable while welding. Some newer type helmets have an auto-darkening feature • Always use helmet when welding. • Provide non-flammable shielding to protect others. • Wear clothing which protects skin while welding. • Heavy, flame-resistant gloves, such as leather, should be worn to protect hands from burns, cuts, and scratches.
Musculoskeletal hazards	• Repetitive handling tasks • Twisting and turning • Fixed and or awkward postures • Handling and lifting heavy objects • Manual handling of welding sets	• Avoid hazardous lifting and manual handling • Carry out suitable and sufficient risk assessment (based on task, individual, load and environment) • Consider how prolonged fixed position/awkward postures in relation to workpiece, can be avoided • Apply controls according to risk assessment (eg risk reduction measures including selection & use of suitable equipment or rotation of tasks) • Suitable task specific training programme for residual risk • Further guidance INDG390 and HSG129
General work area hazards	• Cluttered area	• Keep cables, materials, tools neatly organised.
	• Indirect work (welding ground) connection	• Connect work cable as close as possible to area where welding is being performed. • Do not allow alternate circuits through scaffold cables, hoist chains, ground leads.
	• Electrical equipment	• Use only double insulated or properly grounded equipment.

Hazard	Factors for NLI to consider	Recommended controls
		• Always disconnect power to equipment before servicing.
	• Engine-driven equipment	• Use in only open, well ventilated areas. • Keep enclosure complete and guards in place. • Refuel with engine off.

TS1 Gas tungsten arc welding (GTAW) – also known as Tungsten Inert Gas (TIG) Page 1 of 2

General comment	GTAW/TIG welding generates very little visible particulate fume, but does produce ozone & oxides of nitrogen [nitrogen monoxide (NO) and nitrogen dioxide (NO_2)]. These gases can be irritating to the upper respiratory tract (URT) and worsen any pre-existing bronchial conditions. Ozone production is greater when welding stainless steel and aluminium. The fume composition is directly related to the used metal and the surface material. With metals containing chromium & nickel, the health hazard is greater due to asthma- and cancer-causing components of the particulate fume. Any visible fume is most likely to arise from surface contamination of the metal.
Recommended controls for welding fume	▪ Local exhaust ventilation (LEV) or respiratory protective equipment (RPE) is not normally required. General Ventilation for indoor work. However, LEV or RPE is normally required when, for example: ▪ There is a significant amount of visible fume or the task is carried out in a poorly ventilated area; Or welding galvanised materials.
Possible Actions by National Labour Inspector	**Medium Health Risk** - Consider **action** in situations when undertaken in an enclosed working area or materials with a surface coating, including galvanised metal. **Low Health Risk** - No action required where all controls are present and effective.
Design Out Risks	▪ Automation or remote control will increase distance of worker from weld arc ▪ Using a lower electrical current during welding reduces ozone production. ▪ Use of the correct set-up & operating parameters of welding equipment also minimise fume production. ▪ Ensure metal components are free from surface coatings or contamination. ▪ If de-greasing agents are used then use alternatives to chlorinated degreasing solvents which can react to produce phosgene gas ▪ Shield the welding arc to minimise the available air which can react to produce ozone. ▪ If necessary, provide training of operators on control measures to ensure they understand their contribution and limitations and how to use them effectively.
Maintenance of control equipment & respiratory protective equipment (RPE)	If LEV and/or RPE is used: ▪ Make sure the extraction flow rate is right for the work ▪ Carry out thorough examination and testing on extraction system as required ▪ Inspect and maintain re-usable RPE, use disposable RPE just once ▪ Workers should be trained in the correct operation of the equipment and use of RPE
Other benefits	

TS1 Gas tungsten arc welding (GTAW) – also known as Tungsten Inert Gas (TIG) Page 2 of 2

