Intermediate Meeting 11-12 February 2009, Hannover, Germany

INTERNATIONAL INSTITUTE OF WELDING

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COMMISSION VIII – Health, safety and Environment

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ECONWELD PROJECT : TESTING FUME CAPTURE EFFICIENCY OF GMAW ASPIRING TORCH

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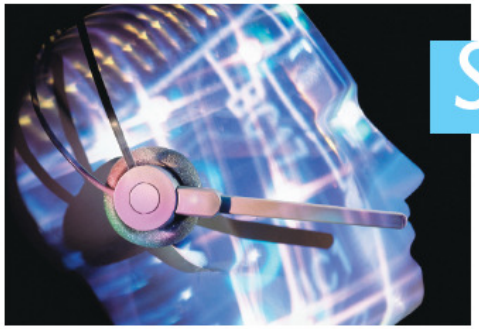
ASPIRMIG Welding&Safety www.aspirmig.com aspirmig@aspirmig.com .... Welding without fumes

CONTENT

SECTION 1



Salute, Sicurezza e Ambiente

ECONWELD PROJECT: THE ASPIRING TORCH

Il progetto di ricerca europeo ECONWELD (Economically welding in a healthy way) Contract No: COLL-CT-2005-516336

HORIZONTAL ACTIVITIES INVOLVING SMES — ECONWELD — SIXTH FRAMEWORK PROGRAMME

Economically welding in a healthy way

Przybyło wielu zagranicznych gości.

Międzynarodowe spotkanie w Gliwicach specjalistów bezpieczeństwa pracy i ochrony środowiska przy spawaniu

Spotkanie VIII Komisji MIS „Zdrowie i bezpieczeństwo pracy w spawalnictwie". Spotkanie partnerów projektu „ECONWELD"

12th INTERNATIONAL WELDING CONFERENCE

Saldatura Flash

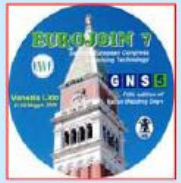
Agenzia Nazionale di Stampa settimanale

Suppl. al n. 1/2008 della Rivista Italiana della Saldatura
Dir. Resp.: *Mauro Scasso* - Redazione: *Franco Lezzi, Franco Ricciardi.*
Segreteria: *Silvia Terrarossa*. Editore: *IIS* - email: saldatura.flash@iis.it
Tel. 010.8341.389 / 392. Aut.Trib.Ge. n.41 del 22/04/1955.
Trasmesso a 8.046 indirizzi - Anno VII, N. 277 del 12/03/2008

La scorsa settimana presso la sede di Genova

Incontro tra IIS, Aspirmig e Plasma-team per il Progetto Europeo di ricerca "Econweld"

-di Carlo Rosellini- (*)



...Collaborate con noi per la riuscita della Manifestazione...

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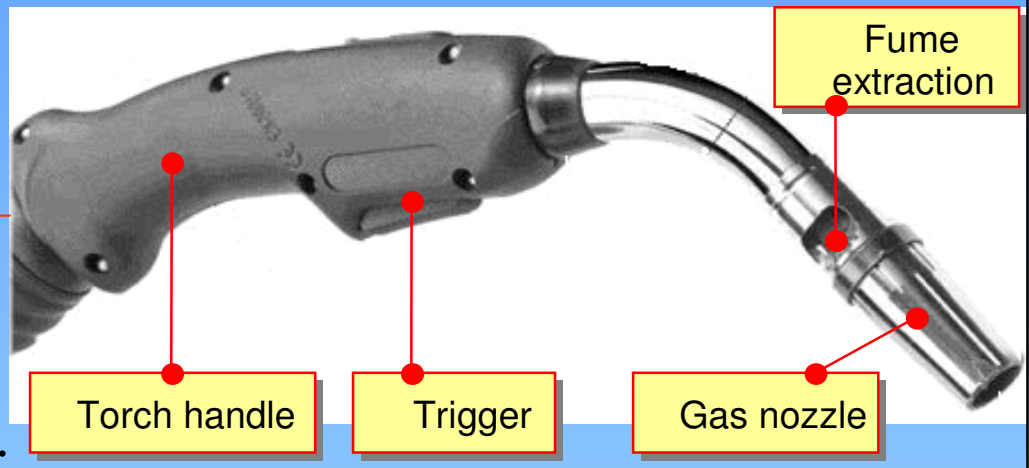
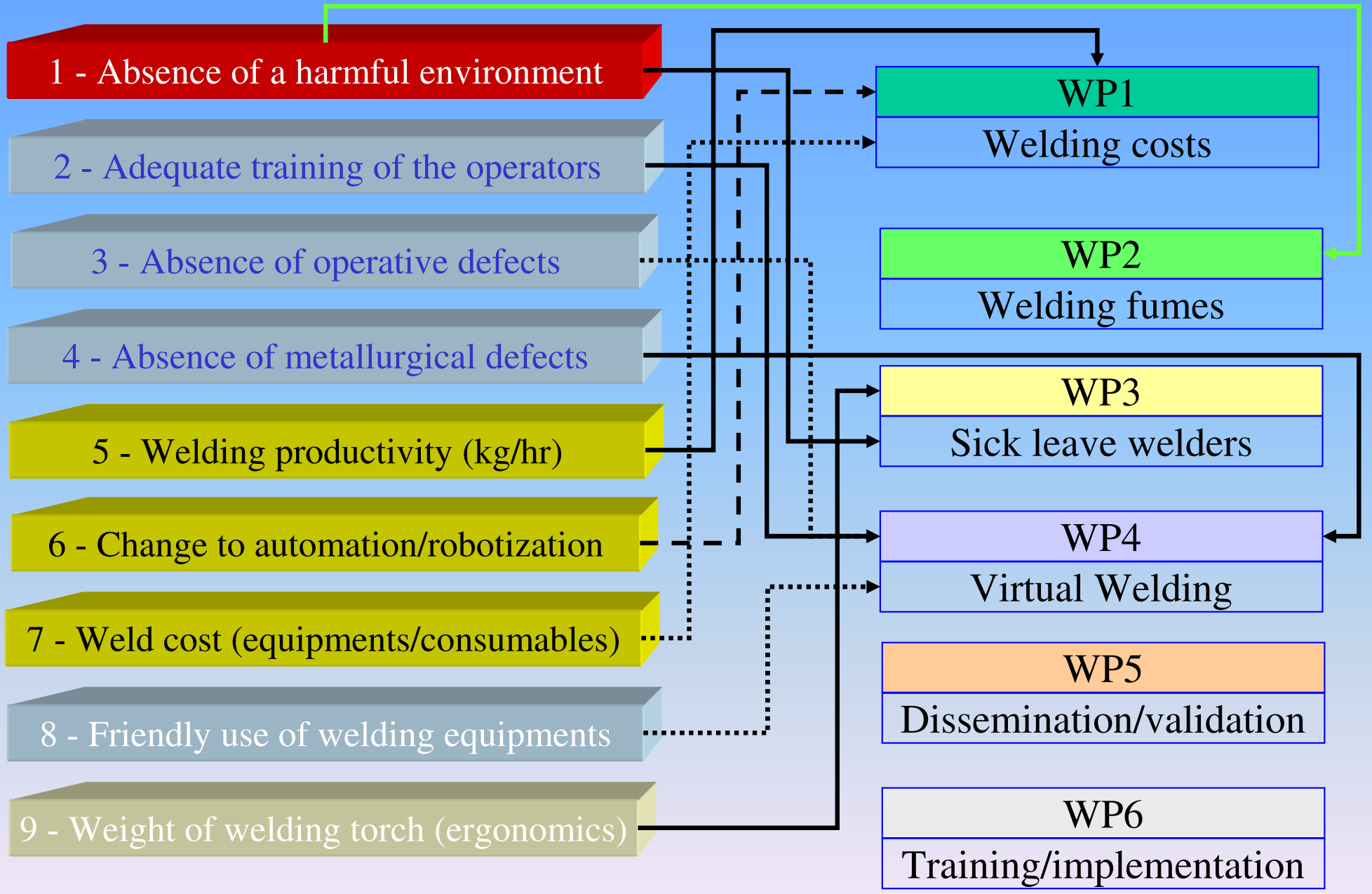
The Project in a Nutshell

- Reduction of welding costs by :
  - ✓ tailored combinations of welding data;
  - ✓ different mixtures of shielding gases;
  - ✓ new developed filler materials;
  - ✓ increasing welding speed;
  - ✓ applying alternative welding techniques;
  - ✓ increasing automation in welding.
- Reduction of sick leave among welders by :
  - ✓ improving both the welding tool and welder's ergonomics;
  - ✓ reducing welding fumes at the source and in the workplace.
- Reduction of exposure to welding fumes.
  - ✓ To assure welder's comfort and adhere to workplace safety and environmental regulations, the SME Partner Aspirmig designed, built and tested an integral fume extraction torch with improved and innovative concept, supported by a CFD model.
  - ✓ The new device incorporates fume capture capability, reducing the need for separate local exhaust equipments (LEV) or the use of personal respirators (RPE) by welders.



Workers are more productive (no need to transport and reposition LEV hoods). In addition, the Econweld torch improves the workplace environment (high capture efficiency) and can be used for extended periods of time owing to its lightweight (ergonomics).

