ARC WELDING & SAFETY SUPPLIES

THE EFFECTIVENESS OF

# WELDING FUME PRODUCT CONTROLS

## A SCIENTIFIC STUDY

# Solutions Not Problems

Welding fume has been linked to multiple forms of cancer, classified as a carcinogen by the International Agency for the Research on Cancer, and studies have concluded that “welders run an increased risk of lung cancer of up to 43% when compared with those who have never welded or been exposed to welding fume”[1]. Welding fume is also linked to a myriad of other short-term and long-term adverse health effects.

There are countless studies that conclude that welding fume is bad for health, yet there seem to be very few that can give us practical guidance on how to effectively control welding fume exposure. Studies have done an effective job in defining the problem; however, few have been able to identify and compare the relative effectiveness of available product control solutions.

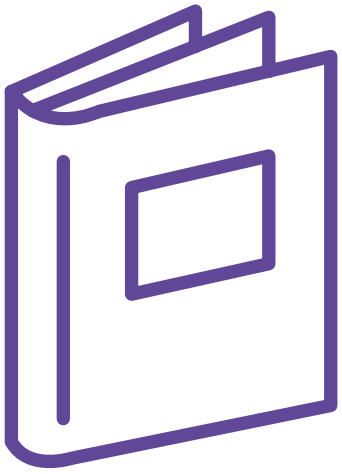
# Requirements of Health and Safety Law*

A ‘Person Conducting a Business or Undertaking’ (employer) must ensure that no person at the workplace is exposed to welding fume in an airborne concentration that exceeds the exposure standards. This includes total welding fume concentrations as well as individual fume components.

However, exposure standards should not be considered as representing an acceptable level of exposure to workers as they do not identify a dividing line between a healthy and unhealthy work environment. Exposure standards simply establish a legal maximum upper limit. Therefore, additionally, employers must also reduce exposure to welding fume to as low as reasonably practicable to protect workers and others in the workplace.

The results of this study can be used to help employers fulfill their legal duties as it relates to:

- Not exceeding welding fume exposure standards.
- Reducing welding fume exposure to as low as reasonably practicable.



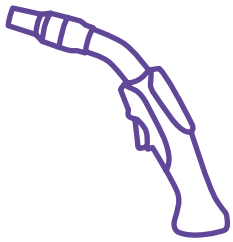
*Disclaimer

This publication contains work health and safety information and is provided as guidance, it should not be relied upon as legal compliance. It includes obligations under legislation that health and safety regulators administer. To ensure you comply with your legal obligations you must refer to the appropriate legislation. This publication does not represent a comprehensive statement of the law as it applies to particular problems or to individuals or as a substitute for legal advice. You should seek independent legal advice if you need assistance on the application of the law to your situation.

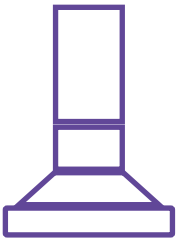
# About the Scientific Study

The intent of the 2022 Scientific Study was to compare the effectiveness of different welding fume product control methods in reducing exposure to welding fume.

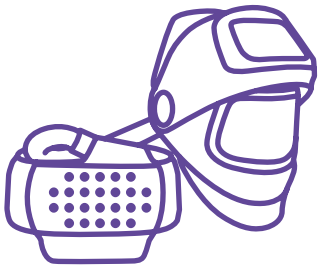
The methods analysed were:



**On-Gun Fume Extraction Local Exhaust Ventilation (LEV)**



**Hooded Capture Local Exhaust Ventilation (LEV)**



**Welding Helmet with a Powered Air Purifying Respirator (PAPR)**

The study included taking air samples while welding under controlled conditions. Fourteen (14) different test scenarios were assessed, including variations of welding techniques and controls commonly used in Australia and New Zealand.

The table below displays the processes, base materials, consumables, and control types analysed. The process combinations below are the most commonly performed welding processes based on the responses of over 1,300 Australian and New Zealand welders in 2021.

