

## **PROBLEMS RAISED BY NOXES CONTROL AT FCAW**

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**Abstract:** Flux cored arc welding (FCAW) is applied due to its remarkable results and advantages (high productivity, joint quality etc) in various fields (industrial construction, naval, chemistry, petrochemistry etc.). FCAW disadvantages, mainly the emission of pollutants, can be counteracted by their rigorous control and local forced ventilation in the production. Control measures that can be used for measuring “in-situ” noxes resulting from the FCAW process are presented. Case studies are presented as well, containing data regarding two new tubular wire produced in order to be used with the flux cored arc welding process.

### **1. INTRODUCTION**

Flux Cored Arc Welding process (FCAW) gains field for joining processes as well as for coatings. FCAW leads to obtain joints with exceptional quality, in conditions of high productivity, while in the case of welding reconditioning, it is necessary to rebuild or to coat active parts of the components submitted to certain loads, such as abrasion or moderate impact.

The main disadvantage of using tubular wire for welding consists in massive noxes emissions. From here results the necessity of measuring “in situ” the noxes content, with the specific purpose to verify their framing within admissible limits, as given by the occupational health organisms.

The problem of ensuring environmental protection at FCAW is of strict actuality. The necessity of working with the FCAW process in open spaces and forced ventilation, with its known variants, as well as the usage of welding guns that provide immediately gas extraction are some of the aspects requiring special attention in this case.

Flux cored arc welding (FCAW) is applied due to its remarkable results and advantages (high productivity, joint quality etc) in various fields (industrial construction, naval, chemistry, petrochemistry etc). FCAW disadvantages, mainly the emission of pollutants, can be counteracted by their rigorous control and local forced ventilation in the production.

### **2. GENERAL PROBLEMS AT FCAW WELDING**

Flux cored arc welding (FCAW) has a wide applicability, due to its numerous advantages [7]:

- FCAW provides high quality weld metal at lower cost with less effort on the part of the welder than SMAW. It is more forgiving than gas metal arc welding and is more flexible and adaptable than submerged arc welding.
- Excellent weld appearance smooth and uniform welds, less liable to porosity.
- Relatively high travel speeds and considerably reduced spatter.
- Visible arc easy to weld.
- Excellent contour of horizontal fillet welds.
- FCAW welds a variety of steels over a wide thickness range.
- High deposition rate high current density.
- Reduced distortion over shielded metal arc welding (SMAW)
- High operating factor can be easily mechanized.

- Economical engineering joint designs.
- Less pre cleaning required than gas metal arc welding.

The limitations of FCAW regarding its applicability [7] are as follows:

- Used only to weld ferrous metals, primarily steels
- FCAW produces a slag covering which has to be removed.
- Electrode wire is more expensive on a weight basis than solid electrode wires.
- Equipment is more expensive and complex than required for shielded metal arc welding; however the increased productivity compensates for this.
- Earlier, self shielding wires, because of their limited mechanical properties and their inability to operate in vertical and overhead positions could not become popular. These inadequacies have now been overcome and today FCAW is widely used for all position welding.

Important to mention are the numerous applications of FCAW [7], such as:

- FCAW is replacing SMAW for many applications, replacing GMAW, primarily the CO<sub>2</sub> version, and replacing submerged arc welding (SAW) for thinner metal.
- FCAW is widely used on medium thickness steel fabricating work where the fine wire GMAW process would not apply and where the fit up is such that SAW would be unsuitable.
- FCAW is also used for surfacing and for build up.
- The metals weldable by FCAW are: Cast iron, low carbon steel, low alloy steel, high and medium carbon steel, alloy steels, stainless steels limited types.
- FCAW has been widely used for welding in bridges, high rise buildings, ship building and offshore drilling platforms.
- Other applications of FCAW are as follows: main frames on bulldozers, bulldozer blades, rotating frames for shovels and cranes, tractor frames, base frames for punch presses, crown assemblies for bending presses, bridge girders, large gantry cranes, furnace tubes, locomotive under frames and diesel engine chassis etc.

### **3. EFFECTS OF THE DECOMPOSITION PRODUCTS AT FCAW WELDING**

Welding fumes and gases and the composition and quantity of both are dependent upon the metal being welded, the process, procedures, and electrodes used. Other conditions which also influence the composition and quantity of the fumes and gases to which workers may be exposed include: coatings on the metal being welded (such as paint, plating, or galvanizing) the number of welders and the volume of the work area, the quality and amount of ventilation, the position of the welder's head with respect to the fume plume, as well as the presence of contaminants in the atmosphere (such as chlorinated hydrocarbon vapours from cleaning and decreasing activities).

Decomposition products of normal operation include those originating from the volatilization, reaction, or oxidation of the materials, plus those from the base metal and coating, etc. It is understood, however, that the elements and/or oxides to be mentioned are virtually always present as complex oxides and not as metals [11].

