Welding Fumes Risks and Solutions

HANDBOOK FOR WELDERS
Welding generates fumes and releases hazardous substances and particles. This also applies for welding related operations such as grinding, cutting and sanding. An unhealthy workshop inevitably results in reduced capacity, disturbances and decreased profit. The awareness of health and environmental effects is increasing - people demand the right to safe and clean workplaces. Companies providing its personnel with adequate protection and safety improve their competitiveness. Quality of life is an opportunity to create a win-win situation.
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MMA: Manual Metal Arc Welding or SMAW: Shielded Metal Arc Welding

Manual Metal Arc (MMA) Welding, also known as Shielded Metal Arc Welding (SMAW) (or informally as stick welding), is a manual arc welding process that uses a consumable electrode coated in flux to lay the weld. An electric current is used to form an electric arc between the electrode and the metals to be joined.

As the weld is laid, the flux coating of the electrode disintegrates, giving off vapors that serve as a shielding gas and providing a layer of slag, both of which protect the weld area from atmospheric contamination. Shielded metal arc welding is one of the world’s most popular welding processes. It dominates other welding processes in the maintenance and repair industry, and though flux-cored arc welding is growing in popularity,

SMAW continues to be used extensively in the construction of steel structures and in industrial fabrication. Materials commonly welded using the SMAW process include mild steel and stainless steel. Aluminum, nickel and copper alloys can also be welded with this method.

Electrode types

Flux-coated electrodes are available in many core wire diameters and lengths. Available types include aluminum bronze, bronze, mild steel, nickel, and stainless steel.
FCAW: Flux-Cored Arc Welding

Flux-cored arc welding (FCAW) is a process that is widely used. The welding procedure is fast and the welder does not have to stop and change rods. A disadvantage is the heavy smoke generation. Good ventilation and fume extraction is necessary. The FCAW method is very similar to the MIG and MAG welding methods (see next page).

FCAW uses a tubular wire, supplied on reels, with the core filled with a mixture of fluxing elements, deoxidizing and denitriding agents, and alloying materials, as well as elements that increase toughness and strength, improve corrosion resistance, and stabilize the arc. Typical core materials may include aluminum, calcium, carbon, chromium, iron, manganese, and other elements and materials.

Additional shielding can be provided by an externally supplied gas or gas mixture. The process is referred to as gas-shielded (FCAW-GS) and it is always used when stainless steel is welded.

The flux filled wire is automatically fed through the center of the gun. A shielding gas is normally used and this is supplied via the gun, to protect the weld pool from oxidation.
MIG (metal inert gas welding) and MAG (metal active gas welding) The GMAW welding process is usually known as MIG or MAG welding. MIG and MAG are commonly used in industries such as the automobile industry, where versatility and speed is necessary. MIG and MAG are suitable for sheet metals and similar materials. MIG is a form of arc welding where the molten weld pool is protected from oxidization by a shielding gas (usually argon). The wire electrode is fed from a reel through the tip of the welding torch simultaneously with the gas. The gas forms a plasma to sustain the arc and channels the weld material from the electrode onto the weld pool. MAG welding uses CO₂ as shielding gas.
TIG: Tungsten Inert Gas Welding

