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CAPTURE EFFICIENCY OF INTEGRAL FUME EXTRACTION TORCHES FOR GMA WELDING

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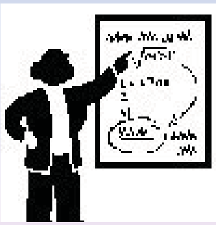
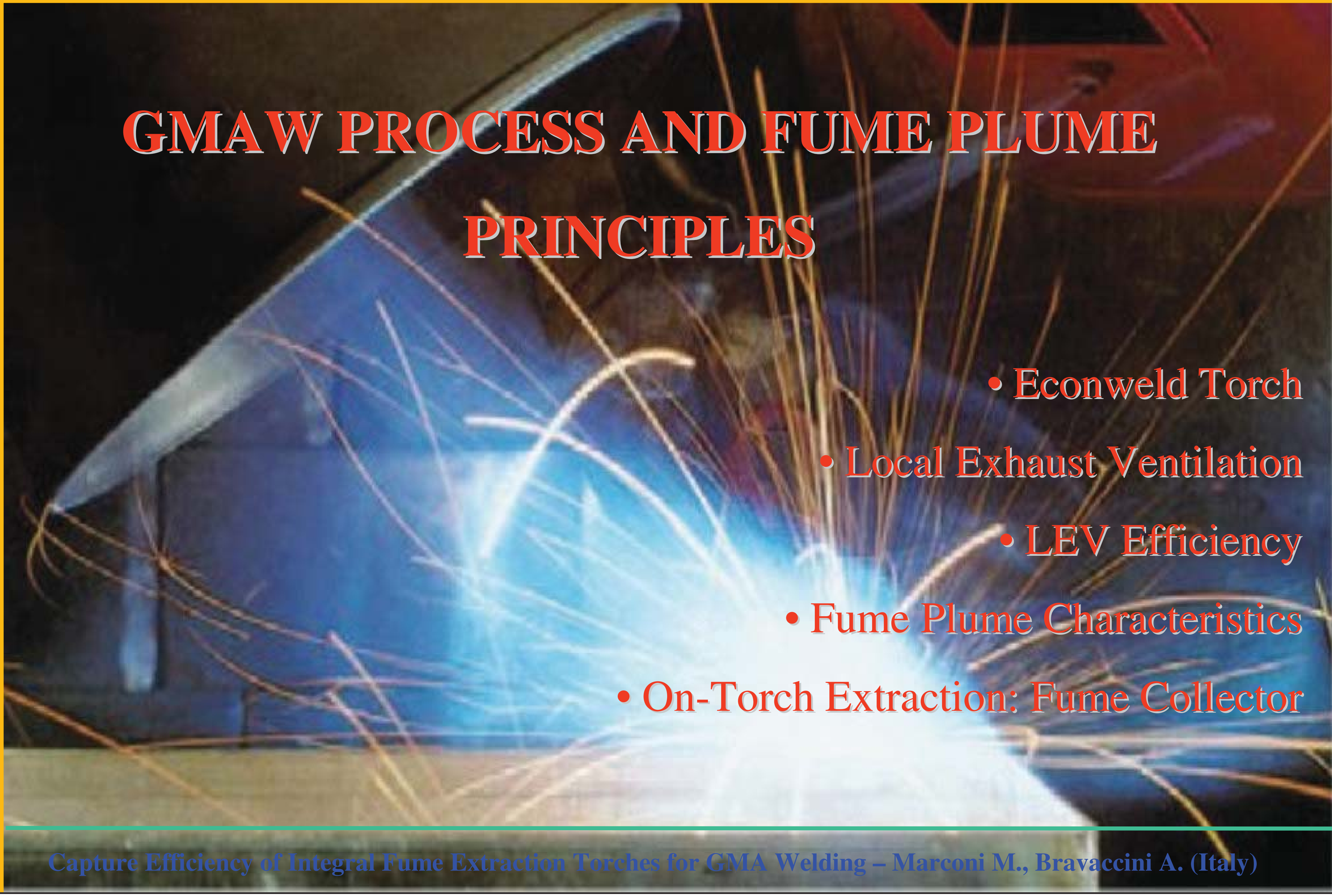
CONTENT

- Section 1 – GMAW Process and Fume Plume: Principles
- Section 2 – Fumes Extraction Torches: Basic Principles
- Section 3 – Fume Capture Efficiency: Test Methods
- Section 4 – Fume Capture Efficiency: a Literature Review
- Conclusions



SECTION 1



GMAW PROCESS AND FUME PLUME PRINCIPLES

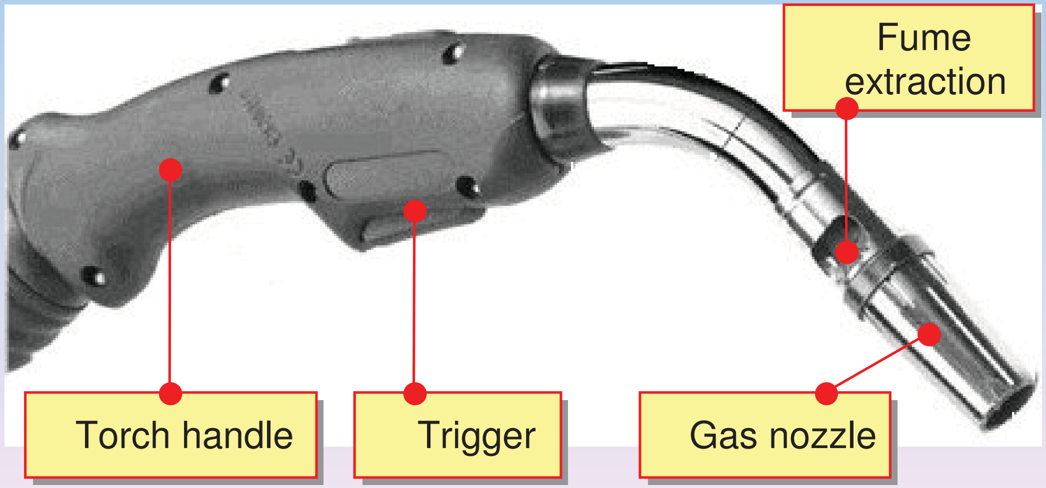
- Econweld Torch
- Local Exhaust Ventilation
- LEV Efficiency
- Fume Plume Characteristics
- On-Torch Extraction: Fume Collector

ECONWELD Torch: Ergonomic and Lightweight Tool

In order to assure welder's comfort and adhere to workplace safety and environmental regulations, the Econweld Project is exploring the use of integral fume extraction torches. These devices incorporate fume capture capability within the handheld welding tool, reducing the need for separate local exhaust equipments (LEV) or the use of personal respirators (RPE) by welders. As a result, workers are more productive because they do not have to transport and reposition extraction equipment each time they work in a new location.

Earlier fume exhaust welding torches had limited flexibility and were bulky to handle, when compared to conventional hand held tools. The new generation of fume extraction torches must both improve the workplace environment and be easier for the welder to manipulate for extended periods of time.

The Econweld Project identified the development of a lightweight and ergonomic fume extraction GMAW torch as a high priority research need. This report has been completed in response to this need.

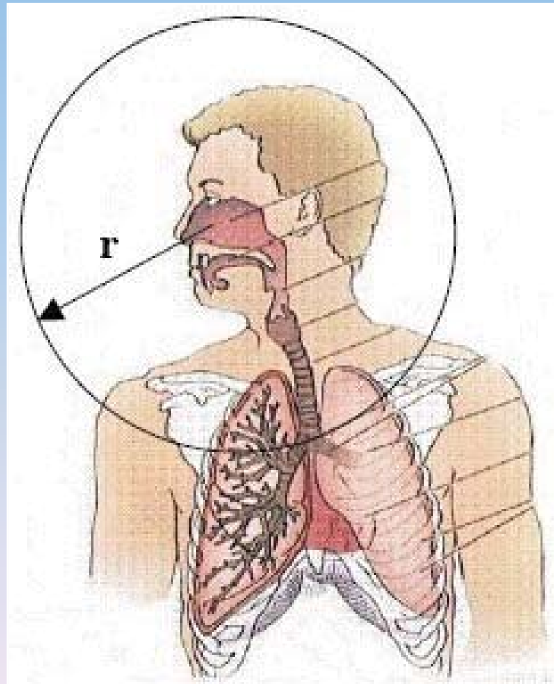


Local Exhaust Ventilation (LEV)

The main purpose of local ventilation is to reduce or preferably avoid exposure of workers to contaminants (including heat). Protection of persons, products or animals and buildings from hazardous contaminants is thereby included. One short definition quoted from the industrial ventilation design guide book (Olander et al., 2001) is:

> *"Local ventilation systems are used to transport contaminants or heat from the occupancy zone."*

Breathing Zone (r=300-500 mm)



In welding workplace, Local Ventilation is used to remove the contaminants (fumes, gases, ozone) at or near the emission source, thus minimizing the opportunity for the contaminants to enter the workplace air; more specifically Local Ventilation is to use as small air flow rate as possible to minimize the amount of airborne contaminants entering a specified volume or passing specified point(s).
These are usually intended to be at the breathing zone.

Olander, L., Conroy, L., Kulmala, I., and Garrison, R. "Industrial Ventilation - Design Guidebook", Vol. 1, Chapter 10, pp. 809-1022, Academic Press, 2001, San Diego (USA)

LEV for Welding

On-torch extraction device uses High Vacuum technology, i.e. High Velocity and Low air Volumes to extract the fumes.

LEV for Welding Fumes

- **Welding Torch with fume extraction**
  Airflow = 50 - 100 cu.m/h
  Removal velocity = 15-18 m/s
  → Extracts fumes at the weld zone through GMAW and FCAW torches

- **High Vacuum source capture hose/duct**
  Airflow =150 - 300 cu.m/h
  Removal velocity = 12-15 m/s
  → Capture fumes with High Velocity Low Volume extraction ducts
  Weld length before Repositioning = 10 - 30 cm

- **Low Vacuum Flexible fume extraction arm**
  Airflow =900 - 1,400 cu.m/h
  Removal velocity = 0.5-5 m/s
  → Draws higher air volume and is easily positioned & repositioned by welder
  Weld length before Repositioning = 30 - 60 cm

Efficiency of LEV

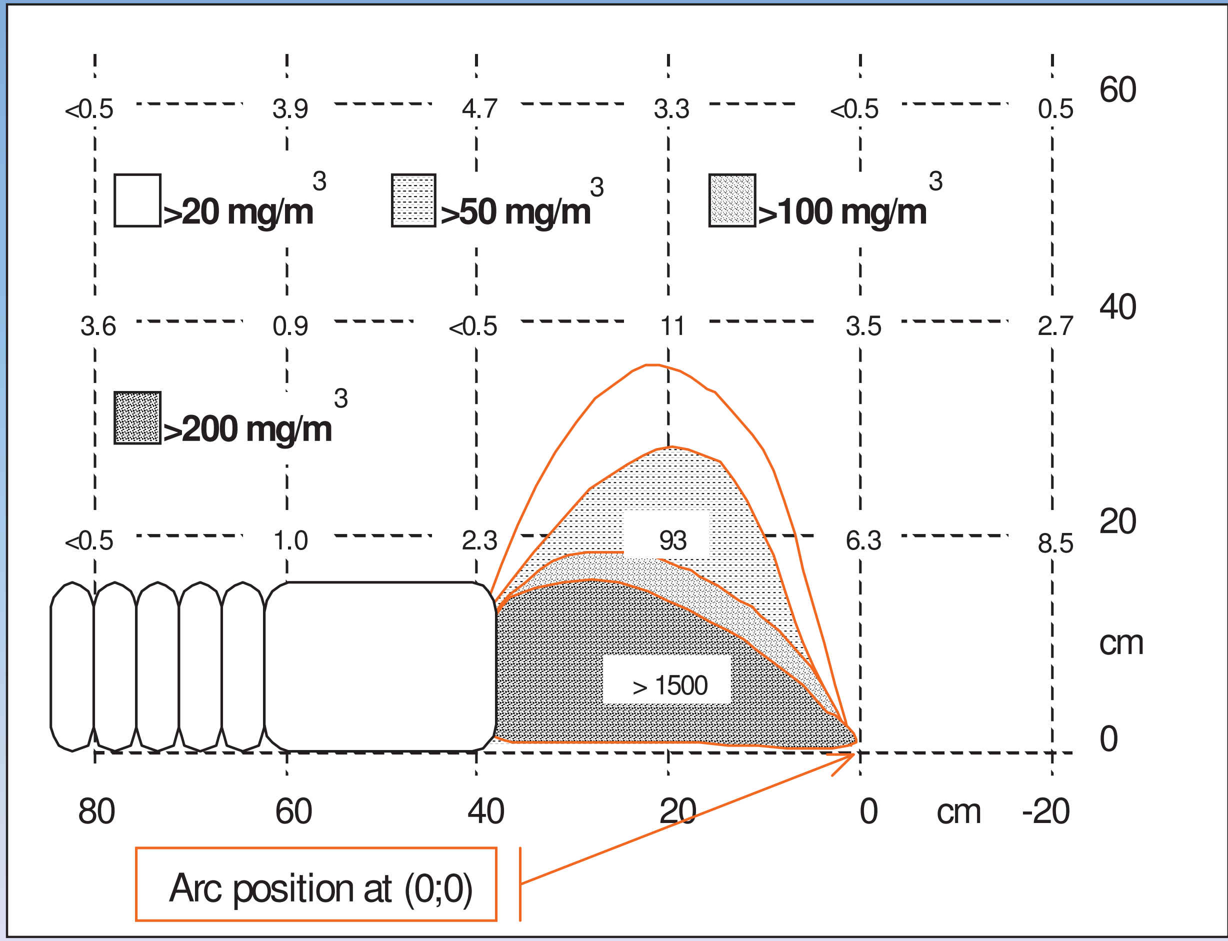
Many different measures and ways to make measurements of the efficiency of a local exhaust exist. These measures can be divided into three main categories:

- Capture velocity : is mostly defined as the air velocity generated from the exhaust opening, necessary to capture a contaminant outside the opening and transport it into the opening. Its advantage is that it makes it possible to calculate the necessary flow rate into the adjacent opening.
- Capture efficiency : describes how large part of a contaminant, generated outside an exhaust, is captured by the exhaust. Its advantage is that it makes possible to calculate how much of the contaminant that is spread in a room (if the source rate is known) and thus to judge if the exhaust is good enough.
- Containment efficiencies : are often called indices, which are calculated and measured in many different ways. They are different from the two preceding measures in that they are exclusively used for partially closed and closed hoods. Their advantages are that they can give a good approximation of the contaminant leakage from a specific workplace.

Fume Dispersion in GMAW

Most of LEV are mounted on the wall and working distances are limited. The collection arms of these devices must be repositioned frequently, which is not done in practice. The position of the suction nozzle is very important for the welding quality in high-vacuum systems. The nozzle must be positioned a certain distance away from the welding point so that the suction flow does not disturb the shielding gas distribution on the welding pool. Therefore, the major challenge in this system is to maintain the welding quality: it is required that the welder fine-tune the exhaust flow rate for each set up.

Fume Dispersion Pattern in GMAW – Spray Transfer Mode – LEV 0.5 m/s at Source

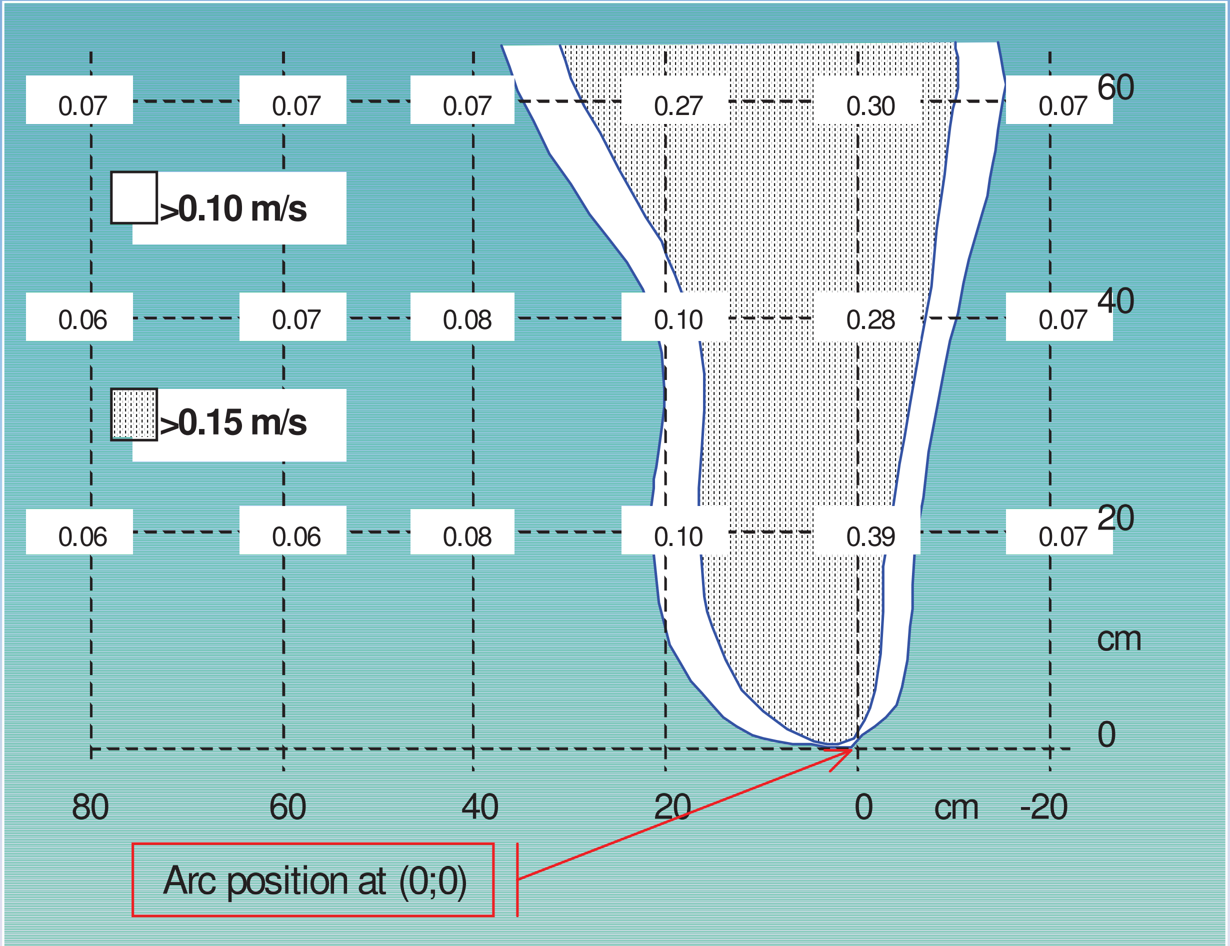


Sutherland R.A., "Exposure to fumes and gases during welding operations", Ph.D. Thesis, University of Deakin, Australia, 1998, 278 pp. – Re-elaborated

Fume Velocity Contour in GMAW

In regard to the air velocity profiles the trend that is most apparent is that in the immediate area above the arc, air velocity increases with increasing arc power.
At high arc power, air velocity may exceed 0.3 m/s in this area .

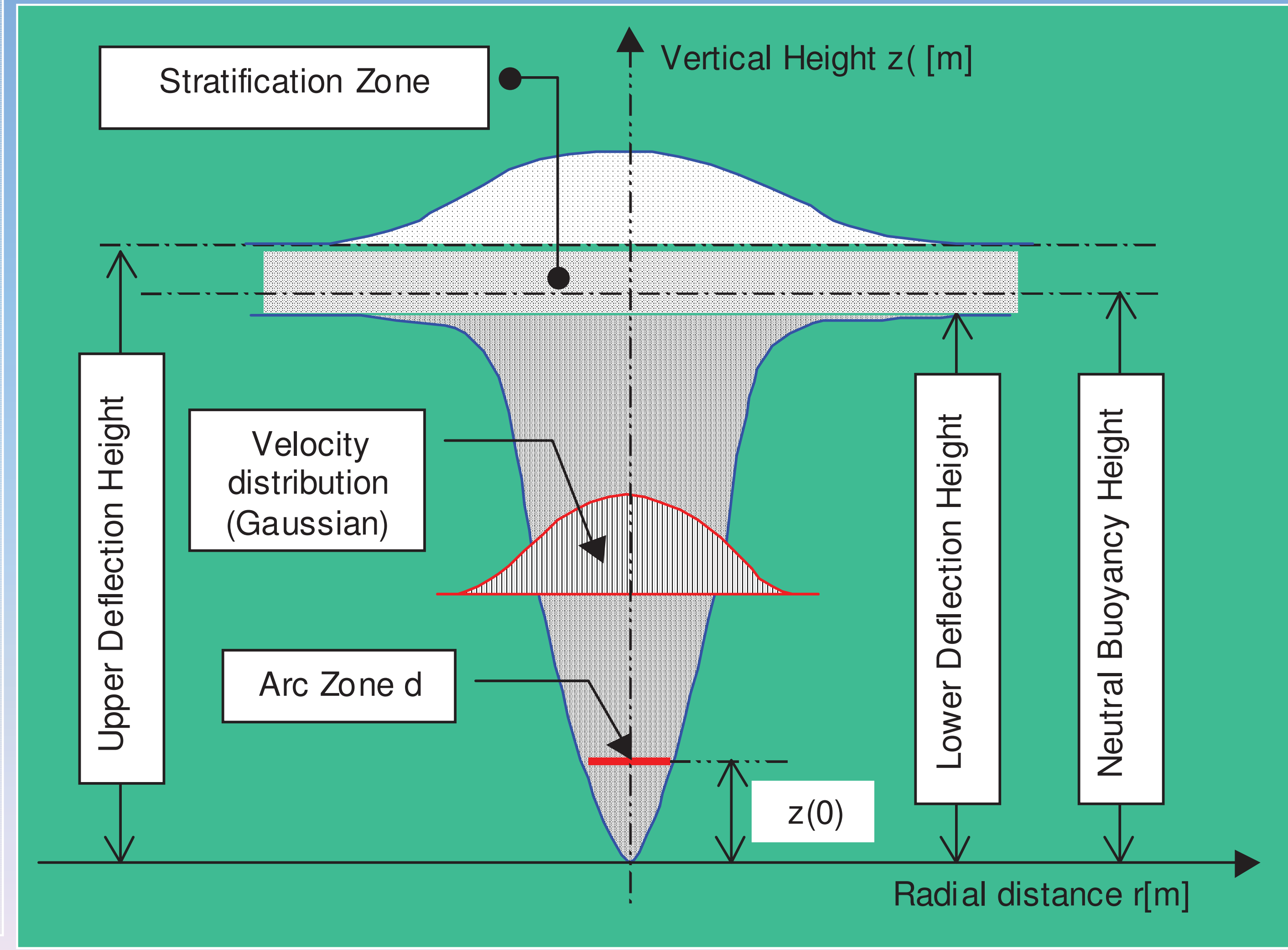
Fume Velocity Contour in GMAW – Spray Transfer Mode



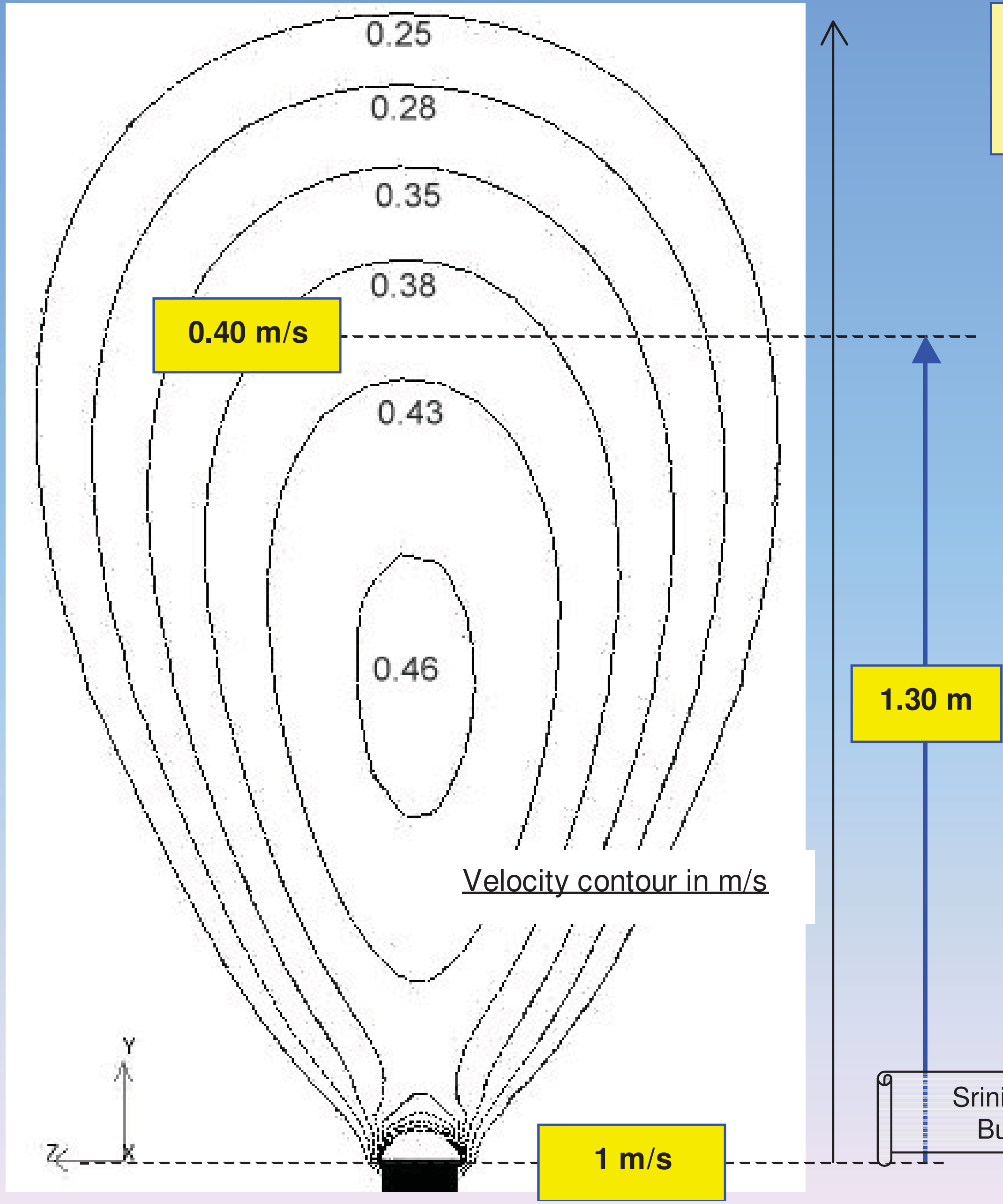
Fume Plume Flow

Since the design parameters of any extraction system depend on the flow characteristics of the fume plume and fume generation rates in the arc welding, calculations of welding fumes are normally performed assuming a turbulent axisymmetric buoyant flow created by a small surface (arc zone) with a very high temperature, as shown in Figure.