**Figure 1 – Process, Base Material, Consumable, and Control Type**

| Process | Base Material | Consumable | Control Type | | | |
|---|---|---|---|---|---|---|
| | | | No Controls | PAPR | On-Gun LEV | Fixed LEV |
| GMAW (MIG) | Steel | ER70S-6 | ✓ | ✓ | ✓ | ✓ |
| FCAW (Flux-Cored) | Steel | E71T1-1M | ✓ | ✓ | ✓ | ✓ |
| MMA (Stick) | Steel | E6013 | ✓ | ✓ | ✗ | ✓ |
| GTAW (TIG) | Stainless Steel | ER316LSi | ✓ | ✓ | ✗ | ✓ |

**Notes:**
On-gun fume extraction is not possible for MMA (Stick) welding.
An on-gun fume extraction system for GTAW (TIG) was not available for this study.
FCAW (Flux-Cored) was the gas-shielded variant in this study.

# Summary of the Results

Without adequate controls, research shows that typical welding fume exposures are highly likely to exceed the regulatory workplace exposure standard, placing workers at risk of irreversible lung disease and other adverse health effects.

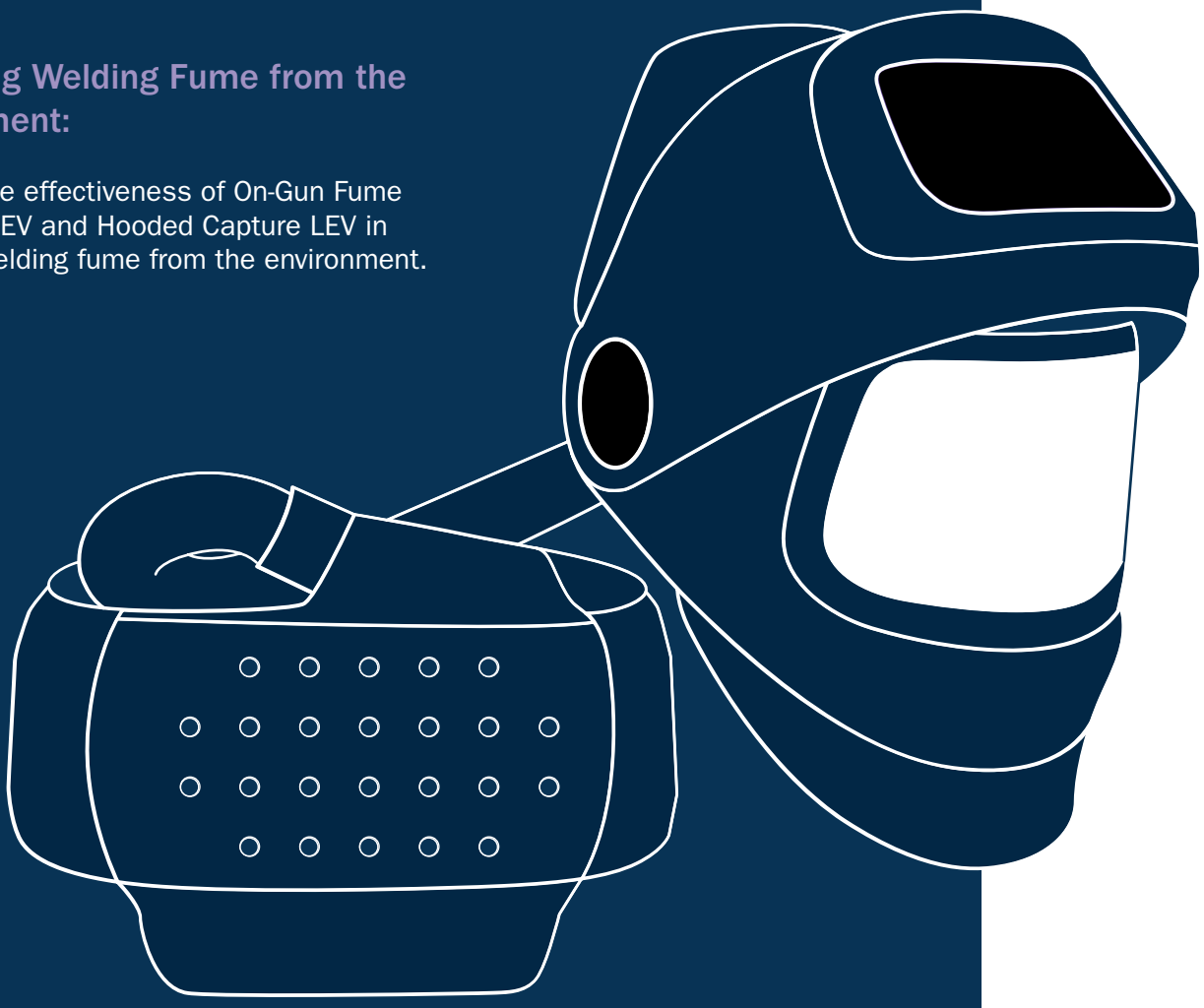
The results of the study are organised into two categories:

