

REACH and the Welding of Metals and Alloys

Important Notice

In accordance with the requirements of REACH (Regulation EC 1907/2006), this document is intended to provide guidance on safe use for downstream users with regard to fume and gases generated during welding of metals and alloys.

It is provided as a summary document and, as such, it is neither intended as a treatise on welding nor as a comprehensive account of all aspects of health and safety associated with the welding process. Thus, the following aspects of welding are not addressed by this document:-

- Fire protection
- Welder Training and Accreditation
- Equipment Maintenance
- Approval of Welding Techniques or Welding Equipment
- Safety of Gas Cylinders and Gas Supply Systems
- Gas Storage Systems
- Treatment of Electric Shock
- Adhesive Bonding

Users are advised to consult their national regulations on all aspects of health and safety related to welding.

The text on health hazards and the health effects of welding is drawn from a number of sources in the public domain. It is, therefore, important to note that neither the contributors nor the authors necessarily agree with all statements made in connection with these aspects of the document. In this respect, no liability is accepted for its content, the accuracy of its content or for the use, which might be made of the following information.

It is also important to note that a risk assessment of welding fume has been undertaken in, at least, one EU Member State. In Germany, welding experts classify welding fume according to the hazards associated with chemical species found in the welding plume is this meant to be fume or plume (e.g. carcinogenic, toxic, etc). However, the contributors and authors of this document have elected to treat all welding fume as potentially harmful (i.e. welding fume is assumed to have a risk ratio > 1) irrespective of the substances involved in the welding process or, indeed, the welding method itself. This approach does not imply that the substrate metals and alloys, filler metals and alloys, welding fluxes or gases are themselves harmful to human health or the environment.

REACH and the Welding of Metals and Alloys

1. Introduction

REACH requires manufacturers and importers to prepare Chemical Safety Assessments for substances that meet the criteria specified in EC Regulation 1272/2008. The concept of “Duty of Care” enshrined in REACH means that Exposure Scenarios are also needed where identified uses of substances generate additional hazards sufficient to require guidance for safe use such as the welding of metals and alloys.

Chemical Safety Assessments include Exposure Scenarios and recommendations for risk management measures and operational conditions for safe use. However, it is important to note that many metals and alloys are placed on the market in the form of articles, which are subsequently welded and, in this context, Article 33 requires safe use information to be available for the article.

A multi-metal, multi-interest group has been formed in an attempt to establish a common basis for incorporation of welding aspects into substance Chemical Safety Assessments. The group agreed to commence work to develop recommendations for Risk Management Measures and to identify Operational Conditions under which metals, alloys and metallic articles may be safely welded.

Few of the metal risk assessments conducted under the Existing Substances Regulation 793/93/EEC specifically addressed the potential human health or environmental impacts of welding processes and associated welding fume/dust. This is not surprising when the variety and complexity of welding techniques are considered. Welding processes have a unique exposure profile, where extreme heat, high radiant energy, high electromagnetic fields, splatter and fume are often featured. There are several reasons why welding is a potentially dangerous occupation:

- there are a multiplicity of factors that can endanger the health of a welder, such as heat, burns, radiation, noise, fumes, gases, electrocution, and even the uncomfortable postures involved in the work;
- the high variability in chemical composition of welding fumes which differs according to the workpiece, welding process employed, and surrounding environment; and
- the routes of entry through which these harmful agents access the body. The adverse health effects of welding come from chemical, physical, and radiation hazards.

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Common chemical hazards include particulates and noxious gases. Physical hazards include electrical energy, heat, noise, optical and vibration.

Electromagnetic radiation occurs at visible, ultraviolet, and infrared wavelengths. Welding is associated with a number of non-respiratory health hazards. Most common among them are the effects of electricity, heat, and electromagnetic radiation. However, the increased risk of lung cancer/respiratory impairment in welders appears to be largely non-substance specific.