Theoretical Model for Fume Plume Flow



Plume Velocity vs. Height



Velocity Contours of a Plume vs. Vertical Height

The plume velocity values are maximum near the source. The velocity of the fume decreases as we move away from the axis of the fume pattern. This is due to the exchange of heat between the thermal buoyant plume and the ambient reducing the steep thermal gradient. The velocity of the plume at y=1.3 m above the source is 0.4 m/s and this value is significant because the welder is directly exposed to these highly buoyant plumes. The plume velocity gradually decreases at higher altitudes.

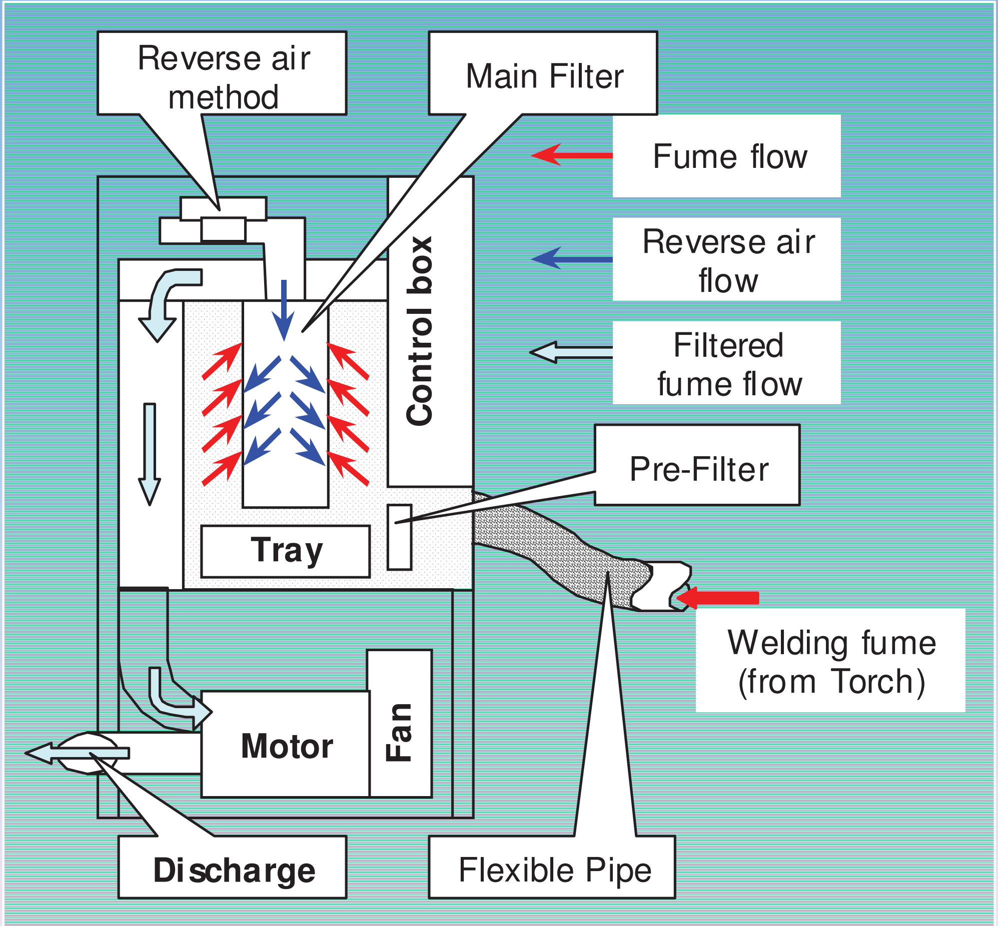
Srinivas S.D., Mukund K., Arun M., “Computational Modelling and Simulation of Buoyant Plume Dynamics”, 2nd ICCMS Congress, 2006, Coimbatore, India.

On-Torch Extraction: Fume Collector

The suction flow rich of the captured fumes of on-torch extraction device is connected through a flexible conduit to the extraction system (exhaust unit or aspirator), able to supply the required extraction flow rate, at a constant pressure.

Modern exhaust units are provided with start-stop devices enslaved to the arc ignition and stop, thus assuring the extraction flow only when required.
The protection of cable and pipes connecting the torch handle to the aspirator is nowadays guaranteed by antiwear materials. Cooling of the conduit and fumes include mixing sufficient ambient air with the welding fumes.
This ambient air, in combination with the positioning of the fumes extracting orifice on the nozzle (but away from the area of the weld) allows the temperature of the handle to be maintained within acceptable limits.

Layout of Welding Fume Collector



FUMES EXTRACTION TORCHES

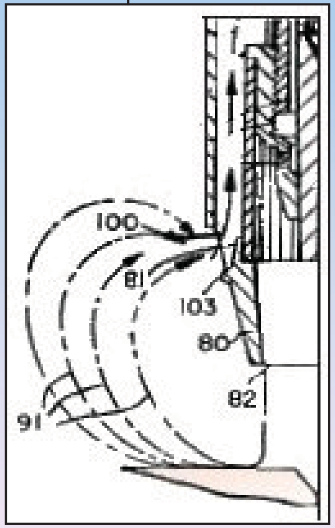
BASIC PRINCIPLES

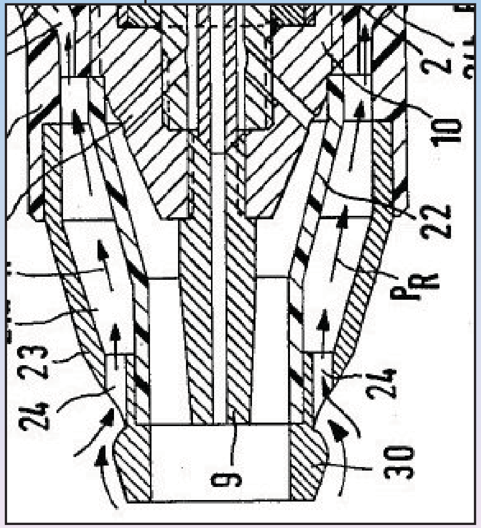
- Suction Field: Axial vs. Radial
- Capture Range: Direct vs. Indirect
- Exhaust Flow: Direct vs. Inverse Capture
- Direct + Radial Air Jet Supply
- Integral vs. Add-on Extraction Torch

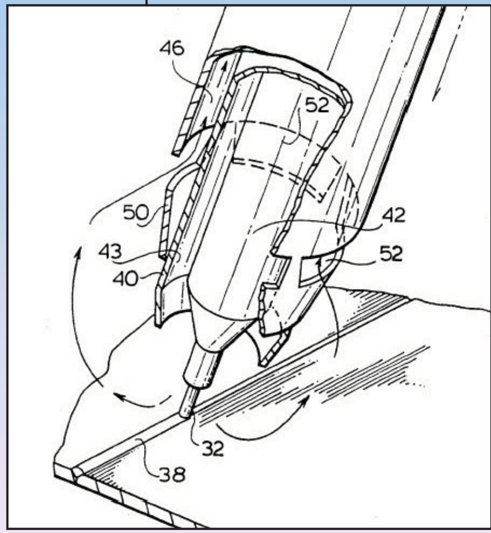
Definitions

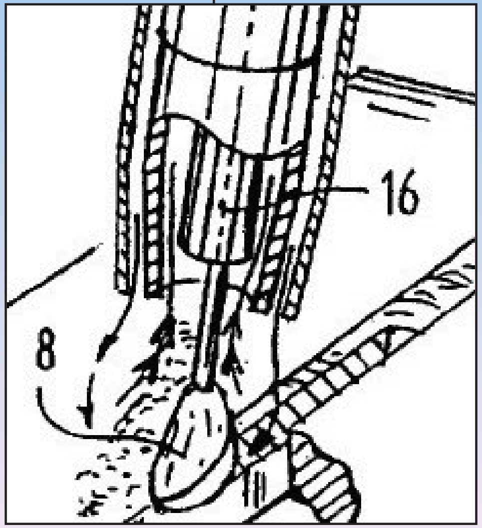
FUME EXTRACTION TORCHES
Definitions

- Suction Field Velocity
  - Radial
  - Axial
- Capture Range Flow
  - Direct
  - Indirect
  - Inverse
- Exhaust Device Tool
  - Integral
    - Air cooled
    - Water cooled
  - Add-on



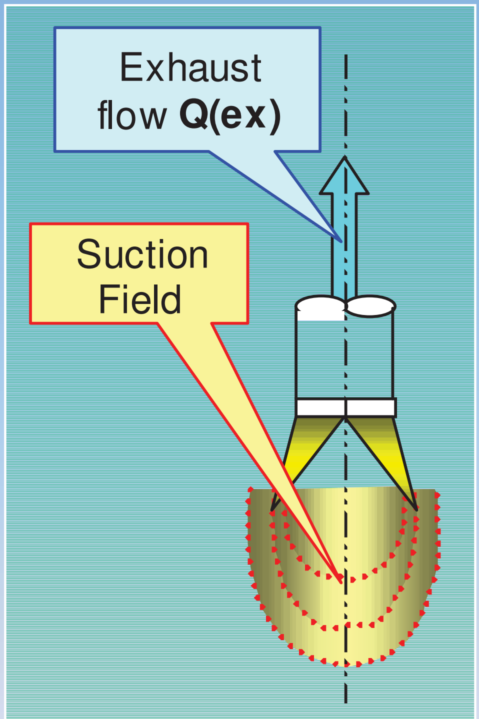




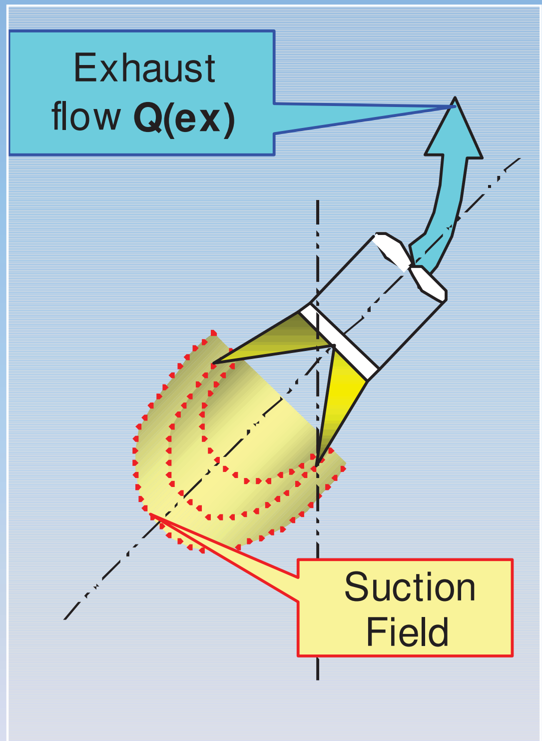


Suction Field: Axial vs. Radial

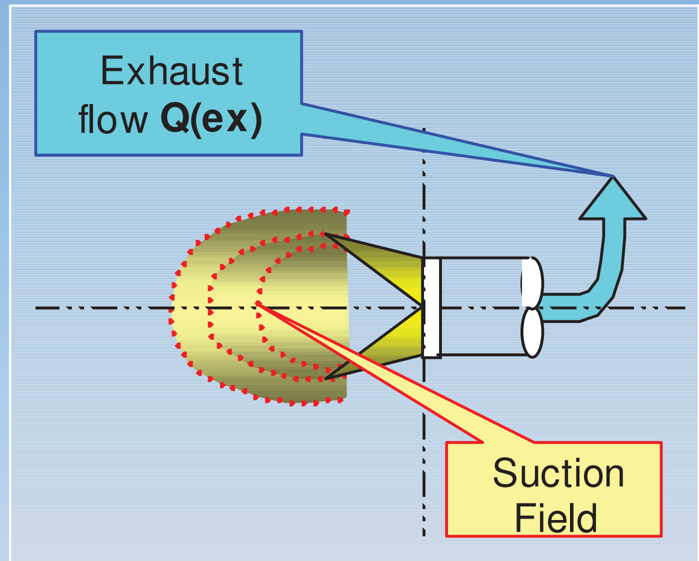
Effective welding fume capture is only achieved when the velocity of the extracted air exceeds 0,3 m/s, the average velocity at which a fume plume rises. Therefore, a velocity of 0.4 m/s has been selected as being sufficient to ensure capture of fume and gases at any given point. This capture velocity can only be achieved by applying a minimum volume air flow rate, which is dependent upon the aspect ratio and cross sectional area of the opening ports.



The suction field is aligned with torch axis (axial).



The suction field is 45° towards torch axis (radial).

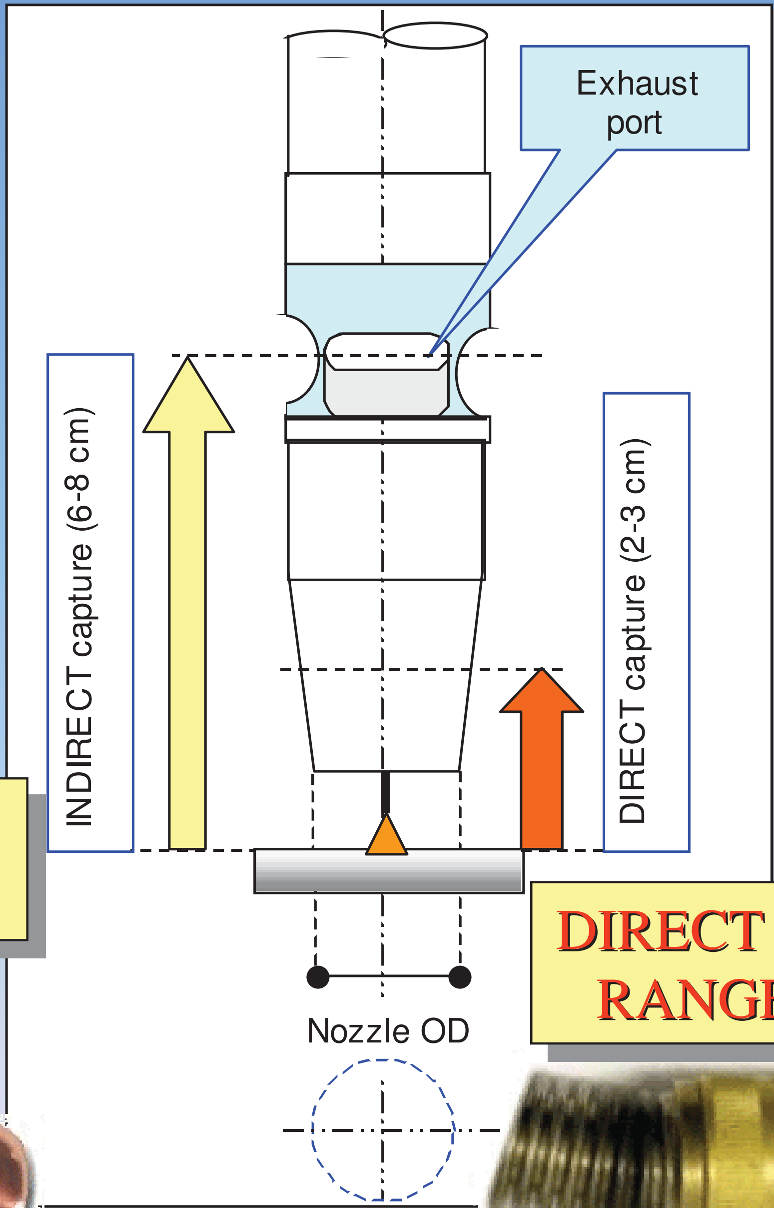


The suction field is orthogonal to torch axis (radial).

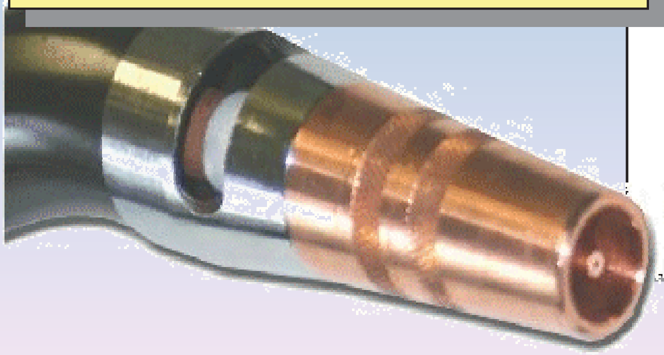
pr EN ISO 15012-2: 2006. "Health and safety in welding and allied processes – Requirements testing and marking of equipment for air filtration – Part 2: Determination of the minimum air volume flow rate"

Suction Openings: Direct vs. Indirect Capture

Their physical configuration is similar to the conventional welding torches, integrated with some suction basic opening (rim, edges, slots, multiple holes) placed around a surface for capturing the fume plume (typically the torch nozzle at the lower end of handle for a direct capture or the torch body far away from the distal end of the nozzle for an indirect capture).



INDIRECT CAPTURE RANGE : 6-8 cm



DIRECT CAPTURE RANGE : 2-3 cm

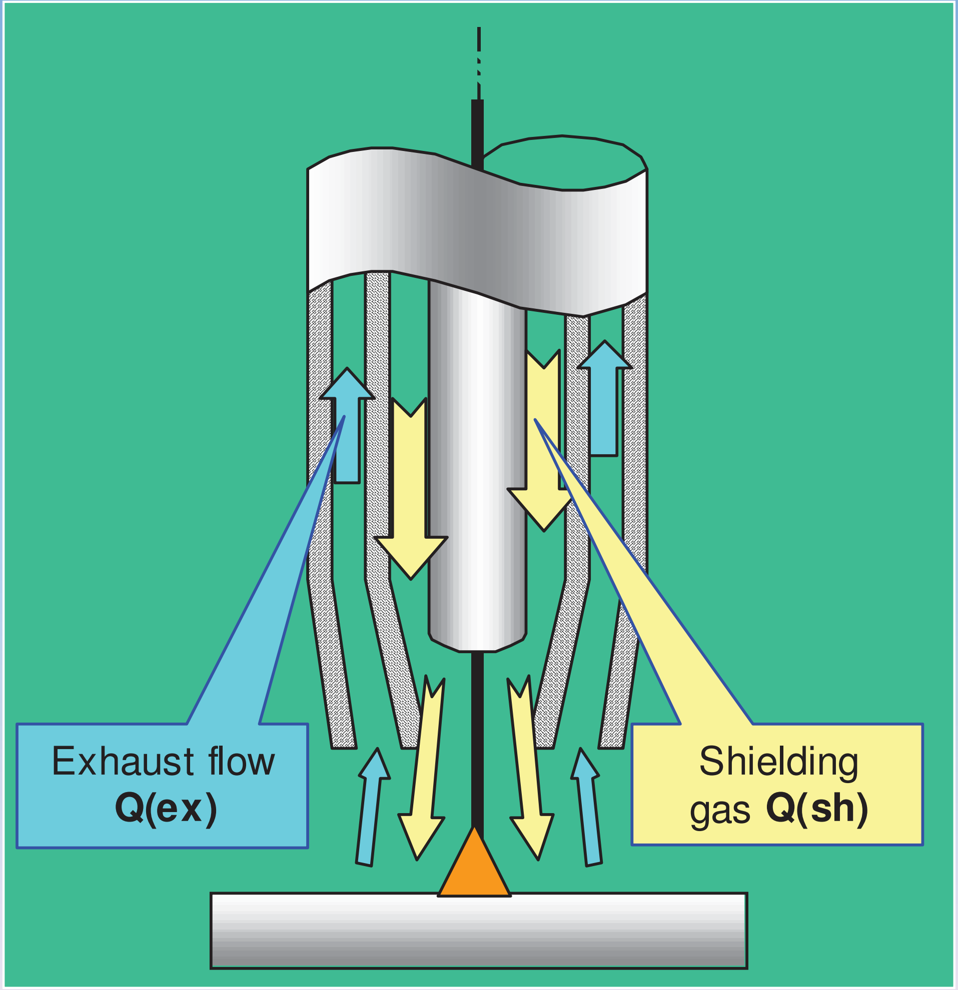
Exhaust Flow: Direct Capture

Direct capture path in the radial wall jet by means of an annular extraction sleeve around the torch nozzle has been shown to be ineffective.

This is due to the fact that only a small region near the inlet to the sleeve is influenced by the extraction, which is generally too close to the axis of the torch and too far from the work surface to capture either the fume-laden wall jet or the rising plume. The location of the extraction port is such that the extraction flow cannot affect the flow in the wall jet to any significant extent.

Although decreasing the extraction nozzle separation from the workpiece may improve fume capture it adversely affects shielding efficiency.