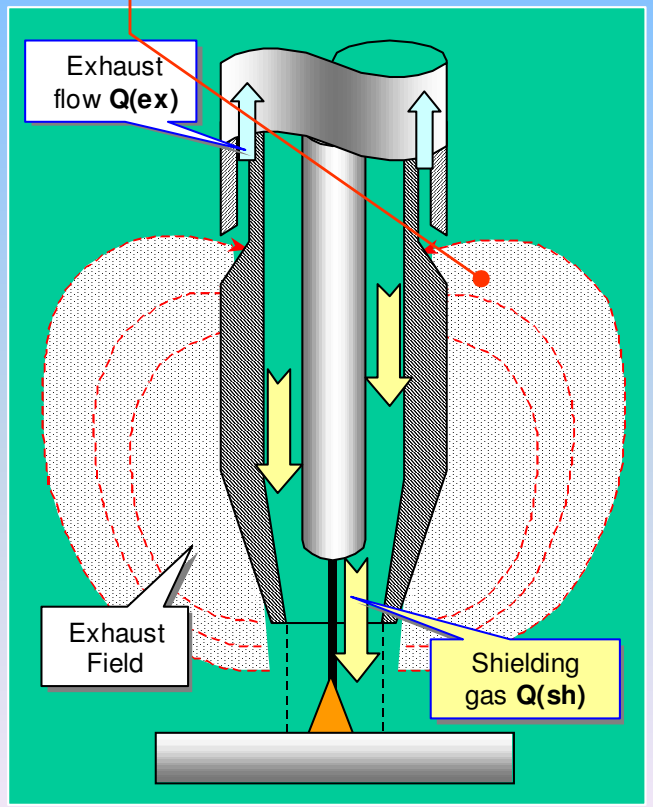
The Project: Priority Needs & Tasks

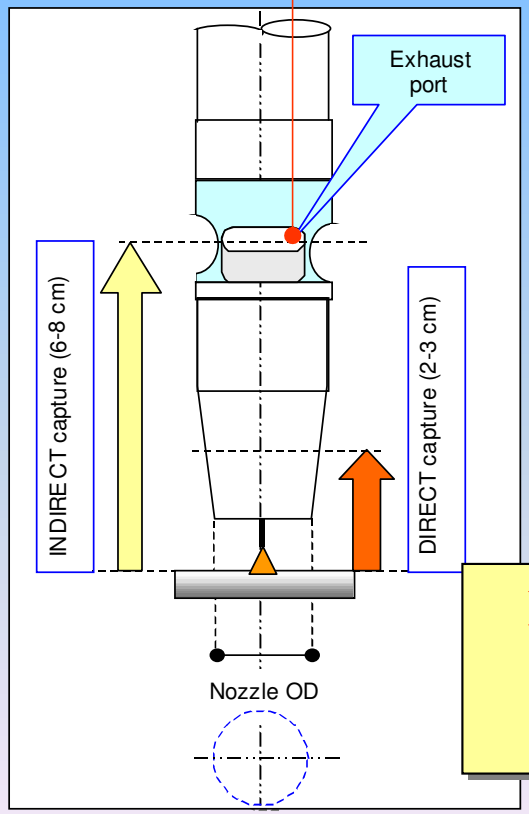


ECONWELD Aspiring Torch - Definitions

FUME ASPIRING TORCH
Definitions - Characteristics

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





ECONWELD / ASPIRMIG TORCH
Indirect Integral Extraction Torch
Air/Water Cooled - Radial Exhaust

Aspiring Torch – Fume Collector

ASPIRING TORCH
High Vacuum - Low Volume

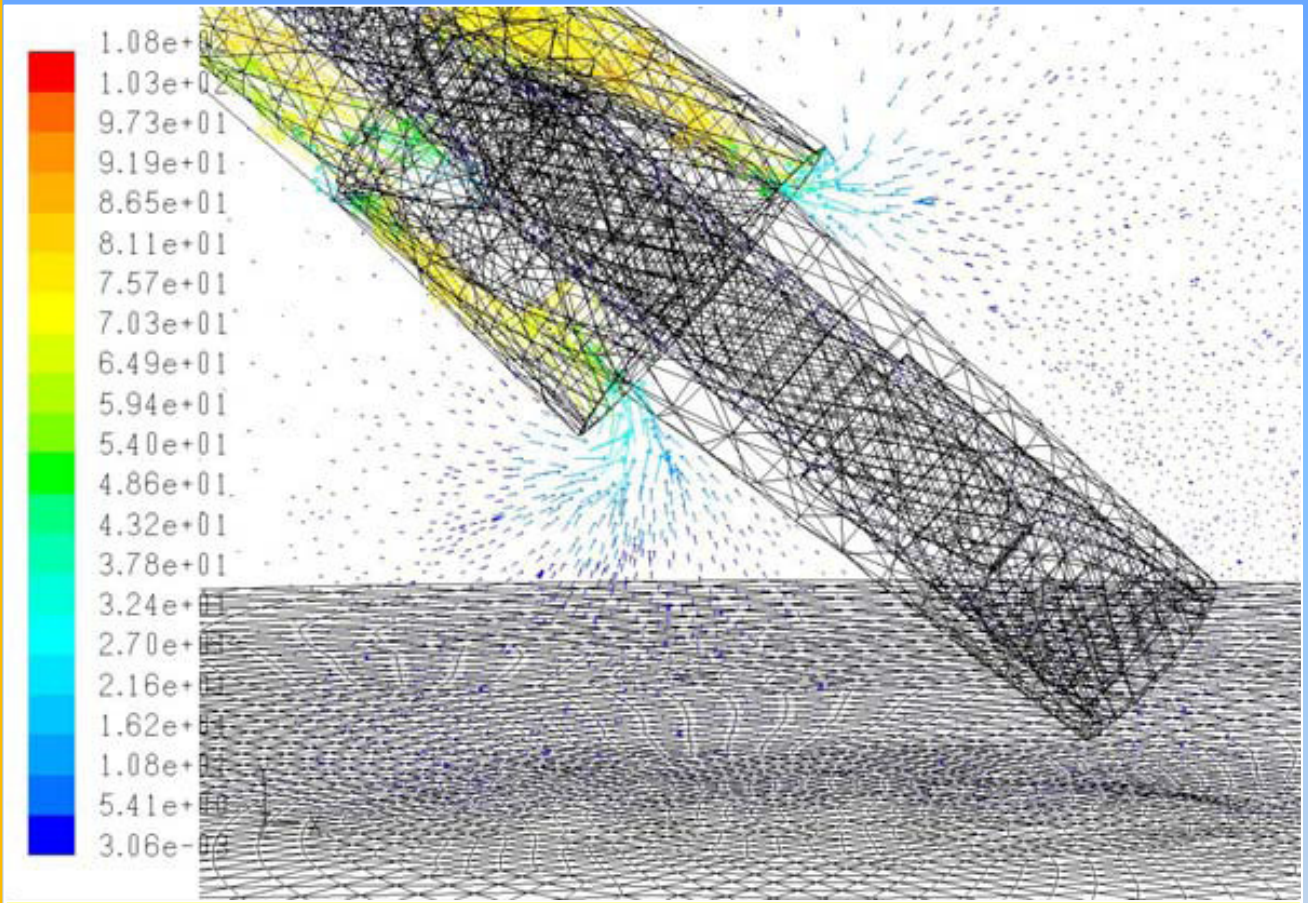
Airflow = 80 - 120 cu.m/h
Air velocity = 40-50 m/s
at suction openings
Pressure differential=15 kPa

The ECONWELD Aspiring torch uses High Vacuum – Low Volume technology, i.e. High Velocity and Low air Volumes to extract the fumes.

Fixed and mobile aspirators to be connected to the Torch

- The suction flow 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.
- The exhaust unit is 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 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 orifices far away from the area of the weld allows the temperature of the handle to be maintained within acceptable limits.

Aspiring Torch : CFD Modelling - Velocity Field



CFD Modelling Aspiring Torch (45° position) - Velocity Field

DATA USED FOR CFD MODELLING

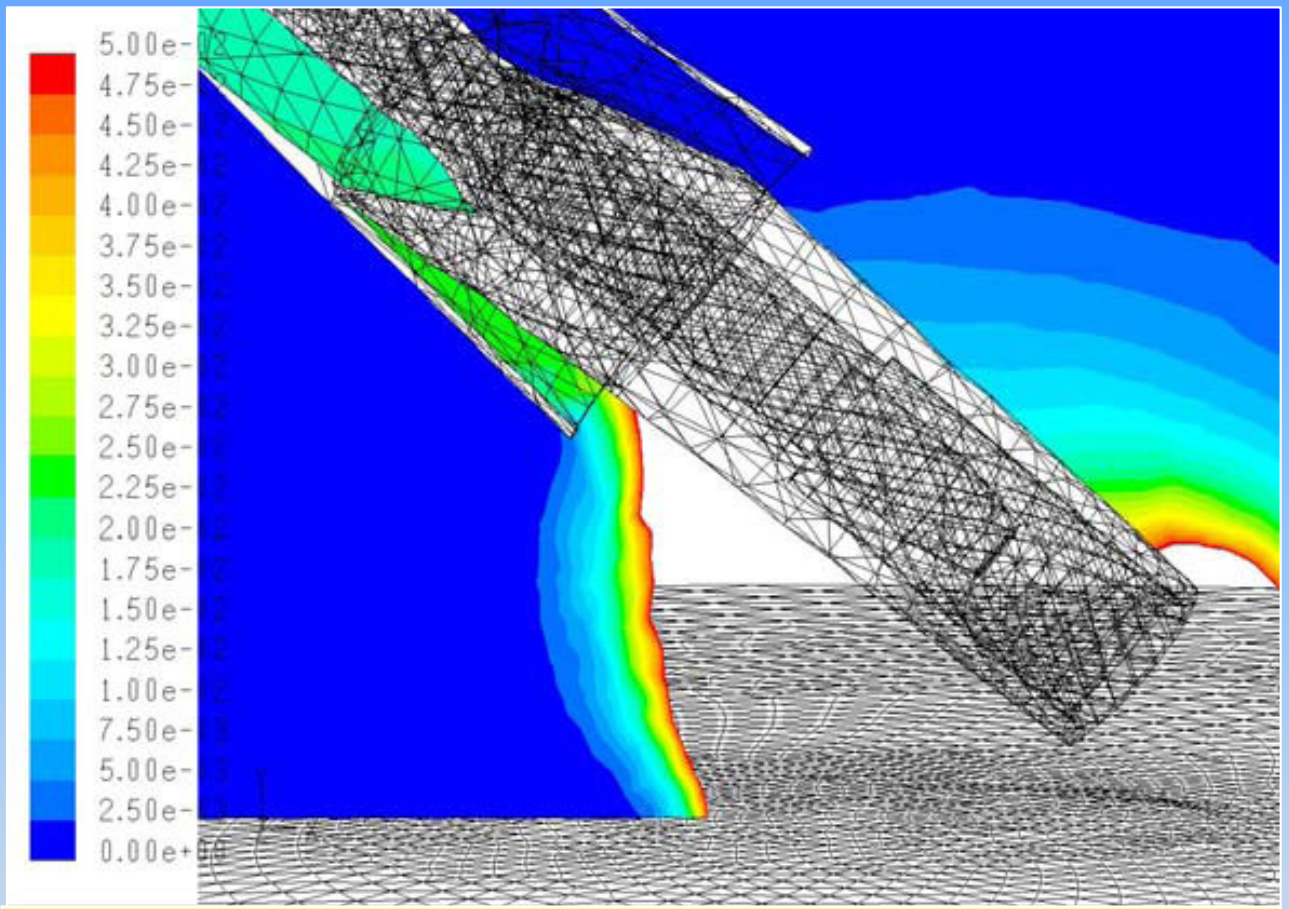
Shielding gas: Ar 100% - Gas flow: 12 l/min – Exhaust static pressure: 9.5 kPa - Exhaust flow rate: 28 l/s=100.8 cu.m/hr - Radiative model: Rosseland

✓A CFD modelling of the Aspiring Torch was performed, using the program *Fluent*, which is able to assess the dynamic characteristics of the motion of many fluids.

✓ A set of fundamental operational parameters (pressure, velocity, flow of the gas, etc.) was properly assumed.