For these reasons, the welding WG proposed that welding fume/dust be treated as potentially hazardous and to collate existing data, existing risk management recommendations substances and welding fume in order to develop welding-related Safe Use Information for REACH. Although it is anticipated that some limited studies may be necessary in order clarify/propose suitable risk management measures, it is not envisaged that these studies would progress towards a full risk assessment of welding processes prior to the submission of the substance technical dossiers.

The project consists of identifying: (i) the welding, cutting and allied processes to be covered by the Exposure Scenario(s), (ii) the dust/fume levels generated by these processes, (iii) operator and operational conditions (e.g. ventilation), (iv) the duration of exposures and (v) existing risk management measures for protection of human health and the environment for welding and hazardous substances found in welding fume. This information was then collated into a matrix from which consultants could develop non-substance specific Exposure Scenarios. Ideally with the support of a member state sponsor, industry will seek discussions with ECHA and the Commission in order to inform them of this approach.

2. Welding processes

Welding is widely used to join pieces of metals and alloys by the use of heat, pressure, or both. Some of the techniques used in welding are also used for metal and alloy cutting.

There are more than 80 different types of welding and associated processes. Some of the most common types of welding include: arc welding, which includes "stick", or shielded metal arc welding (SMAW), the gas-shielded methods of metal inert gas (MIG) and tungsten inert gas (TIG), plasma arc welding (PAW), and submerged arc welding (SAW). Other welding processes may use oxy-acetylene gas, electrical current, lasers, electron beams, friction, ultrasonic sound, chemical reactions, heat from fuel gas, and robots.

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3. Health hazards of welding⁽¹⁾

Welding of metals and alloys is well established. Hazards and control of risks are well understood. Hazards of welding are mainly associated with the fume generated during the process.

It is important, however, to emphasise that, even though welding fume may pose a health hazard, the application of appropriate Risk Management Measures to welding processes conducted in accordance with Operational Conditions designed to minimise the generation of welding are sufficient to provide adequate protection for welders.

Welding fume is a mixture of very fine particles of substances and gases. Generally, welding fumes and gases come from:-

- the base material being welded or the filler materials (in the form of wires, flux coated electrodes, powder cored electrodes, fluxes, slags etc.) that are used;
- coatings, paints and oil on the metal being welded, or coatings covering the electrode;
- shielding gases supplied from cylinders;
- chemical reactions which result by the action of ultraviolet light from the arc, and heat;
- contaminants in the air, for example vapours from cleaners and degreasers;
- dust from insulating materials

Many of the substances such as compounds of chromium⁽²⁾, nickel, manganese⁽²⁾, silicon, beryllium, cadmium, cobalt, copper, selenium, lead, fluorine and zinc as well as dust from insulating materials, nitrogen oxides, phosgene, carbon monoxide and ozone, can be toxic.⁽³⁾⁽⁴⁾

The health and environmental effects of exposure to welding fumes are difficult to list, because they may contain so many different substances that are known to be harmful (depending on the factors listed above). Furthermore the composition of fumes can vary during welding as parameters such as the heat input, voltage and current changes. The individual components of welding fume can affect just about any part of the body, including the lungs, heart, kidneys, and central nervous system as well as presenting potential hazards to the environment. Where appropriate, environmental protection is provided by collection and safe disposal or recycling of the fumes.⁽⁹⁾

The effects of exposure to welding fumes have been extensively studied and reported on. **Results are not entirely consistent and some of the claimed effects are disputed.** Some of these reported short and long-term effects are:

3.1 Short-term (acute) Health Effects

Exposure to fumes containing metal compounds (such as those of zinc, magnesium, and copper) can “cause metal fume fever”. Symptoms of metal fume fever may occur 4 to 12 hours after exposure, and include chills, thirst, fever, muscle ache, chest soreness, coughing, wheezing, fatigue, nausea, and a metallic taste in the mouth. ⁽¹⁾