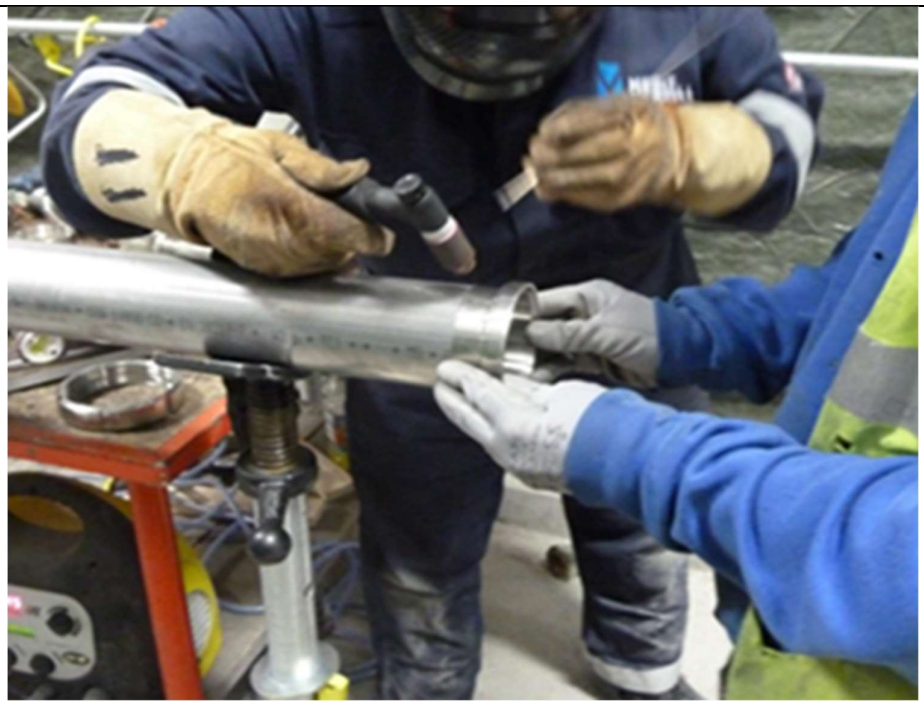

Photo 1 Good Control Practice – with general ventilation - TIG in a well-ventilated area (HSE, GB)

TS 2 Gas metal arc welding (GMAW) – also known as Metal Inert Gas (MIG) & Metal Active Gas (MAG) welding – stainless steel & other chromium & nickel containing alloy Page 1 of 2

General comment	GMAW/MAG/MIG generates varying amounts of fume, depending on a number of factors such as current, metal type, surface coating or contamination, operator practices. The fume composition is directly related to the consumable (wire) and any surface material. With metals containing chromium & nickel, the health hazard is greater due to asthma- and cancer-causing components of the particulate fume.
Recommended controls for welding fume	Ensure clean, uncoated metal Local exhaust ventilation, appropriate to task & workpiece, will be required: ▪ Extracted bench ▪ On-gun ▪ Fixed or mobile hood RPE is also required ▪ APF of at least 20 ▪ Power-assisted or air-fed RPE ▪ Additional filtration will be required if coating/surface contamination present when filtered devices are selected *For short-term tasks, type P3 high-efficiency disposable RPE is acceptable. *Not applicable when welding Cd or Be based alloys [10,11] In oxygen deficient areas, e.g. enclosed spaces, RPE should be air-fed.
Possible Actions by National Labour Inspector	**High Health Risk** - Consider **immediate action** when all controls missing/ineffective (e.g. stop work, use of Notices, use of administrative fines etc.)
	Medium Health Risk - Consider **action** in situations where one control is missing/ ineffective (e.g. use of Notices requiring action) or the **Hierarchy of control** has not been followed, i.e. RPE without consideration of LEV
	Low Health Risk - No action required where all controls are present and effective
Design Out Risks	▪ Replace with TIG/GTAW – if possible ▪ Minimise the amount of welding ▪ Automation of repetitive welding tasks (robotic welding) ▪ Use of the correct set-up & operating parameters of welding equipment can also minimise fume production. ▪ Ensure metal components are free from surface coatings or contamination (Thermal degradation of surface coatings & debris will generate other hazardous substances.) ▪ If de-greasing agents are used then use alternatives to chlorinated degreasing solvents, which can react to produce phosgene gas ▪ Provide training of operators on control measures to ensure they understand their contribution and limitations and how to use them effectively.
Maintenance of control equipment & respiratory protective equipment (RPE)	▪ Maintenance of welding equipment at regular intervals (not greater than annually) ▪ Inspection & maintenance of local exhaust ventilation at regular intervals, with routine thorough examination & testing programme. ▪ Exposure monitoring should be considered as a check on the effectiveness of control measures in place when welding stainless steel, non-ferrous alloys, or painted or coated metals ▪ Manage supply, storage & maintenance of RPE, including testing where appropriate. ▪ Workers should be trained in the correct operation of the equipment and use of RPE
Other benefits	▪ Automation of welding can reduce muscular skeletal disorders & reduces noise exposure.