Like MIG welding, TIG welding is a form of arc welding in which the molten weld pool is protected from oxidization by a shield of inert gas, such as argon. Unlike MIG, the electrode is made of tungsten and is not consumed during welding. If additional material is needed in the weld, a separate filler is required, as in gas welding.
Like TIG welding, the arc in plasma welding and cutting is generated between a non-consumed electrode (typically tungsten) and the workpiece. The electrode tip, however, is positioned within the body of the torch and a plasma gas (separate from the shielding gas) is pumped around the tip through a fine bore inner nozzle. The arc is constricted by the plasma flow and therefore a high energy concentration is achieved with relatively low currents. The high energy concentration and the high speed flow of plasma out of the nozzle makes it possible to cut through metal using the plasma arc, melting just a small area and then blowing out the molten metal. With lower currents and a filler material, the technique can also be used for welding.
In CMT welding the workpieces to be joined and the weld zones remain considerably “colder” than with conventional gas metal arc welding. The process is based on short-circuiting transfer, with systematic discontinuing of the arc. The result is a “hot-cold-hot-cold” sequence, which significantly reduces the arc pressure. Every time short-circuiting occurs, a digital process control interrupts the power supply and controls the retraction of the wire. The forward and back motion takes place at a rate of up to 70 times per second. The wire retraction motion prevents droplet partitioning during the short circuit and the minimal current metal transfer greatly reduces the heat generation in the process.

The reduced thermal input means low distortion and higher precision including higher-quality welded joints, freedom from spatter, ability to weld light-gauge sheet (as thin as 0.3 mm/ 0.118”) as well as the ability to join both steel to aluminum and galvanized sheets. The process is mainly designed for automation and robot-assisted applications.

During the arcing period, the filler metal is moved towards the weldpool.

When the filler metal dips into the weld-pool, the arc is extinguished. The welding current is reduced.

The rearward movement of the wire assists droplet detachment during the short circuit. The short-circuit current is kept small.

The wire motion is reversed and the process begins all over again.
Different welding methods give rise to different amounts of fumes containing different concentrations of hazardous substances. Among the high-risk elements are hexavalent chromium Cr(VI), manganese, nickel and lead. The particles at source are often extremely small; 0.01-0.1 μm which means they are very easy to inhale deep into the lungs.

Furthermore, not only welders are at risk in unsafe environments. Production equipment, as well as end products, are negatively affected from the lack of adequate safety measures. Automated welding equipment such as robots - and its operators - can be subject to residual fumes and also need to be protected.

Airborne particles from 2 weeks welding. One single welder produces 20-40 g fumes per hour which corresponds to about 35-70 kg per year
Welders are exposed to dangerous gases and particulate matter

**Formation/Composition**
Particulate fume is formed mainly by vaporisation of metal and flux. As it cools, the vapor condenses and reacts with the atmospheric oxygen to form fine particles.

The size of the particles (0.01 -1µm) tends to influence the toxicity of the fumes, with smaller particles presenting a greater danger.

Additionally, many processes produce various gases (most commonly carbon dioxide and ozone, but others as well) that can prove dangerous if ventilation is inadequate.

**Fume composition is determined by the composition of the consumable**
Around 90% of the fume originates from the consumable, while the base metal only contributes very little.

The fume contains all the elements present in the consumable, but often in very different proportions. Volatile components have a higher concentration in the fume than in the consumable and the opposite is true for components with a high melting point.

**The welding process affects the fume composition**
The amount of welding fume varies between different welding processes: Fume from manual metal arc (MMA) welding and fluxcored arc welding (FCAW) contains a high proportion of components coming from the electrode coating or the flux core. Comparatively little comes from the filler metal.

Fume from metal inert gas (MIG) and metal active gas (MAG) welding contains high concentrations of the metals being deposited.

*Fume generation during welding.*
The intense heat of the electric arc vaporizes a fraction of the metal in the electrode and weld pool. Any metal vapor that escapes the arc area condenses as it cools and oxidizes into weld fume. The vapor that develops condenses as it cools and oxidizes into weld fume containing a complex mixture of metal oxides.
The diameter of welding fume particles can be from below 0.01 to over 0.1 µm at source. When the particles reach the welder’s breathing zone agglomeration has occurred, creating fume particles in the size of 1–2 µm. The size of the particles is important because it controls the depth to which they penetrate the respiratory system. Particles larger than 5 µm are deposited in the upper respiratory tract. Particles in the range of 0.1 - 5 µm, which includes welding fumes, penetrate the inner parts of the lungs (the alveoli) and are deposited there.

