

Protecting Workers from Welding Fumes

A primer on Controlling Welding Fumes

Prepared By:
Doug Wylie, CIH, ROH, CRSP, CRM
OHG Consulting
(204) 668-3141
email: ohgconsulting@shaw.ca



The results of a two year study sponsored by a grant from the Community Initiatives and Research Program of Workers Compensation Board of Manitoba involving 40 companies across Manitoba shows the effectiveness of existing methods of reducing exposure to welding fumes. Initial testing showed that half of the Metal Inert Gases (MIG) welders tested who were not using respiratory protection or local exhaust ventilation were overexposed to welding fumes. When existing methods of reducing exposure to welding fumes were in place, exposure levels were within allowable levels.

Welding exposures can be a significant hazard in many workplaces. Studies have shown that a large number of workers are overexposed to welding fumes. OHG Consulting completed a study of welding exposures in Manitoba in a project sponsored by the Workers Compensation Board of Manitoba.

Summary of Welding Testing Results

	No Controls	PPE	LEV
Mild Steel			
Number Tested	100	34	30
Number Overexposed	52	0	0
% Overexposed	52%	0%	0%
Average Exposure*	145%	15%	32%
Stainless Steel			
Number Tested	26	8	1
Number Overexposed	8	0	0
% Overexposed	31%	0%	0%
Average Exposure	74%	17%	37%

PPE = personal protective equipment, LEV = local exhaust ventilation

* 100 % = exposure equal to the allowable airborne concentration

Workers' exposures to welding fumes can be controlled by a combination of methods. If your workers are currently overexposed to welding fume, your company should introduce

additional controls to reduce worker exposure to within allowable levels. Many companies use half of the allowable level as a goal for their control program.

The general hierarchy of controls is as follows with the most desirable approaches presented first. The hierarchy is based on primarily on the effectiveness and reliability of the control method but also takes into account the cost effectiveness of the controls.

Substitution

Is it feasible and practical to modify or replace your current welding process, consumable, gas, welding procedure or equipment technology with an alternative process, consumable, gas, welding procedure or equipment technology that generates less welding fumes? Here are some of the options and their benefits.

Change Type of Welding

Different types of welding are associated with different rates of fume generation. In some cases, it may be possible to change the welding process to a type of welding that has a lower rate of generation. The following table categorizes the different types of common welding processes in terms of their welding potential.

Relative Fume Generation Rates of Common Processes

HiGH	Moderate	Low
Flux-cored Arc Welding Shielded metal Arc Welding Arc Gouging	Gas Metal Arc Welding	Gas Tungsten Arc Welding Submerged Arc Welding

Source: Jerome Spear, Spears Consulting, LP presentation at 2010 AIHCE

A large part of the exposure arises from manganese in the welding wire. It has been suggested that as much as 95 percent of the welding fume actually originates from the melting of the electrode or wire consumable. Is it possible to switch to a welding wire which is safer? Substitution of a new welding wire is a way to reduce exposure with essentially zero cost to your company.

In many cases, a large portion of the workers' exposure is the result of manganese in the welding wire. The substitution with a welding wire with a lower percent content of manganese is an extremely effective way to reduce worker exposure. Consider the case study below.

Case Study of reduced exposure with lower manganese wire

One of the companies involved in the Manitoba Study had fairly high exposures from MIG welding. The average exposure of the workers tested was 192% of the allowable exposure. All seven of the workers tested had exposures above the allowable level. The majority of the exposure came from manganese which was present in the welding wire.

The company switched to a welding wire with a lower manganese content. With the new welding wire in place, the company was retested to determine the new exposure levels of the workers. The average exposure with the low-manganese welding was 52% of the allowable exposure. Six of the seven workers were now within the allowable exposure before correcting for respiratory protection. One worker who works at one of the higher production stations had much lower exposures but still somewhat above the allowable. However, due to awareness of welding exposure, that worker now uses a respirator. As a result, all seven of the workers tested were within the allowable levels. The data from the initial survey and the follow-up survey are provided below.