TS 2 Gas metal arc welding (GMAW) – also known as Metal Inert Gas (MIG) & Metal Active Gas (MAG) welding – stainless steel & other chromium & nickel containing alloy Page 2 of 2

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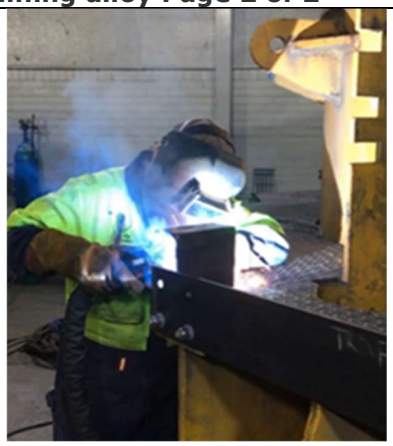
<tr><td>  </td><td> </td></tr>
<tr><td>Photo 1 Poor control practice –MIG without on gun extraction (HSE, GB)</td><td>Photo 4 Good control practice –MIG with effective on gun extraction (RPE also required) (HSE, GB)</td></tr>
<tr><td> </td><td> </td></tr>
<tr><td>Photo 2 Poor control practice -MIG with ineffective LEV (HSE, GB)</td><td>Photo 5 Good control practice -MIG with effective LEV (RPE also required) (HSE, GB)</td></tr>
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<tr><td>Photo 3 Poor control practice - MIG without LEV (HSE, GB)</td><td></td></tr>
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TS 3 Gas metal arc welding (GMAW) – also known as Metal Inert Gas (MIG) & Metal Active Gas (MAG) welding – mild/carbon steels Page 1 of 2

General comment	GMAW/MAG/MIG generates varying amounts of fume, depending on a number of factors: current, metal type, surface coating or contamination, operator practices. The fume composition is directly related to the consumable (wire) and any surface material. Primary fume components of concern are manganese & copper (where coated wires are used). As the process can be more continuous than MMA (SMAW) or 'stick' welding, fume can build up.
Recommended controls for welding fume	Ensure clean, uncoated metal – remove debris or coating where possible. Local exhaust ventilation, appropriate to task & workpiece, will be required: ▪ Extracted bench ▪ On-gun ▪ Fixed or mobile hood Where LEV is not adequate to control fume exposure, RPE is also required: ▪ APF of at least 20 ▪ Power-assisted or air-fed RPE ▪ Additional filtration will be required if coating/surface contamination present when filtered devices are selected ▪ For short-term tasks, type P3 high-efficiency disposable RPE is acceptable ▪ In oxygen deficient areas, e.g. enclosed spaces, RPE should be air-fed.
Possible Actions by National Labour Inspector	**High Health Risk** - Consider **immediate action** when undertaken in an enclosed working area without adequate controls systems (e.g. stop work, use of Notices, use of administrative fines etc.) **Medium Health Risk** - Consider **action** in situations where one control is missing/ ineffective (e.g. use of Notices requiring action) or the **Hierarchy of control** has not been followed**,** i.e. RPE without consideration of LEV **Low Health Risk** - No action required where all controls are present and effective
Design Out Risks	▪ Replace with TIG/GTAW (not often possible) ▪ Minimise the amount of welding ▪ Automation of repetitive welding tasks (robotic welding) ▪ Use of the correct set-up & operating parameters also minimise fume production. ▪ Ensure metal components are free from surface coatings or contamination. (Thermal degradation of surface coatings & debris generates other hazardous substances.) ▪ If de-greasing agents are used then use alternatives to chlorinated degreasing solvents which can react to produce phosgene gas ▪ Provide training of operators on control measures to ensure they understand their contribution and limitations and how to use them effectively.
Maintenance of control equipment & respiratory protective equipment (RPE)	▪ Maintenance of welding equipment at regular intervals (not greater than annually) ▪ Inspection & maintenance of local exhaust ventilation at regular ▪ intervals, with routine thorough examination & testing programme. ▪ Exposure monitoring should be considered as a check on the effectiveness of control measures in place when welding painted or coated metals ▪ Manage supply, storage & maintenance of RPE, including testing where appropriate. ▪ Workers should be trained in the correct operation of the equipment and use of RPE
Other benefits	▪ Automation of welding can reduce muscular skeletal disorders & reduces noise exposure

TS 3 Gas metal arc welding (GMAW) – also known as Metal Inert Gas (MIG) & Metal Active Gas (MAG) welding – mild/carbon steels Page 2 of 2

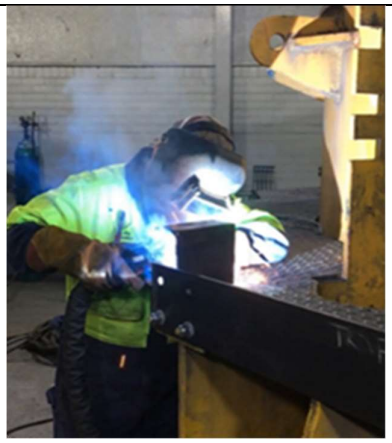	
Photo 1 Poor control practice –MIG without on gun extraction (HSE, GB)	**Photo 4 Good control practice –MIG with effective on gun extraction (HSE, GB)**
Photo 2 Poor control practice -MIG with ineffective LEV (HSE, GB)	**Photo 5 Good control practice -MIG with effective LEV (HSE, GB)**
Photo 3 Poor control practice - MIG without LEV (HSE, GB)	