The welding fume particles agglomerate to form particles up 2 µm in size.
Our respiratory system, particle sizes

10 – 2 µm are separated in the throat

2 – 0.5 µm are separated in the windpipe

<0.5 µm reaches all the way to the lungs

Particles <5 µm are the “respirable part” as they may enter into the lungs
Welding fume health risks

The particles in welding fume are small enough to be suspended in the air for a long time. They can be inhaled and penetrate into the innermost area of the lungs. Over time, the particles can even reach the bloodstream. Fume from MMA and FCAW welding usually contains significant quantities of hexavalent chromium Cr(VI). This is important to observe because hexavalent chromium Cr(VI) has a very low exposure limit. There are also risks due to the presence of manganese, nickel and other elements.

**Chromium VI – Cr(VI)**

Stainless steel is a ferrous alloy with a minimum of 10.5 % chromium content. The chromium in the steel combines with oxygen in the atmosphere to form a thin, invisible layer of chrome-containing oxide, which enhances the corrosion resistance. Hexavalent chromium or Cr(VI) compounds are those that contain the element chromium in the +6 oxidation state. Chromium in the base material and the welding electrode (consumable) does not normally appear in the form of hexavalent chromium.

However, during the welding process the alkali based flux compound reacts with the chromium generating Cr(VI), which emits into the welding fumes. Cr(VI) is a known carcinogen and investigations have clearly shown that exposure to Cr(VI) can have a very dangerous effect on health.

**Manganese**

Manganese is essential to iron and steel production by virtue of its sulfur-fixing, deoxidizing, and alloying properties. Manganese is also a key component of low-cost stainless steel formulations. Long-term or chronic exposure to manganese fumes or dust at high concentrations can damage the nervous system and respiratory tract, as well as having other adverse effects. Wide spectrums of neuropsychiatric illnesses have been described with manganese toxicity. Among the neurological effects is an irreversible Parkinsonian-like syndrome. The neurological disorder resulting from this type of manganese toxicity is known as Parkinson’s Manganism.

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**Consequences of exposure to welding fumes**

- Lung cancer
- Asthma
- Nasal septum ulcerations
- Skin ulcerations (known as chrome holes)
- Allergic and irritant contact dermatitis
- Siderosis (lung disease)
- Reproduction and fertility complications
- Infarction
Standards and regulations

Exposure concentration limits
International health organizations have recognized the importance of preventing potential health hazards associated with fumes and gases generated during welding operations. Laws and regulations are continuously becoming more demanding.

Most countries have also specific health and safety regulations to reduce and control exposure to welding fumes. The regulations limit the amount or concentration of a substance in the air and stipulate concentrations below which the health risks from the substances in question are acceptable. The exposure limits are measured in ppm, mg/m³ etc and may be averaged over a time period or as a maximum acceptable concentration. In USA, OSHA* sets the enforceable permissible exposure limits (PELs), which are based on an 8-hour time weighted average (TWA) exposure.

In 2006 and 2007 dramatically tougher permissible levels for exposure to chromium and manganese were introduced in USA and Sweden. OSHA stipulates the permissible exposure limits shown below.

* Occupational Safety and Health Administration

SOME EXAMPLES OF EXPOSURE LIMITS
OF WELDING FUMES DURING 8 HOURS (mg/m³):

<table>
<thead>
<tr>
<th></th>
<th>Czech Republic</th>
<th>USA</th>
<th>Sweden</th>
<th>Germany</th>
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<tbody>
<tr>
<td></td>
<td>Tel*</td>
<td>HTC**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cr (VI)</td>
<td>0.5</td>
<td>1.5</td>
<td>0.005</td>
<td>0.02</td>
</tr>
<tr>
<td>Manganese</td>
<td>1</td>
<td>2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Nickel</td>
<td>0.5</td>
<td>1</td>
<td>1.5</td>
<td>0.1</td>
</tr>
</tbody>
</table>

*TEL  Tolerance exposure limit
**HTC  Highest tolerance concentration
Welding should always take place in a well ventilated area to allow the toxic fumes and gases to escape. Central ventilation systems or extraction hoods over workbenches are often completely inadequate: the welder or operator cannot avoid inhaling the fumes as these always contaminate the general airflow. Nor are systems like these cost-effective: they require a great deal of power to run as they extract enormous quantities of heated air from the premises.