DIRECT On-torch Extraction with Axial Exhaust Path

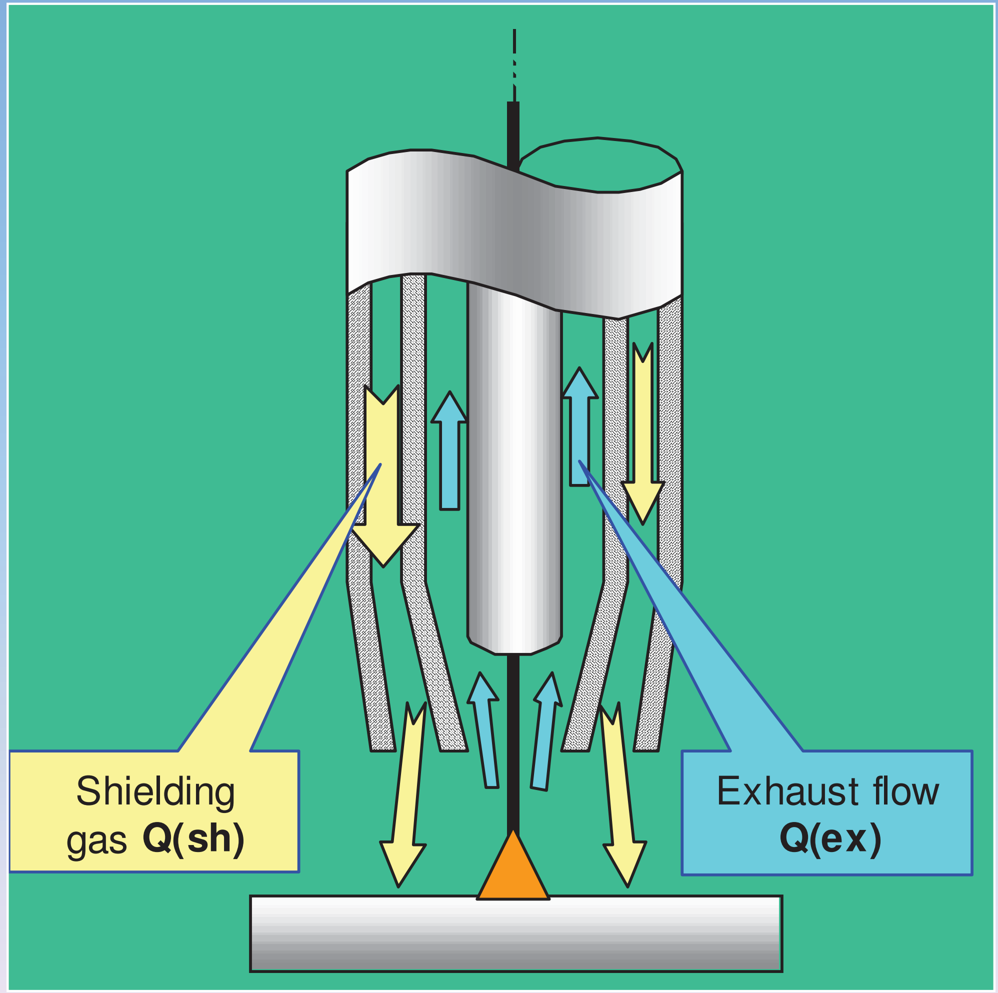


Exhaust Flow: Inverse Capture

A more recent variation is disclosed in US 6,380,515 in which a fume extraction port surrounds the welding electrode and a concentric inert gas supply port surrounds the extraction port. While this configuration assists in confining the bulk of the fume to a region close to the arc and therefore makes the task of extracting fume relatively easy compared to prior art devices, the configuration also dilutes the inert gas concentration to unacceptably low levels with ambient air in the vicinity of the arc and weld pool. This is irrespective of the relative flow rate of shielding gas and rate of fume extraction.

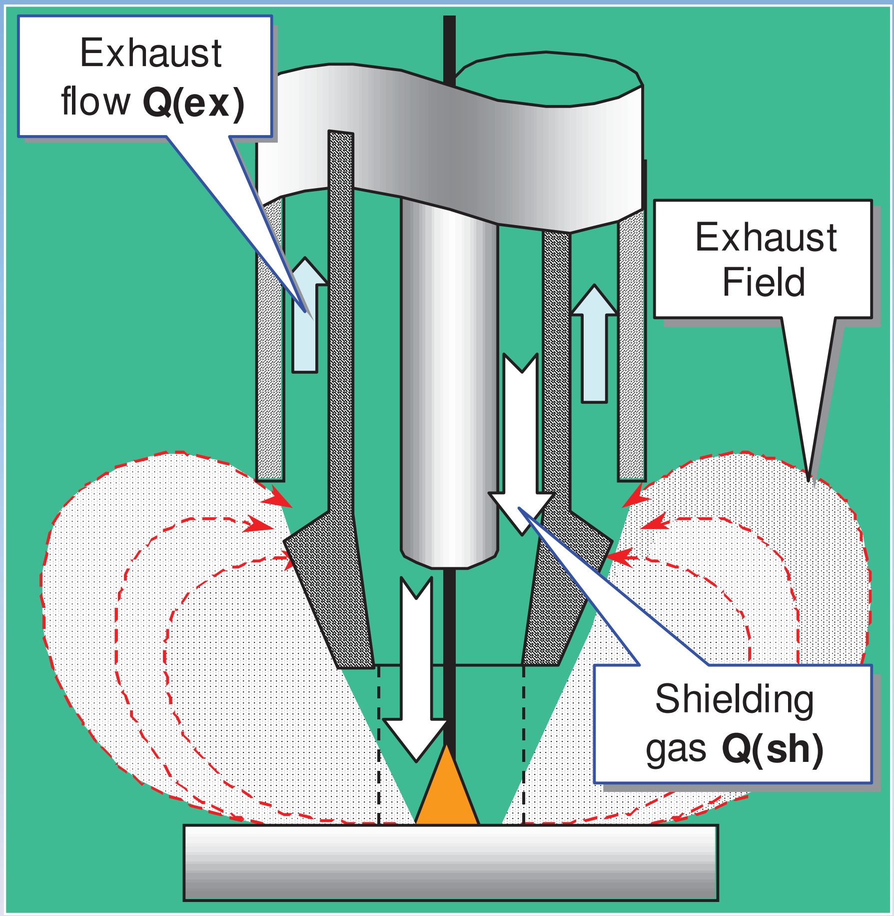
Knoll B. et. al., International Application, "Welding torch with inverse extraction", Patent N. US 6,380,515, April 2002

INVERSE on-torch Extraction with Axial Exhaust Path

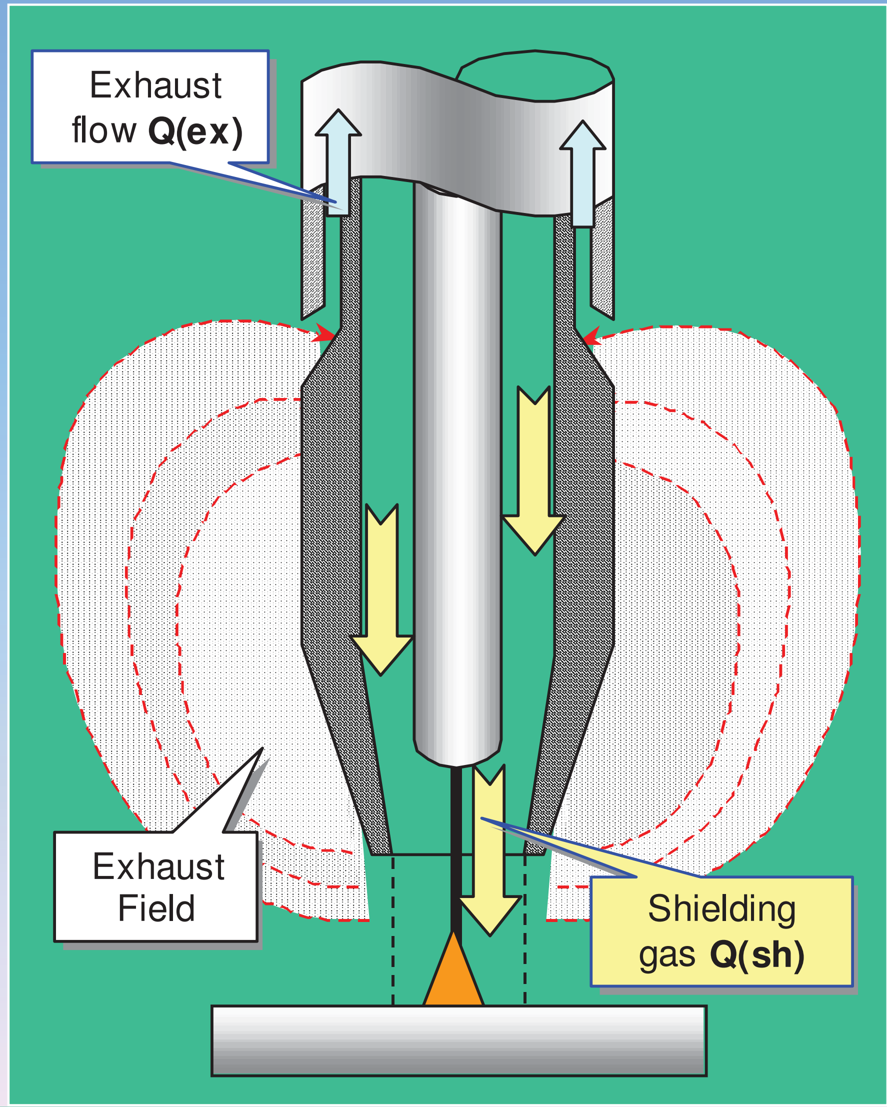


Radial Suction Field: Direct vs. Indirect Capture

DIRECT On-torch Extraction with Radial Exhaust Path

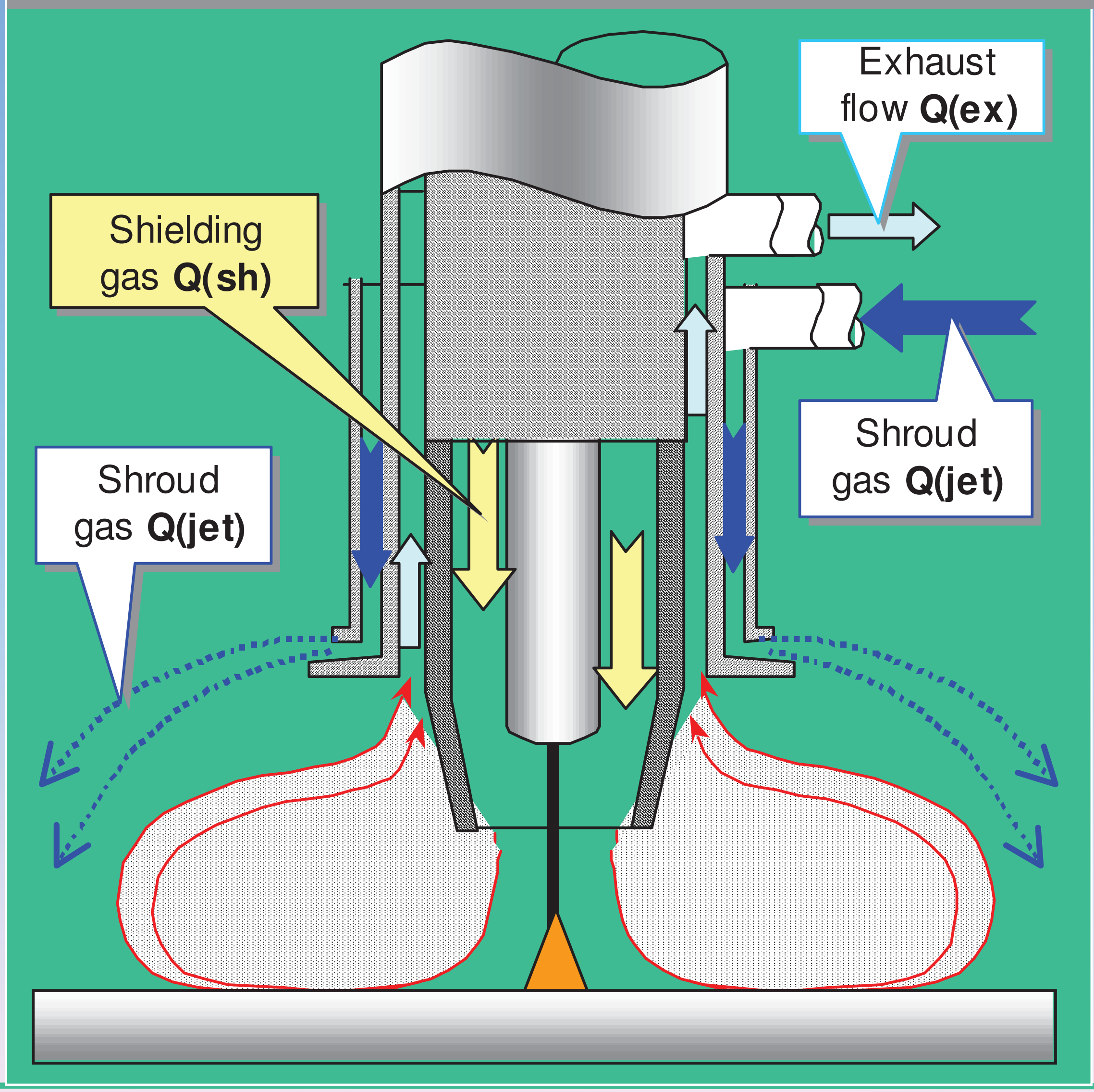


INDIRECT On-torch Extraction with Radial Exhaust Path



Direct + Radial Air Jet Supply (Patent)

Schematic Extraction Nozzle with Radially Directed Shroud Gas Jet



According to applicants, their invention provides an arc welding torch and a method of extracting fume gas from a welding site.

The torch comprises a metal electrode and at least one shield gas port adapted to direct a shield gas curtain around the metal electrode and a welding site.

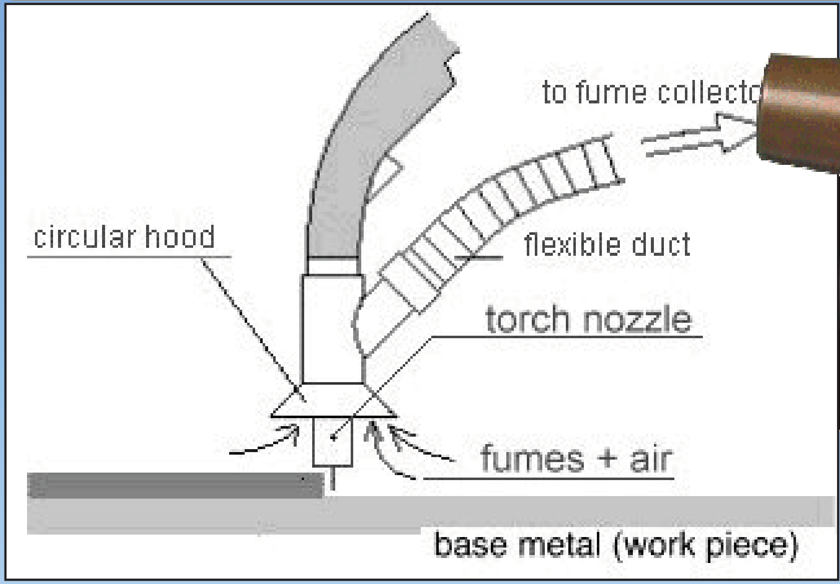
At least one shroud gas port is spaced radially outward from the shield gas port and adapted to impart to an exiting shroud gas a radially outward component of velocity (aerodynamic flange).

Fume gas is preferably extracted from a position radially intermediate the shield gas curtain and the shroud gas curtain.

Cooper P., Godbole A., Norrish J., International Application, “Apparatus and method for welding”, Patent N. WO 2007/106925 A1, September 2007

Integral vs. Add-on Extraction Torch

Direct Add-on Extraction Torch with Axial Exhaust Path



Bravaccini A., International Application, "Suction head for welding torch", Patent N. 2087534, September 2000

ECONWELD

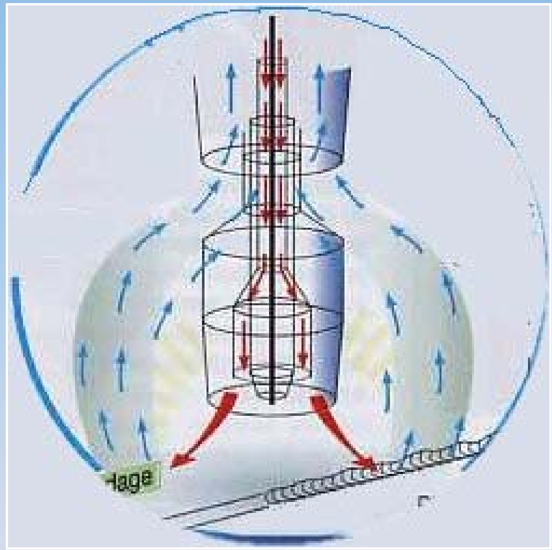
ECONWELD / ASPIRMIG TORCH

Indirect Integral Extraction Torch with Radial Exhaust Path (Nozzle nomenclature)

EC funded Collective Research Project, Contract N. CT-2005-516336, "Economically welding in a healthy way (Econweld)" - Project website: http://www.ewf.be/econweld/

FUME CAPTURE EFFICIENCY: TEST METHODS

- Balance method
- Total particulate method
- Tracer gas (Helium) method



Fume Capture Efficiency: Methods

CAPTURE EFFICIENCY METHODS

Four principal methods of evaluating capture efficiency of fume extracting torches have been developed in the past:

- **Total particulate fume**: The total fume emitted is collected, first powering on the extraction system and then switching off the extraction system. Relatively simple and widely used, but with low accuracy (about 20-25%).
- **Breathing zone measurements**: This method directly measures the quantity of most interest, the fume exposure of the welder, but tend to be subject to large variations (size and position of welder, general environment, position of weldments).
- **Use of photography**: This method allows only a qualitative evaluation. It was used by early workers and is still employed in marketing literature to graphically illustrate the effect of fume extracting torches.
- **Tracer gas techniques**: Tracer gas (I.e. Helium) is employed to make continuous and recordable measurements. The method requires a mass spectrometer to measure the tracer gas concentration

Balance Method - Definition

Some boundaries should be defined in order to develop a standard procedure for measuring the capture efficiency. The method :

- must be implemented both in laboratory and welding workshops;
- must be friendly to use and must assure wide circulation;
- must have high sensitivity and assure fast response to transitory welding phases.

The balance method defines the capture efficiency (η) of the extraction system as the ratio between the mass captured by the extraction ports m(c) and the fume mass emitted during the welding process m(e):

$$\eta = m(c) / m(e) \times 100\ [\%] \qquad (1)$$

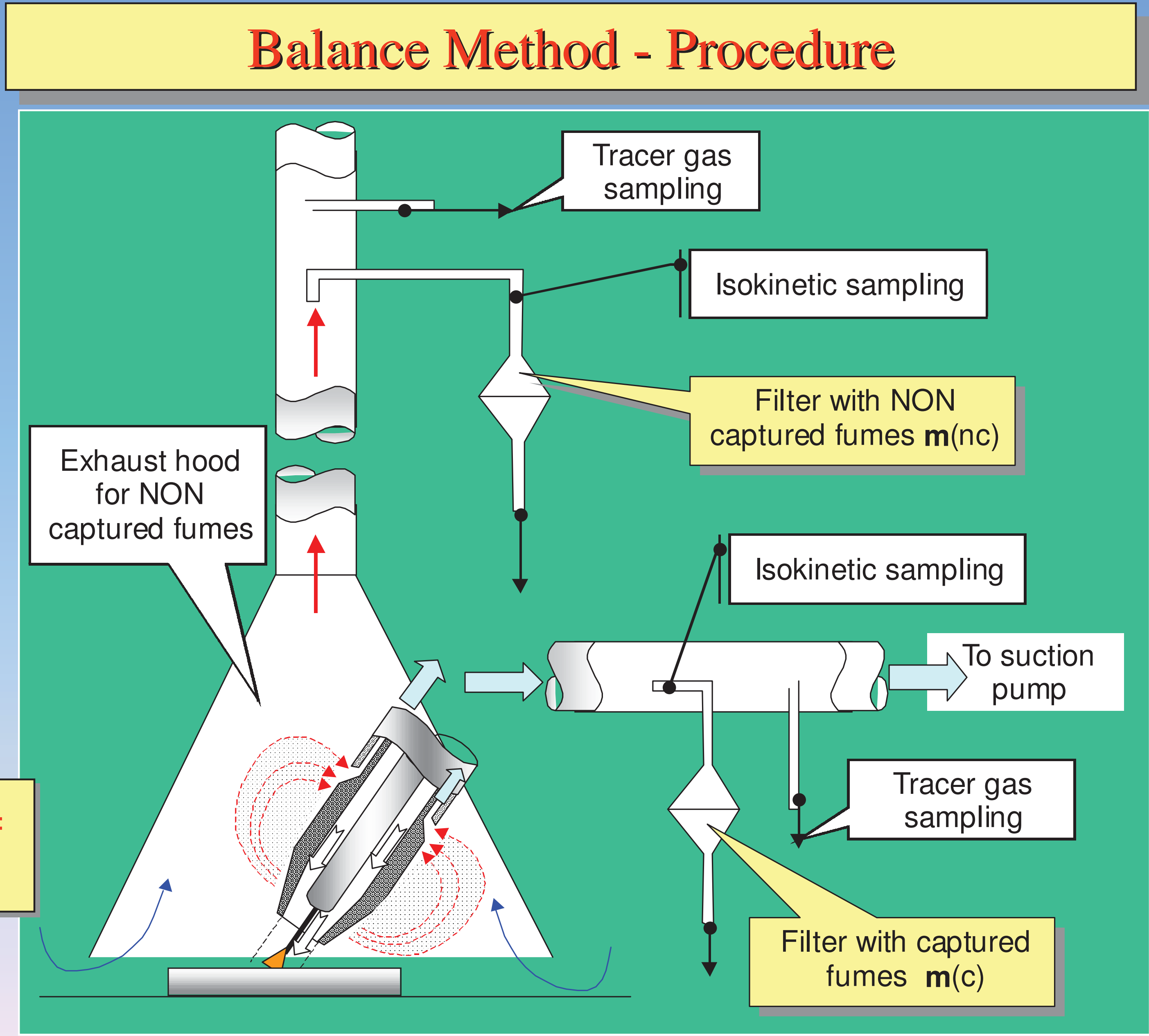
The method is based on the following statement:

the sum of the fume mass captured by the suction torch m(c) and the fume mass which is not captured by the suction torch ***m(nc)*** *must be equal to the fume mass emitted during the welding process* ***m(e),*** *being all the masses expressed in [mg/s].*

Balance Method - Procedure

The evaluation procedure consists in measuring m(c) through an isokinetic sampling of the captured fume inside the extraction tube on the torch hosing, while m(nc) is measured trough an isokinetic sampling of the air and plume surrounding the suction torch placed in a fume box.

η= m(c) / m(e) x 100 [%] = (1-m(nc) / m(e)) x 100 [%]



Particulate Method - Definition

This relative method allows to determine the ratio between the mass of fume really captured by the extracting torch and the mass of fume extracted when the ideal efficiency is supposed to be η=100%.

We define :

- M1 = mass of the particulate matter collected by the filter during the welding time (mg);
- t = welding time (s);
- M2 = mass of the particulate matter collected by another filter within the same extraction conditions, but without welding, during the same time t (mg).