TS 4 Shielded metal arc welding (SMAW) – also known as Manual Metal Arc (MMA) welding stainless steel & other chromium & nickel containing alloy Page 1 of 2

General comment	SMAW/MMA welding generates significant amounts of fume, including hexavalent chromium & soluble nickel. The fume level can be greater in the presence of surface coatings and/or debris. The size of the consumable (rod) determines the current & fume level.
Recommended controls for welding fume	Ensure clean, uncoated metal Local exhaust ventilation appropriate to task & workpiece: ▪ Extracted bench ▪ Fixed or mobile hood RPE is also required ▪ APF of at least 20 ▪ Power-assisted or air-fed RPE ▪ Additional filtration will be required if coating/surface contamination present when filtered devices are selected *For short-term tasks, type P3 high-efficiency disposable RPE is acceptable. *Not applicable when welding Cd or Be based alloys [10,11] In oxygen deficient areas, e.g. enclosed spaces, RPE should be air-fed.
Possible Actions by National Labour Inspector	**High Health Risk** - Consider **immediate action** when undertaken in an enclosed working area without adequate controls systems (e.g. stop work, use of Notices, use of administrative fines etc.) **Medium Health Risk** - Consider **action** in situations where one control is missing/ ineffective (e.g. use of Notices requiring action) or the **Hierarchy of control** has not been followed**,** i.e. RPE without consideration of LEV **Low Health Risk** - No action required where all controls are present and effective
Design Out Risks	▪ Replace with MIG/MAG/GMAW – lower fume processes, with less post-weld dressing ▪ Automation of repetitive welding tasks (robotic welding) ▪ Use of the correct set-up & operating parameters of welding equipment ▪ Ensure metal components are free from surface coatings or contamination. (Thermal degradation of surface coatings & debris ▪ Provide training of operators on control measures
Maintenance of control equipment & respiratory protective equipment (RPE)	▪ Maintenance of welding equipment at regular intervals (not greater than annually) ▪ Inspection & maintenance of local exhaust ventilation at regular intervals, with routine thorough examination & testing programme. ▪ Exposure monitoring should be considered as a check on the effectiveness of control measures in place when welding stainless steel, non-ferrous alloys, or painted or coated metals ▪ Manage supply, storage & maintenance of RPE, including testing where appropriate ▪ Workers should be trained in the correct operation of the equipment and use of RPE
Other benefits	▪ Reduced post-weld dressing can improve production

TS 4 Shielded metal arc welding (SMAW) – also known as Manual Metal Arc (MMA) welding stainless steel & other chromium & nickel containing alloy Page 2 of 2

Photo 1 Poor control practice - MMA without LEV (NLI, SK)

Photo 2 Good control practice - MMA with an effective welding bench (RPE also required) (Plymovent, GB)

TS 5 Shielded metal arc welding (SMAW) – also known as Manual Metal Arc (MMA) welding – mild/carbon steels Page 1 of 2

General comment	SMAW/MMA welding generates significant amounts of fume. The fume level can be greater in the presence of surface coatings and/or debris. The size of the consumable (rod) determines the current & fume level. Composition of the rod & flux coating may include metals & fluorides not present in the base metal, which can add to the overall health risk**.**
Recommended controls for welding fume	Ensure clean, uncoated metal Local exhaust ventilation appropriate to task & workpiece: ▪ Extracted bench ▪ Fixed or mobile hood Where LEV is not adequate to control fume exposure, RPE is also required: ▪ APF of at least 20 ▪ Power-assisted or air-fed RPE ▪ Additional filtration will be required if coating/surface contamination present when filtered devices are selected ▪ *For short-term tasks, type P3 high-efficiency disposable RPE is acceptable. In oxygen deficient areas, e.g. enclosed spaces, RPE should be air-fed.
Possible Actions by National Labour Inspector	**High Health Risk** - Consider **immediate action** when undertaken in an enclosed working area without adequate controls systems (e.g. stop work, use of Notices, use of administrative fines etc.)
	Medium Health Risk - Consider **action** in situations where one control is missing/ ineffective (e.g. use of Notices requiring action) or the **Hierarchy of control** has not been followed**,** i.e. RPE without consideration of LEV
	Low Health Risk - No action required where all controls are present and effective
Design Out Risks	▪ Replace with MIG/MAG/GMAW (not often possible) ▪ Minimise the amount of welding ▪ Automation of repetitive welding tasks (robotic welding) ▪ Use of the correct set-up & operating parameters also minimise fume production. ▪ Ensure metal components are free from surface coatings or contamination. (Thermal degradation of coatings or debris may generate other hazardous substances ▪ If de-greasing agents are used then use alternatives to chlorinated degreasing solvents which can react to produce phosgene gas
Maintenance of control equipment & respiratory protective equipment (RPE)	▪ Maintenance of welding equipment at regular intervals (not greater than annually) ▪ Inspection & maintenance of local exhaust ventilation at regular intervals, with routine thorough examination & testing programme. ▪ Exposure monitoring should be considered as a check on the effectiveness of control measures in place when welding stainless steel, painted or coated metals ▪ Manage supply, storage & maintenance of RPE, including testing where appropriate. ▪ Workers should be trained in the correct operation of the equipment and use of RPE
Other benefits	▪ Change to lower fume welding method. ▪ MIG/MAG/GMAW with on-gun extraction improves flexibility of welding activity. ▪ Post-weld dressing is not usually required – this reduces noise & vibration exposure & can increase production rate