Welding fume can also irritate the eyes, nose, chest, and respiratory tract, and cause coughing, wheezing, shortness of breath, bronchitis, pulmonary oedema (fluid in the lungs) and pneumonitis (inflammation of the lungs). Gastrointestinal effects, such as nausea, loss of appetite, vomiting, cramps, and slow digestion, have also been associated with welding. ⁽¹⁰⁾⁽¹¹⁾

Some components of welding fume, for example cadmium, can be fatal in a short time. Gases given off by the welding process can also be extremely dangerous. For example, ultraviolet radiation given off by welding, causes oxygen and nitrogen in the air to react to form ozone and nitrogen oxides. These gases are deadly at high doses, and can also cause irritation of the nose and throat and serious lung disease ⁽⁹⁾

Ultraviolet rays given off by welding can also catalyse the formation of phosgene gas from hydrocarbon solvents, such as trichloroethylene, 1,1,1-trichloroethane, methylene chloride, and perchloroethylene. Even a very small amount of phosgene may be deadly, although early symptoms of exposure - dizziness, chills, and cough - usually take 5 or 6 hours to appear. ⁽¹⁾

3.2 Long-term (chronic) Health Effects

Studies of insufficiently protected welders, flame cutters, and burners have shown that welders have an increased risk of lung cancer, and possibly cancer of the larynx (voice box) and urinary tract. ⁽¹⁾

These findings are not surprising in view of the large quantity of toxic substances in welding fume, including cancer-causing agents such as compounds of cadmium, nickel, beryllium, and chromium. Welders may also experience a variety of chronic respiratory (lung) problems, including bronchitis, asthma, pneumonia, emphysema, pneumoconiosis (refers to dust-related diseases), decreased lung capacity, silicosis (caused by free crystalline silica exposure), and siderosis (a dust-related disease caused by iron oxide dust in the lungs). ⁽⁵⁾

Other health problems that appear to be related to welding include: heart disease, skin diseases, hearing loss, and chronic gastritis (inflammation of the stomach), gastroduodenitis (inflammation of the stomach and small intestine), and ulcers of

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the stomach and small intestine. Welders exposed to fumes containing compounds of chromium and nickel have also experienced kidney damage but a study of stainless steel (that contains both chromium and nickel) reported no significant renal impairment. ⁽⁶⁾

Welding also poses reproductive risks to welders. A recent study found that welders, and especially welders who worked with stainless steel, had poorer sperm quality than men in other types of work. ⁽⁷⁾ Several studies have shown an increase in either miscarriages or delayed conception among welders or their spouses. ⁽¹⁾ Possible causes include exposure to: (1) metal compounds, such as those of aluminium, chromium, nickel, cadmium, iron and copper, (2) gases, such as nitrous gases and ozone, (3) heat, and (4) ionising radiation (used to check the welding seams).

3.3 Other Health and Safety Hazards

Other hazards associated with welding include exposure to heat, noise, electrical and radiation hazards, muscular injuries, optical injuries (arc eye), etc. that are not specifically related to substances and therefore outside the scope of REACH.

4. Existing Risk Management of Welding

Information on safe practices to be used in welding is generally provided with safety data sheets that accompany welding consumables. They include requirements on all safety aspects including hazards and risk management measures.

Welding and allied processes generate fume and gases, which, if inhaled, can be harmful to human health. Control is often required to maintain exposure at acceptable levels and this is achieved as far as possible by capturing the fume and gases using local exhaust ventilation (LEV), which consists of a capture device, such as a captor hood or nozzle, connected, via ducting, to an exhaust system, or by the use of an on-gun welding fume extraction device. This is supplemented by room ventilation (RV) and personal protective equipment (PPE) including masks and filters when necessary.

There are no EU or international standards on welding fume. Many jurisdictions specify maximum allowed levels of fume and often limits for individual substances within the fume as well (e.g. Austrian legislation BGBl. II Nr. 119/2004 revised under BGBl. II Nr. 243/2007). There are also standards for routine monitoring of air quality to detect hazardous substances. (UK HSE Guidance EH54 "Assessment of exposure to fume from welding and allied processes").