## 1. The Welder's Exposure to Welding Fume:

Compare the effectiveness of On-Gun Fume Extraction LEV, Hooded Capture LEV, and a Welding Helmet with a Powered Air Purifying Respirator in reducing the welder's exposure to welding fume.

## 2. Removing Welding Fume from the Environment:

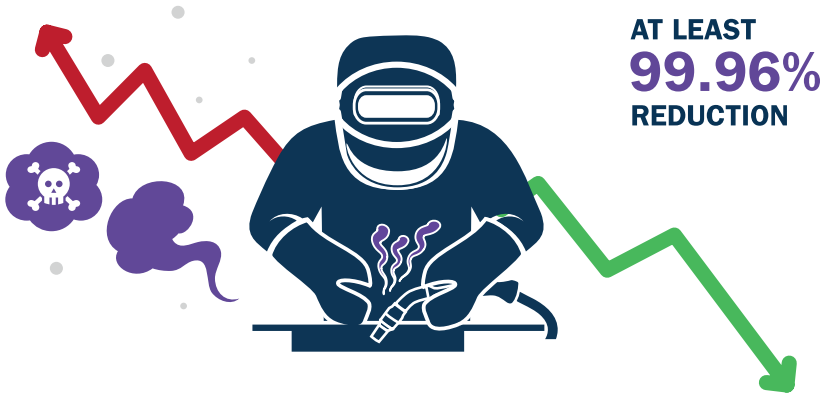
Compare the effectiveness of On-Gun Fume Extraction LEV and Hooded Capture LEV in removing welding fume from the environment.



# 1. The Welder's Exposure to Welding Fume

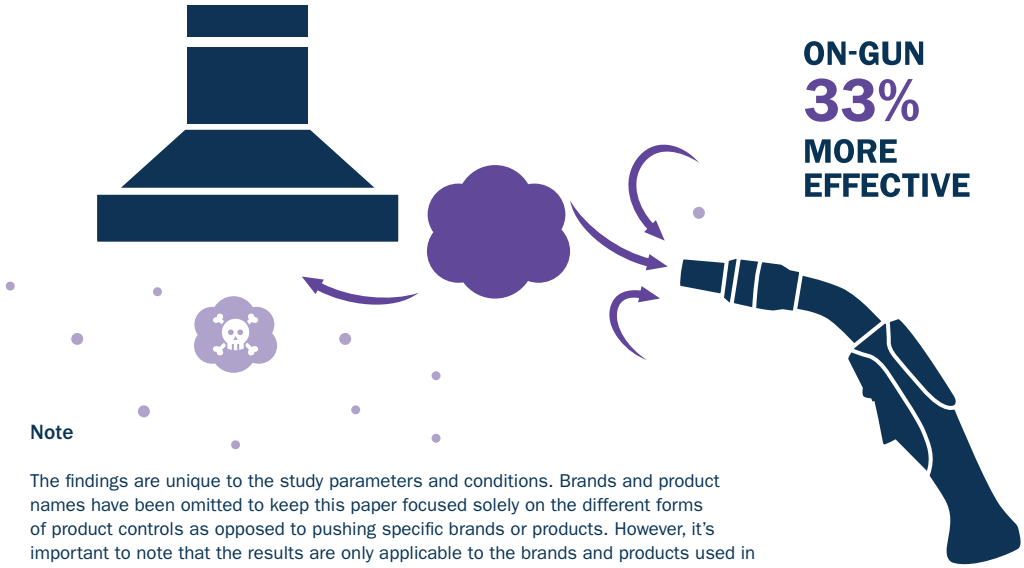
- With a reduction in exposure of at least 99.96%, the Welding Helmet with an Integrated Powered Air Purifying Respirator was by far the most effective control measure in protecting the welder from welding fume exposure when compared to On-Gun Fume Extraction and Hooded Capture LEV.