TS 5 Shielded metal arc welding (SMAW) – also known as Manual Metal Arc (MMA) welding – mild/carbon steels Page 2 of 2

<table>
<tr><td> </td><td> </td></tr>
<tr><td>Photo 1 Poor control practice -MMA without LEV (NLI, SK)</td><td>Photo 4 Good control practice - MMA with effective LEV (NLI, SK)</td></tr>
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<tr><td>Photo 2 Poor control practice – MMA without LEV (HSE, GB)</td><td></td></tr>
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<tr><td>Photo 3 Poor control practice – MMA without LEV (HSE, GB)</td><td></td></tr>
</table>

TS 6 Plasma cutting Page 1 of 2

General comment	Plasma cutting utilises the principle of a welding arc to cut metal with a clean profile. The majority of plasma cutting is pre-programmed [CNC] with operator at a distance from the fume source. The particulate fume produced is wholly from the metal being cut. The fume composition is related to the metal alloy being cut. Gases are produced from the arc in a similar manner to welding. Some plasma cutting can be submerged in a water bath, minimising any emission of particulate fume.
Recommended controls for welding fume	Ensure clean, uncoated metal Submerge under water If in an open workshop apply local exhaust ventilation such as a down-draught table. Install panels to segregate from adjacent processes (optional). Where LEV is not adequate to control fume, RPE may also be required for workers to enter the cutting bed area. ▪ APF of at least 20 ▪ Power-assisted or air-fed RPE ▪ Additional filtration will be required if coating/surface contamination present when filtered devices are selected *For short-term tasks, type P3 high-efficiency disposable RPE is acceptable. *Not applicable when welding Cd or Be based alloys [10,11] ▪ In oxygen deficient areas, e.g. enclosed spaces, RPE should be air-fed.
Possible Actions by National Labour Inspector	**High Health Risk** - Consider **immediate action** when undertaken in an enclosed working area without adequate controls systems (e.g. stop work, use of Notices, use of administrative fines etc.) **Medium Health Risk** - Consider **action** in situations where one control is missing/ ineffective (e.g. use of Notices requiring action) or the **Hierarchy of control** has not been followed**,** i.e. RPE without consideration of LEV **Low Health Risk** - No action required where all controls are present and effective
Design Out Risks	▪ Use submerged plasma cutting facility.
Maintenance of control equipment & respiratory protective equipment (RPE)	▪ Maintenance of equipment at regular intervals (not greater than annually) ▪ Inspection & maintenance of local exhaust ventilation at regular intervals, with routine thorough examination & testing programme. ▪ Exposure monitoring should be considered as a check on the effectiveness of control measures in place when welding stainless steel, non-ferrous alloys, or painted or coated metals ▪ Workers should be trained in the correct operation of the equipment
Other benefits	▪ Reduced noise levels.

TS 6 Plasma Cutting Page 2 of 2

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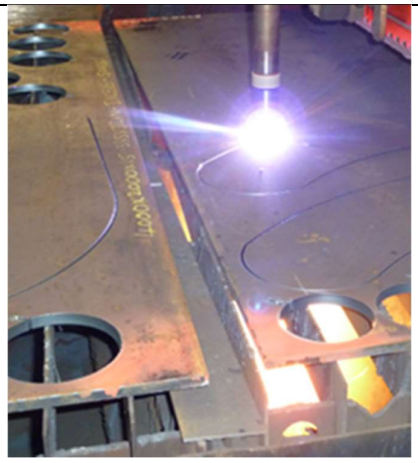
<tr><td> </td><td>  </td></tr>
<tr><td>Photo 1 Poor Control Practice - Plasma cutting without extraction (Miller, GB)</td><td>Photo 3 Good control practice -Plasma cutting with extraction table (Miller, GB)</td></tr>
<tr><td> </td><td> </td></tr>
<tr><td>Photo 2 Poor control practice Plasma cutting table – poor maintenance (Miller, GB)</td><td>Photo 4 Good control practice Plasma cutting table – good maintenance (Miller, GB)</td></tr>
<tr><td></td><td> </td></tr>
<tr><td></td><td>Photo 5 Good control practice -Plasma cutting with helmet and exhaust (NLI, SK)</td></tr>
</table>