Extraction-at-source most effective

Wherever it is a viable solution, it has been proven that extraction-at-source is the most effective and efficient method of capturing and removing welding and similar fumes. Using this method, the risk of the welder or operator being subject to hazardous fumes is minimized.
Extraction arms

The fume extraction hood must be positioned close to and above the arc at an angle of about 45°. To avoid the risk of fume inhalation, the welder’s head must be kept outside the extraction zone. The extraction is carried out with low vacuum. The recommended air volume is 353 – 1120 cfm (= 600 - 1900 m³/h) depending on type of extraction arm.

If the nozzle is placed on a surface, the extraction efficiency is increased.

Nederman extension arms (4.2 and 6 m / 13.8 ft and 19.7) extend the working areas of extraction arms.

The extraction air velocity is a quadratic function of the distance.
Welding torches with integrated extraction (On-torch extraction)

Welding torches with integrated extraction (on-torch extraction) is a form of extraction-at-source which allows the welder to work over big areas as well as inside constructions. Extraction efficiency ranges from 70-98% depending on the welding method, type of shielding gas, the material and the skills of the welder. On-torch extraction is especially suitable for robotic welding.

On-torch extraction implies that lower air volumes are extracted from the work shop, which is cost effective as it reduces the amount of heated/conditioned air extracted from the premises.

Welding torches with on-torch extraction have an integrated vacuum hose. The diameter of the hose is normally about 25 mm (1 inch). Most welders will get used to the increased diameter and size of the torch within 1-2 weeks. The disadvantage of having an increased diameter is, however, compensated by minimizing the risk of the welder being subject to hazardous fumes. Should it be necessary a balancer may be used to relief the welder from retaining the entire weight of the torch.

On-torch needs high vacuum
On-torch extraction uses high vacuum technology, i.e. high speed extraction and low air volumes to extract the fumes. The extent of disturbance created in the shielding gas depends on the type of gas used. Argon and Mison are light gases that are disturbed more easily, while CO₂ is a heavy gas that is less sensitive. By increasing the gas pressure the effects of shielding gas disturbance are eliminated.
Robotic welding

Welding operations using automated welding equipment require careful monitoring. Operators and service personnel overseeing robotic welding equipment can be subject to residual fumes and need to be protected in a similar way to manual workers. Nederman solutions for robotic welding include both on torch-extraction and extraction systems with hoods.

On-torch extraction is especially suitable for robotic welding. On-torch extraction uses high vacuum technology, i.e. high speed extraction and low air volumes to extract the fumes.

Nederman solutions for automatic welding processes include both on-torch extraction and extraction systems with hoods.
1. **Extraction at-source with arms**  
A range of arms in different designs and arm lengths, hose diameters etc. Full flexibility in all directions and easy to position.

2. **Arm on rail**  
When extraction from extended working areas is required.

3. **Extension arm**  
When extra reach is needed.

4. **Mobile extraction/filtering units**  
A range of easy to move around mobile filter units solve most demands regarding welding fumes and dust.

5. **On-torch extraction**  
Welding torches with integrated extraction allow the welder to work over big areas as well as inside constructions.

6. **Robotic welding**  
Nederman solutions for automatic welding processes include both on-torch extraction and extraction systems with hoods.

7. **On-tool Extraction**  
Cutting, grinding and sanding are common operations in welding workshops generating dangerous concentrations of dust and particles. On-tool extraction is the most efficient way to capture them. Nederman offers a wide range of on-tool extraction kits for more than 600 tools.