Exposures at Initial Survey
Average Exposure is 192% of Allowable Exposure

Worker	Activity	Controls	Exposure before PPE
A	Frames	none	176 %
B	Production Booth	HFAPR	101 %
C	Platforms	none	163 %
D	Production Booth #1	none	157 %
E	Frames	none	403 %
F	Headers	none	156 %

Note: HFAPR = half face air purifying respirator

Exposures at Resurvey
Average Exposure is 59% of the Allowable Exposure

Worker	Activity	Controls	Exposure before PPE
A	Frames	none	61 %
B	Tacking on mild steel	none	35 %
G	MIG Welding on mild steel	none	58 %
D	Production Booth #1	HFAPR	113 %
F	MIG Welding on mild steel plates	none	27 %

Note: HFAPR = half face air purifying respirator

Administrative Controls

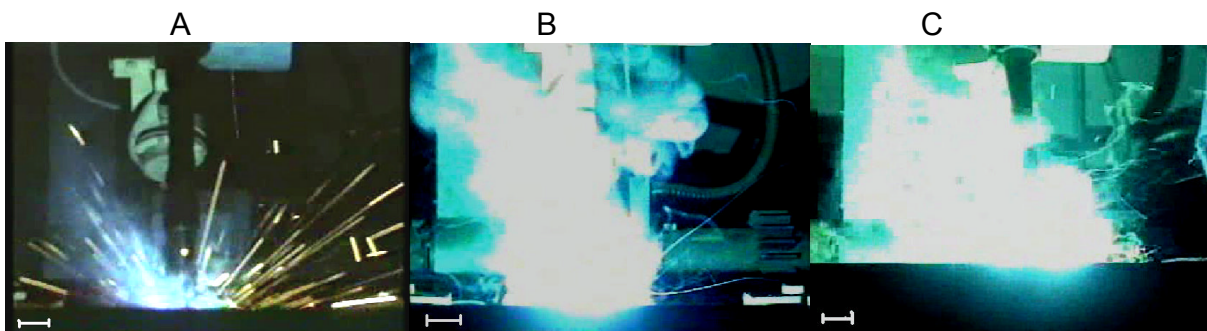
Limiting the generation of welding fume begins at the design stage. All other things being equal, a properly sized weld will result in the lowest amount of welding fume for a given process and set of procedures. Overwelding, on the other hand, unnecessarily increases welding fume. As the amount of weld metal increases, the amount of fume also increases.

The welding engineer should be aware of the role that weld size plays in the creation of fume.

In addition to the welding process, studies have shown that the fume generation rate is also influenced by the following factors:

- **Electrical current:** In general, the fume generation rate is exponentially proportional to the current.
- **Arc voltage:** The fume generation rate generally increases when the arc voltage increases. Increasing arc voltage tends to increase puddle fluidity, flatten the weld bead, increase edge wetting and increase spatter. Higher voltages also reduce penetration and may cause additional loss of alloying elements.
- **Electrode diameter:** The electrode diameter has a modest effect on the fume generation rate because of the differences in voltage and current. In general, a small diameter electrode has a higher fume generation rate than a large diameter electrode.
- **Electrode angle:** The angle of the electrode to the workpiece has a slight (but unpredictable) affect on the fume generation rate.
- **Shielding gas:** In gas-shielding arc welding, the fume generation rate tends to be greater when 100% carbon dioxide (CO₂) is used as compared to argon for the shielding gas. In practice, using 100% CO₂ will require a procedure increase of 1-2 volts compared to Argon blends. This adds energy to the arc, boiling off more metal and creating more fume
- **Steady/current pulsed current welding:** With pulsed gas metal arc welding, for example, less fume is typically produced than with a conventional constant voltage power source. In this mode, the arc is controlled by pulsing the current from a background level to a peak level at a specified frequency. This reduces the total arc energy and decreases the amount of metal that is vaporized, which leads to reduced fume generation. Studies have shown that utilizing a pulsing current during welding generates fewer fumes than under steady current welding process.

Studies have shown that reducing the voltage of the welding process can significantly reduce the welding fume emissions. The following images show the difference in fume generated by different welding voltages.



Photographs of fume plume in (a) dip transfer (20–26 V); (b) globular transfer (26–29 V); and (c) spray transfer (30–36 V). The scale bar represents ~25 mm

Arranging the work so that the welder is out of the rising plume (rotate material so that worker is welding beside a vertical or angled surface rather than above a horizontal surface) can also significantly reduce worker exposure. Administrative costs like these are also essentially free ways to permanently reduce worker exposure to welding fumes.



The plume on the left rises without entering the breathing zone of the worker.

The worker on the right is directly in the plume of welding fume



The welding position plays a significant role in welding fume exposure primarily due to the plume's path of travel. Welding in a down-flat position (such as a tank bottom or where the workpiece is positioned below the welder's waist) tends to present the highest potential fume exposures. Welding in a horizontal direction (such as when welding the girth seam of a tank) can also create relatively high fume exposures depending on plume's path of travel in relation to the welder's breathing zone. Welding in a vertical direction (such as a vertical seam of a tank shell) tends to have the lowest potential fume exposure since the welder's breathing zone is typically not in the plume's travel path and the plume stays close to the heat-affected zone as it naturally rises.