The total mass of the particulate matter collected by the two filters is expressed by:

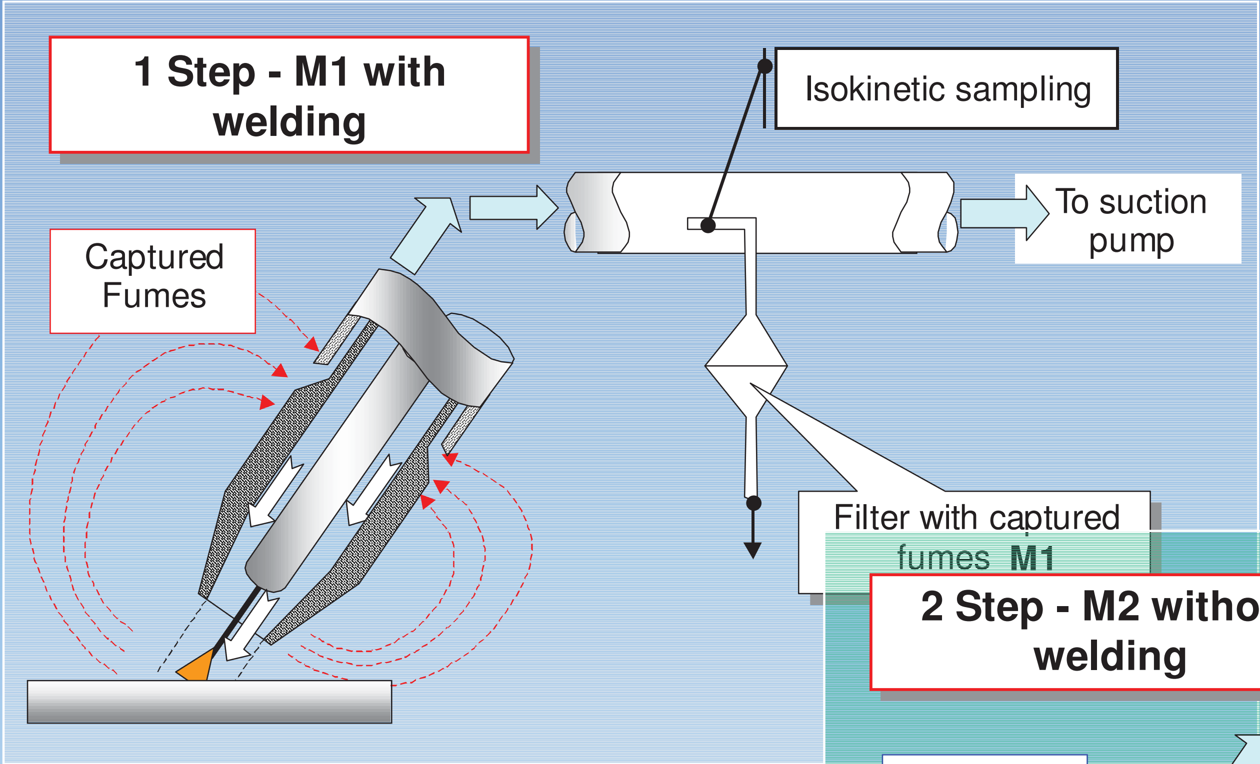
• M = (M1 - M2) / t [mg/s]

Performing a third test while welding using ideal suction conditions, for instance using an extraction flow rate higher than the normal set, we can expect to collect on a third filter a particulate mass M(max) corresponding to a capture efficiency of 100% and then :

• η = M / M(max) x 100 [%]

Cornu J.C., Muller J.P. and Guélin J.C. “Torches aspirantes de soudage MIG/MAG – Méthode de mesure de l’efficacité de captage. Etude de paramètres d’influence" . Cahier de notes documentaires de l’INRS (France) N. 145, 1991

Particulate Method - Procedure

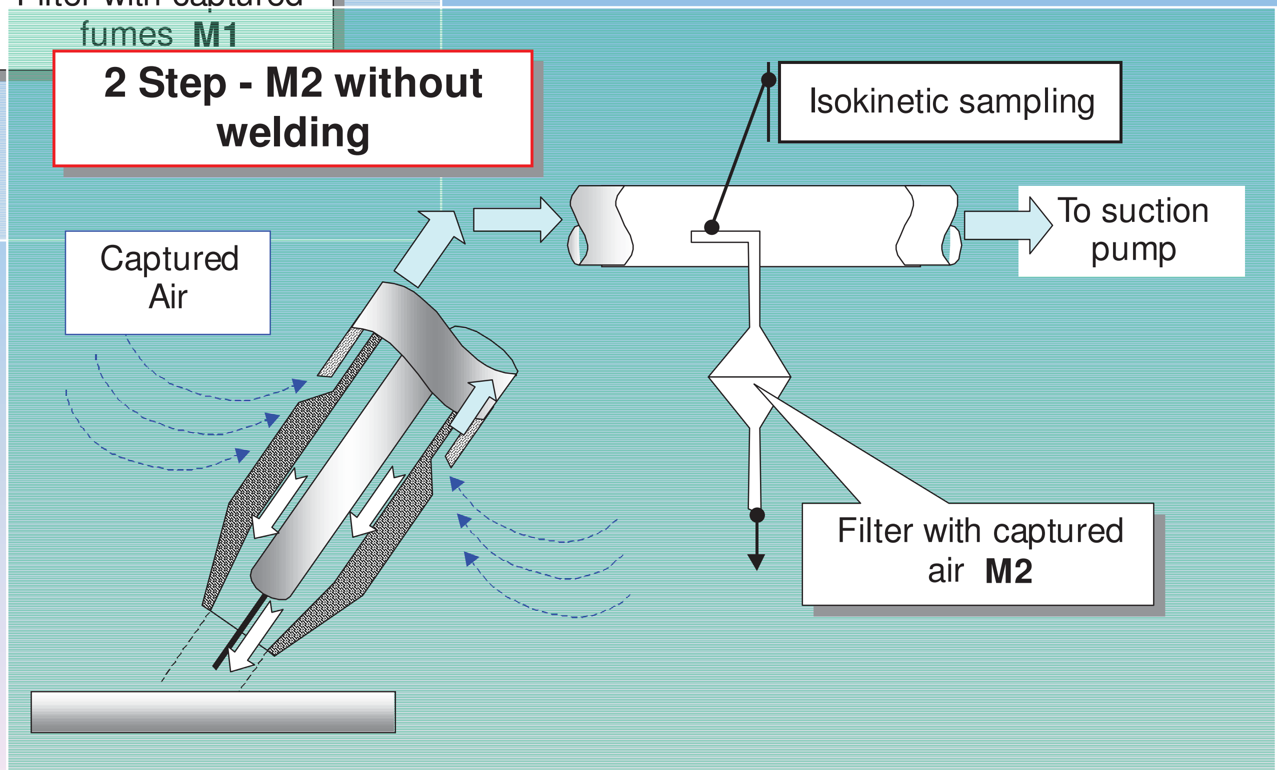


1st Step

$$M = (M1 - M2) / t \ \ [mg/s]$$

$$\eta = M / M(max) \times 100 \ [\%]$$

2nd Step



Tracer Gas Method: Definition

This method has been developed by the Institut National de Recherche et de Sécurité (INRS), France, for measuring the efficiency of fume exhaust devices on MIG-MAG welding torches. Applicable both in laboratory and on site, it is based on the use of a tracer gas (Helium) which may be a component of the welding gas or be mixed with it.

Basically, the evaluation of capture efficiency of a suction torch is performed using a tracer gas with the same behavior of the welding fume. The choice of tracer gas is done under some general requirements:

- absence of toxicity;
- chemical stability;
- no interference with the fume plume;
- easy to be measured, even at low concentrations;
- low cost.

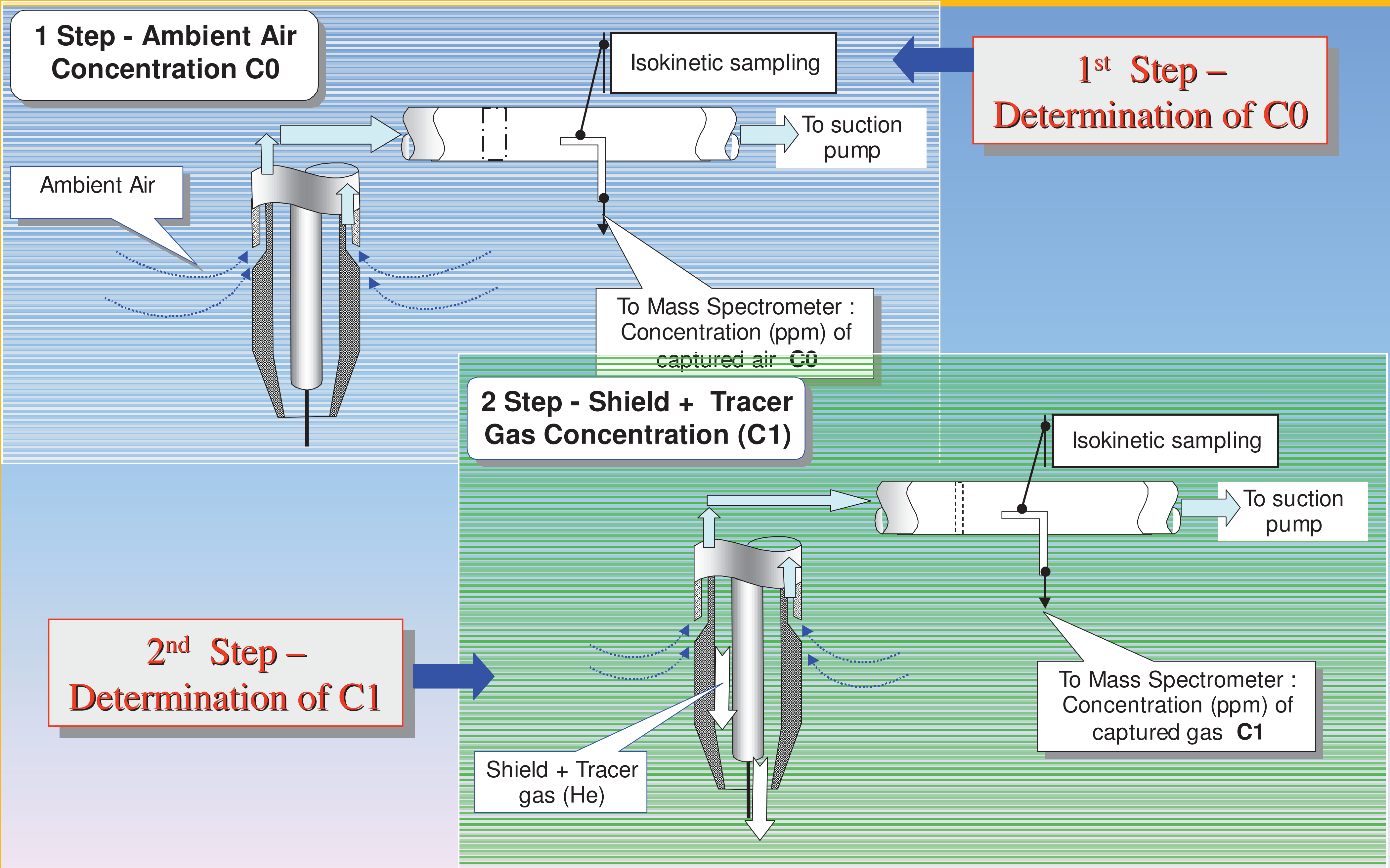
C0, ambient air concentration (ppm), measured without tracer gas;

C1, gas concentration (ppm), measured supplying the torch with the shield gas mixed with the tracer gas (Helium in the proportion of about 1%), both present in the suction ports of the torch without welding

C2, gas concentration (ppm), measured under standard welding conditions, supplying the torch with the shield gas mixed with the tracer gas in the emission zone of the fumes, using the same suction flow rate.

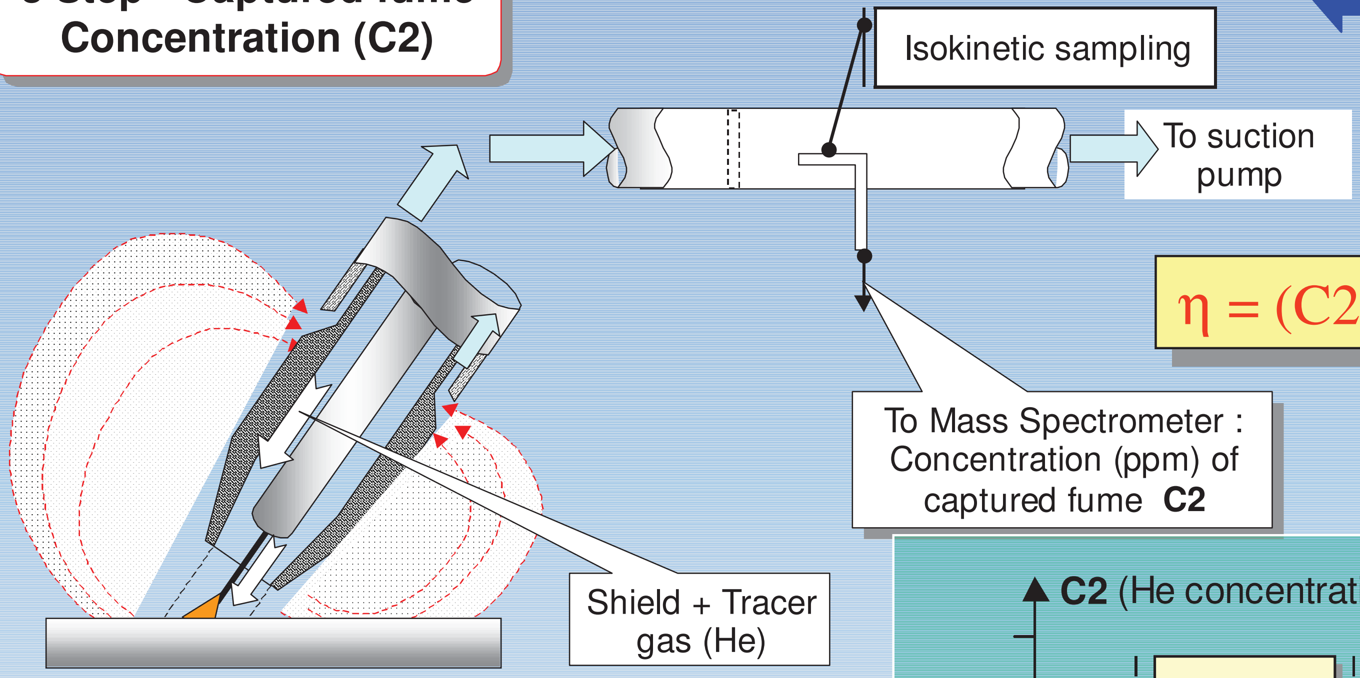
Cornu J.C., Muller J.P. and Guélin J.C. “Torches aspirantes de soudage MIG/MAG – Méthode de mesure de l’efficacité de captage. Etude de paramètres d’influence” . Cahier de notes documentaires de l’INRS (France) N. 145, 1991

Tracer Gas Method - Procedure



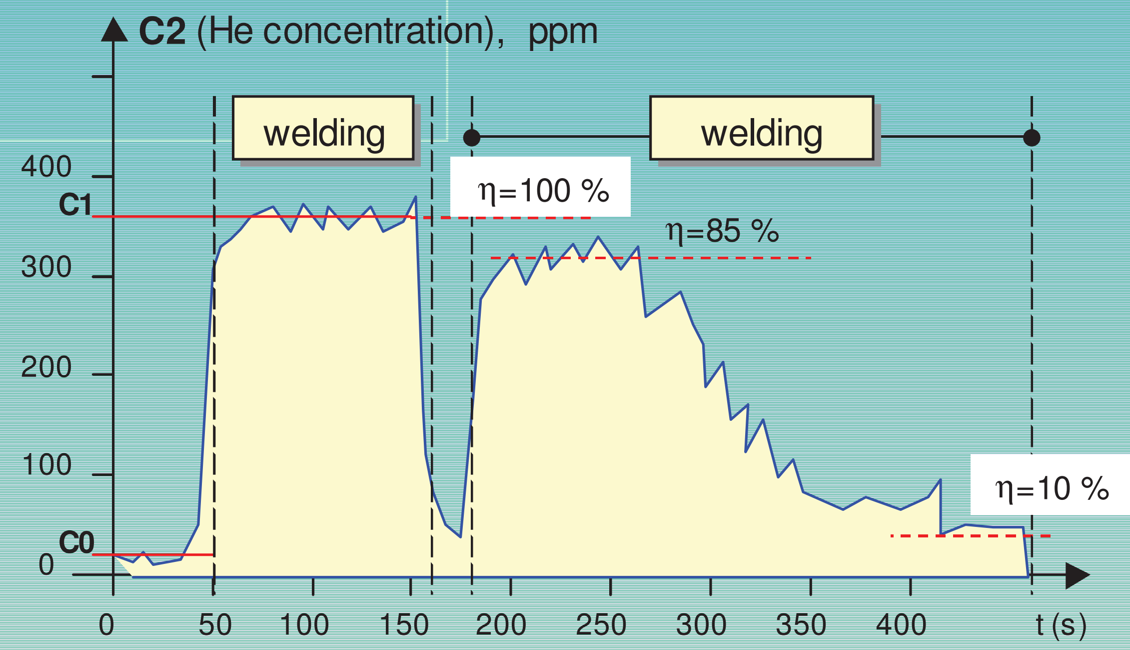
Tracer Gas Method - Procedure

3 Step - Captured fume Concentration (C2)



3[st] Step – Determination of C2

$$\eta = (C2 - C0) / (C1 - C0) \times 100\ [\%]$$



Spectrometer recording of capture efficiency evaluated by Tracer Gas Method – Welding Position = PF – Torch angle: variable

SECTION 4

FUME CAPTURE EFFICIENCY: A LITERATURE REWIEW

- Early developments (1968-1974)
- Improvements of Extraction Torches (1975-2002)
- CFD modelling (2003 and after)
- Robotics Extraction Torches
- ECONWELD Project – Aspirmig Torch

Early developments (1968 – 1974)

Fume extraction torches were developed concurrently by several companies in North America and Europe in the late 1960's and early 1970's.

Earlier fume exhaust welding torches had limited flexibility and were bulky to handle, when compared to conventional handheld tools. Moreover, the integrated suction capability raised severe restrictions on both the head nozzle and handle cooling, together with a great emphasis on minimizing the negative effect on weld quality arising from the suction flow path influencing the shield gas envelope. The introduction of fume extraction openings close to the arc point must satisfy conflicting requirements.

On one hand, the downward flow of shielding gas must be non-turbulent, on the other, an upward and inward flow of hot fume must be drawn back into the torch head by the exhaust system.
The balance that must be struck between these opposing forces to ensure maximum extraction efficiency (without loss of weld quality because of reduced or disturbed gas flow) has been in practice the main, concurrent task of the early designed torches.

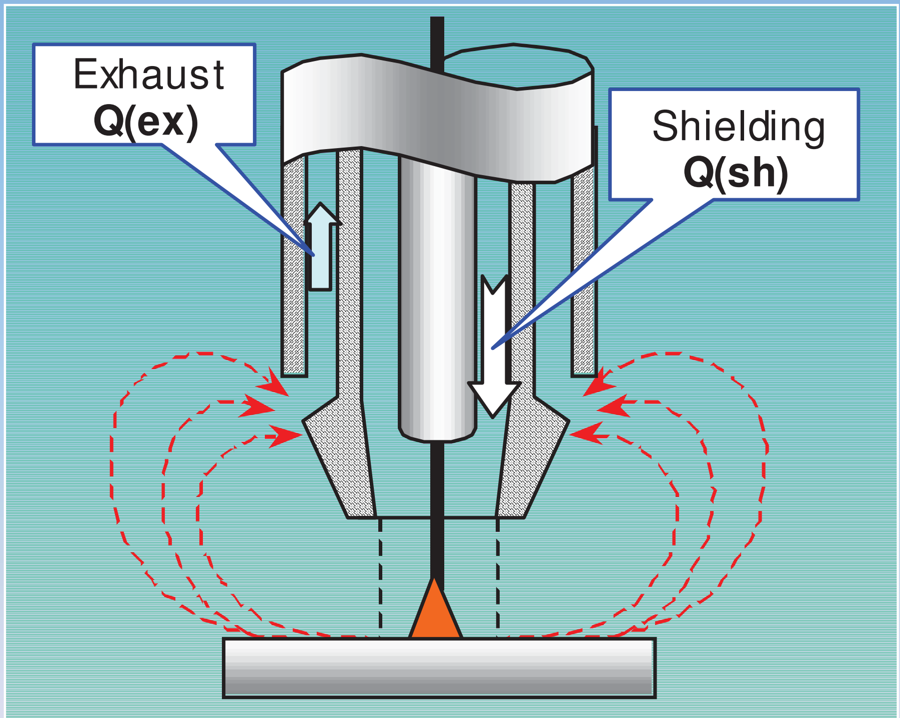
Laminar Stream flow (left) vs. Turbulent Flow (right)

Wildenthaler, L. and Cary, H.B., "A progress report on fume extracting system for gas metal arc welding unit", Welding Journal, September 1971

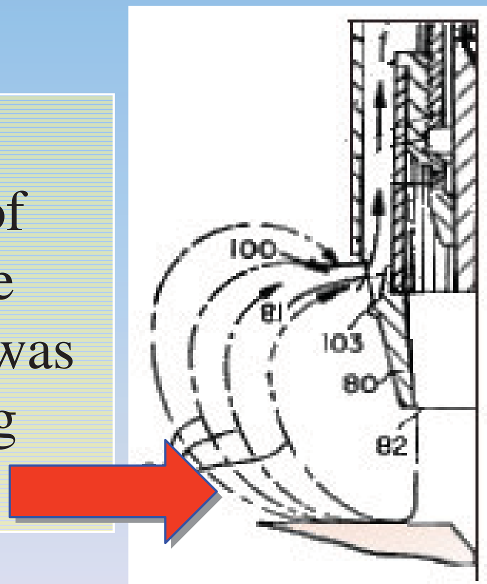
Early developments (1968 – 1974) - Cary

Wiehe, Cary, and Wildenthaler reported of a system that uses an outward tapering cone around the gas nozzle. The extraction was provided by a blower rated at 60.0 m^3/h and pressure equivalent to 20 kPa. Breathing zone measurements gave an estimated 85% capture efficiency.

Exhaust Nozzle Studied by Cary



Wildenthaler and Cary describe the development of an add-on nozzle to remove fumes. Capture efficiency was evaluated by photographing the fume plume.