- The Welding Helmet with an Integrated Powered Air Purifying Respirator provided an Effective Protection Factor (EPF) of at least 2,600. Meaning a PAPR could reduce welding fume exposure to at least 1/2600th of the outside concentration. The results of this study show a level of performance at least 52 times better than the Required Minimum Protection Factor (RMPF) of 50 as specified in the Australian and New Zealand standard AS/NZS 1715:2009.




# 2. Removing Welding Fume from the Environment

- On-Gun Fume Extraction LEV was 33% more effective than Hooded Capture LEV in extracting welding fume from the environment. On-gun fume extraction was able to extract up to 97% of the welding fume with an average of 90% across all tests.




**Note**

The findings are unique to the study parameters and conditions. Brands and product names have been omitted to keep this paper focused solely on the different forms of product controls as opposed to pushing specific brands or products. However, it's important to note that the results are only applicable to the brands and products used in the study – these can be made available upon request.

# Interpretation of the Results

## 1. The Welder's Exposure to Welding Fume

The welder is typically exposed to the highest concentrations of welding fume and therefore has the highest welding fume exposure risk in the workplace. The employer must ensure that the welder's exposure to welding fume does not exceed the relevant welding fume exposure standards and that welding fume exposure is reduced to as low as reasonably practicable.

A Welding Helmet with an Integrated Powered Air Purifying Respirator was found to be the most effective welding fume product control in reducing the welder's exposure to welding fume based on the results of this study.

Whilst Engineering Controls currently available in the welding industry (eg. On-Gun Fume Extraction and Hooded Capture LEV) can be effective at reducing the airborne concentrations of welding fumes in the workplace, the Welding Helmet with an Integrated PAPR was demonstrated to be more effective in protecting the welder from welding fume. A Welding Helmet with an integrated PAPR also provides protection to the welder's eyes and face from radiation, heat, sparks, splatter, and foreign objects.

Compared to a half mask respirator, a welding helmet with a PAPR can offer:

- Superior respiratory protection.
- No breathing resistance.
- A cooling flow of fresh air to improve comfort.
- No requirement for fit testing.
- No requirement for a complete shaven condition (if relevant).
- Potential long term cost saving.

A PAPR should be considered a priority in situations where the welder is the only person requiring protection from welding fumes.

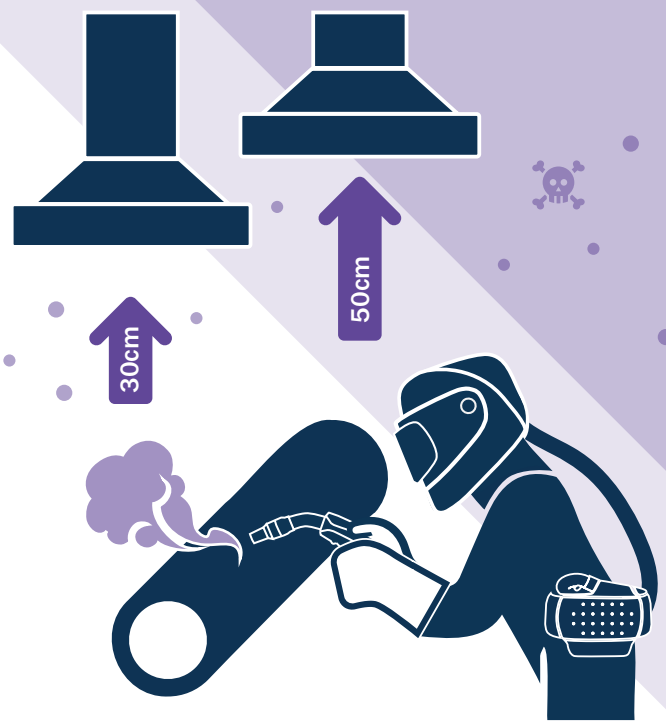
**AT LEAST**
**2,600**
**EFFECTIVE PROTECTION FACTOR (EPF)**

## 2. Removing Welding Fume from the Environment

It is an employer's legal responsibility to reduce welding fume exposure to as low as reasonably practicable for all persons, not just the welder. On-Gun Fume Extraction LEV and Hooded Capture LEV are two common methods used to reduce welding fume exposure to all workers by capturing welding fume at the source and removing it from the environment.