✓ The results of such a model (supplied by an expert Partner) showed that the hydraulic behaviour of the suction openings works in a satisfactory manner, capturing the bulk of fumes produced in welding.

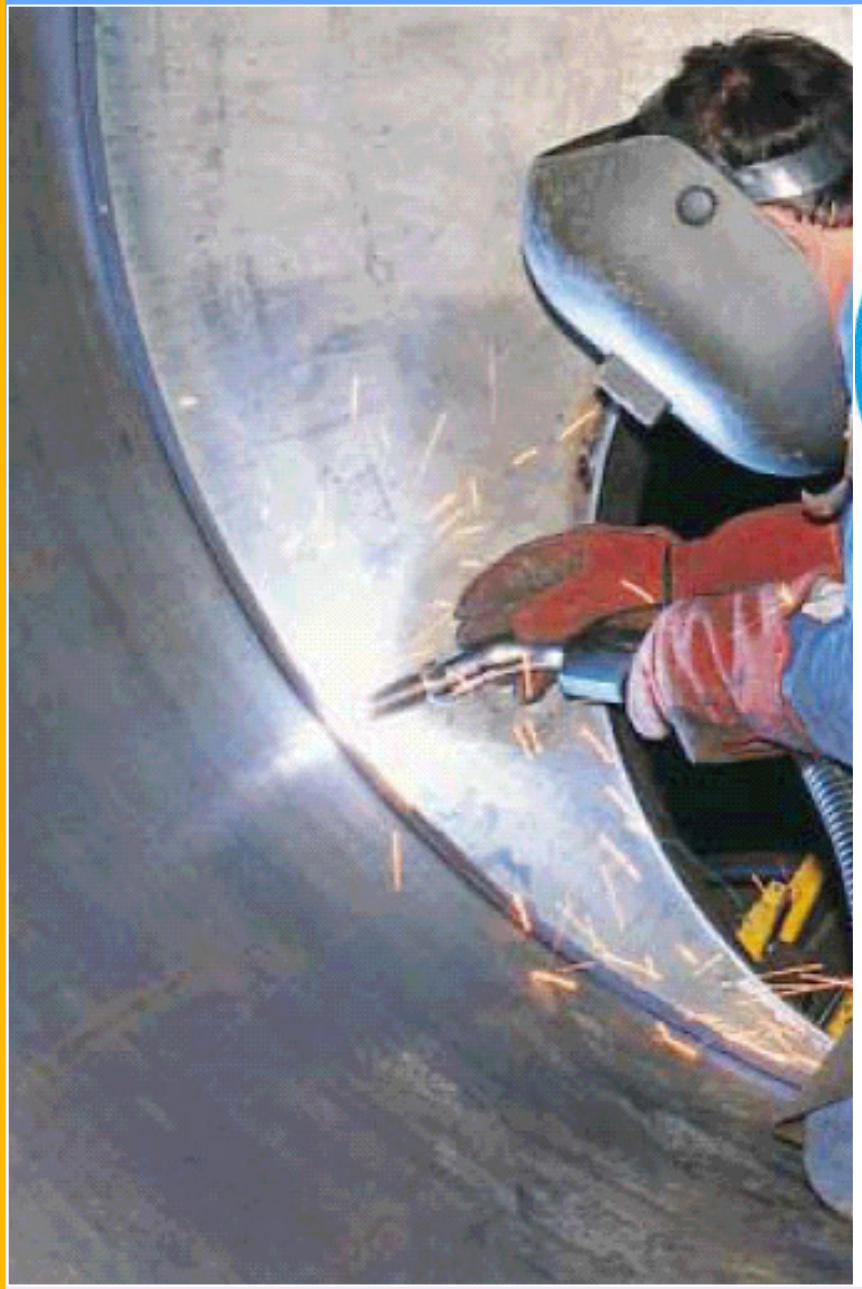
Torch Modelling : Shielding Gas Concentration

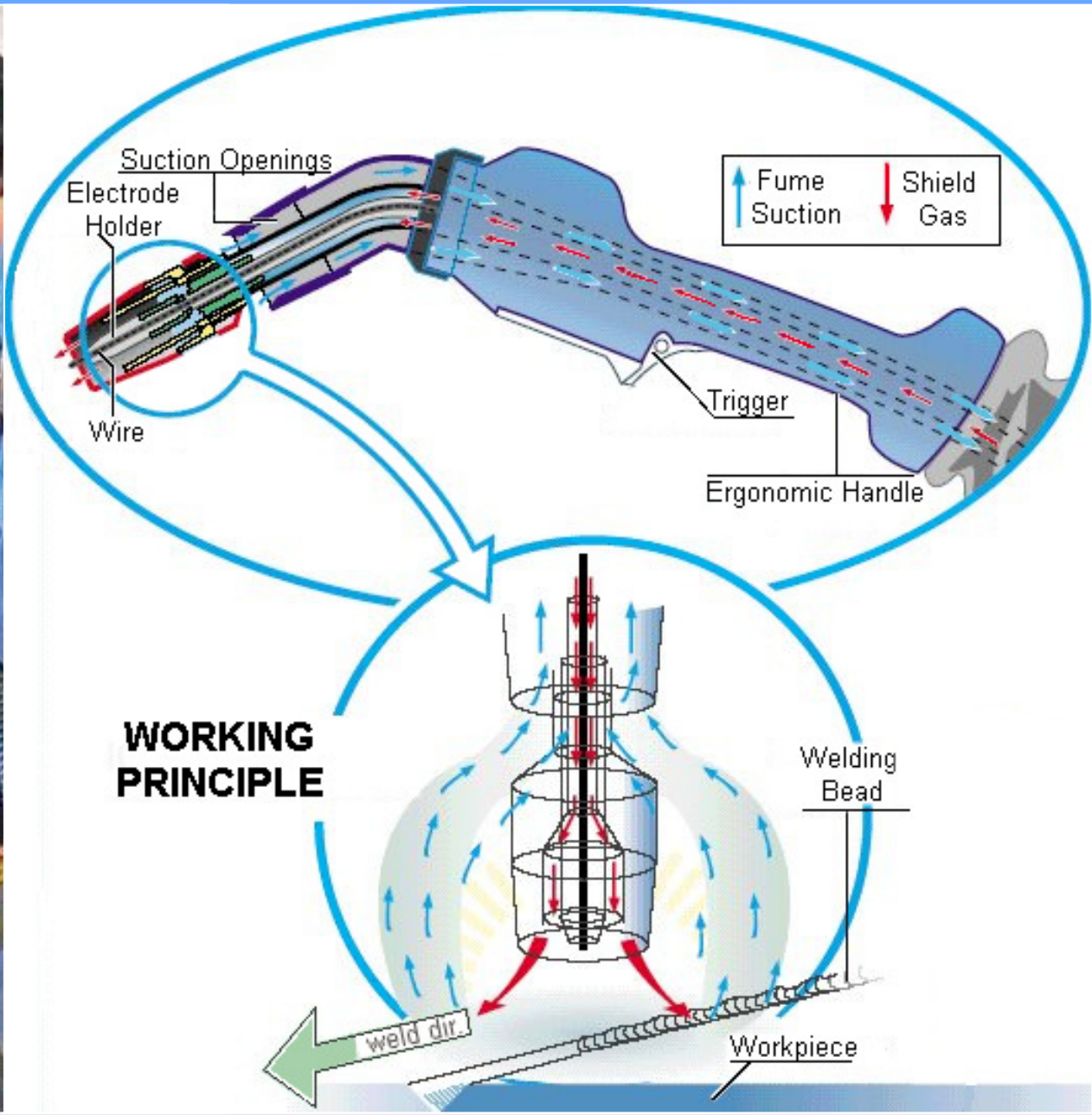


CFD Modelling of Aspiring Torch (45° position) – Shielding Gas Concentration in the workplace

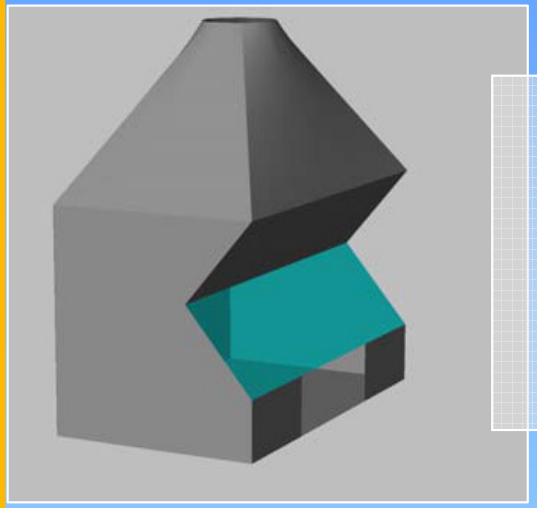
- ✓ The CFD Model in the Figure represents the concentrations of the shielding gas in the space around the tip of the torch.
- ✓ The concentration of shielding gas (Ar) is expressed as a mass fraction (non-dimensional) of Ar, i.e. the ratio between the argon mass flow and the total mass (Ar and air flow).
- ✓ In the Figure only a fraction (up to 5%) of the argon mass is shown, in order to get a higher resolution of the field, showing in greater detail the distribution of shielding gas around the aspiration zone (skirt inlet).