Wiehe, A.E., Cary, H., and Wildenthaler, L., "Application of a smoke extracting system for continuous electrode welding", Welding Journal, June 1974

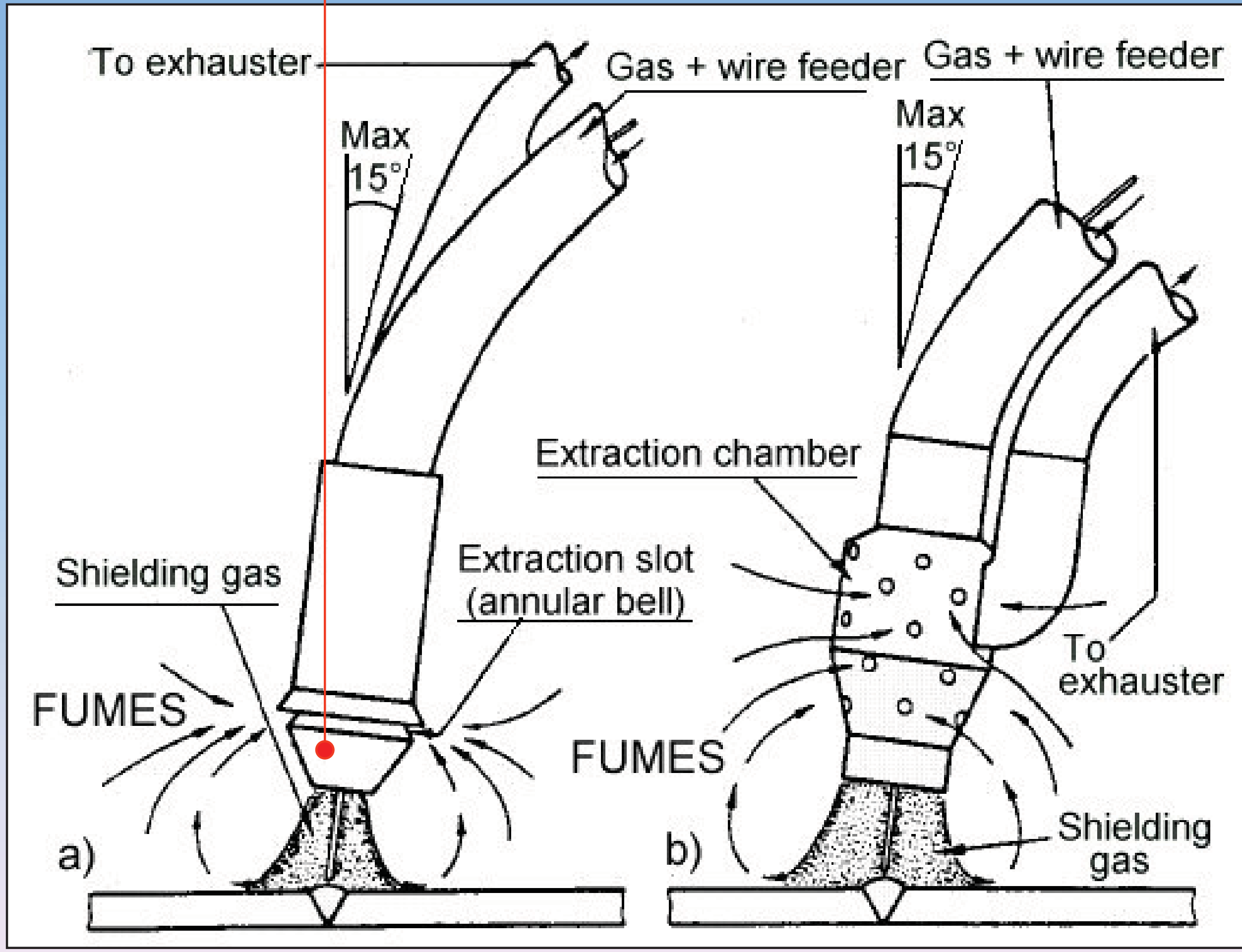
Early developments (1968 – 1974) - Head

Head defines two basic types of exhaust nozzles, which are concentric with the torch head to promote uniform extraction flow field in all welding positions.
In the first type extraction is via an annular exhaust slot or bell shaped skirt located about 12 mm behind the gas nozzle (direct suction).

In the second type an extraction chamber is used, having a number of small holes distributed over the surface, spreading the suction zone over a greater area.

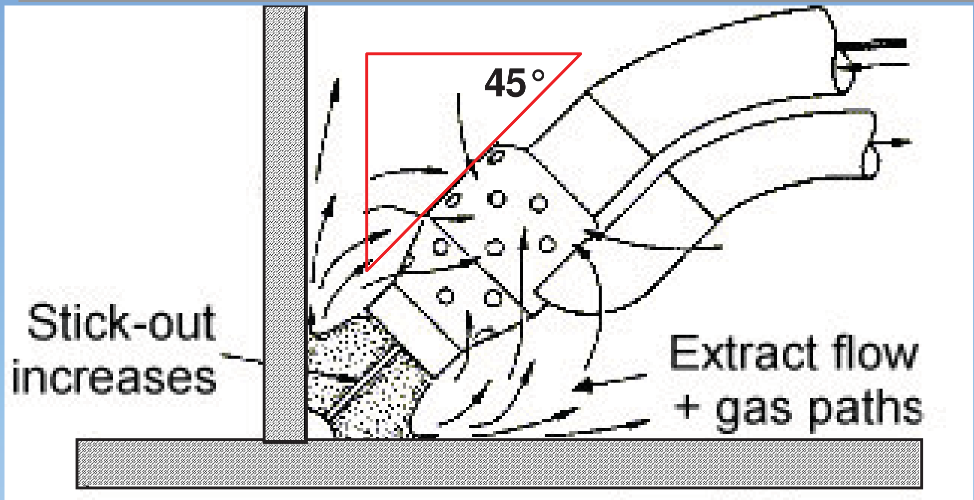
- Flat Bead on Plate Weld – The PA position assures a good control on capture efficiency.

Welding torches with integral fume extraction – a) Annular slot type; b) Multi-hole chamber. Source: Head



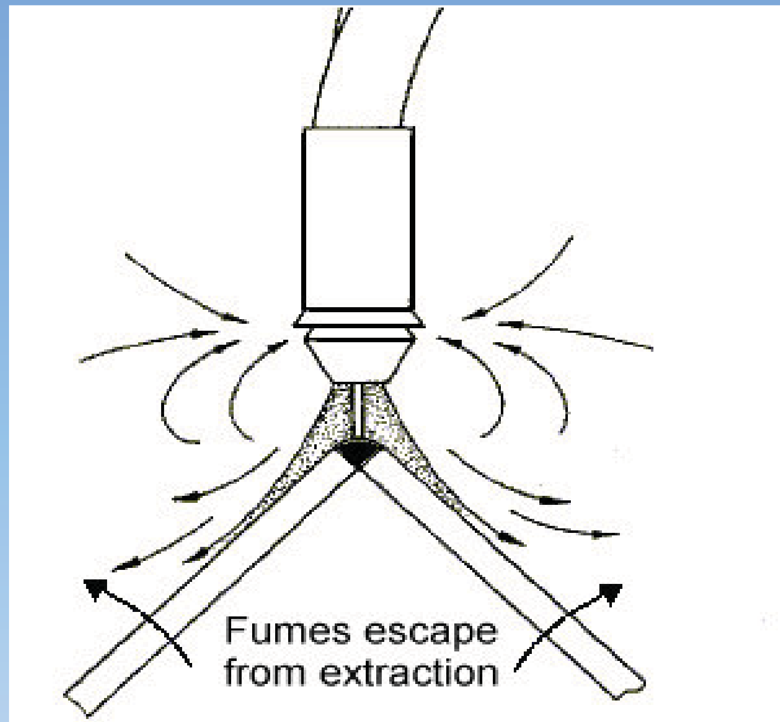
Early developments (1968 – 1974) - Head

Fillet Weld – Fumes escape when torch angle is not 45°. Source: Head



➢ Fillet Weld – The 1F-2F positions has a concentrating effect on gas and extract flows, increasing velocity. The fume control is generally satisfactory, unless torch angle deviates from a line bisecting the weld (45°). Increased electrode stick-out will decrease capture efficiency.

Open Corner Weld



➢ Open Corner Weld – The shield gas is not turned back to the extraction flow path and fumes escape the capture zone.

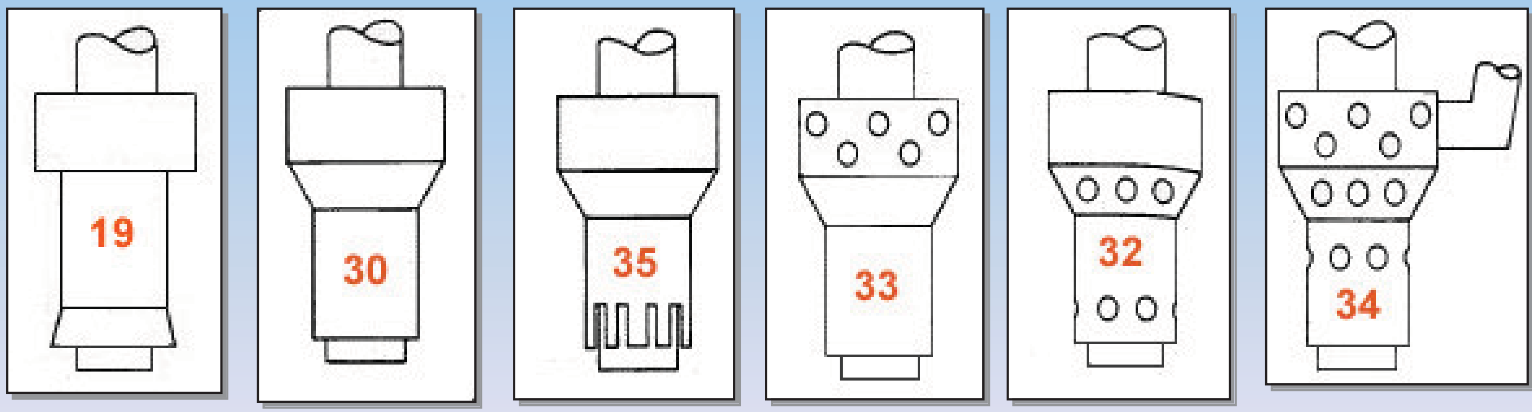
Head, I.W., "Integral fume extraction in MIG/CO2 welding", Metal Construction, December 1979

Improvements of Extraction Torches (1975-2002) - TWI

The major improvements of commercial fume extraction torches have been addressed both to promote ergonomic arrangements of torch handle and design more efficient suction nozzles, thus allowing the welder to manipulate the welding tool for extended periods of time.

Wright at The Welding Institute, London, describes the development of a fume extracting nozzle that could be used with different torches. The nozzle is coaxial with the torch and a variety of nozzle designs were evaluated.

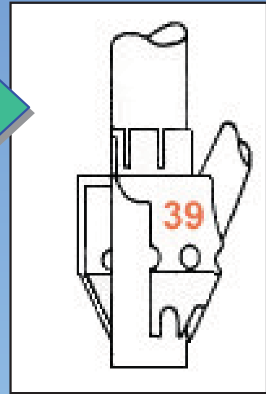
Evaluation of Different Fume Extraction Nozzles by TWI



N.B. In red are shown the maximum extraction flow rates in m^3/h , before suction flow affects shield gas coverage).

TWI – Wright Tests

An inward tapering nozzle with both slots and holes (O.D.= 22 mm) has been selected for testing fume capture efficiency.

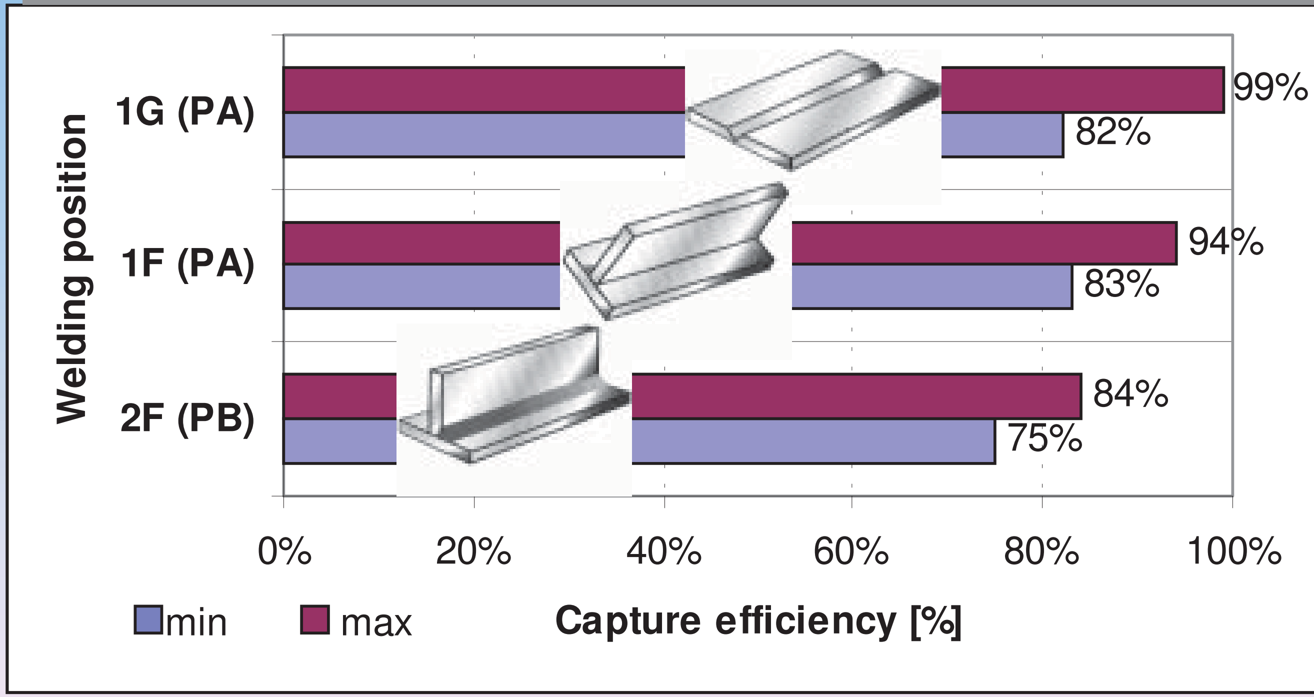


A fume collector with a maximum extraction rate of 60 m^3/h was used, with a 2.8 m extraction hose. Wright tested this system both by taking breathing zone measurements and by measuring fume not collected by the extraction torch.

Wright, R.R., "Fume removal for semi-automatic welding", International Conference on Exploiting Welding in Production Technology, The Welding Institute, London, April 1975

The extraction nozzle under test removed 90% of fumes. Fairly consistent results were obtained both from total fume and breathing zone measurements.

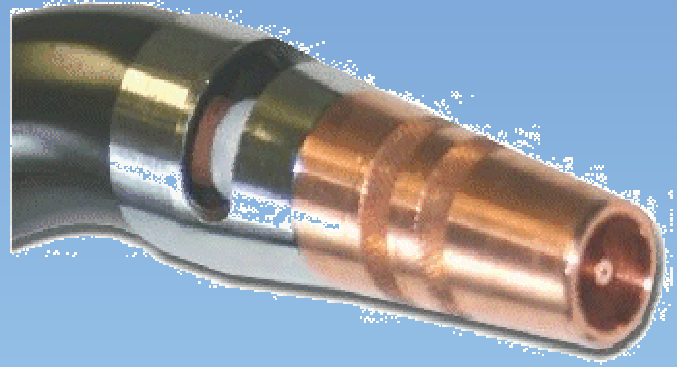
Capture Efficiency from Wright tests



Research at INSR - France

Cornu devised a method to measure fume capture efficiency using Helium as a tracer gas. The Helium was mixed with the shielding gas, with a proportion of about 1 to 5%.

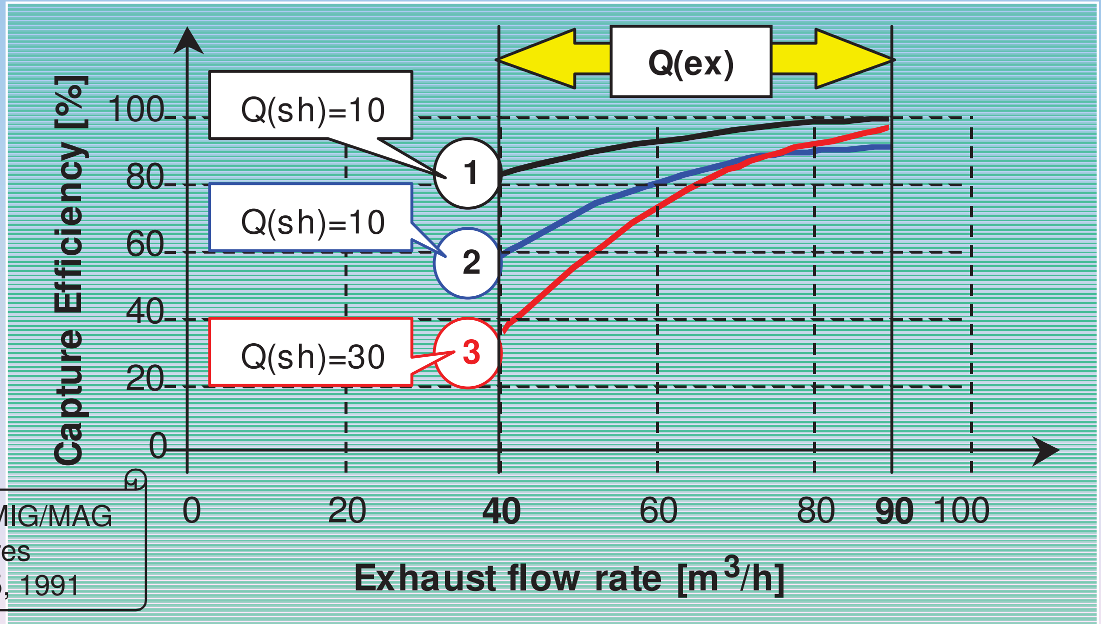
Cornu used a range of suction flow rates from 40 to 90 m^3/h to compare the performance of two fume extraction torches from French manufacturers (Torch A).
The welding process was FCAW using an $Ar+CO_2$ gas mixture to which Helium was added as the tracer.



Welding parameters

- ✓ Welding current: 250 A
- ✓ Welding voltage: 33 V
- ✓ Welding technique: FCAW with flux cored wire Φ= 1.6 mm
- ✓ Filler wire speed: 48 cm/min
- ✓ Welding speed: 13.8 cm/min
- ✓ Shielding gas type: Ar=82%, CO_2=13%, He=5%
- ✓ Shielding gas flow rate: 10 L/min and 30 L/min

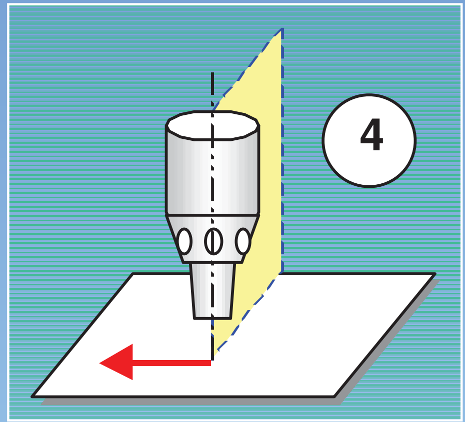
Capture Efficiency (Torch A)

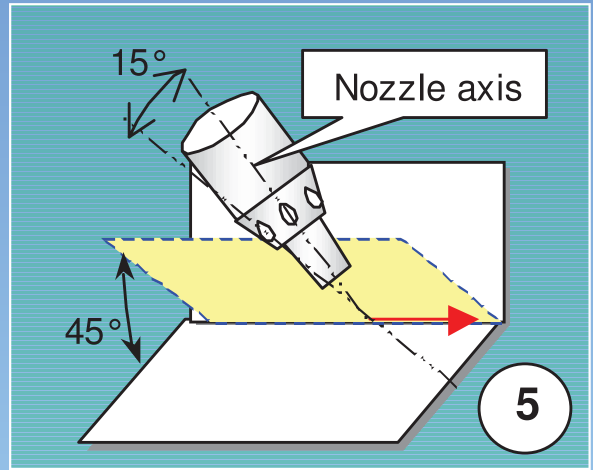


Cornu J.C., Muller J.P. and Guélin J.C. "Torches aspirantes de soudage MIG/MAG – Méthode de mesure de l'efficacité de captage. Etude de paramètres d'influence" . Cahier de notes documentaires de l'INRS (France) N. 145, 1991

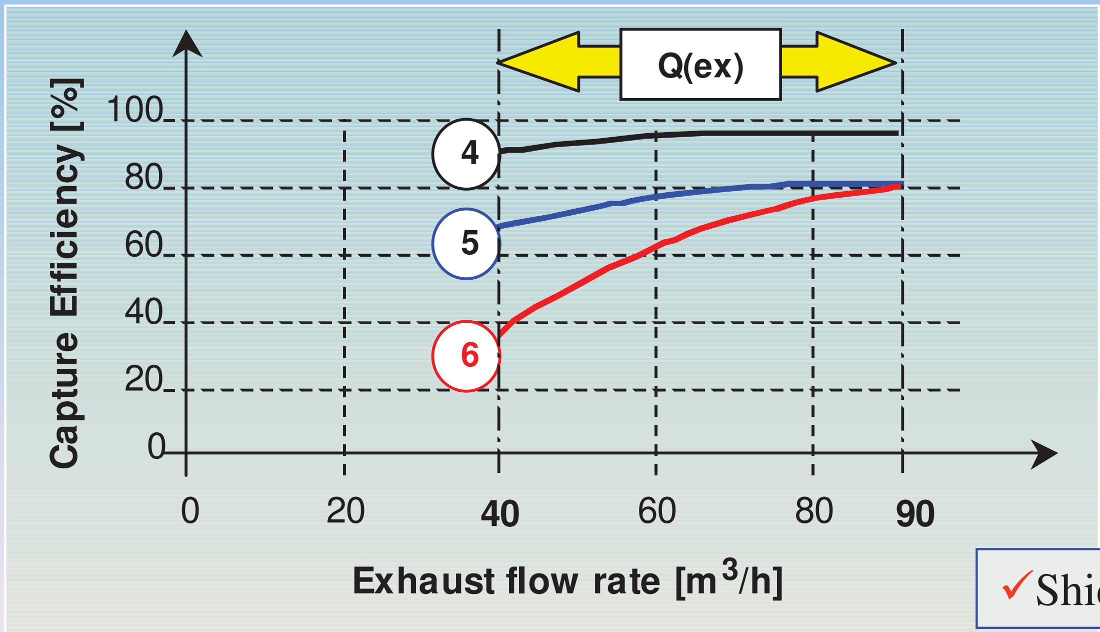
INRS - Cornu Tests

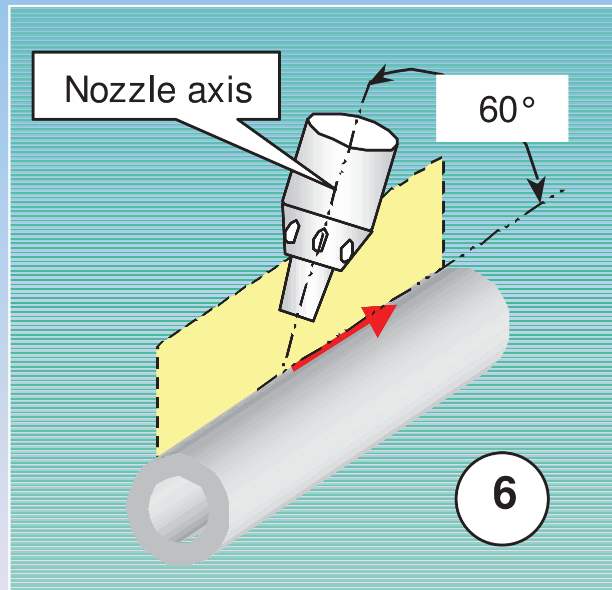
Cornu tested a second model of suction torch (Torch B) both in manual and automatic welding (welding positions 4-5-6).