Difference in Welding Exposure between Horizontal and vertical welding

Measures	Horizontal	Vertical
Number of Samples	12	6
Maximum	38.0 µg/m ³	2.5 µg/m ³
Median	4.45 µg/m ³	0.78 µg/m ³
% > Allowable Exposure	41.7%	0.0%

<http://www.steeltank.com/LinkClick.aspx?fileticket=99H%2BRv8K0Lw%3D&tabid=95>



Image of a work jig that tilts to allow the material to be welded to be put the desired angle. This not only allows the welder to be out of the much of the welding plume but also improves the ergonomics of the welding position.

The tilted work bench on the right has a number of different clamps on it. This allows for the same frame to be used to hold a large number of different parts. The degree or angle of tilt can be adjusted so that it is flat to allow the parts to be placed on the jig and then tilted when performing welding



Ventilation:

Ventilation is a means of moving air to control or reduce airborne concentrations in the workplace and reduce worker exposure to airborne contaminants. There are two general approaches to ventilation. The first is local exhaust ventilation where contaminated air is exhausted from the building. The second is general ventilation where fresh air is brought into the building to purge and dilute the airborne contaminants.

Local Exhaust Ventilation

Local exhaust ventilation is uses an extraction system located very close to the point of welding fume generation to extract the fumes immediately from the work environment without allowing the air to enter the worker's breathing zone. Local exhaust ventilation can be in the form of a bench for small parts or a flexible trunk that can be positioned where needed for welding on large objects.



Examples of Local Exhaust Ventilation

Left: a backdraft welding bench is good for welding small parts.

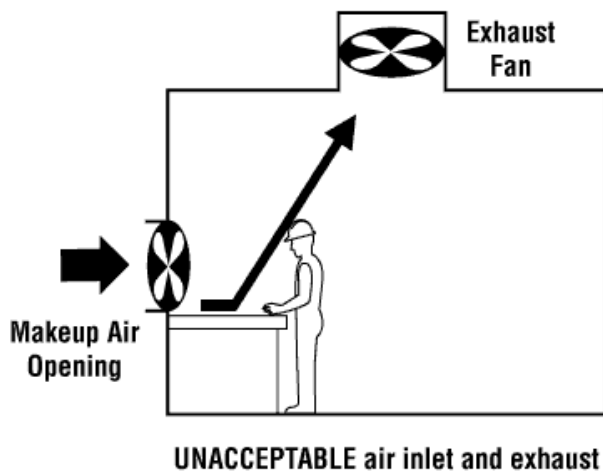
Right: trunk hose draws away the fume away from a welder's breathing zone.



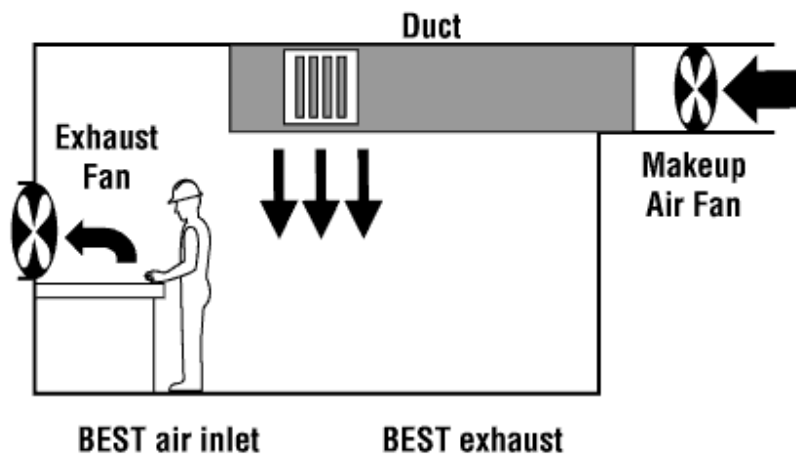
Local exhaust ventilation is a proven effective way of reducing exposure. Of the 30 welders tested who were using local exhaust ventilation, none of them were overexposed. While most of the units were commercial products, even the units put together in house were effective in protecting workers.