TS 7 Laser cutting Page 1 of 2

General comment	Laser-cutting utilises a focussed laser beam, usually with an annular gas jet to create a fine cut, with minimal loss of material and a quality profile. The majority of laser cutting is pre-programmed [CNC] with operator at a distance from the fume source. The particulate fume produced is wholly from the metal being cut. The fume composition is related to the metal alloy being cut. The majority of the gases released are from the laser 'gun', usually CO_2.
Recommended controls for welding fume	Ensure clean, uncoated metal Apply local exhaust ventilation down through cutting table. Where LEV is not adequate to control, RPE may also be required for workers to enter the cutting bed area. RPE is also required ▪ APF of at least 20 ▪ Power-assisted or air-fed RPE ▪ Additional filtration will be required if coating/surface contamination present when filtered devices are selected ▪ *For short-term tasks, type P3 high-efficiency disposable RPE is acceptable. *Not applicable when welding Cd or Be based alloys [10,11] ▪ In oxygen deficient areas e.g. enclosed spaces, RPE should be air-fed.
Possible Actions by National Labour Inspector	**High Health Risk** - Consider **immediate action** when all controls missing/ineffective on chrome steels (e.g. stop work, use of Notices, use of administrative fines etc.) **Medium Health Risk** - Consider **action** in situations where one control is missing/ ineffective (e.g. use of Notices requiring action) or the **Hierarchy of control** has not been followed**,** i.e. RPE without consideration of LEV **Low Health Risk** - No action required where all controls are present and effective
Design Out Risks	
Maintenance of control equipment & respiratory protective equipment (RPE)	▪ Maintenance of equipment at regular intervals (not greater than annually) ▪ Inspection & maintenance of local exhaust ventilation at regular intervals, with routine thorough examination & testing programme ▪ Exposure monitoring should be considered as a check on the effectiveness of control measures in place when welding stainless steel, non-ferrous alloys, or painted or coated metals ▪ Workers should be trained in the correct operation of the equipment.
Other Benefits	▪ Reduced noise levels

TS 7 Laser cutting Page 2 of 2

NO PHOTOGRAPHS AVAILABLE – PROCESS IS ENCLOSED

TS 8 Flame cutting (Torch or Oxy-gas cutting) Page 1 of 2

General Comment	Flame cutting utilises a high temperature oxygen-gas mix to melt & cut through metal. Typical gases are propane or acetylene. The metal being cut determines the gas & settings. This can be a manual or automated operation. The manual task requires the worker to adjust the rate of cut & distance from the substrate metal. An automated cutting system can operate several torches to simultaneously perform a series of parallel cuts. The particulate fume produced is wholly from the metal being cut and can be produced in significant amounts. The fume composition is related to the metal alloy being cut. The majority of the gases released are from the effect of intense heat & radiation [non-ionising] from the flame, e.g. oxides of nitrogen, oxides of carbon.
Recommended controls for welding fume	Ensure clean, uncoated metal. Ensure cutting torch adjusted correctly – blue flame. Manual flame cutting – local exhaust ventilation (mobile or swing arm hood) Automated/fixed installation - Apply local exhaust ventilation down through cutting table. Where LEV is not adequate to control, RPE may also be required for manual workers, or those working alongside the cutting bed area, RPE is also required ▪ APF of at least 20 ▪ Power-assisted or air-fed RPE ▪ Additional filtration will be required if coating/surface contamination present when filtered devices are selected ▪ *For short-term tasks, type P3 high-efficiency disposable RPE is acceptable. *Not applicable when welding Cd or Be based alloys [10,11] In oxygen deficient areas, e.g. enclosed spaces, RPE should be air-fed.
Possible Actions by National Labour Inspector	**High Health Risk** - Consider **immediate action** when all controls missing/ineffective on chrome steels (e.g. stop work, use of Notices, use of administrative fines etc.)
	Medium Health Risk - Consider **action** in situations where control is missing/ineffective on mild/carbon steel (e.g. use of Notices requiring action)or the **Hierarchy of control** has not been followed**,** i.e. RPE without consideration of LEV
	Low Health Risk - No action required where all controls are present and effective
Design Out Risks	▪ Alternative cutting e.g. plasma, laser. ▪ Automate manual cutting, where possible.
Maintenance of control equipment & respiratory protective equipment (RPE)	Inspection & maintenance of local exhaust ventilation at regular intervals, with routine thorough examination & testing programme. ▪ Exposure monitoring should be considered as a check on the effectiveness of control measures in place when welding stainless steel, non-ferrous alloys, or painted or coated metals ▪ Workers should be trained in the correct operation of the equipment.
Other benefits	▪ Reduced noise levels. ▪ Reduced maintenance & cleaning