8. **Stationary vacuum/ filtering systems**  
Nederman solutions include central vacuum systems with fans, filters and duct system to extract welding smoke from a number of workstations via extraction arms or from welding torches. The systems are also used for extraction of particles from grinding, sanding etc., and for cleaning of workplaces, premises and machines.
9. Mobile vacuum units
For cleaning, collection of scale rags etc. Air or electrically powered.

10. Cable and hose reels
For convenient supply of gases, compressed air, water, and electric power. Hoses and cables are out of the way when not in use which improves safety.

11. Energy saving system
With Nederman fan control unit, motor dampers and fan inverter substantial savings in energy and operation cost are made.
Vacuum/filtering systems

Control of exposure to welding fumes can usually be achieved with the help of extraction and ventilation. The choice of technique depends on the circumstances. The aim is to capture the fumes as close as possible to the source. This protects not only the welder but also other workers.

Vacuum technology can be divided into two categories: High and Low vacuum. In most systems both techniques are needed. Nederman masters them all and can therefore offer the most practical and cost-effective solution.

Vacuum/filtering systems can be divided into Low and High vacuum:

**Low vacuum**, i.e. low velocity extraction, is used for extraction of fumes, dust exhaust and other airborne particles. The extraction is carried out with extraction arms, exhaust nozzles, enclosures and canopies over machines, robots etc.

**High vacuum** is used for central systems covering many workplaces via a duct system. Typical high vacuum applications are extraction from welding guns, on-tool extraction from grinding and sanding tools as well as floor and machine cleaning.

<table>
<thead>
<tr>
<th></th>
<th>Low Vacuum</th>
<th>High Vacuum</th>
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<tbody>
<tr>
<td>Air volume, m³/h</td>
<td>600 – 1800</td>
<td>150 – 250</td>
</tr>
<tr>
<td>Air volume, cfm</td>
<td>353 – 1059</td>
<td>88 – 147</td>
</tr>
<tr>
<td>Removal velocity, m/s</td>
<td>0.5 – 5.0</td>
<td>15 – 18</td>
</tr>
<tr>
<td>Removal velocity, feet/s</td>
<td>1.64 – 16.40</td>
<td>49.21–59.06</td>
</tr>
<tr>
<td>Transport velocity, m/s</td>
<td>6.0 – 14.0</td>
<td>18 – 25</td>
</tr>
<tr>
<td>Transport velocity, feet/s</td>
<td>19.69 - 45.93</td>
<td>59.06 – 82.02</td>
</tr>
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</table>

The table shows the approximate flow data per welding point for low and high vacuum applications.
Central vacuum/filtering systems

Nederman central vacuum/filtering system is a versatile and cost-effective solution offering improved working conditions and reduced load on the environment. The system provides overall high vacuum power for capturing of fumes from welding torches, extraction of dust from grinding, sanding and cutting, collection of scraps from process lines and for general housekeeping etc. The system, placed in a separate room, offers quiet operation at the workplaces. Continuous around the clock operation and minimum maintenance means optimal production uptime.

Nederman offers complete customized systems including vacuum and filter units, containers, and a complete selection of tubes, fittings and inlets.
Nederman Modular Filter System - MFS

Virtually any combination can be achieved, from a single filter assembly, to larger multi-stage filter systems for larger air volumes combining particle, HEPA* and Gas.

FilterMax is a modular filter system to provide extraction for the entire workshop.

FilterMax handles the air pollution from metal industries as well as non-explosive dust from other industries. A wide range of cartridges for different purposes are available.

Workshops where stainless steel and other metals containing carcinogenic substances are handled must be especially aware of the airborne contaminants exhausted the extraction system. Emissions must comply with national and local regulations and specifications set by the company. These regulations regarding the recirculation of filtered air differ from country to country.