Indirect Aspiring Torch : Working Principle

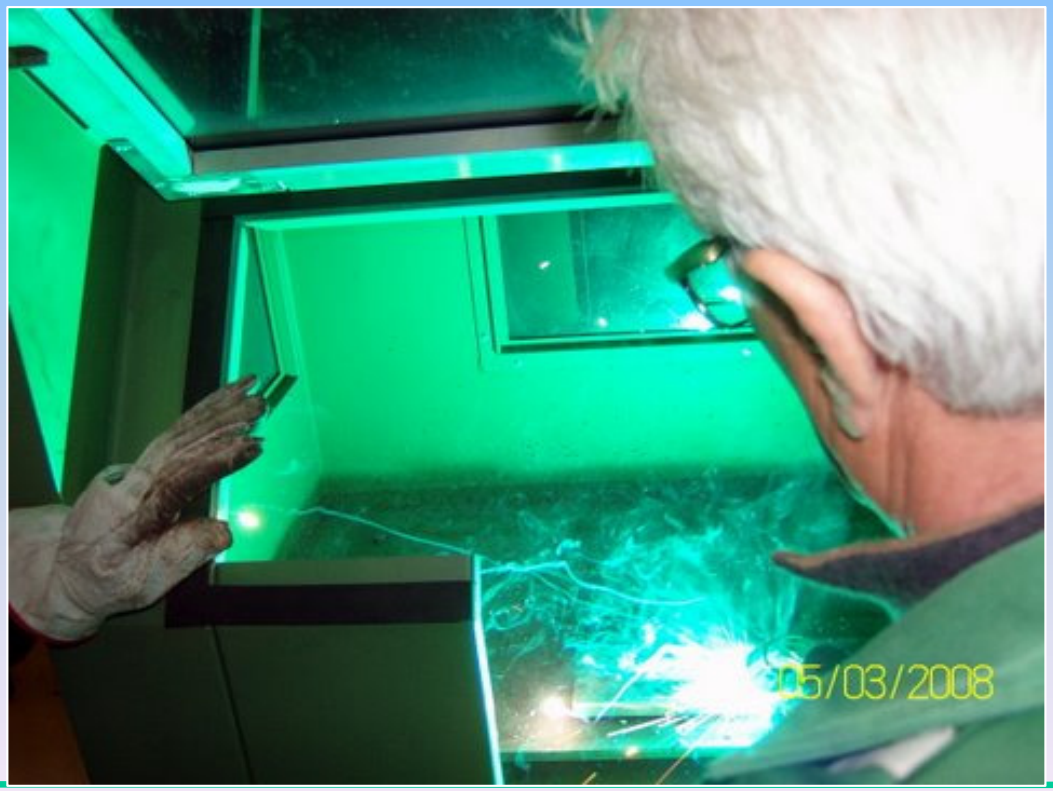




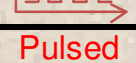
SECTION 2



TESTING CAPTURE EFFICIENCY: WELDING TRIALS



Planning of Welding Trial Execution

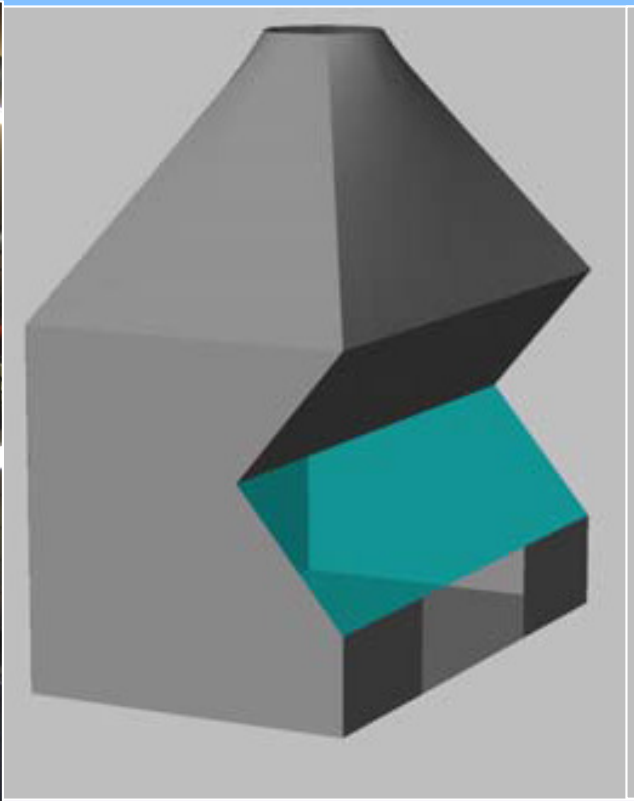
Base Material	Filler metal	Shielding gas	Current waveform	Welding torch	Executor	Test condition
C-Mn Steel S 355 JR (Fe510)	Normal wire	*82% Ar-18% CO_2*	Without pulsing	With aspiration (by Aspirmig) 	IIS	1
	Green wire	*82% Ar-18% CO2*	Without pulsing	Normal type (without aspiration)	IS	2
	Normal wire	Ternary mixture	Pulsed 	Normal type (without aspiration)	IS	3
	Green wire	Ternary mixture	Without pulsing	Normal type (without aspiration)	IS	4
Stainless Steel AISI 316L	Normal wire	Ternary mixture	Without pulsing	Normal type (without aspiration)	IST	5
	Normal wire	*99% Ar-1% O_2*	Pulsed 	Normal type (without aspiration)	IST	6
	Normal wire	*99% Ar-1% O_2*	Pulsed 	With aspiration (by Aspirmig) 	IIS	7
	Normal wire	*97,5% Ar-2,5% CO_2*	Pulsed 	Normal type (without aspiration)	IST	8
	Normal wire	*97,5% Ar-2,5% CO_2*	Pulsed 	With aspiration (by Aspirmig) 	IIS	9
Aluminium Alloy EN AW 5354	Normal wire	*99,99% Ar*	Pulsed 	Normal type (without aspiration)	IIS	10
	Normal wire	*99,99% Ar*	Without pulsing	With aspiration (by Aspirmig) 	IIS	11
Aluminium Alloy EN AW 6061	Normal wire	*99,99% Ar*	Pulsed 	Normal type (without aspiration)	IIS	12
	Normal wire	*99,99% Ar*	Without pulsing	With aspiration (by Aspirmig) 	IIS	13

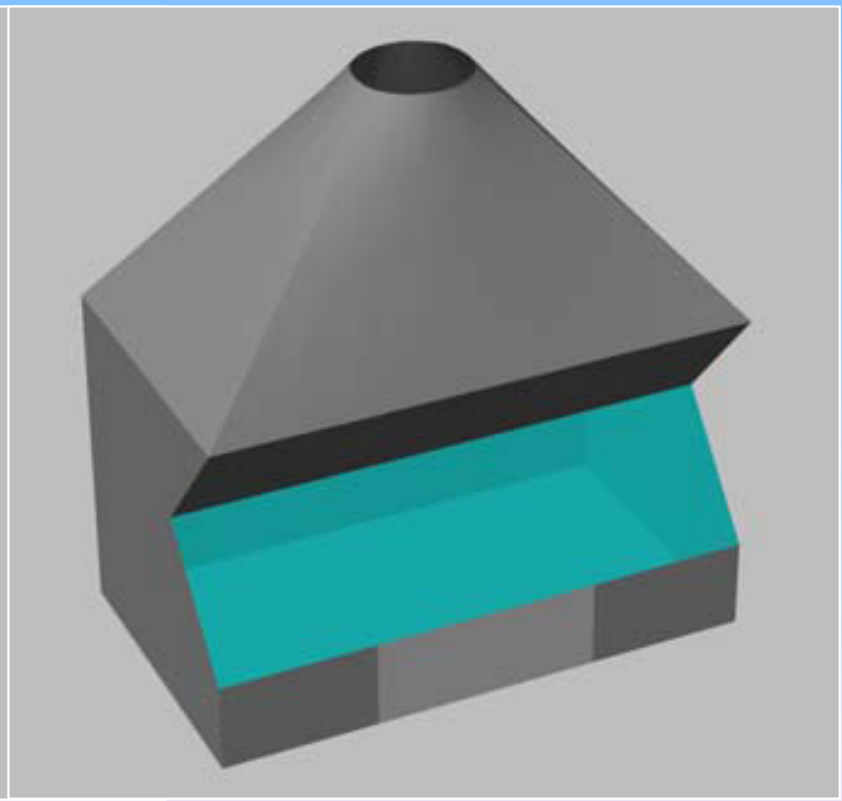
- ✓ Tests divided among IIS-IS-IST;
- ✓ Innovative methods / tools to reduce fume emissions at source i.e. “green wires”, ternary gas mixtures, pulsed waveforms (CDP);
- ✓ N. 5 trials on aspiring torch (capture efficiency) performed by IIS;
- ✓ N. 13 different test conditions for total 105 welding trials.

Fume Box for Welding Trial Execution

Modified Fume Box at Italian Institute of Welding

Internal CFD Optimisation - Improved View Accessibility





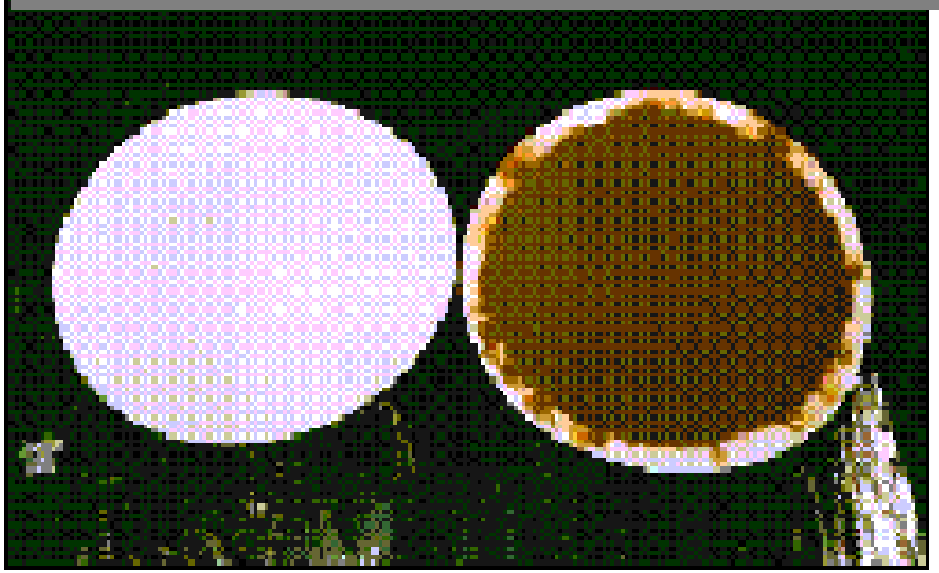
Fume Emission Rate: Total Particulate Method