Capture Efficiency (Torch B)

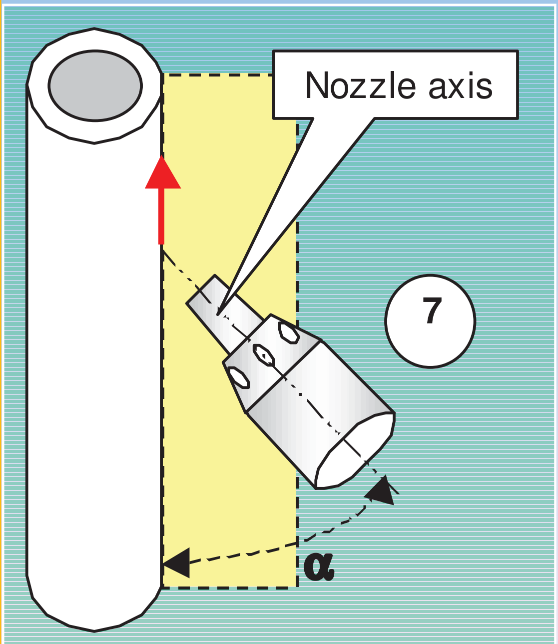




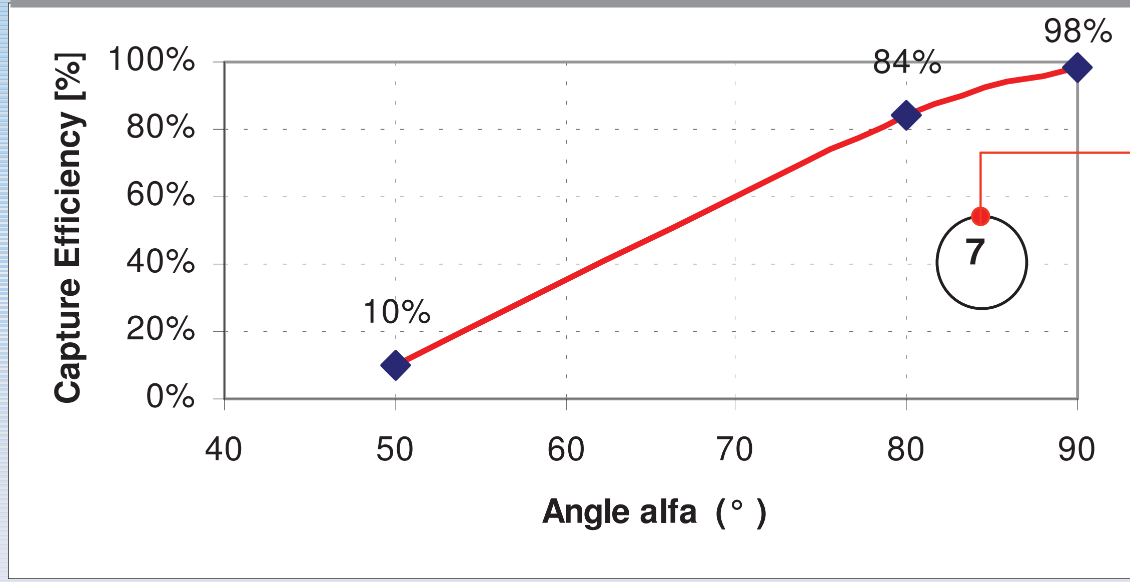
✓Shielding gas flow rate: 16 L/min

INRS - Cornu Tests

Cornu tested the same Torch B in welding trials performed on vertical up position (welding position 5G-PF) on the lateral contour of a cylinder with Φ=115 mm (curve 7). During the ascending path, the welder forearm position has been continuously modified and the torch inclination angle has been changed from 80° to 50° The capture efficiency is shown rapidly decreasing while the suction openings depart from the ascending fume plume.



Capture Efficiency (Torch B)



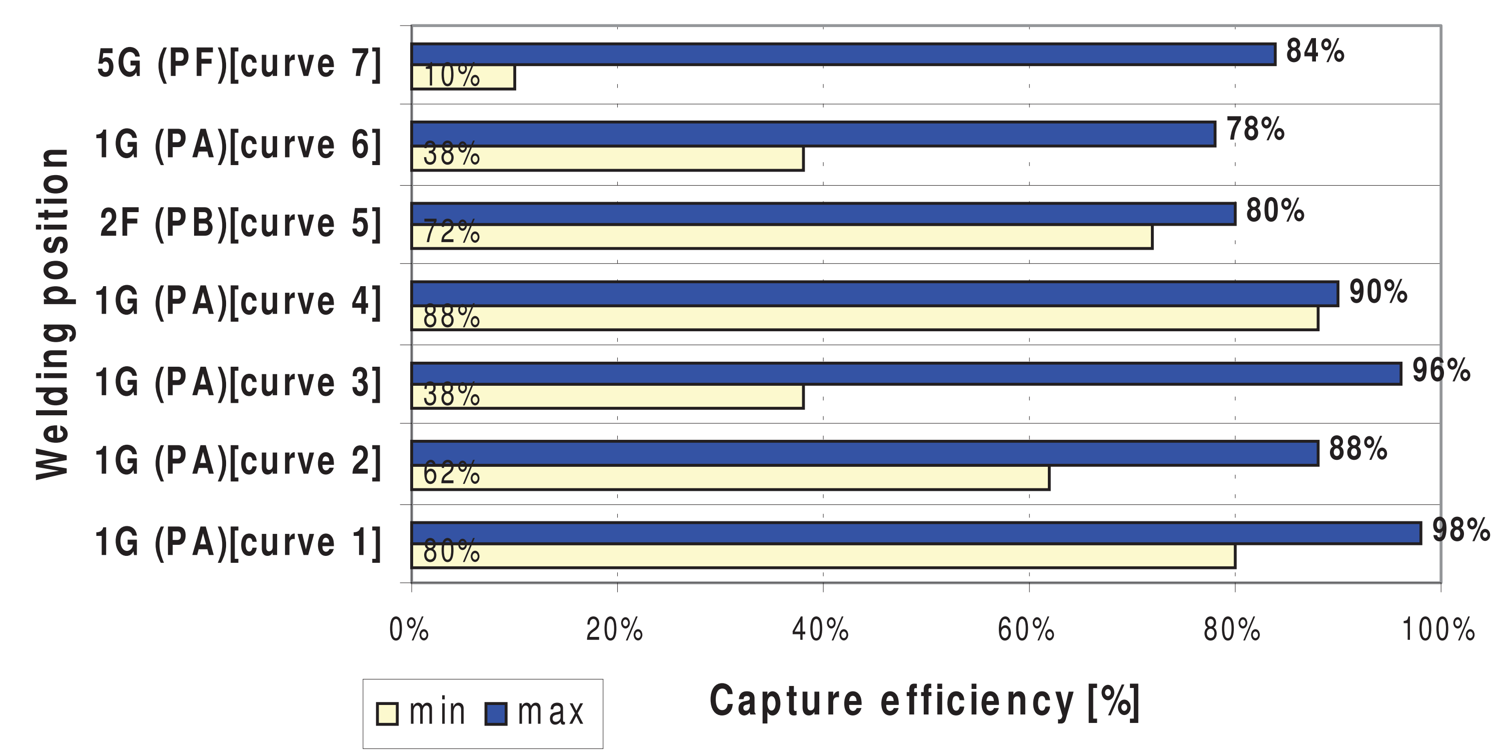
Cornu J.C., Muller J.P. and Guélin J.C. "Torches aspirantes de soudage MIG/MAG – Méthode de mesure de l'efficacité de captage. Etude de paramètres d'influence" . Cahier de notes documentaires de l'INRS (France) N. 145, 1991

INRS - Cornu Tests

Cornu concluded that there were some differences in performance between the two torches and that capture efficiency is affected directly by suction flow rate.

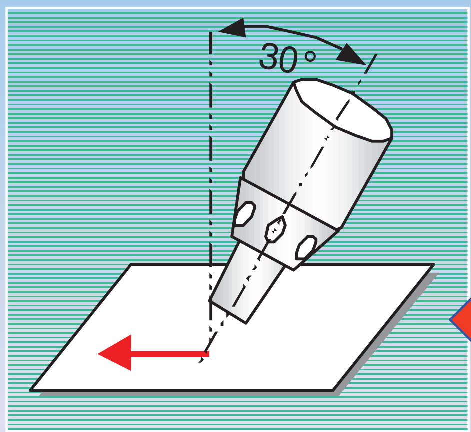
Measurements on flat plate (PA) always gave higher efficiency. Both welding position and shape of part have a significant affect on capture efficiency. The graph summarizes the results of min-max capture efficiency ranges investigated at the French Institute.

Capture Efficiency min-max Ranges - Cornu Tests

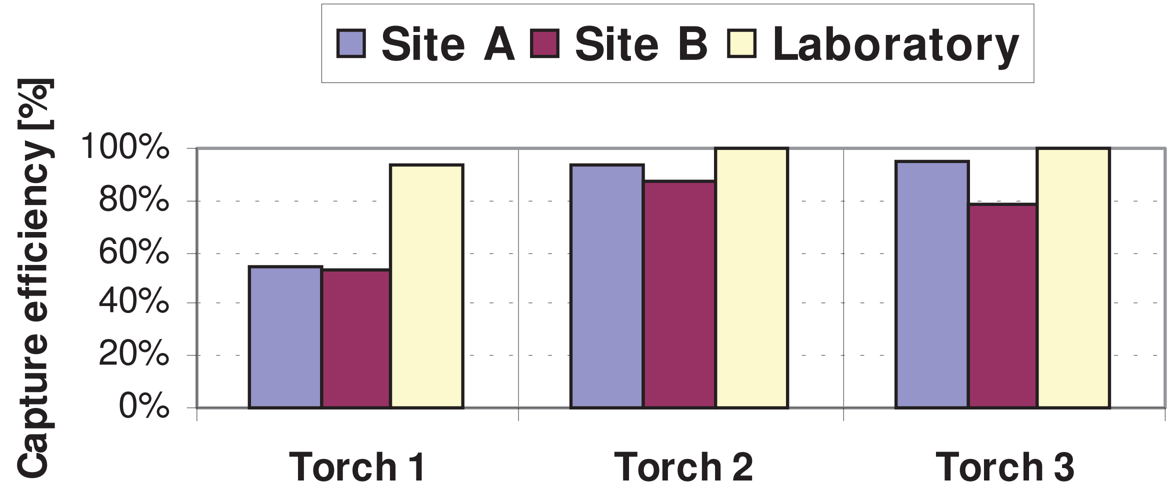


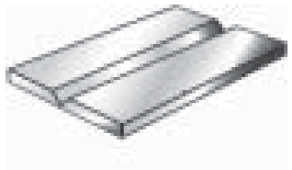
Research at IRSST - Canada

Perrault et al. carried out a study to compare the fume collection rates of commercial suction torches in the laboratory and in industry with a fume collection system which is comparable to the generation rate of the measuring system. An ergonomic study was also carried out to briefly explore first the muscular load imposed on the shoulder, elbow and wrist in relation to the type of suction torch, and second a few indices of the subjective acceptability of the welding tools by welders.



Capture Efficiency Ranges from IRSST





Welding position: 1G (PA)
Flat, bead on plate

Perrault G., Lazure L., Nguyen V. H., Létourneu C. "Efficacité du captage des fumées de soudage par les torches aspirantes de type MIG-MAG" , Rapport de recherche, IRSST, Québec, Janvier 1993, 12 pp.

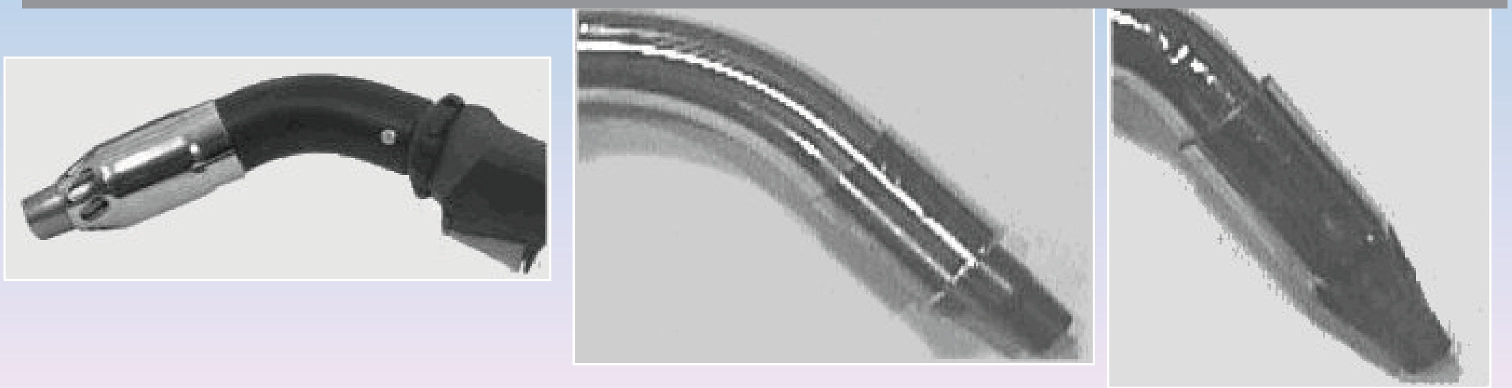
Research at Edison Welding Institute - USA

Under the National Shipbuilding Research Program, Advanced Shipbuilding Enterprise (ASE), a project has been undertaken for Welding Panel to develop a lightweight fume extraction welding torch for shipyard use.

The Edison Welding Institute evaluated five fume extraction welding torches of commercial production, developed a prototype torch which incorporates ergonomic engineering to improve usability, and evaluated this experimental torch during shipyard trials.

Five fume extraction torches were obtained from three manufacturers for usability evaluation and compared to five conventional torches for a range of ergonomic factors. Three of the fume extraction torches also were evaluated for fume capture efficiency.

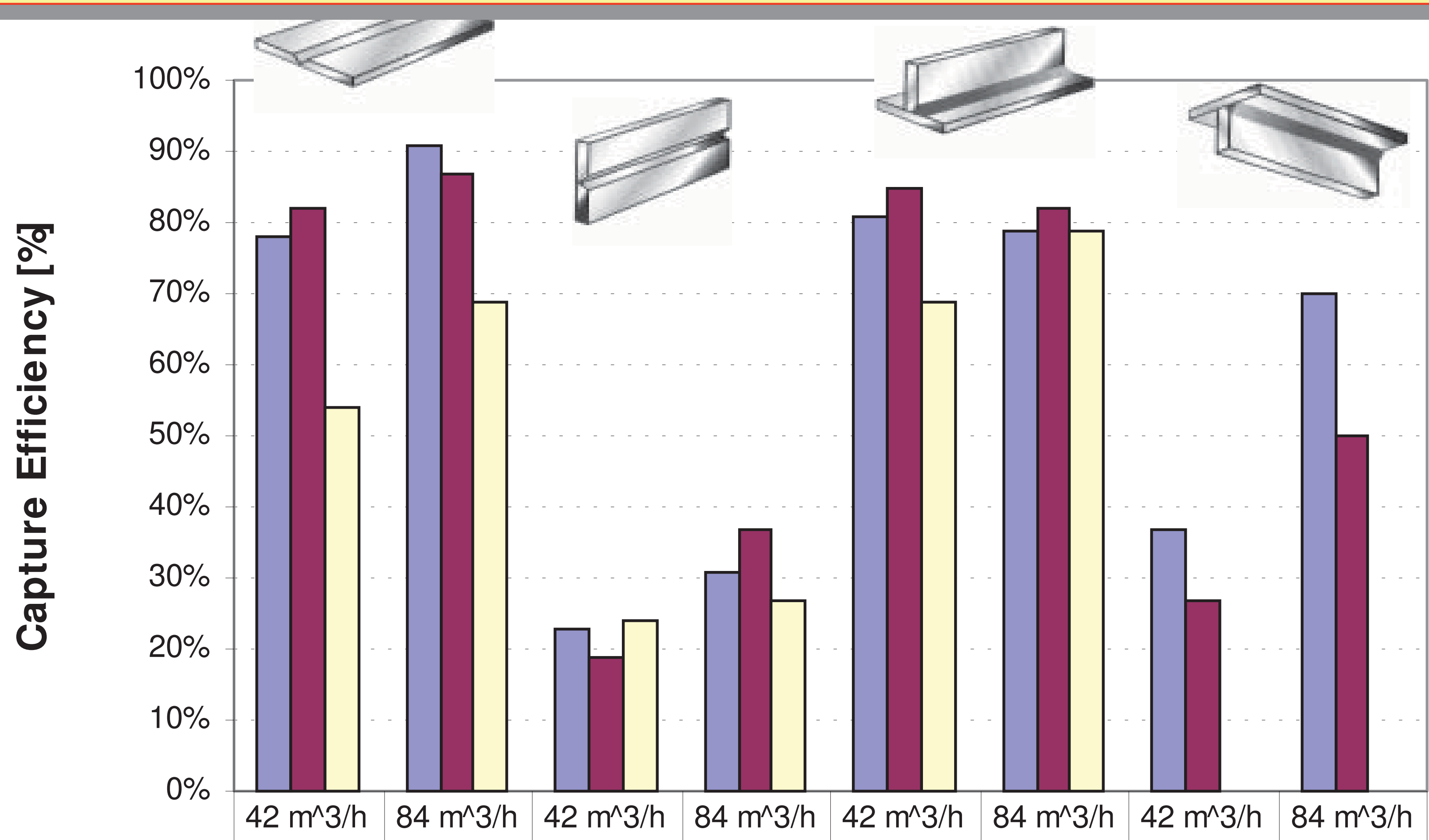
Capture Nozzles of Three Torches Evaluated by EWI



EWI - Tests

Yapp D., Lawmon J., Castner H. "Development of lightweight fume extraction welding gun", National Shipbuilding Research Program SP-7 Final Report, Edison Welding Institute, May 2001

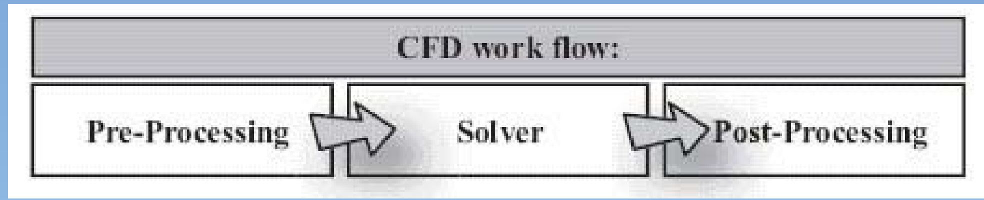
Capture Efficiency Ranges from EWI Tests



	42 m^3/h	84 m^3/h	42 m^3/h	84 m^3/h	42 m^3/h	84 m^3/h	42 m^3/h	84 m^3/h
Torch A	78%	91%	23%	31%	81%	79%	37%	70%
Torch B	82%	87%	19%	37%	85%	82%	27%	50%
Torch C	54%	69%	24%	27%	69%	79%		

CFD Modelling (2003 and after)

The Computational Fluid Dynamics (CFD) approach has been used to model many fluid flow situations including process plants and large-scale heating and ventilating systems The technique involves three steps:



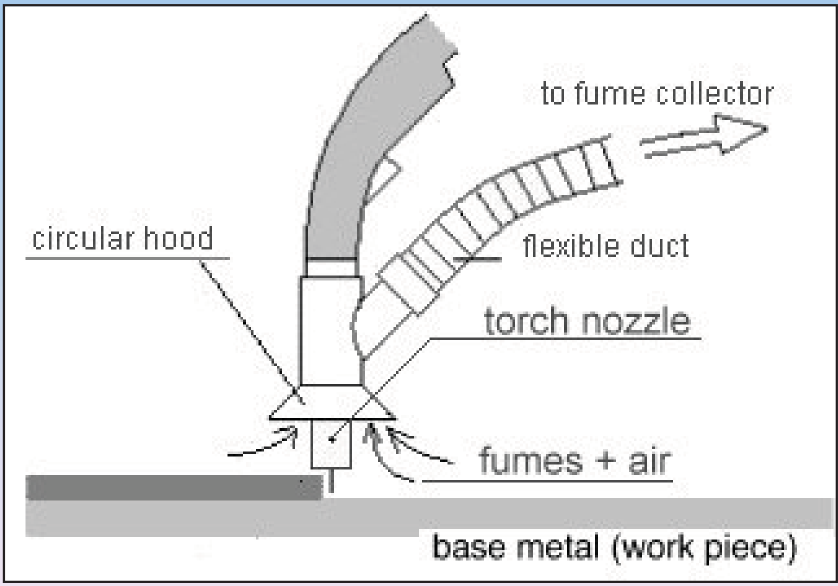
- Pre-processing: The first step of CFD analysis consists of several tasks: defining the geometry of the region of interest, selecting the physical models to be considered, specifying fluid properties and boundary conditions, creating a mesh of control volumes.
- Solving: The main part of a CFD analysis is solving the governing equations. The partial differential equations for the flow quantities (velocity, pressure, energy, turbulent quantities and additional scalars such as contaminant concentration) - called the Navier Stokes equations - are integrated over the control volumes in the region of interest (flow domain).
- Post-processing: The third step of CFD analysis involves visualization of the results as e.g. vector plots, streamline plots or colored slices (maybe as animations) as well as quantitative analysis of the velocity or contaminant concentrations.

Research at National Institute of Industrial Health - Japan

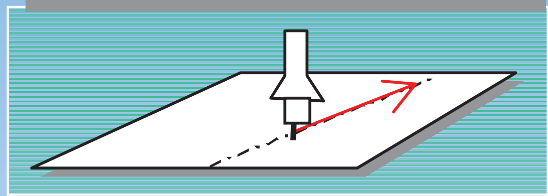
Ojima in a series of investigations for fume reduction in workplace describes the development of an ordinary fume exhaust torch system, consisting of a welding torch integrated with a suction hood which exhausts the fume plume around the welding arc, a fume collector and a flexible duct connecting the hood to the collector.