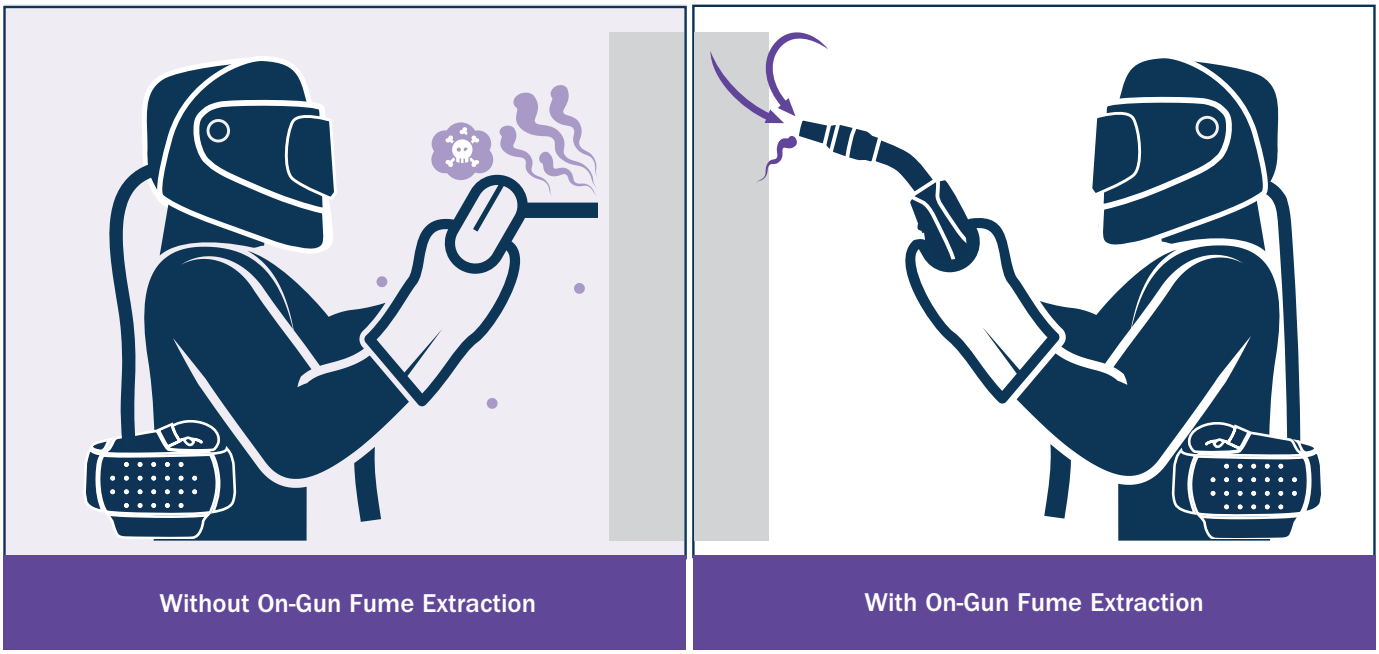
On-gun fume extraction was found to remove 33% more welding fume from the environment compared to LEV hooded capture. On-gun fume extraction also has the added benefit of following the welder as the welder moves, unlike fixed LEV hooded capture that requires the welder to be perfectly positioned relative to the capture hood and for the welder and welding arc location to remain relatively stationary.

Measurements taken during the study suggested that exposure to welding fume can approximately double when the capture hood distance from the arc increased from 30cm (correct distance from the arc based on manufacturer's instructions) to 50cm. This has large implications for welders who do not remain stationary or for those who are doing long welds.




**2X EXPOSURE**

View how the distance from an LEV capture hood to the welding arc can impact exposure to welding fume.



Without On-Gun Fume Extraction

With On-Gun Fume Extraction

On-gun fume extraction is the only welding fume product control that removes welding fume from the environment and follows the welder as they move.