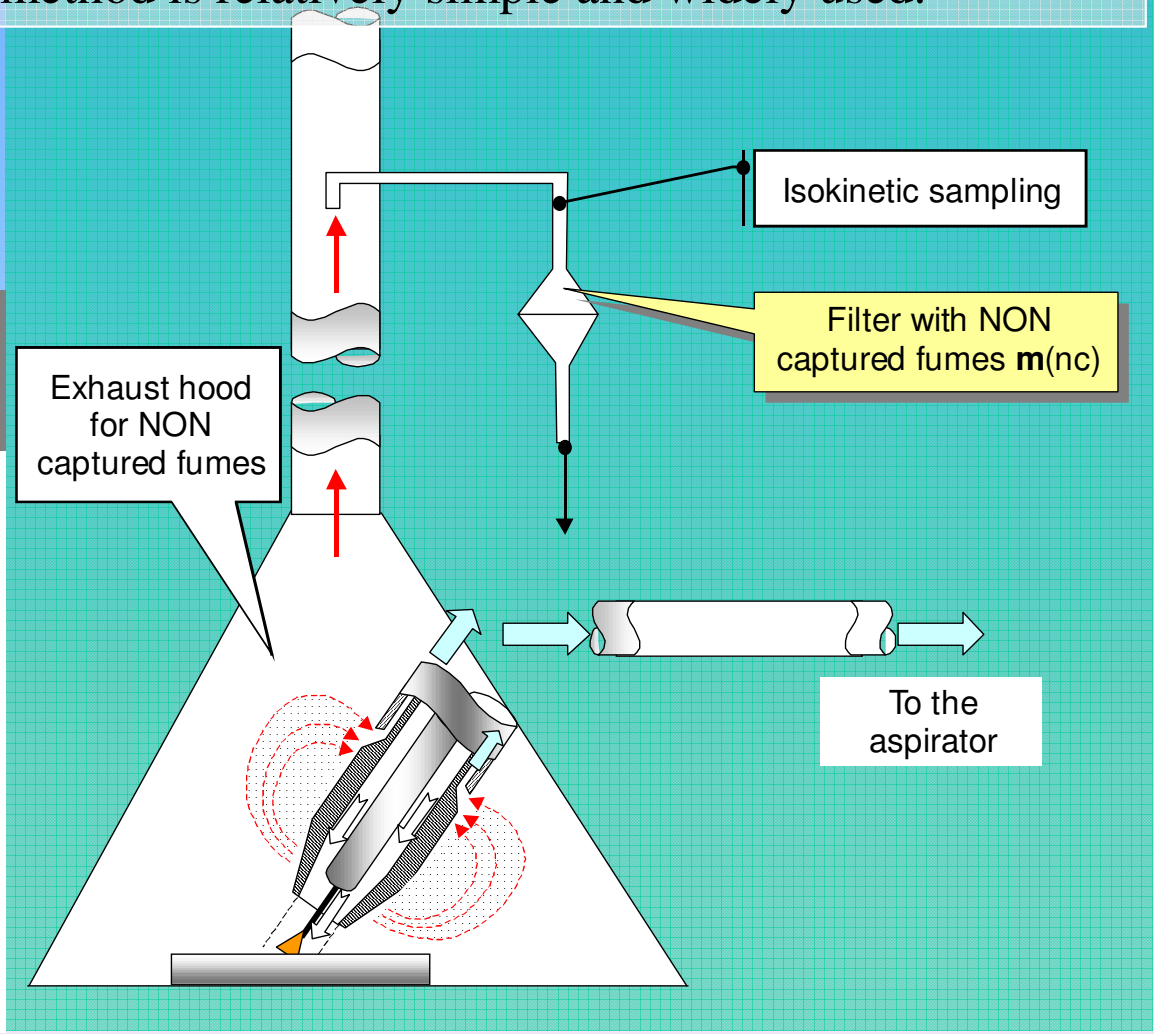
CAPTURE EFFICIENCY
Method used at IIS

Total particulate fume

The total particulate fume emitted is collected on filters by isokinetic sampling in the fume box, first powering on the extraction system and then switching off the aspirator. This method is relatively simple and widely used.

Clean Filter (left) – The same filter after sampling fumes (right).





Fume Emission Testing – Fume Box Layout at IIS

The fume emissions produced during welding had been tested by different partners (IIS, IST and IS) within fume boxes, in accordance with the European Standards → EN ISO 15011-1/2.

Fume Emission Testing – Operative Steps

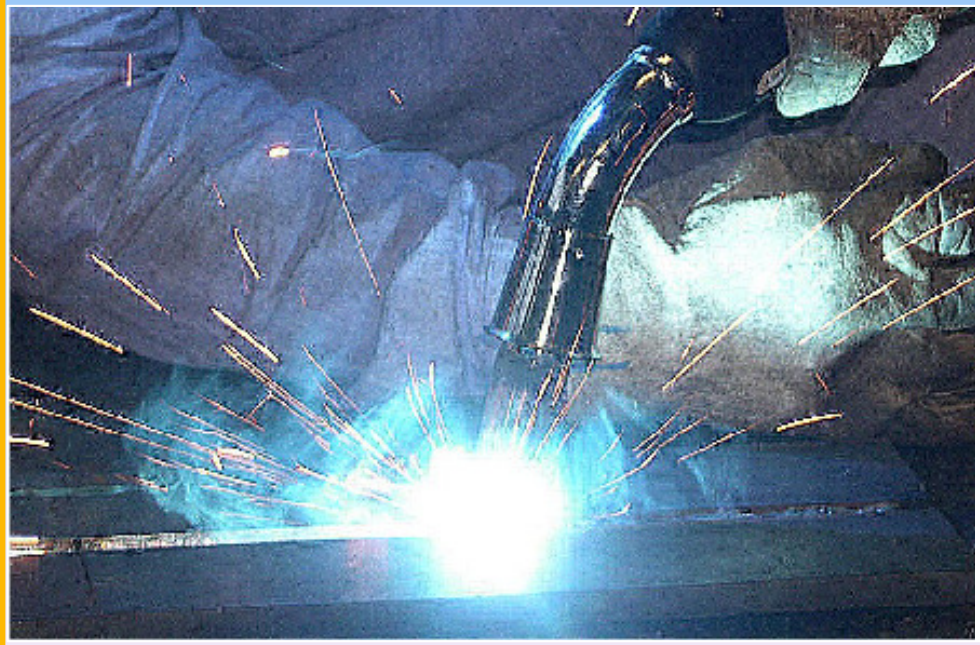
1. Performing Manual GMA Welding (PA position) with / without Aspiring Torch
2. Checking Welding Time = 60 s
3. Each Filter removed from Fume Box
4. Filter weighed before and after test, fume emission rate calculated, measurements in mg/s (then converted to mg/min)

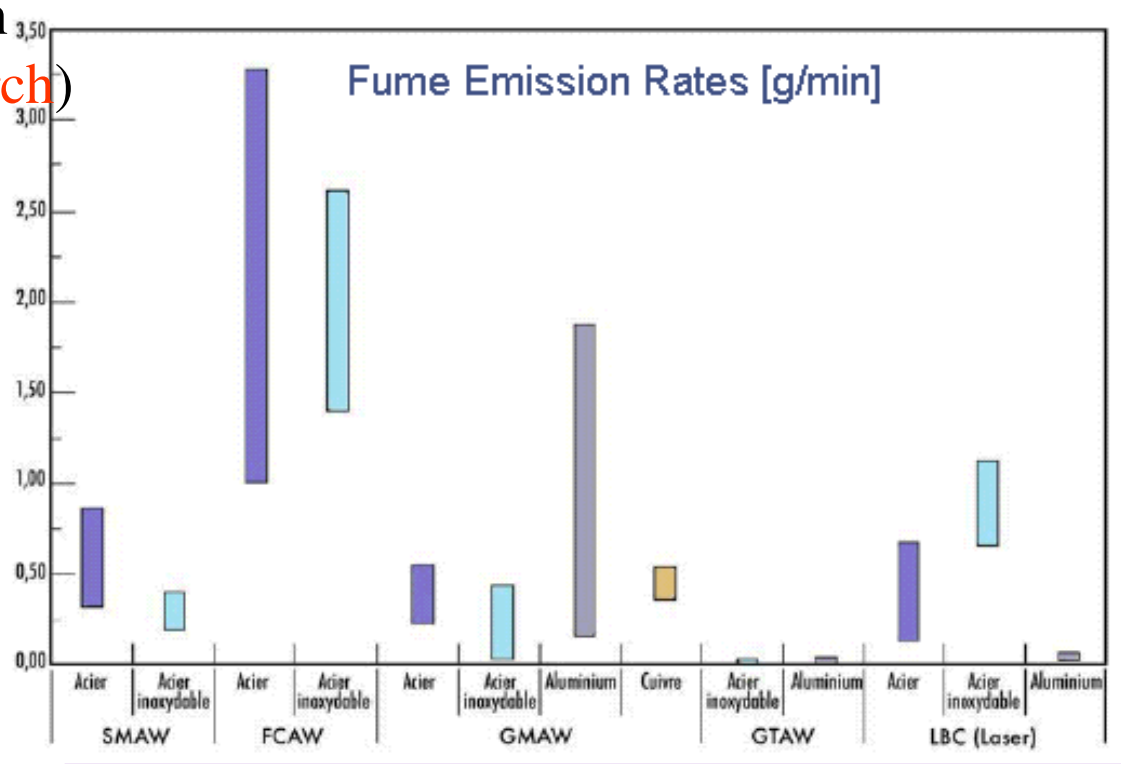
Factors Affecting the Fume Emission Rate

THE MAIN FACTORS INFLUENCING THE FER

- Type of shielding gas if applicable to the process
- Welding current / Welding voltage
- Arc length / Arc Polarity
- Current density
- Humidity
- Base material
- Electrode angle / Type / Formulation
- Torch (conventional or Aspiring Torch)

With Aspiring Torch the Fume Emissions are greatly reduced (well below 30 mg/min).





SECTION 3

FUME CAPTURE EFFICIENCY: ANALYSIS OF THE RESULTS

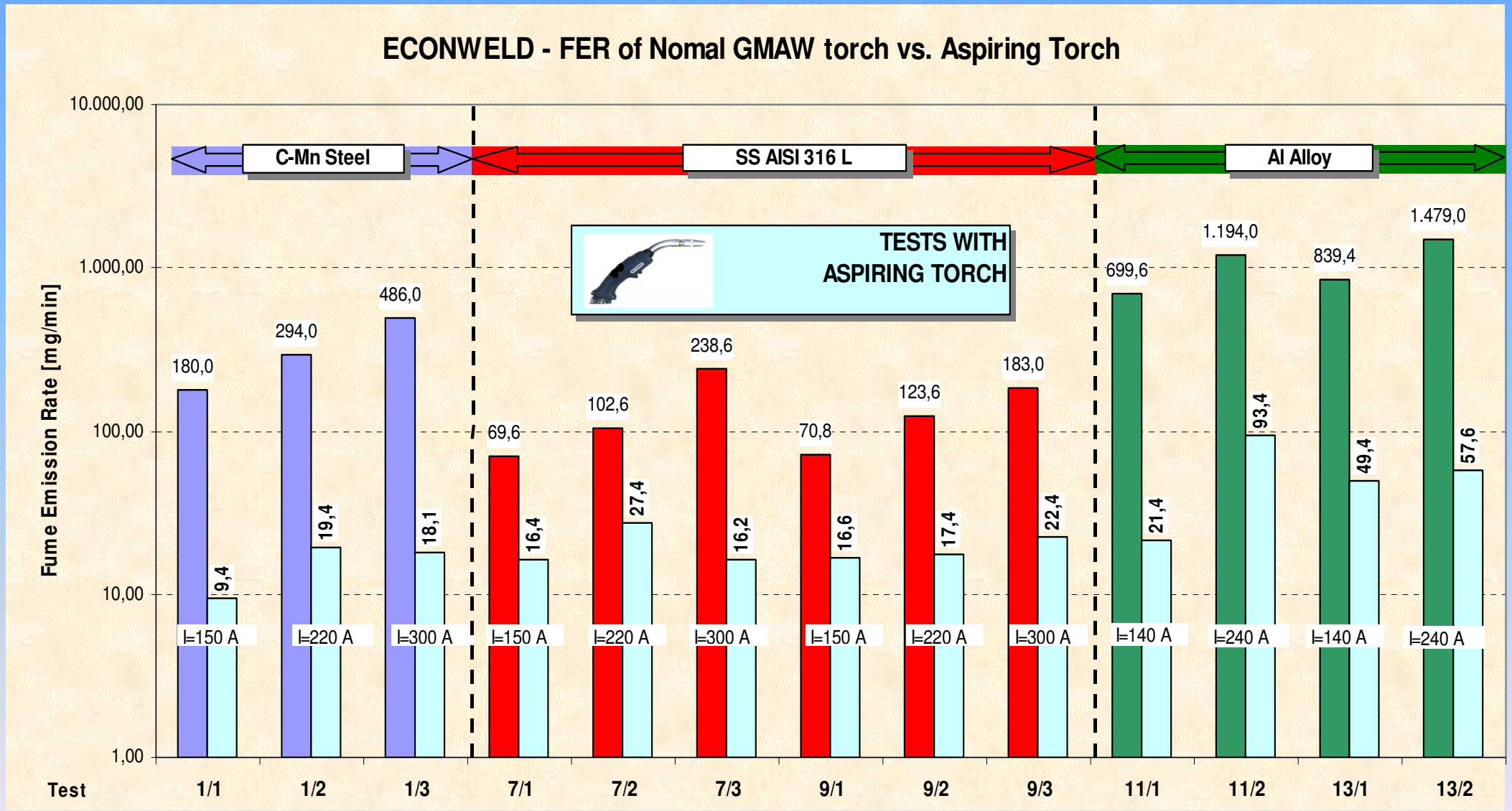
FER (mg/min) – Test Results of Normal vs. Aspiring Torch