Exhausted welding fume, with exception of that generated from welding unalloyed steel and aluminium, is filtered and the dust collected for disposal or

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recycling before discharge into the environment. National maximum allowable limits apply to such discharges, while the collected dust is regarded waste that must be characterized in accordance with European Waste Catalogue and treated appropriately as hazardous or non-hazardous waste.

5. Proposal for Risk Assessment and Risk Management Measures of Welding Processes and Compliance with REACH

5.1 Risk from Substances in Welding Fume

The welding process is characterised by the presence of a number of substances potentially hazardous to health, present both as part of the welding materials (rod, core etc.), components of the surfaces to be welded and dust forming materials in the environment.

The purpose of carrying out a risk characterisation for a specific substance in REACH is to lead to a conclusion, which, where appropriate, results in a proposal for a risk reduction strategy or for further information. An analysis of a complex process involving a possibly large number of potentially hazardous substances is not well addressed by risk characterisations for any single component of the process, unless the effects seen can be directly attributed to the presence of that component. For example, the available evidence on welding of nickel and nickel containing alloys does not suggest that the effects seen after exposure to welding fumes are directly attributable to nickel alone, so that specific risk reduction measures for nickel are not appropriate.

It is therefore concluded that the welding process should be considered as a candidate for a process oriented risk assessment. Such a risk assessment would lead to risk reduction measures addressing all relevant aspects of the process, rather than only those aspects related to the presence of the many individual substances present in the generated fume.⁽⁸⁾

5.2 Welding Fumes and REACH Annex V

The UK Health and Safety Executive documentation (hse.gov.uk exemptions) includes welding fume as an example of process gases that are exempt from REACH registration according to Annex V. However, ECHA draft guidance on Annex V (echa.europa.eu) states that any risks from the process gas should be covered in the Chemical Safety Assessment of the substances involved in the process itself. This means for example, that in considering the welding of steel the Chemical Safety Assessments in the registration documents for all the substances within the steel and consumables, including binders and fluxes, will have to include consideration of welding in Exposure Scenarios and appropriate welding risk management measures.

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5.3 Risk Categorisation for Welding and Risk Management

The degree of risk during welding depends on the composition of the fume, concentration of the fume and duration of exposure. The concentration of the fume varies greatly between the different welding processes and the ventilation at the welding site. A large database of information has been compiled by TWI with sponsorship provided by the UK Health and Safety Executive and the Nickel Institute with the objectives of

- examining the health effects of exposure to welding fume
- establishing exposure limits
- examining the economic effects of prescribing exposure limits
- examining exposure levels for a particular welding process etc.

Risks are well understood and risk management measures including personal protective equipment requirements are described in existing data sheets provided with welding consumables.

Based on this information it is possible to incorporate risks for all welding situations into one of eight categories suitable for use in Chemical Safety Assessments for REACH registration for substances.

A draft of the proposal is illustrated in the following table and provides a basis for guidance for safe use of all welding processes and consumables. Category 1 includes very low risk welding processes such as resistance welding of steel that produces little if any fume. Other higher risk categories include welding of metals classified as toxic, processes that produce larger amounts of fume and welding in confined spaces etc. For each category, risk management measures for safe working, including use of appropriate personal protective equipment, to meet exposure limits in all jurisdictions are defined.

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Recommendations for Exposure Scenarios, Risk Management Measures and to identify Operational Conditions under which metals, alloys and metallic articles may be safely welded

Welding/Brazing produces fumes, which can affect human health and the environment. Fumes are a varying mixture of airborne gases and fine particles, which, if inhaled or swallowed, constitute a health hazard. The degree of risk will depend on the composition of the fume, concentration of the fume and duration of exposure. The fume composition is dependent upon the material being worked, the process and consumables being used, coatings on the work such as paint, galvanizing or plating, oil or contaminants from cleaning and degreasing activities. A systematic approach to the assessment of exposure is necessary, taking into account the particular circumstances for the operator and ancillary worker that can be exposed.