In the past, on-gun fume extraction has been big, heavy, cumbersome, and in many cases, either was not as effective as desired or adversely impacted the shielding gas. However, recent technological advancements have meant that some on-gun fume extraction options are now lighter, smaller, and more ergonomic than many standard welding guns and have zero impact on the shielding gas while delivering extremely high capture efficiency.

On-gun fume extraction can also reduce the costs associated with maintaining welding helmet and PAPR consumables (eg. outside cover lenses, particle filters) and workshop cleaning costs by capturing welding fume at the source. As an example, the table below outlines the quantity of welding fume that on-gun fume extraction can remove from the environment across a range of different consumable scenarios.

| Consumable | Type | Size | Weld Time (min) | Fume Weight (g) | One Week (g)* | One Year (kg)* |
|---|---|---|---|---|---|---|
| ER70S-6 | Gas Shielded MIG Wire | 0.9 | 8.25 | 0.58 | 84 | 4 |
| E71T1-1M | Gas Shielded Flux Cored Wire | 1.2 | 5.4 | 1.25 | 278 | 13 |
| E70C-6M | Gas Shielded Metal Cored Wire | 1.2 | 5.55 | 1.55 | 335 | 16 |
| ER70S-6 | Gas Shielded MIG Wire | 1.2 | 8.15 | 0.78 | 115 | 6 |
| E71T-11 | Gasless Flux Cored Wire | 1.2 | 5.5 | 1.53 | 334 | 16 |
| E71T-8 | Gasless Flux Cored Wire | 1.6 | 5.2 | 2.02 | 466 | 22 |

*The quantities for 'One Week' and 'One Year' have been calculated using the measured weld times and respective fume weights in the table above and assume 4 hours a day, 5 days a week, and 48 work weeks in a year.

Where capturing welding fume at the source to protect the welder and other workers in the workplace is a priority, on-gun fume extraction (if suitable for the application*) should be adopted and complement the use of a Welding Helmet with an integrated Powered Air Purifying Respirator.

Use the QR codes below to view on-gun fume extraction across a range of different welding positions:

**Downhand**

**Overhead Fillet**

**Vertical-Up**

*Please note that On-Gun Fume Extraction is not suitable for all welding applications (eg. MMA stick welding) and certain variables can impact effectiveness (eg. design of the on-gun extraction system and welding gun, weld position, and environmental factors).

# Bringing it All Together: Practical Guidance

Based on the conclusions of the 2022 welding fume product control study, the following product control guidance is offered to reduce welding fume exposure to as low as reasonably practicable when welding using the most common materials (aluminium, steel, stainless steel, galvanised steel etc.) in environments with good ventilation^.

This guidance assumes that all efforts to mitigate risk associated with welding fume through elimination, substitution, and isolation controls have been carried out.

## Protecting only the welder from welding fume^:

Please be aware that it is an employer's legal responsibility to reduce welding fume exposure to as low as reasonably practicable for all persons, not just the welder. This guidance is only applicable to situations where there are no other people sharing the environment with the welder/s.

Introduce Welding Helmets with integrated Powered Air Purifying Respirators (PAPR).

Ensure staff are trained in the proper use and maintenance of the PAPR. Many suppliers offer in-person and online training programs for free.

Remove surface coatings and look to mitigate risk by using a welding technique that produces less fume or introduce less hazardous materials where possible.

Welders should position themselves to ensure they keep their heads away from the plume where possible and take advantage of any ventilation available.

## Protecting the welder and surrounding workers from welding fume^:

Introduce a dedicated area for welding away from other workers and restrict access to this area where possible.