Ojima investigated the following welding positions:

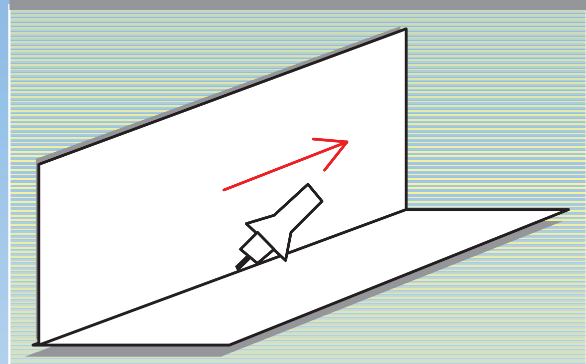
Fume Exhaust Arrangement from Ojima



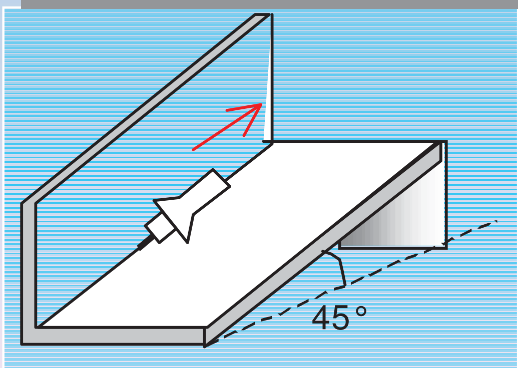
Code: PA (0°)



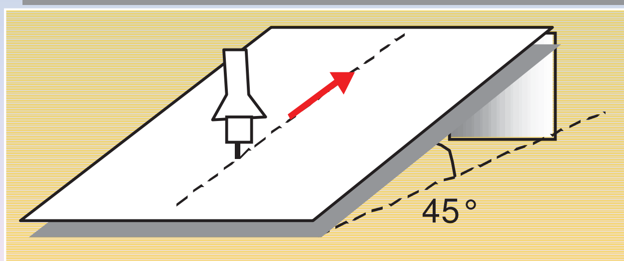
Code: PB (0°)



Code: PB (45°)

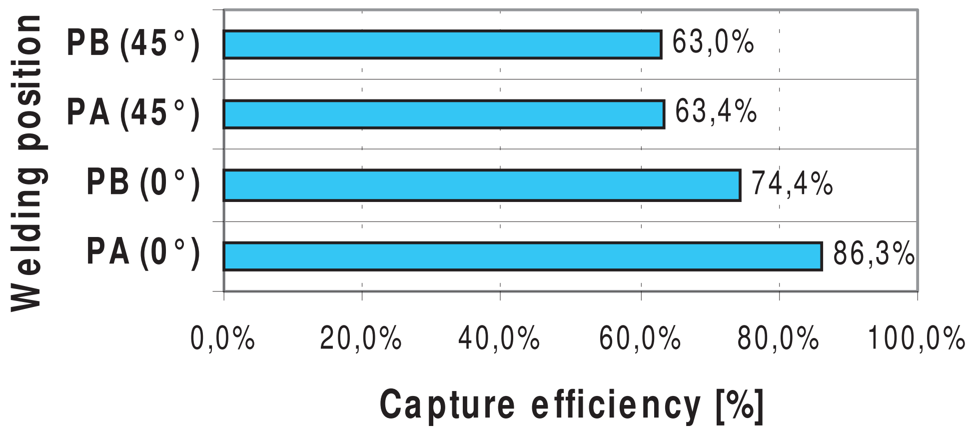


Code: PA (45°)

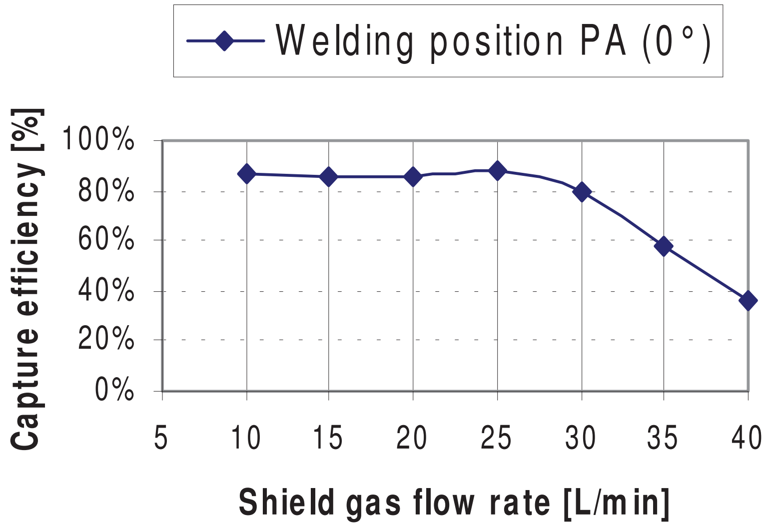


NIIH – Ojima Tests

Capture Efficiency from Ojima



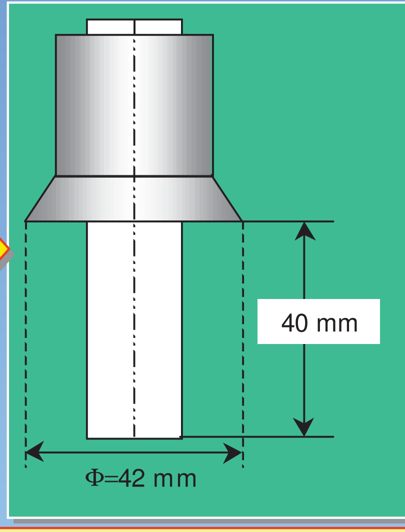
Effect of Shield gas Flow Rate on Capture Efficiency at PA(0°)



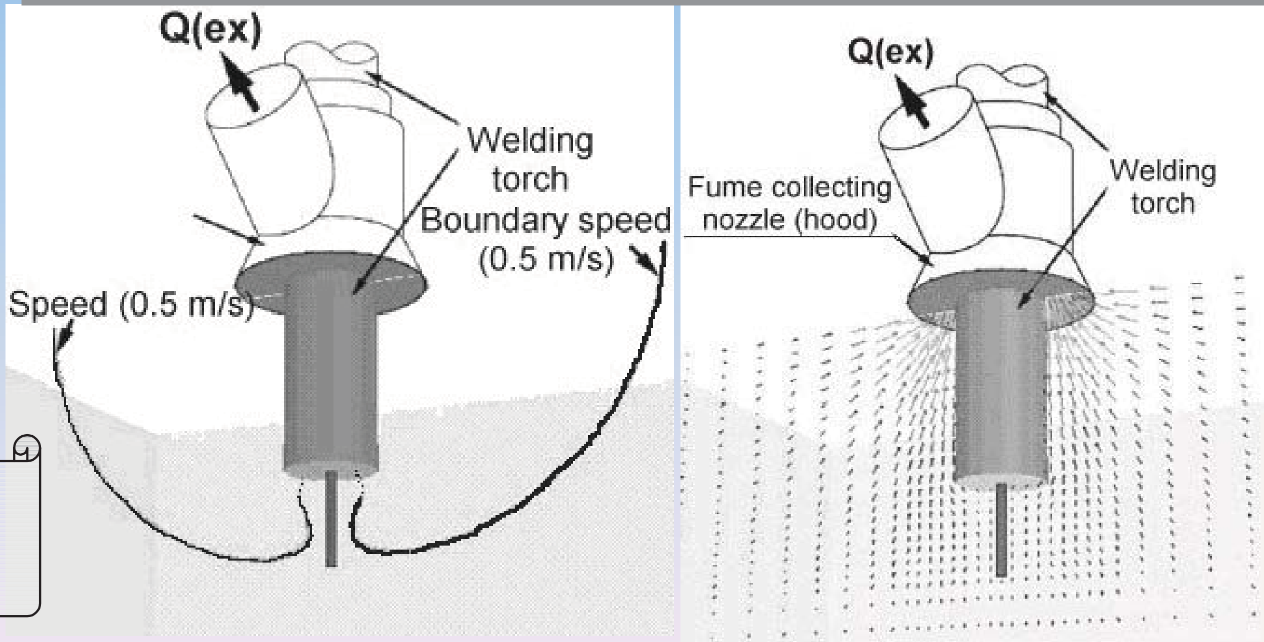
Ojima J. "Performance of a fume-exhaust gun system in CO_2 arc welding", Journal of Occupational Health, N. 48, 2006

NIIH –Iwasaki Tests

Iwasaki describes the development of an ordinary fume exhaust system as described by Ojima, performing some investigations on capture efficiency by CFD modelling. The nozzle is coaxial with the torch and a variety of nozzle designs were evaluated. Figure shows the fume collecting torch with a plain bell mouth opening; by this kind of hood, almost all fume near the welding torch can be captured.



Air Velocity Near Hood Opening from Iwasaki



When operated with an exhaust air volume 120 m^3/h, the capture velocity near arc point was measured as about 0.5 m/s.

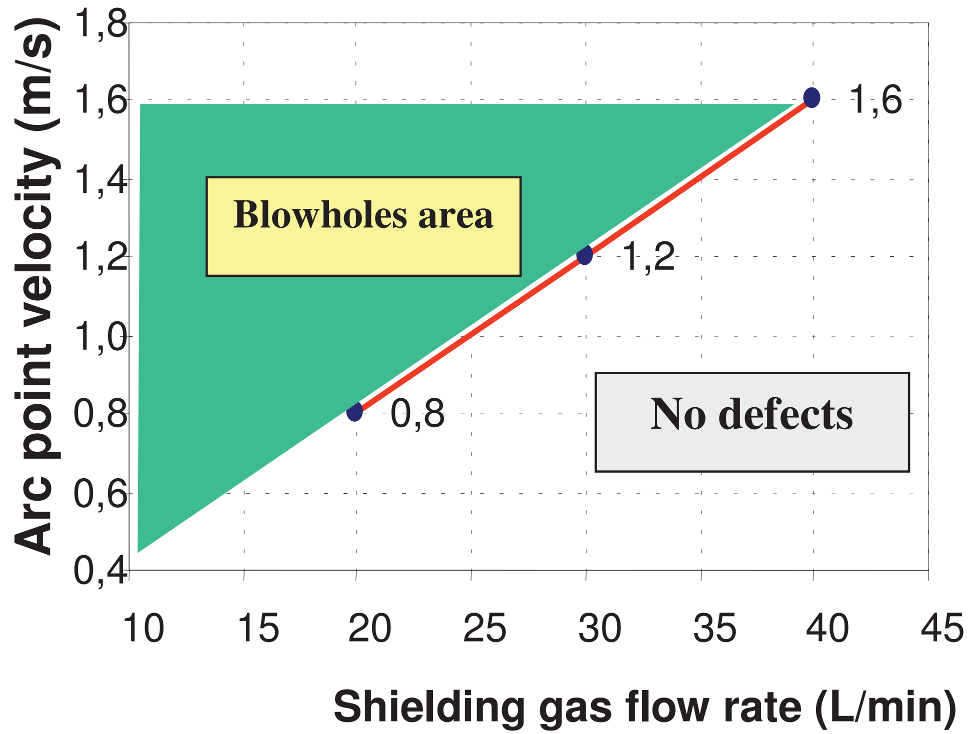
Iwasaki T., Fujishiro Y., Kubota Y. et al. “Some engineering countermeasures to reduce exposure to welding fumes and gases avoiding occurrence of blowholes in welded material” Industrial Health, N. 43, 2005

NIIH –Iwasaki Tests

The torch showed an adequate capture efficiency in robotized welding at a car manufacturing factory,. When welding fume collector was not operated, the fume concentration was 2.33 mg/m^3 and when operated it went down to 0.25 mg/m^3 thus achieving a 90% reduction of fume concentration at welder's breathing zone.

Graph shows the relationship between the uniform stream air velocity at the arc point and the welding quality (by radiographic examination) when the CO_2 gas flow rate was changed. When the shielding gas flow rate is 20, 30 and 40 L/min, blowholes occur at a uniform stream air velocity of 0.8, 1.2 and 1.6 m/s respectively. The uniform air stream velocity recommended value is within 0.3-0.7 m/s, which reduces fume concentration at the welder breathing zone below the occupational exposure limits without any production of blow holes or defects.

Arc Point Velocity vs. Shield Gas Flowrate

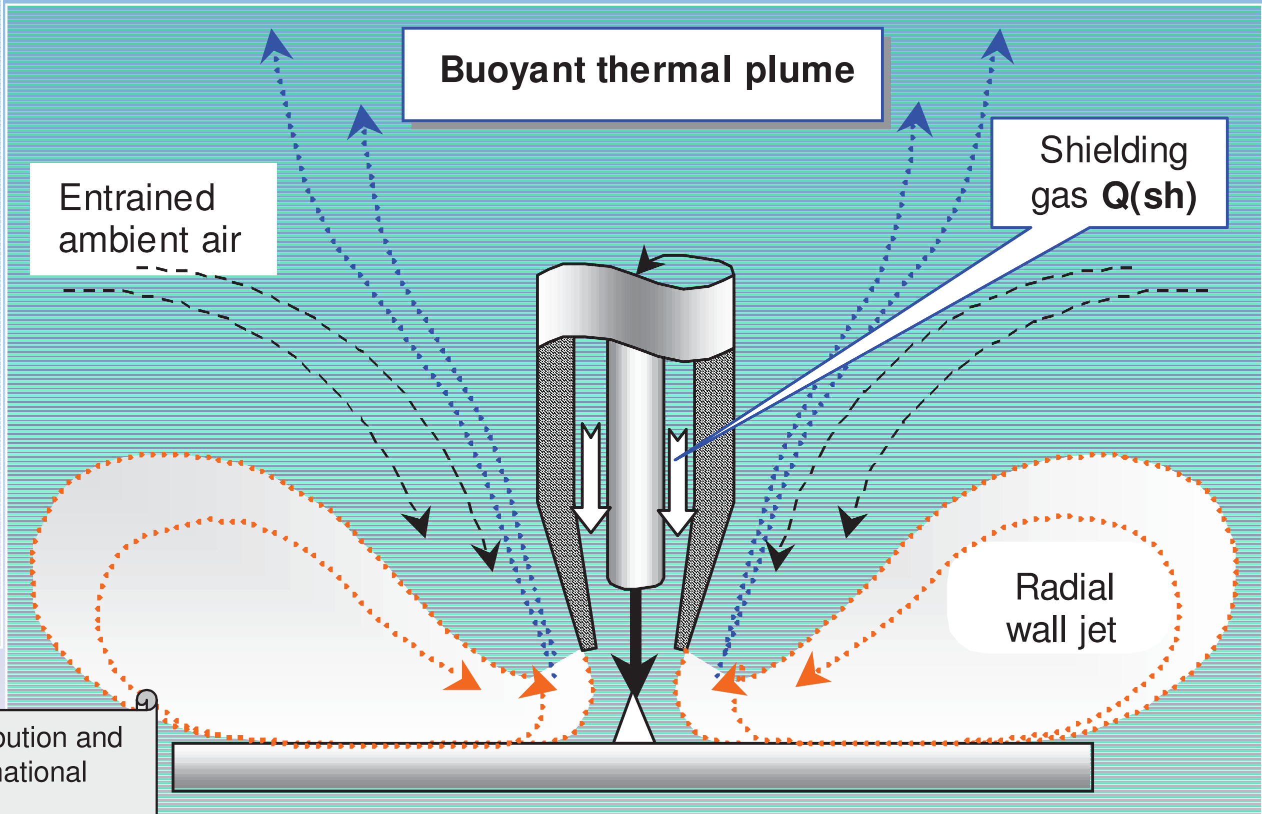


Research at Wollongong University - Australia

Many experimental investigations were undertaken at School of Mechanical Materials and Mechatronic Engineering, University of Wollongong to determine the natural fume distribution and the resultant breathing zone exposure for gas metal arc welding.

The fume plume is formed in close vicinity to the arc area, and tends to be dispersed and diluted into the surroundings by the shielding gas.
The extent of the radial spread of the impinging fountain model is crucial, as this determines the initial size of the buoyancy driven plume.
The metal vapour fume tends to be conveyed first by the wall jet, radially outwards (Coanda effect) and after may be transmitted directly into the breathing zone of the welder.

Radial Wall Jet Effect of Shield Gas Flow Field on a Flat Surface (Coanda Effect)



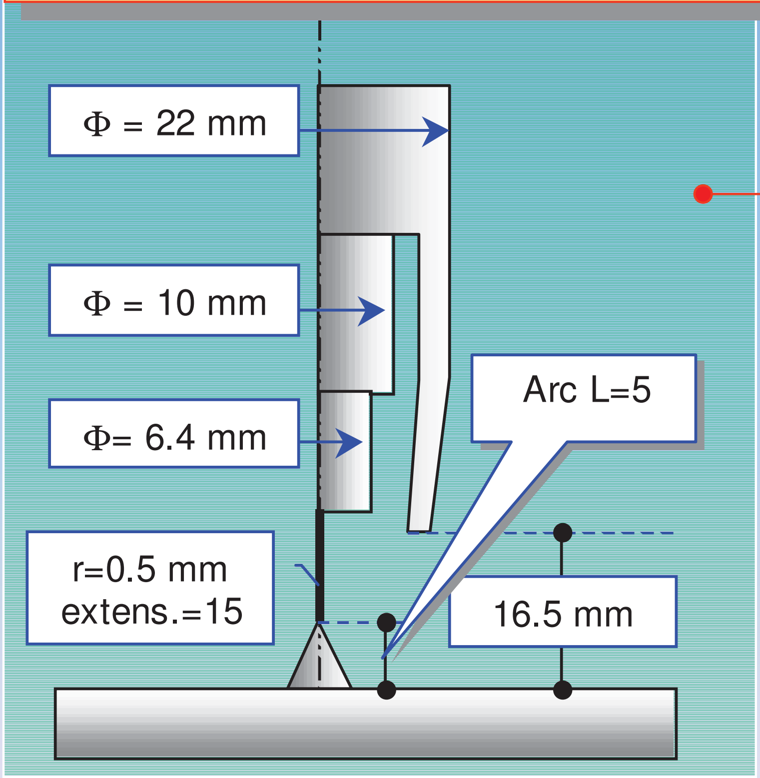
Norrish J., Slater R., Cooper P. "Particulate fume plume distribution and breathing zone exposure in Gas Metal Arc Welding ", International Conference Copenhagen, 9-11 May 2005

Wollongong – Norrish Tests

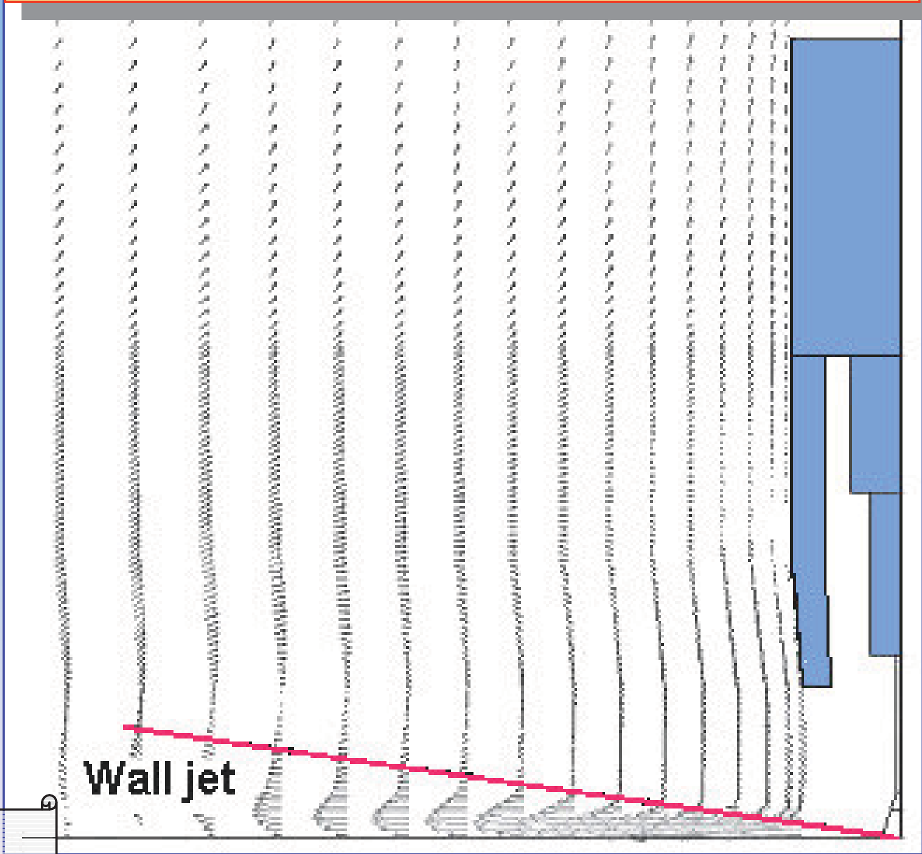
CFD simulations were carried out for different extraction system configurations to facilitate comparison of their effectiveness in capturing the welding fume.

A typical set of operating dimensions was chosen by Norrish and his team, as summarized in Figure.

Typical Nozzle Dimensions



Velocity Vector Field of Shield Gas Flow Rated at Q(sh)=15 L/min

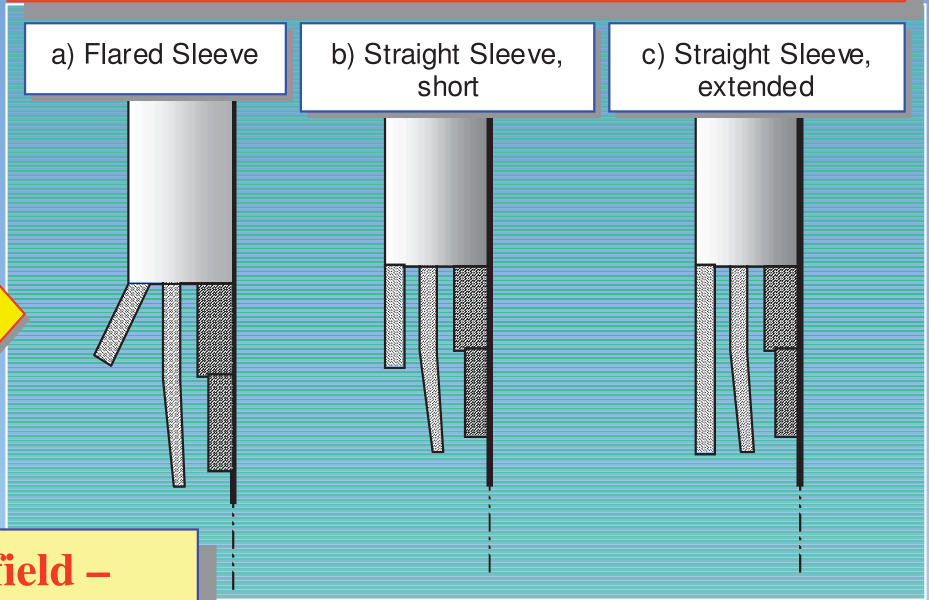


Godbole A., Cooper P., Norrish J., "Computational fluid dynamics analysis of on-torch welding fume extraction", Australasian Welding Journal, Volume 52, 2007

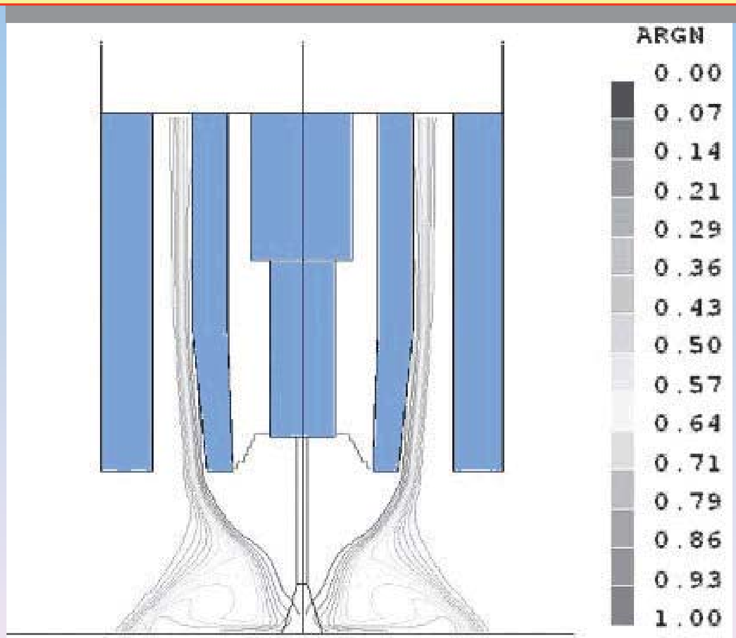
Wollongong – Norrish Tests

Attempts to capture the fume in the radial wall jet by means of an annular extraction sleeve placed around the GMAW nozzle of a conventional torch have been investigated by Norrish and his team using CFD simulations carried out for different extraction designs, to test their effectiveness in capturing the fume plume.