Considering the emission of fumes when welding, brazing or cutting of metals, it is recommended to (1) arrange risk management measures through applying general information and guidelines provided by this guidance on safe use and (2) using the information provided by Safety Data Sheets, issued in accordance with REACH, by the substance producer, the alloy manufacturer or the welding consumable manufacturer.

The employer shall ensure that the risk from welding fumes to the safety and health of workers is eliminated or reduced to a minimum. The following principles shall be applied:

- 1- Select the applicable process/material combinations with the lowest class, whenever possible.
- 2- Set welding process with the lowest emission parameter.
- 3- Apply the relevant collective protective measures in accordance with the class number. In general, the use of PPE is taken into account after all other measures are/is applied.
- 4- Wear the relevant personal protective equipment in accordance with the duty cycle.

In addition, compliance with the National Regulations regarding the exposure to welding fumes of welders and related personnel shall be verified.

In the table “Risk Management Measures for individual process / material combinations” below, reference is made to the following standards for collective and personal protection measures:

ISO 4063	Welding process Reference Numbers according to ISO 4063
EN ISO 15012-1:2004	Health and safety in welding and allied processes - Requirements testing and marking of equipment or air filtration - Part 1: Testing of the separation efficiency for welding fume
EN ISO 15012-2:2008	Health and safety in welding and allied processes - Requirements, testing and marking of equipment for air filtration - Part 2: Determination of the minimum air volume flow rate of captor hoods and nozzles
EN 149:2001	Respiratory protective devices - Filtering half masks to protect against particles - Requirements, testing, marking (FFP1 - FFP2 - FFP3)

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EN 1835:2000	Respiratory protective devices. Light duty construction compressed air line breathing apparatus incorporating a helmet or a hood. Requirements, testing, marking (LDH1 - LDH2 - LDH3).
EN 12941:1998	Respiratory protective devices. Powered filtering devices incorporating a helmet or a hood. Requirements, testing, marking (TH1 - TH2 - TH3).
EN 143:2000	Respiratory protective devices — Particle filters — Requirements, testing, marking (P1, P2, P3) Directive 1998/24/EC Article 6.2 on the protection of the health and safety of workers from the risks related to chemical agents at work
BGR 190	Benutzung von Atemschutzgeräten (Berufsgenossenschaftliche Regel für Sicherheit und Gesundheit bei der Arbeit)
TRGS 528	Schweisstechnische Arbeiten (Technische Regeln für Gefahrstoffe)

Also in the table “Risk Management Measures for individual process / material combinations”, reference is made to footnotes.

The description of these footnotes:

- ¹ Class: approximate ranking to mitigate risk by selecting process/material combinations with the lowest value. Identified collective and individual risk management measures shall be applied
- ² Personal Protective Equipment (PPE) required avoiding exceeding the National Exposure Limit Value (DC: Duty cycle expressed on 8 hours)
- ³ General Ventilation (GV) Low. With additional Local Exhaust Ventilation (LEV) and extracted air to the outside, the GV or LEV capacity may be reduced to 1/5 of the original requirement.
- ⁴ General Ventilation (GV) Medium (double compared to Low)
- ⁵ Filtrating half mask (FFP2)
- ⁶ When an alloyed consumable is used, measures from "Class V" are required
- ⁷ General Ventilation (GV) Low. When no Local Exhaust Ventilation, the ventilation requirement is 5-fold
- ⁸ Filtrating half mask (FFP3), helmet with powered filters (TH2/P2), or helmet with external air supply (LDH2)
- ⁹ Reduced (negative) pressured Area: A separate, ventilated area where reduced (negative) pressure, compared to the surrounded area, is maintained
- ¹⁰ Local Exhaust Ventilation (LEV) High, extraction at source (includes table, hood, arm or torch extraction)
- ¹¹ Helmet with powered filters (TH3/P3), or helmet with external air supply (LDH3)
- ¹² Local Exhaust Ventilation (LEV) Low, extraction at source (includes table, hood, arm or torch extraction)
- ¹³ Local Exhaust Ventilation (LEV) Medium, extraction at source (includes table, hood, arm or torch extraction)
- ¹⁴ Recommended measures to comply with national maximum allowable limits. Extracted fumes, for all materials except unalloyed steel and aluminium, shall be filtered before release in the outside environment.
- ¹⁵ A confined space, despite its name, is not necessarily small. Examples of confined spaces include ship, silos, vats, utility vaults, tanks, etc.
- ¹⁶ Improved helmet, designed to avoid direct flow of welding fumes inside
- n.a. Not applicable
- n.r. Not recommended