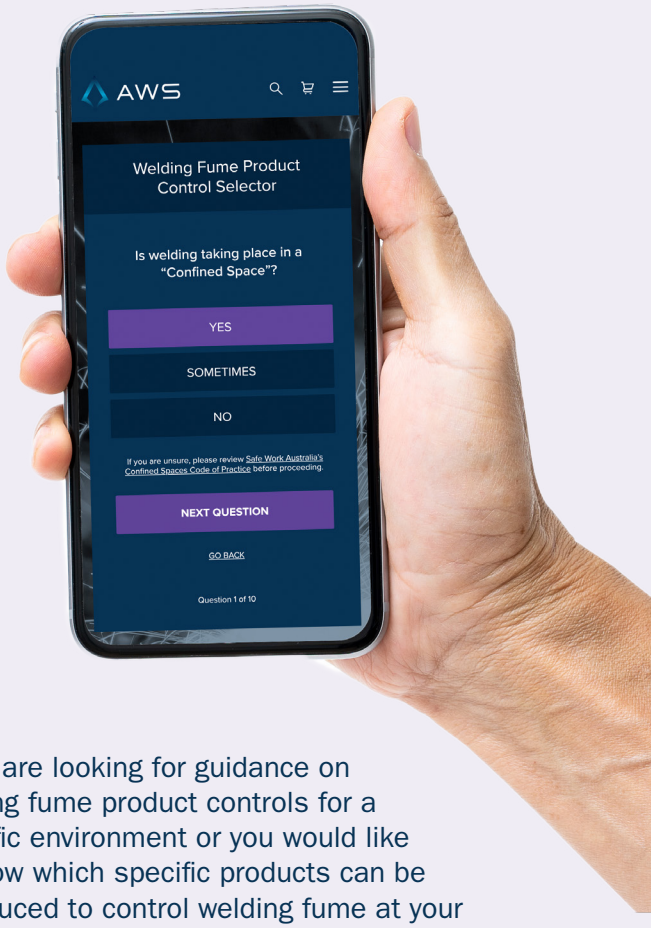
Introduce Local Exhaust Ventilation in combination with a Welding Helmet with an integrated Powered Air Purifying Respirator to protect the welder and control the spread of welding fume throughout the environment. If suitable for the application, on-gun fume extraction is the most effective and practical engineering LEV welding fume control.

Have staff trained in the proper use and maintenance of the PAPR and LEV system. Many suppliers offer in-person and online training programs for free.

Remove surface coatings and look to mitigate risk by using a welding technique that produces less fume or introduce less hazardous materials where possible.

Welders should position themselves to ensure they keep their heads away from the plume (if applicable) where possible.

# WELDING FUME PRODUCT CONTROL SELECTOR




If you are looking for guidance on welding fume product controls for a specific environment or you would like to know which specific products can be introduced to control welding fume at your workplace – please try the Welding Fume Product Control Selector using the QR code or website link below.

The solutions generated in this selector are based on the results of the Australian independent scientific study that was conducted in 2022 to compare the effectiveness of welding fume product controls.

Scan to use the **Welding Fume Product Control Selector or visit www.weldingfume.com.au**

# Are You Waiting for the Law to Change?

Without effective protection, welders are exposed to a carcinogenic substance. Even within the current Workplace Exposure Standards (WES) for welding fume in Australia and New Zealand, unprotected welders are notionally “allowed” to breathe up to 11 grams of a known carcinogen every year[2].

However, by law, it is the employer’s responsibility to reduce welding fume exposure to as low as reasonably practicable. The results of this study give clear and practical guidance on effective engineering and PPE control methods to reduce welding fume exposure.

On-gun fume extraction, the most effective engineering control measured in this study, had an average capture rate of 90% across all tests. The law in Australia and New Zealand clearly states that if there is any remaining risk after higher controls, such as engineering controls, have been implemented, it must be minimised with suitable personal protective equipment (PPE).

Unlike many industries, welders have PPE specifically designed for their occupation to protect them from welding fume and other welding hazards – a welding helmet with a powered air purifying respirator. Based on the results of this study, a PAPR correctly worn and maintained, will ensure that the welder is well below all relevant Workplace Exposure Standards for most common welding applications^, and can reduce welding fume exposure by a factor of at least 2,600 corresponding to a minimum 99.96% reduction.

Therefore, where an employer has already implemented engineering controls (On-Gun Fume Extraction or Hooded Capture LEV), a welding helmet with PAPR is an extremely effective method to minimise the remaining risk for the welder.

Even when operating within the workplace exposure standard for welding fume, unprotected welders could inhale up to 11 grams of a known carcinogen (welding fume) every year.