*) A Nederman extraction system equipped with a particle filter can capture up to 99 % of contaminants. With a HEPA filter even the ultra fine particles are separated with a filtering efficiency of up to 99.95 %.
Vacuum and filtering units

L-PAK

E-PAK

FlexPAK

C-PAK

Vacuum units

VAC unit

RBU
Energy saving solutions

Letting the extraction system run when not in use is bad economy. If the premises are heated or cooled, a lot of energy is also wasted by unnecessary extraction. Nederman offers several solutions to save energy and improve working conditions.

**Nederman Fan Inverter**

With a Nederman fan inverter the fan operation is constantly adjusted to the number of extractions points in use to ensure the required airflow. The noise, which otherwise occurs in an underloaded system, is reduced. The easy-to-program fan timer starts and stops the fan depending on working hours, holidays etc.

**Nederman motor damper**

Combined with Nederman motor dampers which open and shut the connections to each extraction point, the efficiency and operation cost is further improved. The dampers have a closing delay of up to 5 minutes to ensure extraction of remaining dust and fumes.

The motor dampers are connected in series and one of them is connected to a Fan Contactor that starts and stops the central fan. You can connect as many motor dampers as required in series.

**Nederman fan control unit**

Nederman fan control unit (often used in smaller systems) activates the central fan to run only during welding operations. The fan is activated manually or automatically at welding.

Extractor arms on a duct system with a central fan. The sensor clamps detects the current in the welding machine cable and initiate the fan to start/stop.
Nederman extraction arms

**Standard**

For welding, grinding, or other industrial applications in welding schools and industries with light production.

**Telescopic**

For welding, grinding, or other industrial processes in welding schools or for production in small welding booths.

**Original**

For welding, grinding, or other industrial processes where an easily positioned arm is required. The arm is equipped with a damper in the hood as standard.

**NEX MD**

An extraction arm for medium to heavy duty applications.

**NEX HD**

For working environments with very heavy smoke, vapours or non explosive dust.

**Welding table**

Industrial welding and grinding table for extraction of fumes, dust and particles at welding and grinding operations. It can also be used in explosive environments, if grounded accordingly.
Fume extractor arm on rail when extraction from long working areas is required.

Extension Arm, 4.2 m or 6.0 m (14 ft. or 20 ft.), is designed to be used in combination with a Nederman arm when extra reach is needed.

Nederman Bodywork extraction arm based on the Original arm. Available in a length of 5 m (16½ ft.).
Mobile extraction units – a versatile complement

**Fume Eliminator 840/841**
Lightweight, portable extraction unit for welding torches and extraction nozzles.

**FilterCart**
Mobile extraction/filtering unit for light welding and extraction applications.

**FilterBox**
A modular extraction/filtering system that can be combined to a mobile or a stationary unit with expandable capacity. Manual, semi-automatic or fully automatic (compressed air cleaning) filter cleaning depending on model.
One of the most important factors in welding shop safety is to keep floors, benches and surfaces clean of welding dirt, scrap, grease and oil. Otherwise it can result in bad fire hazards. In welding shops working with stainless steel, special care must be taken with dust contaminated with Cr(VI). (The OSHA Cr(VI) standard for general industry includes special requirements for housekeeping measures.) Nederman offers a wide range of solutions for efficient housekeeping, from mobile vacuum units to stationary, central vacuum system. The range also includes EX approved equipment.

Surfaces contaminated with Cr(VI) must be cleaned by HEPA-filtered vacuuming or other methods that minimize exposure to Cr(VI). Dry methods: shoveling, dry sweeping and brushing is not allowed.

Cleaning equipment must be handled in a way that minimizes the re-entry of Cr(VI) into the workplace. HEPA-filtered vacuum equipment must be cleaned and maintained carefully to avoid unnecessary exposure to Cr(VI). Filters must be changed when needed, and the contents must be disposed of properly to avoid unnecessary Cr(VI) exposure.