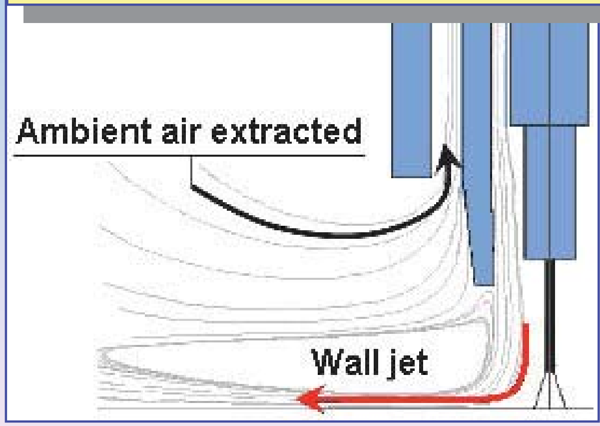
Typical Extraction Nozzles



Shield Gas concentration field at Q(ex) / Q(sh) = 6 (extended sleeve)



Velocity vector field – Shield gas Q(sh)=15 L/min - Q(ex) / Q(sh) = 12.5 (short sleeve)



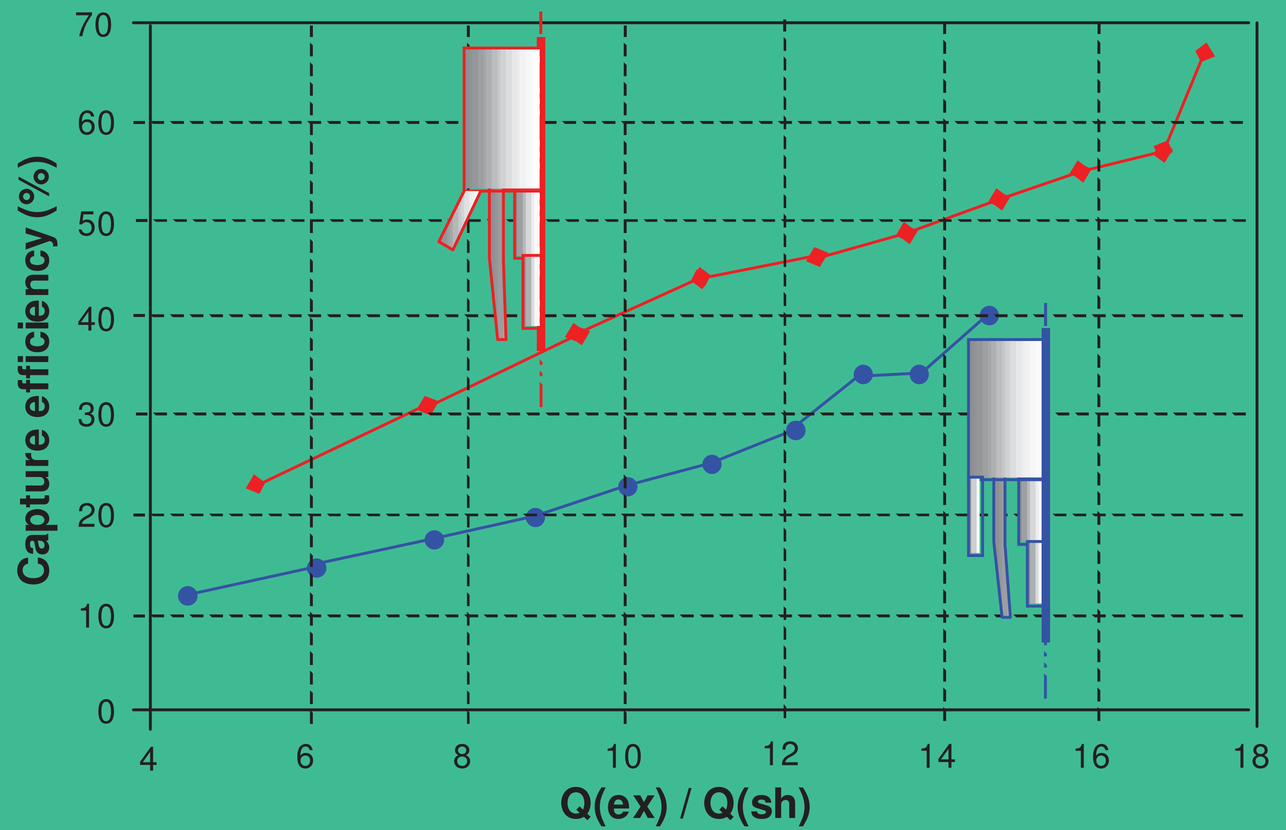
The flow fields show that the on torch extraction by a concentric sleeve does not cause significant reduction in the concentration of the fume plume, even with extremely high extraction flow rates which would not be achievable in practice.

Wollongong – Fume Capture Efficiency

A summary of these CFD results on the fume capture efficiency as a function of the extraction flow rate is presented in Figure (two short sleeve designs).

Fume capture efficiency rises approximately linearly with extraction flow rate Q(ex), however, extremely high flow rates are required to achieve a useful fume capture efficiency. The flared sleeve is somewhat more effective than the cylindrical straight sleeve. Higher extraction flow rates (of the order of 90 L/min) will draw away the essential shielding gas envelope from the weld, thus adversely affecting weld quality, entraining air and potentially increasing fume generation.

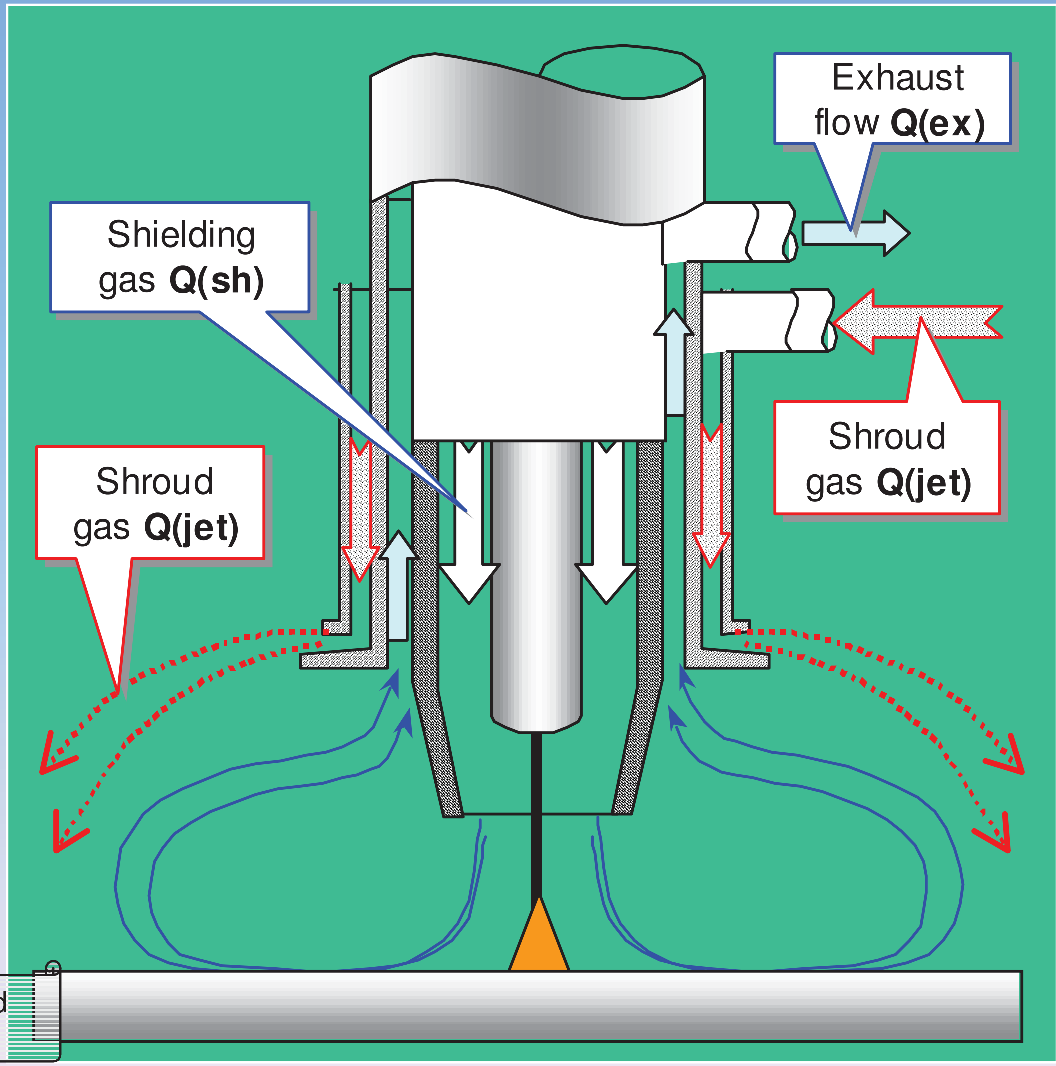
Fume Capture Efficiency vs. Normalized Extraction Flow Rate Q(ex)/Q(sh) with Q(sh)=15 L/min



International Application - Patent WO 2007/106925

According to applicants (Cooper, Godbole, Norrish), their invention provides an arc welding torch having a shield gas port adapted to direct a shield gas curtain around the electrode and welding pool, and one shroud gas port spaced radially outward from the shield gas port and adapted to impart to an exiting shroud gas a radially outward component of velocity (aerodynamic flange).

Schematic Extraction Nozzle with Radially Directed Shroud Gas Jet

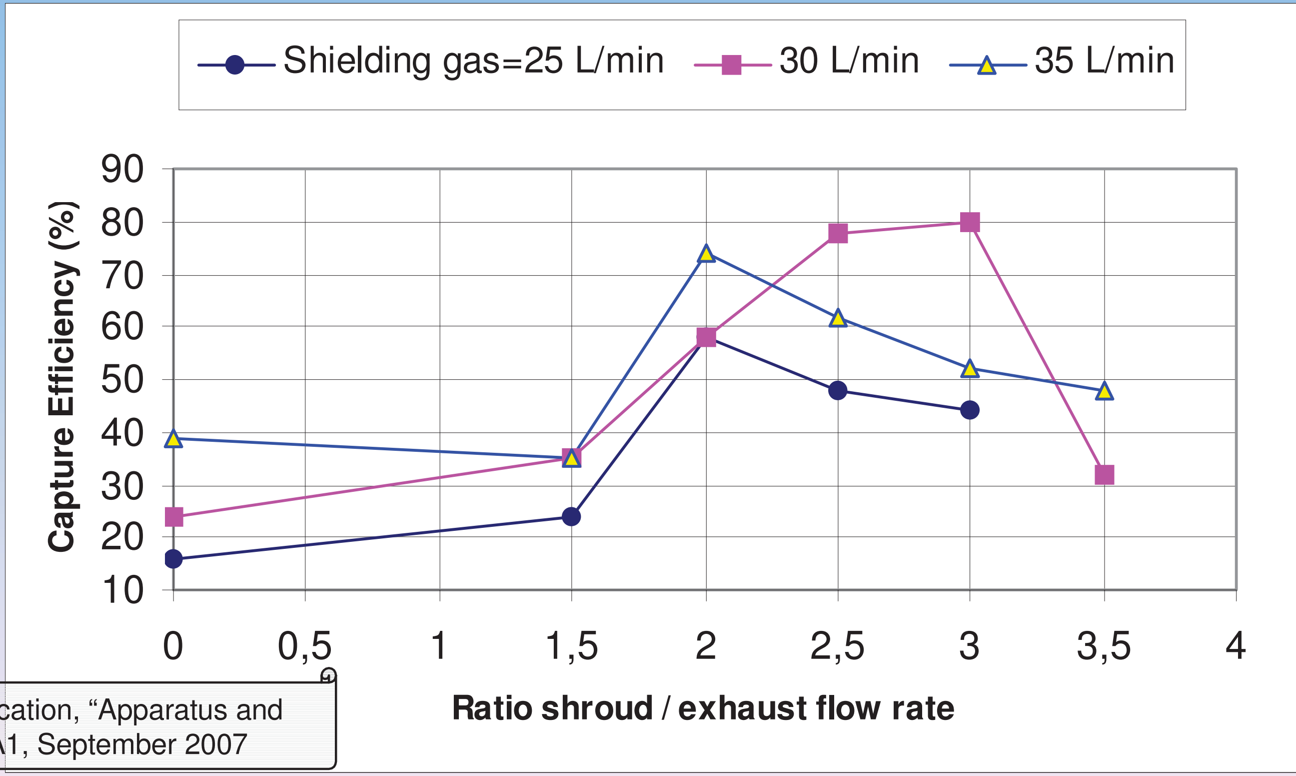


Cooper P., Godbole A., Norrish J., International Application, “Apparatus and method for welding”, Patent N. WO 2007/106925 A1, September 2007

Patent WO 2007/106925 - Results

The applicants have used a commercial GMAW torch adapted according to the patent and configured with a wire Φ=1.2 mm, using Argoshield universal gas.
Welding parameters have been chosen to have high fume generation with typical welding current set at 250 A and welding voltage at 32 V.

Fume Capture Efficiency vs. Ratio Shroud to Exhaust Flow Rate



Welding parameters

- ✓ Shield gas flow rate = 15 L/min
- ✓ Fume gas extraction rate = 15 L/min
- ✓ Welding current: 250 A

Cooper P., Godbole A., Norrish J., International Application, “Apparatus and method for welding”, Patent N. WO 2007/106925 A1, September 2007

Robotic torches

The new welding torches for fume capture at source are compact in design and can be used on both manual or robotic welding. Their collection nozzles are strategically located above the welding nozzle for optimum capture of the welding contaminants.

Dual or triple orifice openings remove the fume plume and related fragments close to the source before they have an opportunity to dissipate into the atmosphere.

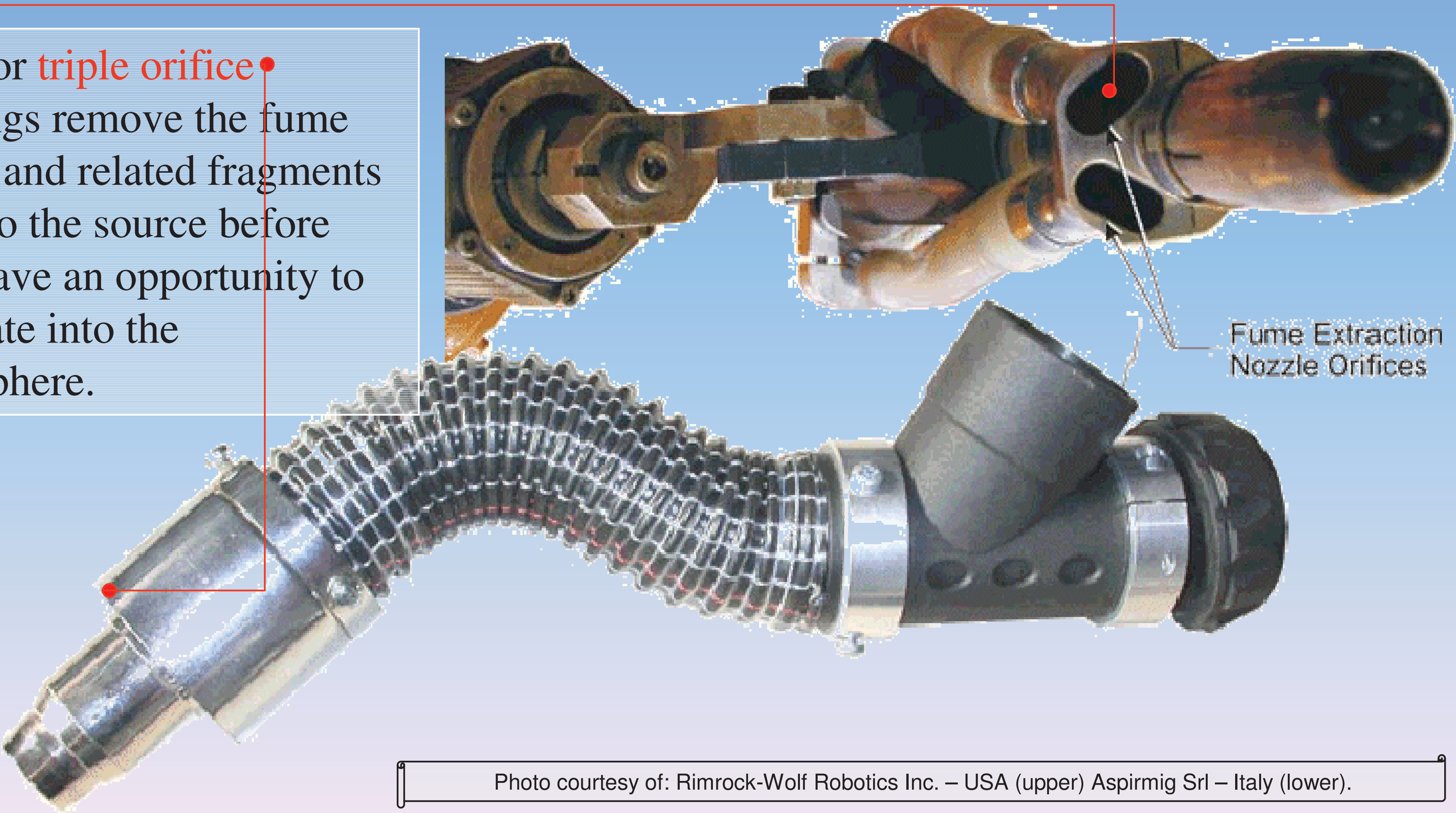
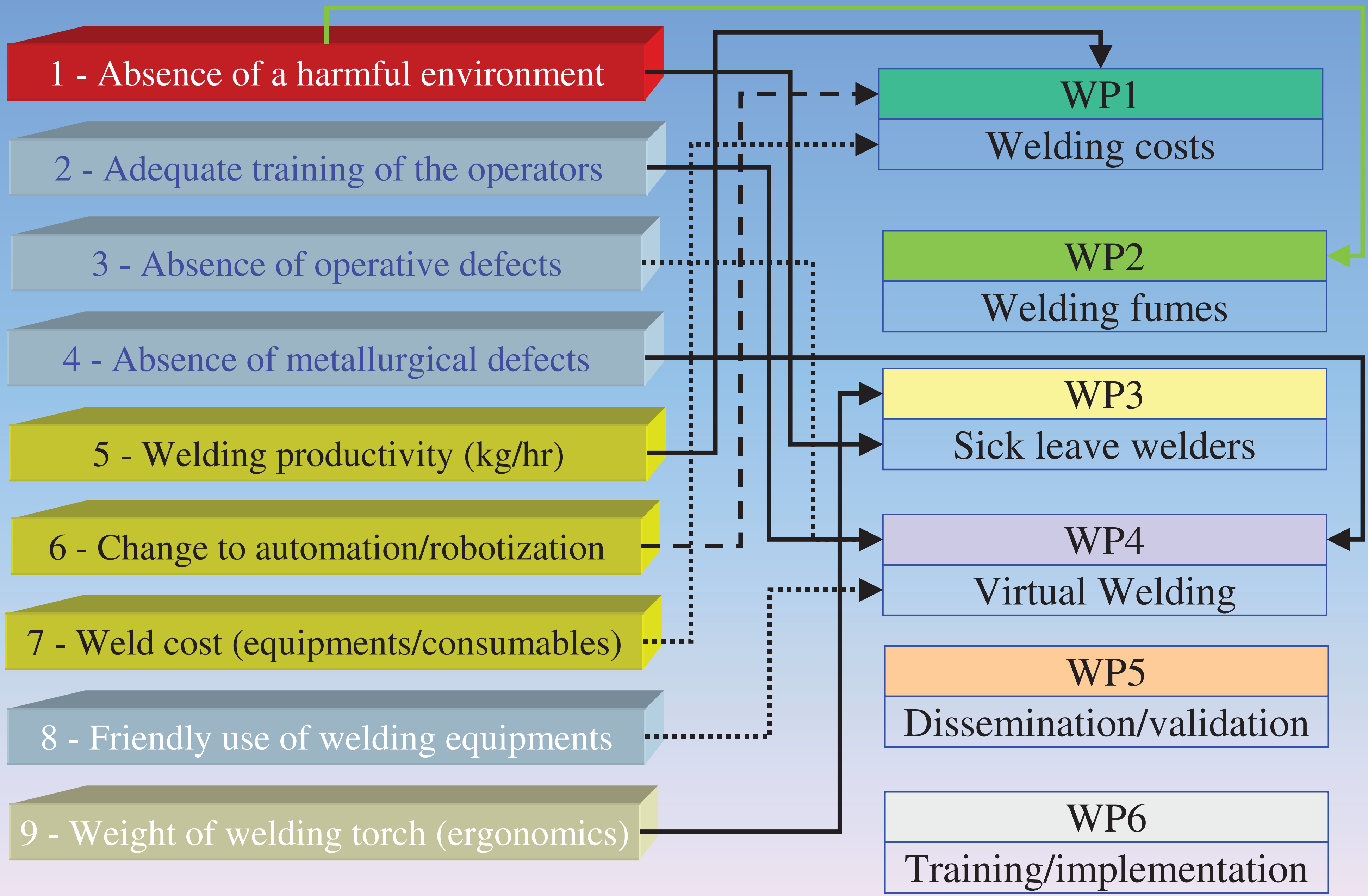


Photo courtesy of: Rimrock-Wolf Robotics Inc. – USA (upper) Aspirmig Srl – Italy (lower).

ECONWELD Project – Priority Needs & Tasks



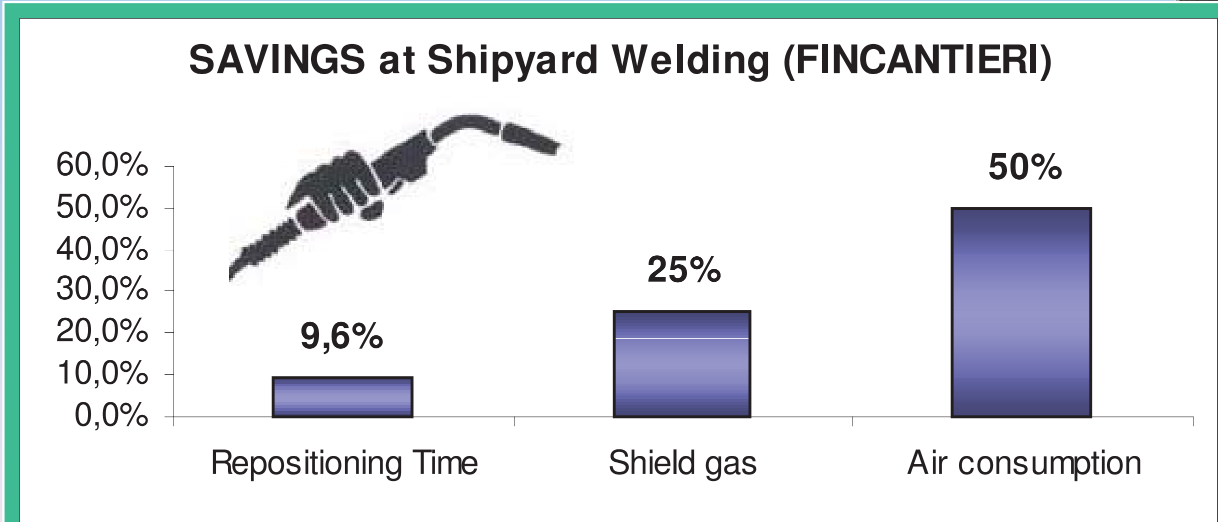
Aspirmig Torch: Ergonomic and Lightweight Tool

During an 8 hour shift, each welder performs at Fincantieri 40 m fillet welds and every 40 cm the operator must stop welding for hood repositioning. A time analysis shows :

- N of repositioning in 8-hrs shift : 4000 cm of welding : 40 cm each = 100 repositionings;
- Time required for each repositioning: about 30 s;
- Repositioning time in 8-hrs shift: (100 repositionings x 30 s) : 60 s = 50 min each shift;
- Welder efficiency increases of about (8 hrs x 60) : 50 min = 9,6 %.

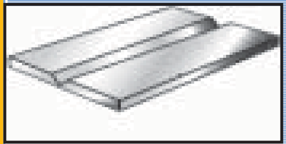
Two samplings in personnel breathing zone at IVECO-FIAT (Bolzano - Italy) showed a fume concentration of : 1° welder → 2.36 mg/m^3; 2° auxiliary → 1,63 mg/m^3

Source: Studio ESP/90001, "Torcia per saldatura MIG-MAG con aspirazione fumi", Fincantieri – Cantieri Navali Italiani – Ancona, Gennaio 1990.



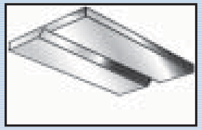
- ✓ Reduction of shield flow rate: 25% thanks to the suction field envelope which protects the fusion bath;
- ✓ Reduction of air consumption: 50% in comparison to a conventional mobile hood.

CONCLUSIONS



Horizontal weld. The torch is held overhand and almost vertically above the weld (in the path of fume movement). In this position the fume extraction nozzle is best sited to extract fume. Capture efficiencies can be in excess of 90%. Capture efficiency for a fillet weld is in the order of 15% to 20% lower. Welding on external corners gives least effective capture reducing as radii decrease.

Vertical weld. Where components are in the vertical plane the angle of the welding torch to the components would typically vary between 50° to 80° (the torch nozzle would be nominally horizontal to the weld). The capture efficiency falls from about 90% to 10% because the torch is held at an angle where the fume extraction nozzle is not in the path of the welding fume.



Overhead weld. The torch is held vertical below the weld . When welding overhead, fume is often observed rising at such a rate that it is not totally captured by the on-torch extraction system.

- Required ventilation flow rates typically are in the range 60 m^3/h to 100 m^3/h. These flow rates normally cannot be set higher as removal of the shielding gas may result. Static pressures required are in the range 13 KPa to 20 KPa. Conventional extract fans do not provide sufficiently high suction for on-torch systems, and multi-stage exhausters or positive displacement pumps are needed.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