General Ventilation

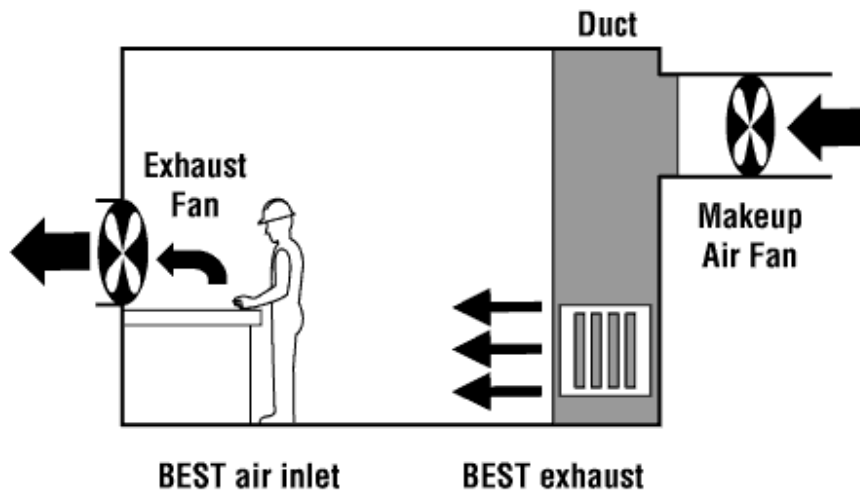
General ventilation requires a much greater volume of air and that can result in greater heating/cooling costs than local exhaust ventilation. General ventilation may also only be partially effective because the main pathway of exposure is between the welding fume generation and the breathing zone of the welder. By contrast, local exhaust ventilation captures and exhausts the welding fumes before they enter the worker's breathing zone and are an excellent form of control. Of the 30 workers tested in the OHG Welding Study, none of the workers were overexposed and their average exposure was 32% of the allowable exposure.



This setup is unacceptable because it draws the welding fume through the workers breathing zone before being exhausted



This setup is acceptable because it extracts the fume from the building without letting the welding fume enter the workers breathing zone before



This setup is also acceptable because it also extracts the fume from the building without letting the welding fume enter the workers breathing zone before being exhausted

Diagram of General Ventilation Principle

General ventilation requires much larger volumes of air than local exhaust ventilation.

Choosing Between General and Local Exhaust Ventilation

General exhaust ventilation (dilution ventilation) is appropriate when:

- Emission sources contain materials of relatively low hazard. (The degree of hazard is related to toxicity, dose rate, and individual susceptibility);
- **Emission sources are primarily vapors or gases, or small, respirable-size aerosols (those not likely to settle);**
- Emissions occur uniformly;
- Emissions are widely dispersed;
- Moderate climatic conditions prevail;
- Heat is to be removed from the space by flushing it with outside air;
- Concentrations of vapors are to be reduced in an enclosure; and
- Portable or mobile emission sources are to be controlled.

Local exhaust ventilating is appropriate when:

- **Emission sources contain materials of relatively high hazard;**
- Emitted materials are primarily larger-diameter particulates (likely to settle);
- **Emissions vary over time;**
- **Emission sources consist of point sources;**
- **Employees work in the immediate vicinity of the emission source;**
- **The plant is located in a severe climate; and**
- Minimizing air turnover is necessary.

The criteria that relate specifically to welding are bolded in the above table. Clearly, for welding in Manitoba, local exhaust is the overall better choice.

Personal Protective Equipment

Personal protective equipment is useful as an interim measure until engineering controls can be installed or when engineering controls are impracticable. Most are



E: half face air purifying respirator (protection factor of 10)

F: full face air purifying respirator built into a welding mask (protection factor of 50)

G: Powered air purifying respirator with loose fitting headpiece (protection factor of 25)

H: Half face air purifying respirator with hoses to filters that attach to back of welders belt (this takes up less room under the welding mask and the cassettes last longer as they are away from the welding plume).

Respiratory protection is rated in terms of its Protection Factor (PF). The Protection Factor is simply the ratio of the concentration outside the respirator divided by the concentration inside the respirator. Another way of looking at it is that the workers exposure equals the outside concentration divided by the protection factor. For example if a worker is exposed to 200% of the allowable exposure but wears a respirator with a Protection Factor of 10, the worker's corrected exposure is $200\%/10 = 20\%$ of the allowable exposure.

Respirators should always be used as part of a comprehensive respiratory protection program that includes worker education, fit testing, and record keeping.

Respiratory protective equipment (RPE) must be used as required by Provincial health and safety legislation. According to the law:

- Respirators must be of an approved type.
- Respirators must be suitable for the hazard.
- Respirators must be selected and fit tested according to the CSA Standard Z94.4-03, *Selection, Use and Care of Respirators*.

The employer must establish a Code of Practice for the selection, use and maintenance of respirators at the work site. The employer is responsible for providing appropriate equipment and training workers on their proper use.

All respirators are uncomfortable to a degree, especially for the first-time user. Selecting the right type goes a long way toward making wearing it more bearable. You may want to consult with an occupational hygienist or supplier before making your final selection

Typical Ventilation Specifications for Welding Applications