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Risk Management Measures for individual process / base material combinations

Class ¹	Process (according to ISO 4063)	Base Materials	Remarks	Ventilation / Extraction / Filtration ¹⁴	PPE ² DC<15%	PPE ² DC>15%
Unconfined space¹⁵						
I	GTAW 141	All	Except Aluminium	GV low ³	n.r.	n.r.
	SAW 12					
	Autogeneous 3					
	PAW 15					
	ESW/EGW 72/73					
	Resistance 2					
	Stud welding 78					
	Solid state 521					
Gases Brazing 9	All	Except Cd- alloys	GV low ³	n.r.	n.r.	
II	GTAW 141	Aluminium	n.a.	GV medium ⁴	n.a.	FFP2 ⁵
III	MMAW 111	All	Except Be-, V-, Mn-, Ni- alloys and Stainless ⁶	GV low ⁷ LEV low ¹²	Improved helmet ¹⁶	FFP2 ⁵
	FCAW 136/137	All	Except Stainless and Ni- alloys ⁶			
	GMAW 131/135	All	Except Cu-, Be-, V- alloys ⁶			
	Powder Plasma Arc 152	All	Except Be-, V-, Cu-, Mn-, Ni-alloys and Stainless ⁶			
IV	All processes class I	Painted / primed / oiled	No Pb containing primer	GV low ³	FFP2 ⁵	FFP3, TH2/P2, or LDH2 ⁸
	All processes class III	Painted / primed / oiled	No Pb containing primer	GV low ⁷ LEV low ¹²		
V	MMAW 111	Stainless, Ni-, Be-, and V- alloys	n.a.	LEV high ¹⁰	TH3/P3, LDH3 ¹¹	TH3/P3, LDH3 ¹¹
	FCAW 136/137	Stainless, Mn- and Ni- alloys				
	GMAW 131	Cu-alloys				
	Powder Plasma Arc 152	Stainless, Mn-, Ni-, and Cu- alloys				
VI	GMAW 131	Be-, and V- alloys	n.a.	Reduced (negative) pressured area ⁹ LEV low ¹²	TH3/P3, LDH3 ¹¹	TH3/P3, LDH3 ¹¹
	Powder Plasma Arc 152					
VII	Self shielded FCAW 114	Un-, high alloyed steel	Cored wire, not containing Ba	Reduced (negative) pressured area ⁹ LEV medium ¹³ LEV high ¹⁰	TH3/P3, LDH3 ¹¹	TH3/P3, LDH3 ¹¹
	Self shielded FCAW 114	Un-, high alloyed steel	Cored wire, containing Ba			
	All	Painted / primed	Paint / Primer containing Pb			
	Arc Gouging and Cutting 8	All	n.a.			
	Thermal Spray	All	n.a.			
	Gases Brazing 9	Cd- alloys	n.a.			
Closed system or Confined space¹⁵						
I	Laser Welding 52	All	Closed system	GV medium ⁴	n.a.	n.a.
	Laser Cutting 84					
	Electron Beam 51					
VIII	All	All	Confined space	LEV high ¹⁰ External air supply	LDH3 ¹¹	LDH3 ¹¹

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