TS 8 Flame cutting (Torch or Oxy-gas cutting) Page 2 of 2

Photo 1 Poor control practice -Flame cutting without LEV (NLI, SK)

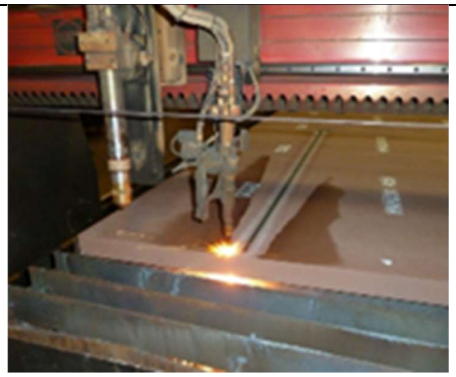


Photo 3 Good control practice - Flame cutting with effective extraction table and remote worker (Miller, GB)

Photo 2 Poor control practice Flame cutting table – poor maintenance (Miller, GB)

Photo 4 Good control practice Flame cutting table – good maintenance (Miller, GB)

TS 9 Arc-air gouging Page 1 of 2

General comment	Arc-air gouging uses the welding principle of an electric arc to melt the metal, but instead of laying down a metal pool, it removes metal. It is mainly used in refurbishment and the exact composition of the bases metal may be unknown. This is predominantly a manual operation/activity. The process produces large quantities of particulate fume, consistent with the base metal. Gases are also produced, similar to MMA/SMAW. The process is also very noisy (>110dBA).
Recommended controls for welding fume	Alternative method for metal removal. Dedicated enclosed area, with extraction & acoustic measures. RPE will be required for all gouging workers: APF of 40 - Powered RPE for tasks less than 30 minutes. Air-fed RPE required for tasks greater than 30 minutes to accommodate high fume levels.
Possible Actions by National Labour Inspector	High Health Risk - Consider immediate action when all undertaken in open shop (e.g. stop work, use of Notices, use of administrative fines etc.) Medium Health Risk - Consider action in situations where any control measure is Ineffective or missing (e.g. use of Notices requiring action) or the Hierarchy of control has not been followed, i.e. RPE without consideration of LEV Low Health Risk - No action required where all controls are present and effective
Design Out Risks	▪ Alternative cutting e.g. plasma, laser. ▪ Automate manual cutting, where possible
Maintenance of control equipment & respiratory protective equipment (RPE)	▪ Maintenance of equipment at regular intervals (not greater than annually) ▪ Inspection & maintenance of local exhaust ventilation at regular intervals, with routine thorough examination & testing programme. ▪ Exposure monitoring should be considered as a check on the effectiveness of control measures in place when welding stainless steel, non-ferrous alloys, or painted or coated metals ▪ Workers should be trained in the correct operation of the equipment.
Other benefits	▪ Reduced noise levels. ▪ Reduced maintenance & cleaning

TS 9 Arc-air gouging Page 2 of 2

NO PHOTOGRAPHS AVAILABLE at this time

APPENDIX 1– NLI Welding Inspection Decision Tool

This '**Welding Inspection Decision Tool**' is provided to assist with the Inspector's judgement on the adequacy of the workplace, but this is not an exposure assessment. It is a semi-quantitative tool which takes the inspector through the steps to consider and gives an *indication* of the level of NLI Action enforcement that may be required, to be considered alongside the employer's assessment.

Due to variability of welding activities in fabrication, it is necessary to determine whether to take action to protect workers performing a wide range of welding tasks. A tool has been devised to assist in this area, especially for Labour Inspectors who are not familiar with welding activities and this contributes to **an initial appraisal**.

The tool addresses four [4] key factors in relation to worker exposure, without engineering controls or RPE. Consideration of the control measures are applied later in the tool.

If any rating category is 'X', then immediate control is likely to be required, as this is likely to equate to a **High** health risk. If the inspector is unsure, **Specialist assistance** should be sought.

The tool focuses on MMA, MAG, MIG, & FCA processes where fume is visible. TIG/GTAW has been omitted on these grounds and the likelihood of requiring engineering control measures is low.

Factors

1. **Fume composition (a)**

The composition is determined by the base metal & compatible consumable [wire or rod], together with a number of potential contaminants & coatings. These can be assigned a rating or numerical value, based on the likely health effects.