Base Material	Wire type	Shielding gas type	Test N.	FER, mg/min		Torch efficiency, %
				WITHOUT aspiration	WITH aspiration	
Mild Steel (C-Mn) S355 JR (Fe510)	Solid wire EN 440 G2Si Dia=1.2 mm	*82%Ar+18 % CO_2*	1/1	180,00	9,40	94,8%
			1/2	294,00	19,40	93,4%
			1/3	486,00	18,10	96,3%
Stainless Steel AISI 316L	Solid wire EN 10072 G19 12 3 (AISI 316L) Dia=1.2 mm	*98%Ar+2 % O_2*	7/1	69,60	16,40	76,4%
			7/2	102,60	27,40	73,3%
			7/3	238,60	16,20	93,2%
		97.5%Ar+ 2.5% O_2	9/1	70,80	16,60	76,6%
			9/2	123,60	17,40	85,9%
			9/3	183,00	22,40	87,8%
Aluminium Alloy EN AW 5354	Solid wire EN 18237 S Al 5356 Dia=1.2 mm	99.99%Ar	11/1	699,60	21,40	96,9%
			11/2	1.194,00	93,40	92,2%
Aluminium Alloy EN AW 6061			13/1	839,40	49,40	94,1%
			13/2	1.479,00	57,60	96,1%

Welding Parameters - Tests using Normal / Aspiring Torch

Test	Sub test	Φ(wire), mm	Current, A	Voltage, V	Wire speed, cm/min	Shield gas, l/min	Weld Position
N. 1-7-9	1	1,2	150	22	180	15	 Bead on plate (PA)
	2	1,2	220	24	280	15	
	3	1,2	300	28	380	15	
N. 11-13	1	1,2	140	23	220	15	
	2	1,2	240	25	300	15	

FER – Comparison Graph of Normal vs. Aspiring Torch



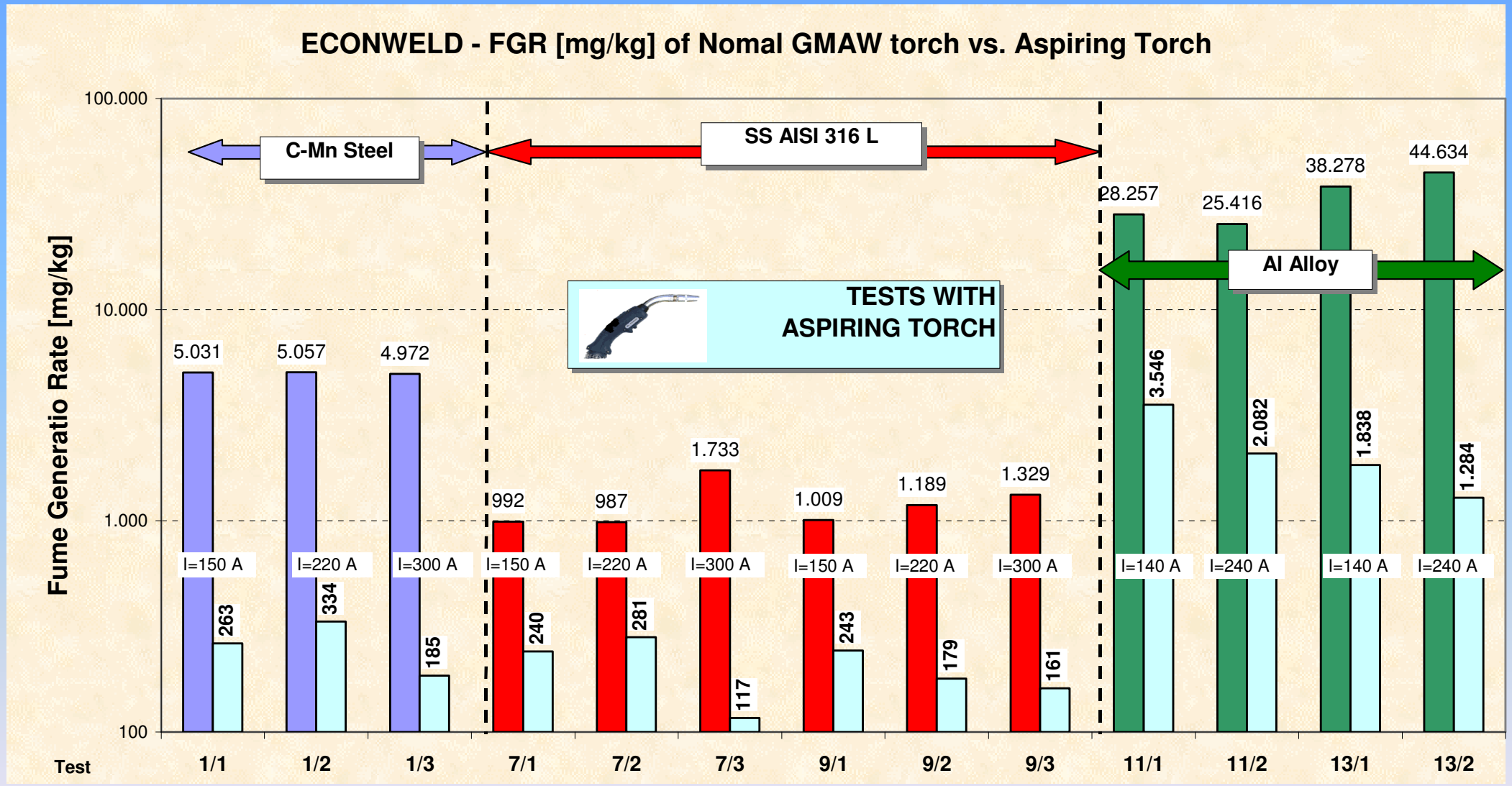
FGR(mg/kg) - Test Results of Normal vs. Aspiring Torch

Base Material	Wire type	Shielding gas type	Test N.	FGR, mg/kg		Torch efficiency, %
				WITHOUT aspiration	WITH aspiration	
Mild Steel (C-Mn) S355 JR (Fe510)	Solid wire EN 440 G2Si Dia=1.2 mm	*82%Ar+18 % CO_2*	1/1	5.031,00	262,73	94,8%
			1/2	5.056,80	333,68	93,4%
			1/3	4.971,70	185,16	96,3%
Stainless Steel AISI 316L	Solid wire EN 10072 G19 12 3 (AISI 316L) Dia=1.2 mm	*98%Ar+2 % O_2*	7/1	992,24	240,48	75,8%
			7/2	987,32	281,25	71,5%
			7/3	1.732,87	116,56	93,3%
		97.5%Ar+ 2.5% O_2	9/1	1.009,35	243,40	75,9%
			9/2	1.189,41	178,60	85,0%
			9/3	1.329,07	161,20	87,9%
Aluminium Alloy EN AW 5354	Solid wire EN 18237 S Al 5356 Dia=1.2 mm	99.99%Ar	11/1	28.257,01	3.546,10	87,5%
			11/2	25.416,36	2.081,97	91,8%
Aluminium Alloy EN AW 6061			13/1	38.278,44	1.838,17	95,2%
			13/2	44.634,41	1.283,95	97,1%