3M
Speedglas

# More Information on the Study

The study “Welding fume; a comparison study of industry used control methods” was published in the Safety Journal in 2023.

The study will be made available completely free of charge to help the welding industry make better decisions regarding the protection of welders.

If you would like a copy of the study, please contact us.

# ^ Important

This document does not address confined spaces.

Confined spaces should be avoided where possible. All of today’s current welding fume product controls have their limitations in a confined space. There should be a suitably trained and knowledgeable person doing the assessment and design of a safe system for any confined space entry.

Consultation with a welding fume product control expert should always be carried out to understand the limitations of each product control within a confined space. For more information on welding fume product controls within confined spaces please contact AWS.

All guidance is provided to give an example of how to control welding fume and is provided as a basic guideline only. It should not be used as the only means of selecting a respirator or control method. It’s always recommended to have a welding fume product control expert visit your premises as onsite variables can impact product control effectiveness (eg. weld position, and environmental factors).

Powered and supplied air respirators must never be used in atmospheres Immediately Dangerous to Life or Health (IDLH). Always consult your Safety Engineer or Occupational Hygienist. Air monitoring should take place if you are unsure about the level of welding fume exposure to workers.

The findings are unique to the study parameters and conditions. Brands and product names have been omitted to keep this paper focused solely on the different forms of product controls as opposed to pushing specific brands or products. However, it’s important to note that the results are only applicable to the brands and products used in the study – these can be made available upon request.

# Conflict of Interest

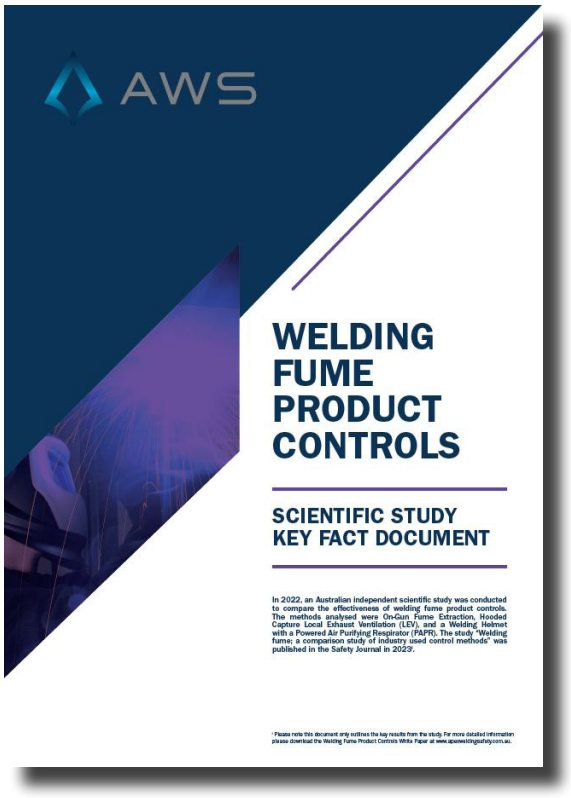
AWS commissioned this independent study and engaged GCG Health Safety & Hygiene (GCG) to conduct the study. GCG are a WHS and Occupational Hygiene Consultancy that specialises in worker health.

The initial project scoping was in consultation with both AWS and GCG Certified Occupational Hygienists (COH® ).

All results, outcomes, and conclusions were made based on analysis of real-time aerosol and gravimetric welding fume air samples taken and analysed using NATA certified methods and accredited laboratories.

AWS played no role in the analysis or interpretation of the final results.

The outcomes of the study are to assist in reducing welding fume exposure to workers across a range of commonly used welding techniques. This study provides valuable and practical information, backed by scientific methods.




# Key Fact Document

Would you like a quick summary of the results and the guidance within this document?

The Key Fact Document presents the main results from this White Paper in an 'infographic-style' brochure and offers practical guidance with clear next steps based on scientific data.

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**www.arcweld.co.nz**

0800 272 935

9 Bandon Street, Hamilton 3204

References

1. 2019 Honaryar MK, Lunn RM, Luce D, et al. Occup Environ Med
2. Based on the current Workplace Exposure Standard (WES) of 5mg/$m^3$ and the typical respiratory rate of 20 litres of air per minute or 2,300 $m^3$ of air per year.