Process/activity	Source	Hazardous substance(s)	Rating
GMAW/MIG/MAG	Shield gases + uV	Ar; He; Ar/CO_2; Ozone	0.5
GMAW/MIG/MAG/SMAW/MMA	Mild steel	Fe; Mn	1
GMAW/MIG/MAG/SMAW/MMA	Stainless/chromium steel	Fe; Mn; Cr(VI); Cr(III); Ni	2
All welding	Surface debris, e.g. oil, grease	CO; CO_2; aldehydes	1
All welding	Degreasing residues	HCl; phosgene; chlorinated hydrocarbons	1
SMAW/MMA	Anti-corrosion primers	Fe; Zn; (Cr)	1(2)
SMAW/MMA (repair/refurbishment)	Historic coatings	Pb; Cr;	2
FCAW	Flux	CO; NH_4; Aldehydes	1

The rating is the sum of the values applicable, e.g. MIG on stainless with surface debris – 1 [ozone] + 2 [Cr(VI)/Ni] + 1 (surface debris) = 4

2. **Fume Concentration (b)**

In the absence of exposure monitoring data, it may be necessary to estimate the fume concentration from a visual appraisal. The following is a rough guide to select a 'Rating' for the Inspection Tool.

No persistent fume during welding	0
Light visible fume, slow dispersal, no evident accumulation	1
Visible fume, not dispersing, accumulation in some areas	2
Accumulation resulting in diminished visibility	X

3. Exposure time (c)

This is an estimate of the '**arcing time**' – the percentage of the working period when the arc is struck. This requires observation and careful questioning of welders or their supervisor.

Less than 5%	Spot welders	0
5 – 10%	Platers, Intermittent welding	1
10 – 25%	Full time manual welders	2
>25%	Full time welders, with pre-set activities*	X

Note: these percentages assume the arcing time is spread out across a working shift and not a short period of continuous welding.

* Pre-set activities – where a non-welder sets up the fabrication work, by spot welding & may even undertake the post-weld dressing.

4. Location or working environment (d)

The environment in which welding & associated process are undertaken can have a major effect on an individual's exposure. This can be viewed as the number of sides present in a regular hexahedron (rectangular cuboid).

Outdoors		0
Large open shop	Base plus 1 vertical side	1
Smaller shop*	Base plus 2 or 3 sides	2
Enclosed	Base plus 4 or 5 sides	X

* This may be a welding booth within a larger fabricated unit

Addition of the ratings will give the initial indication of fume exposure. The next stage is to introduce a factor relating to the level of control, excluding RPE.

5. Control Factors (e)

The inspector should assess what level of control is present:

Effective LEV – appropriately design, maintained and used	1
LEV present but poor design OR poor maintenance OR non-use	2
No LEV or other engineering controls	3

The added ratings (paragraphs 1 to 4 above) will give a figure, usually between 3 and 10 [a + b + c + d]. This summed rating is then multiplied by the 'Control Factor' [(a+b+c+d) x e].

Note: this is for guidance and there may be other factors which could affect the actions taken by the NLI.

This final value will give an *indication* of the level of NLI Action enforcement that may be required:

Low = <7; Medium = 8 to 20; High >20

Possible Actions by National labour Inspector	**High Health Risk** - Consider **immediate action** when all controls missing/ineffective (e.g. stop work, use of Notices, use of administrative fines etc.)
	Medium Health Risk - Consider **action** in situations where one control is missing/ ineffective (e.g. use of Notices requiring action) or the **Hierarchy of control** has not been followed**,** i.e. RPE without consideration of LEV
	Low Health Risk - No action required where all controls are present and effective

Additional information on welding work can be found in TRGS 528[7]

APPENDIX 2– List of SLIC CHEMEX Long Latency Sub-Working Group member organisations

MEMBER STATE	REPRESENTATIVE
BELGIUM	Federal Public Service Employment Labour and Social Dialogue General Directorate Wellbeing at Work Department of the supervision on chemical risks Laboratory for Industrial Toxicology (LIT) WTC III - Simon Bolivarlaan 30 bus 6 - 1000 Brussels Belgium
ESTONIA	Labour Inspectorate of Estonia Mäealuse 2/3 12618 Tallinn Estonia
IRELAND	Chemical and Prevention Division Health and Safety Authority Government Buildings The Glen Waterford Ireland
ITALY	National Institute for Insurance against Work Accidents (INAIL) Piazzale Giulio Pastore, 6 00144 Rome Italy Department of Occupational and Environmental Medicine, Epidemiology and Hygiene and Department of Technical Advice for Risk Assessment and Prevention
NETHERLANDS	Occupational Hygiëne and Chemical Safety Centre for Expertise Dutch Labour Inspectorate Inspectie SZW Parnassusplein 5 P.O. Box 90801 2509 LV The Hague
SWEDEN	Swedish Work Environment Authority Department of Regulation SE-112 79 Stockholm Sweden
UNITED KINGDOM	Health and Safety Executive (HSE) Field Operations Division, Occupational Hygiene / Noise & Vibration Unit Redgrave Court Merton Road Bootle, L20 7HS United Kingdom