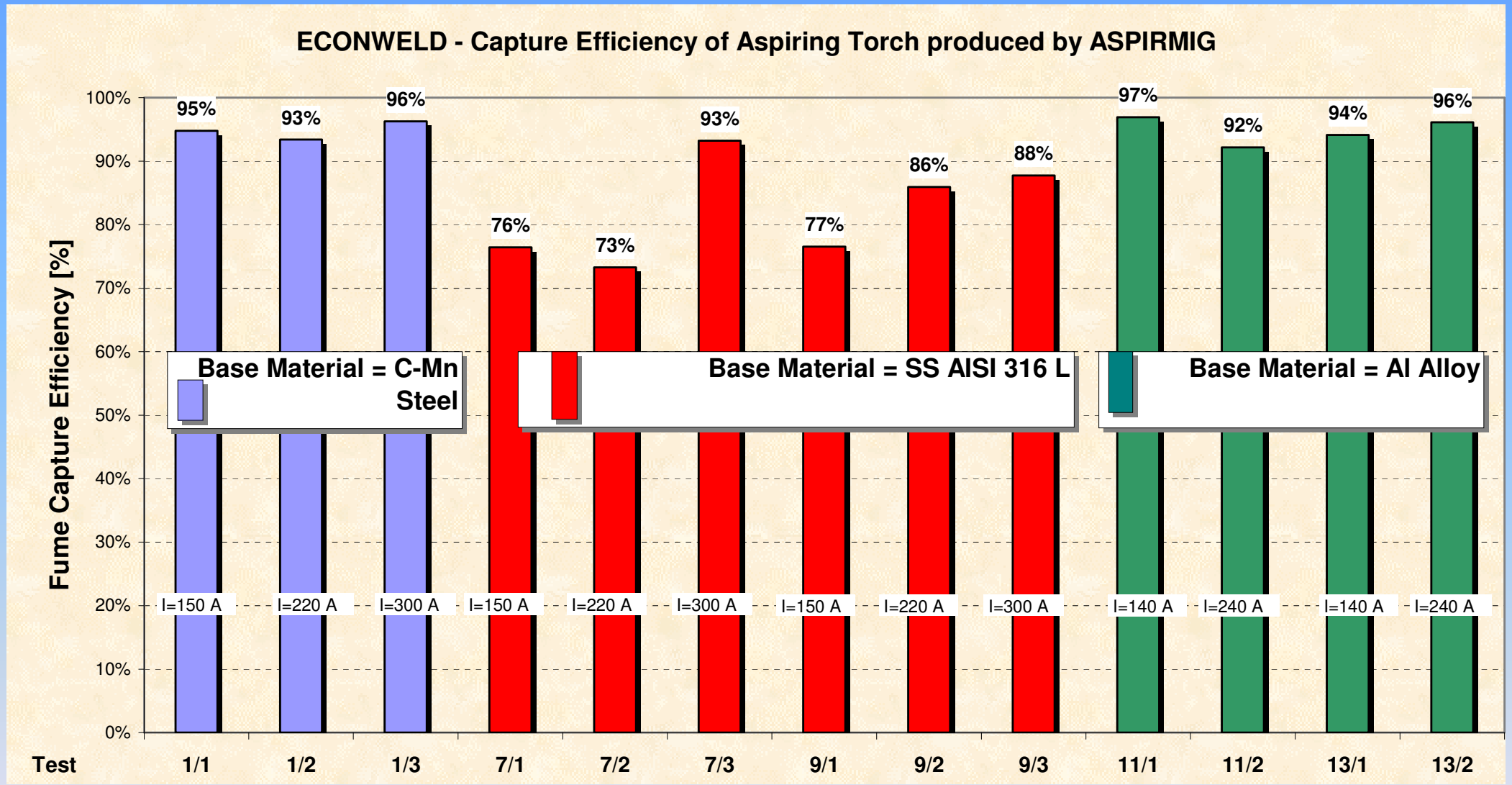
Welding Parameters - Tests using Normal / Aspiring Torch

Test	Sub test	Φ(wire), mm	Current, A	Voltage, V	Wire speed, cm/min	Shield gas, l/min	Weld Position
N. 1-7-9	1	1,2	150	22	180	15	 Bead on plate (PA)
	2	1,2	220	24	280	15	
	3	1,2	300	28	380	15	
N. 11-13	1	1,2	140	23	220	15	
	2	1,2	240	25	300	15	

FGR - Comparison Graph of Normal vs. Aspiring Torch



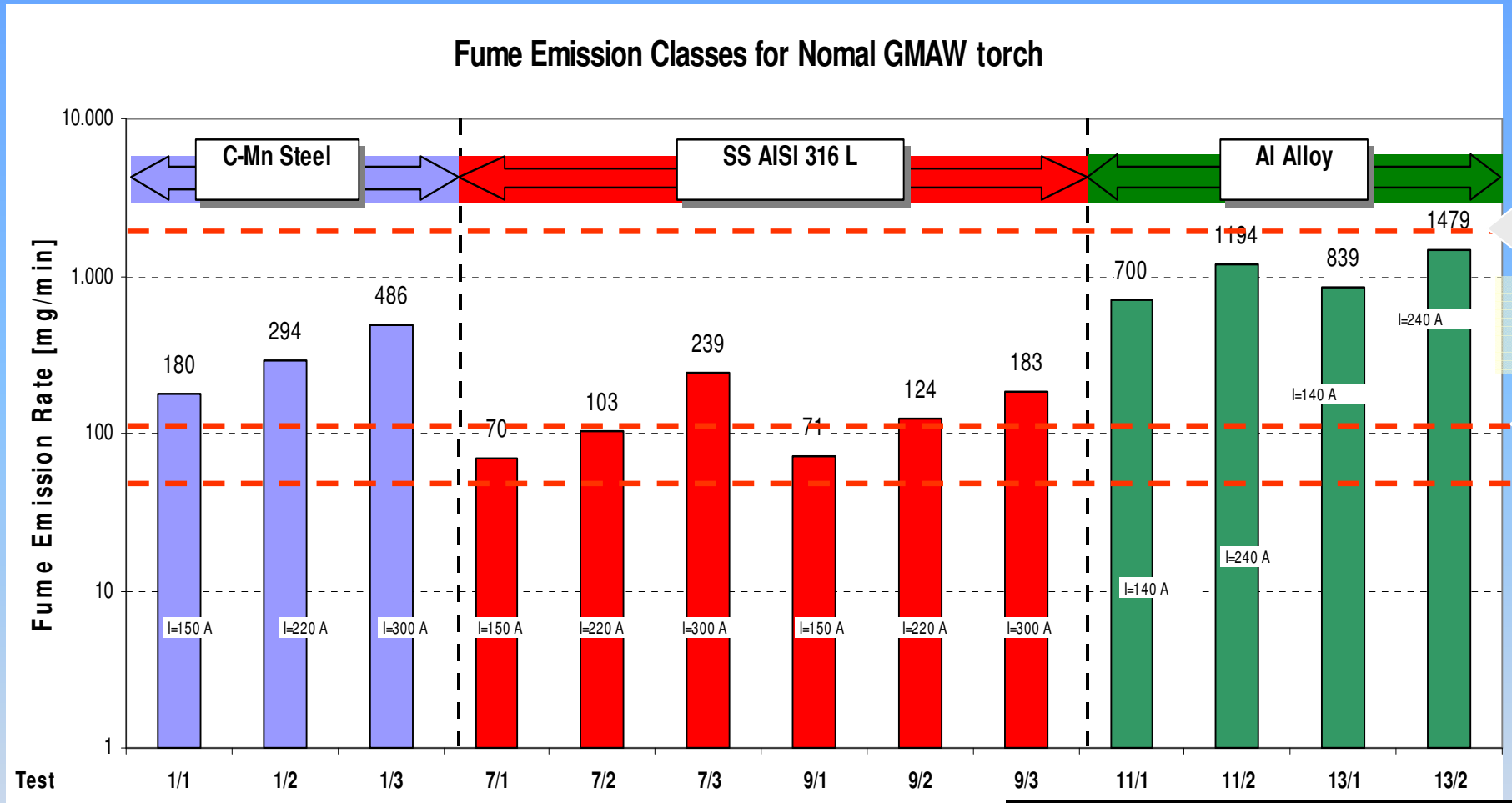
Fume Capture Efficiency Graph of Aspiring Torch



FCE(min) → C-Mn Steel = 93 % AISI 316 L = 73 % Al Alloy = 92 %

FCE(max) → C-Mn Steel= 96 % AISI 316 L = 93 % Al Alloy = 97 %

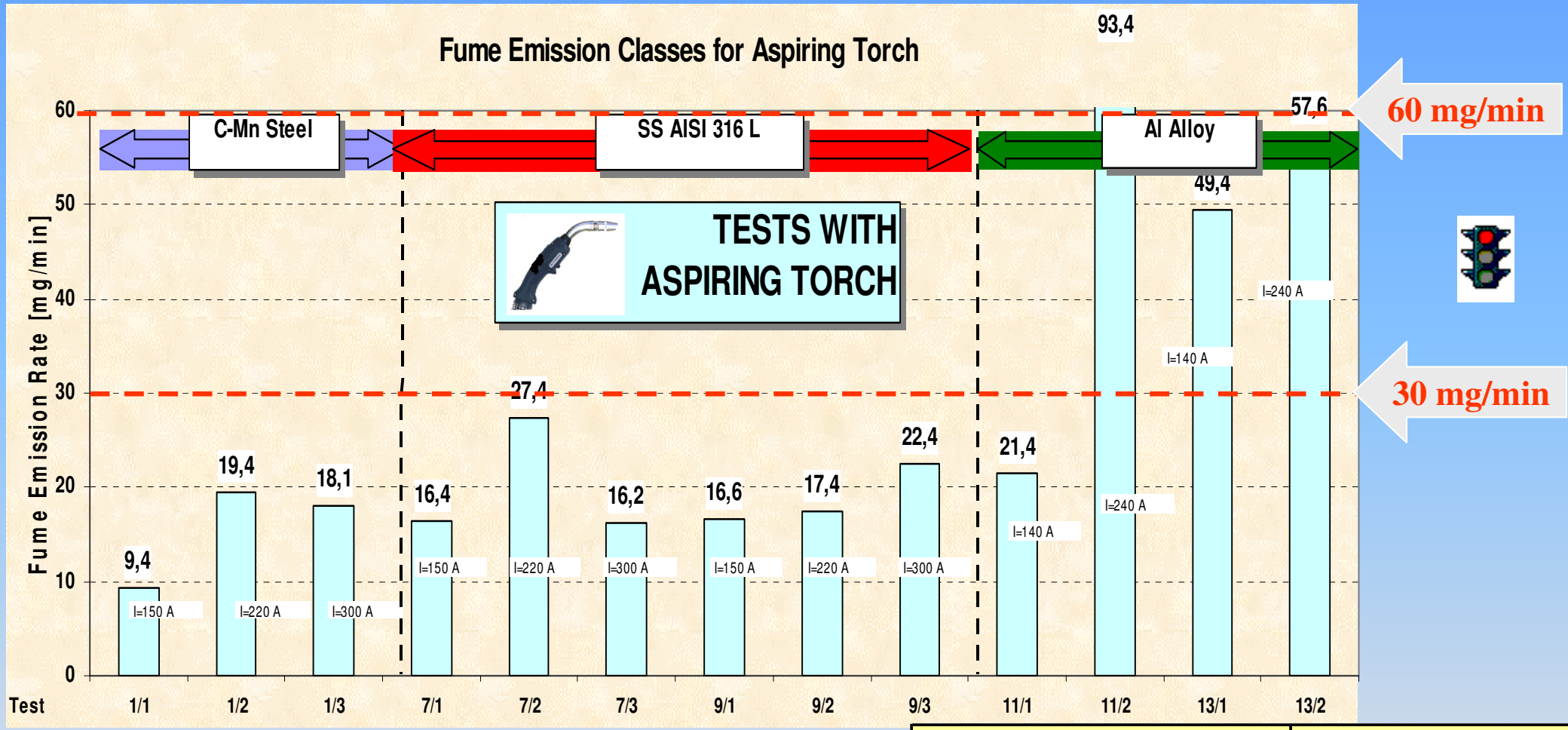
Fume Emission Classes for Normal GMAW Torch



➢ With Normal Torch medium (trials 7/1, 7/2, 9/1on SS al low currents) and high emission rates (all C-Mn and Al trials) are obtained, with fume concentrations greatly exceeding the recommended PEL of 3 mg/m^3.

Emission Classes		Emission rates	
		mg/s	mg/min
1	**Low** emissions rates	< 1	< 60
2	**Medium** emission rates	1 - 2	60 - 120
3	**High** emission rates	2 - 25	120 - 1.500
4	**Very High** emission rates	> 25	> 1.500
Source: BGR 220 - Welding fumes			

Fume Emission Classes for Aspiring Torch



➢ With Aspiring Torch low emission rates are achieved in all the trials (excluding Trial 11/2 on Al). Fume concentrations in the breathing zone are by experience in the range of 3 mg/m^3 or well below for emission classes tested below the half (30 mg/mc^3) of the limit.

Emission Classes		Emission rates	
		mg/s	mg/min
1	**Low** emissions rates	< 1	< 60
2	**Medium** emission rates	1 - 2	60 - 120
3	**High** emission rates	2 - 25	120 - 1.500
4	**Very High** emission rates	> 25	> 1.500
Source: BGR 220 - Welding fumes			

Results of Fume Emission Measurements

- General dust limit value (PEL) is the concentration specified for the respirable (lung penetrating) dust fraction, actually 3 mg/m^3.
- For low emission rates, concentrations of hazardous substances in the breathing zone of the welder are by experience in the range of 3 mg/m^3 or below.
- For processes with medium and high emission rates, exceeding the PEL, the general state of the art is to take ventilation measure (fume capture at the source of emissions). Moreover, additional measures are necessary for the protection of the welder (PPE).
- With Aspiring Torch low emission rates are achieved in all the trials (excluding an Al test). Many trials were below the half (30 mg/min) of the class limit, with fume concentrations in the breathing zone (around 1.5-1.8 mg/m^3) lesser than the PEL.
- The bulk of the fumes produced in the trials appeared to be captured by the aspiring torch, with consistent quality of the welding beads, visually checked.

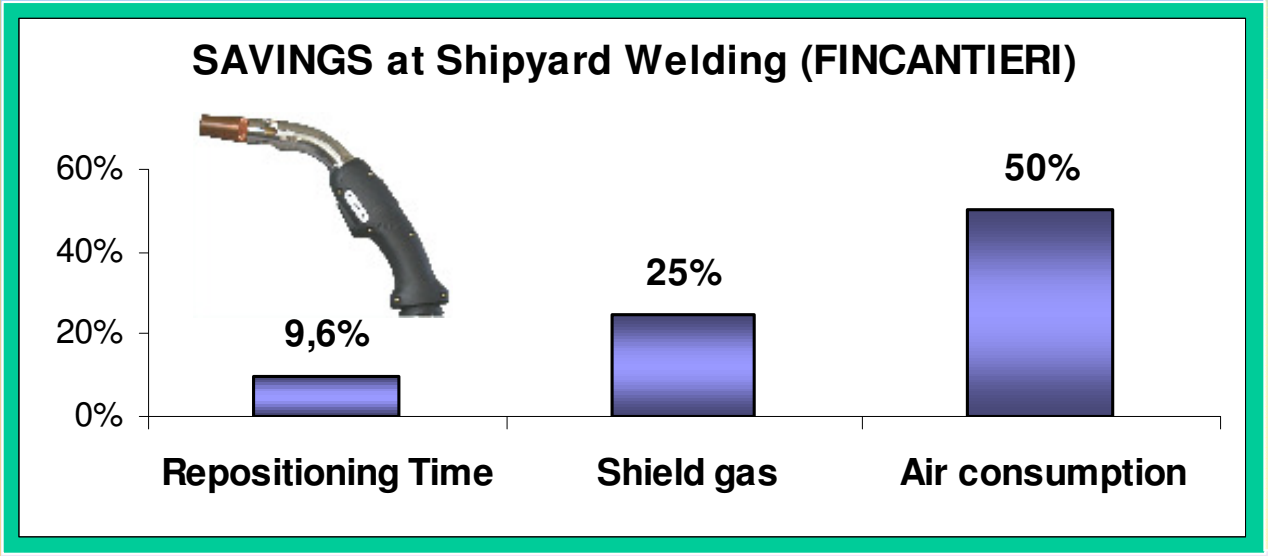
The performance at Charpy V notch impact tests (specimens from C-Mn steel samples) revealed satisfactory results, higher than the minimum values required by the Standard EN 10025-3.

Aspiring Torch Working in Real Workshop

During an 8 hour shift, each welder performs at chief Italian Shipyard 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 performed at IVECO-FIAT by a Health Officer showed a fume concentration of : 1° welder → 2.36 mg/m^3; 2° auxiliary → 1,63 mg/m^3

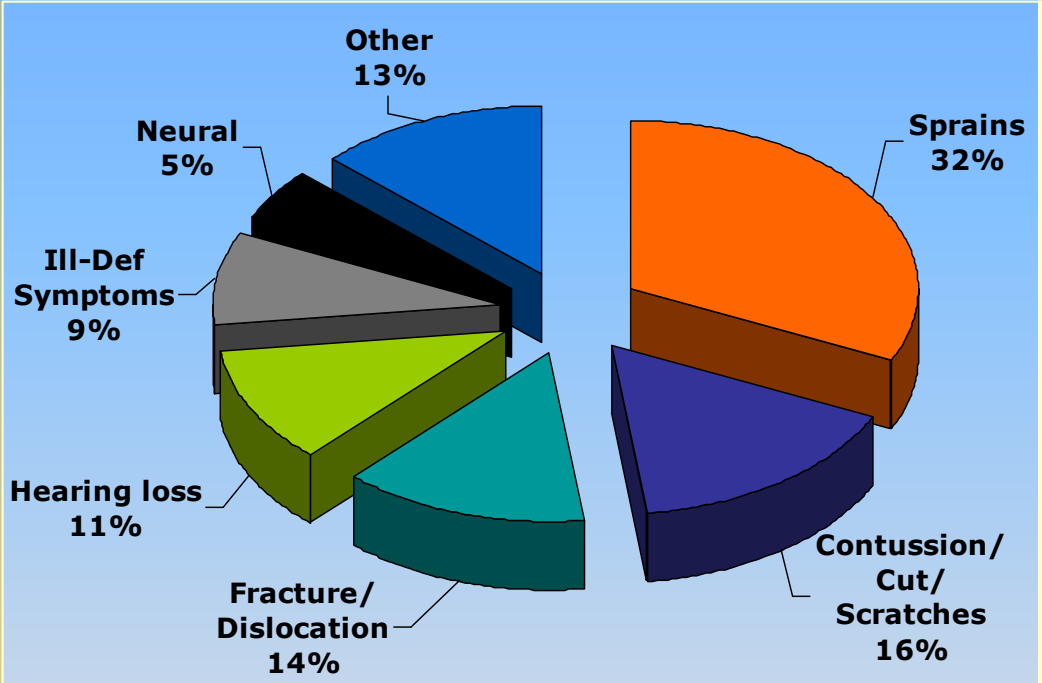


✓ Reduction of shield gas flow rate: 25% thanks to the suction field envelope which protects the fusion bath;

✓ Air consumption: 50% less when compared to a conventional mobile hood for fume capture at the source of emissions.

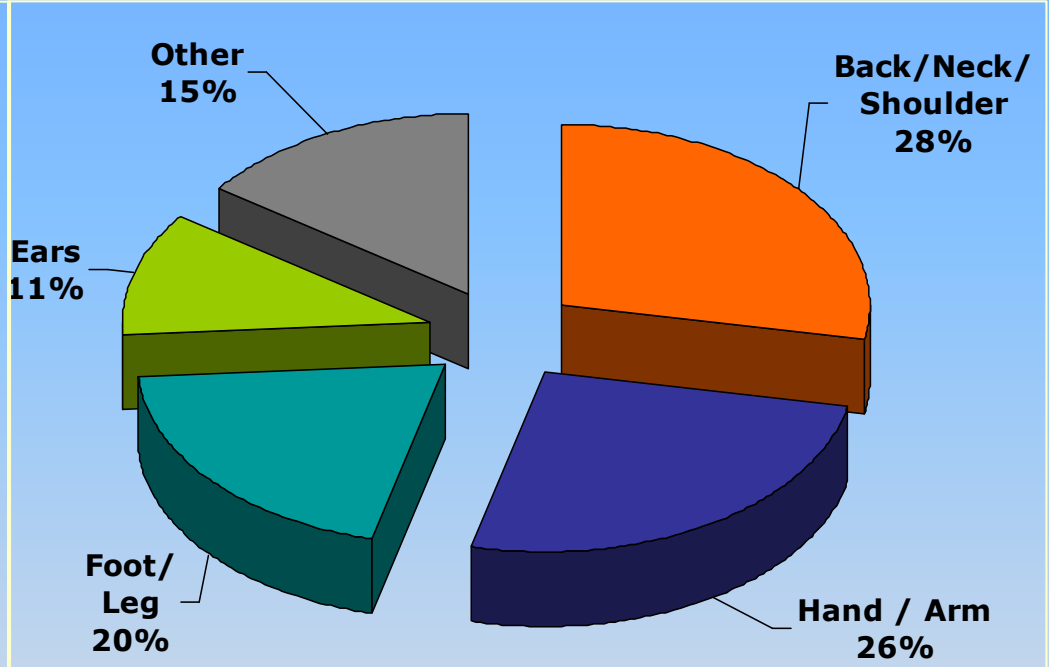
Introducing Ergonomics: Aspiring Torch - Articulated Arm

Washington State - Funded Compensable Claims (1994-2004) - Welders & Cutters



By Nature of Injury

Sprains account for more than 1/3 of the claims among welders. Some of those can be caused by hazardous WMSD exposures.

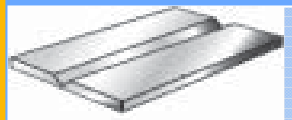


By Body Part

The back, neck and shoulder together with the arm and hand regions make up more than one half of the injuries among welders.

VIDEO ON INNOVATIVE ASPIRING TORCH

MAIN CONCLUSIONS



Bead on plate weld. The torch is held overhand and almost at 15° angle, vertically above the weld. In this tested position the fume extraction nozzle is best suited to extract fumes. Capture efficiencies have been measured from 93% to 97% (excluding some trials on SS); for fillet welds the torch efficiency is in the same range, thanks to the indirect suction field capturing the fume plume spreading-out (wall jet effect).

Vertical up-down weld. Where components are in the vertical plane (with angle from 85° to 90°), the capture efficiency of indirect suction torches (from Health Safety Executive - UK tests) is around 90%.

Overhead weld. This position assures the best performance of the capture efficiency of indirect aspiring torch. Capture efficiencies is over 98% (fumes are totally captured by the aspiring torch).

- The welding beads, visually checked, showed consistent quality. The performance at Charpy V notch impact tests (specimens from C-Mn steel samples) revealed satisfactory results, higher than the minimum values required by the Standard EN 10025-3.

Thank you for your attention

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