The elements or oxides listed in table 1 correspond to the ACGIH (American Conference of Government Industrial Hygienist) categories located in TLV (Threshold Limit Values for Chemical Substances and physical Agents in the Workroom Environment).

Expected constituents of the fume would include: complex oxides of iron, manganese, silicon, titanium, magnesium, barium and aluminum. Fluorides are also present.

*Table 1 Substances and exposure limits [11]*

Substance	Exposure Limit (mg/m <sup>3</sup> )	
	OSHA PEL	ALGIH TLV
Iron Oxide	5	10 (as Fe <sub>2</sub> O <sub>3</sub> )
Manganese	5 CL*	1 CL* (fume)
Silicon Oxide	5	3
Titanium Oxide	15	10,20 STEL**
Magnesium Oxide	15	10
Fluorides	2.5 (as F)	2.5 (as F)
Aluminum Oxide	nothing found	10
***Nickel (Soluble)	1 (as Ni)	0.1 (as Ni)
***Nickel Oxide	nothing found	1 (as Ni)
Barium	0.5 (sol.)	0.5

\*CL - Ceiling Limit \*\*STEL - Short Term Exposure Limit \*\*\*Present in E71T-GS

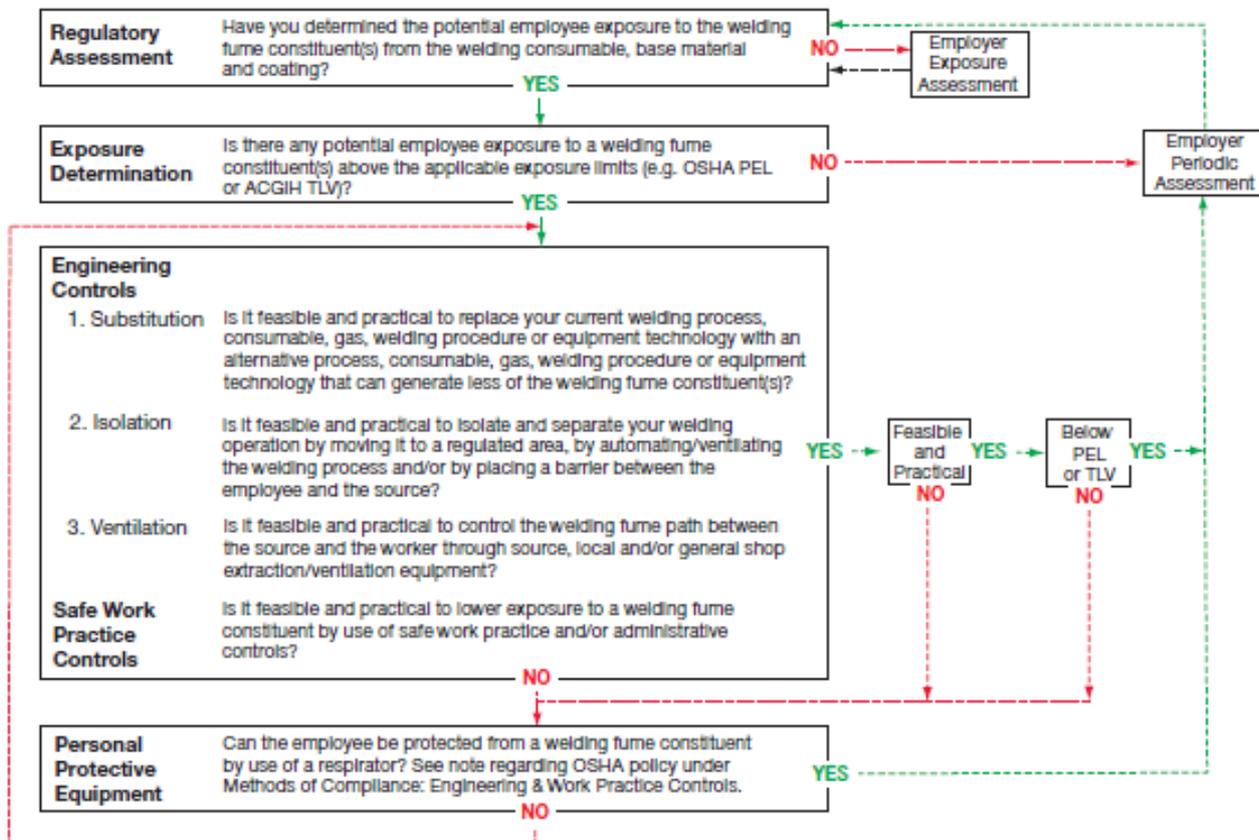
#### **4. CONTROL MEASURES AND PRECAUTIONS FOR SAFE HANDLING AND USE**

Some of the precaution measures to be taken when using flux cored arc welding include:

- ventilation: it is necessary to use plenty of ventilation and/or local exhaust at the arc, to keep the fumes and gases below the threshold limit value within the worker's breathing zone and the general work area. Welders should be advised to keep their head out of the fumes.
- respiratory protection: it is recommended to use respirable fume respirator or air supplied respirator when welding in a confined space or general work area where local exhaust and/or ventilation does not keep exposure below the threshold limit value.
- eye protection: the welders should wear a helmet or face shield with a filter lens shade number 12-14 or darker. Other workers must be shielded by providing screens and flash goggles.
- protective clothing: the personnel must wear approved head, hand and body protection which help to prevent injury from radiation, sparks and electrical shock. This would include wearing welder's gloves and a protective face shield and may include arm protectors, apron, hats, shoulder protection, as well as dark substantial clothing. Welders should be trained not to allow electrically live parts to contact the skin or wet clothing and gloves. The welders should insulate themselves from the work and ground.

The persons responsible for welding, respectively the managers of the enterprises that use flux cored welding, are forced, by legislation, by the environment management requirements, by the regulations of Occupational Safety and Health Administration (OSHA) to apply direct measures to control the noxes emissions, and to fit the Permissible Exposure Limit (PEL). It is only like this that the welders are accepted to perform any work with flux cored wire.

Lincoln Electric, [7] renowned by its preoccupation, tradition and exceptional achievements in the field of cored wire (fabrication, consulting etc.) provide us with a schematic representation of the process of noxes control (figure 1).



**Fig. 1. Lincoln Electric' welding fume control methodology [4]**

After applying engineering controls to the FCAW welding process, Franke obtained the results presented in table 2. One can observe that significant reductions in fume exposure levels were achieved when using either the fume gun or the portable fume extractor.

An analysis of the data suggests that the fume gun is very successful in reducing fume emissions in FCAW where values were decreased by at least an order of magnitude.

**Table 2 – Results of investigation of engineering controls in welding of Navy steels. Fume extraction gun and portable fume extractor [6]**

		Cr(VI) Proposed OSHA PEL 0.5 µg/m <sup>3</sup> TWA (µg/m <sup>3</sup> )		
Process	Weld	Engineering control	Pers.	Area
FCAW 71T-1	Flat 60"	NONE	<b>2.38</b>	0.20
FCAW 71T-1	Flat 60"	FUME GUN	0.01-0.12	0.01
FCAW 71T-1	Flat 17"	PFE	0.49	0.01
FCAW 71T-1	Flat 34"	PFE	<b>1.64</b>	0.06
FCAW 309L	Flat 60"	NONE	<b>130.5</b>	<b>16</b>
FCAW 309L	Flat 60"	FUME GUN	<b>5-13</b>	0.17-0.31

**Mn** Proposed OSHA PEL 200 µg/m<sup>3</sup>TWA (µg/m<sup>3</sup>)

Process	Weld	Engineering control	Pers.	Area
FCAW 71T-1	Flat 60"	NONE	<b>1282</b>	127
FCAW 71T-1	Flat 60"	FUME GUN	22-25	1-3
FCAW 71T-1	Flat 17"	PFE	<b>255</b>	5
FCAW 71T-1	Flat 34"	PFE	<b>1189</b>	41
FCAW 309L	Flat 60"	NONE	<b>1120</b>	120
FCAW 309L	Flat 60"	FUME GUN	<i>59-101</i>	5-6

**Ni** Proposed OSHA PEL 50 µg/m<sup>3</sup> TWA (µg/m<sup>3</sup>)

Process	Weld	Engineering control	Pers.	Area
FCAW 71T-1	Flat 60"	NONE	<1	<1
FCAW 71T-1	Flat 60"	FUME GUN	<1	<1
FCAW 71T-1	Flat 17"	PFE	<1	<1
FCAW 71T-1	Flat 34"	PFE	<1	<1
FCAW 309L	Flat 60"	NONE	<b>224</b>	20
FCAW 309L	Flat 60"	FUME GUN	<i>21-34</i>	1-2

**Bold** values exceed the proposed OSHA permissible exposure limit (PEL)  
*Italicized* values exceed the OSHA Action Level of one-half the PEL, TWA = Eight hour time weighted average, PFE = portable fume extractor

## 5. CASE STUDY

### 5.1 Case study 1

New generation flux cored arc wire have been produced lately, such as „low fume” tubular wire, Stardual 208 HP, T 42 3 M M 1 H5 according to EN ISO 17632-A, that ensure low levels of fumes at welding [10].

This new „low fume” copper coated metal cored wire generates less fume than similar standard products. It enables fume emission rate reduction of up to 40% (standard shielding gas M 21).

Other advantages include:

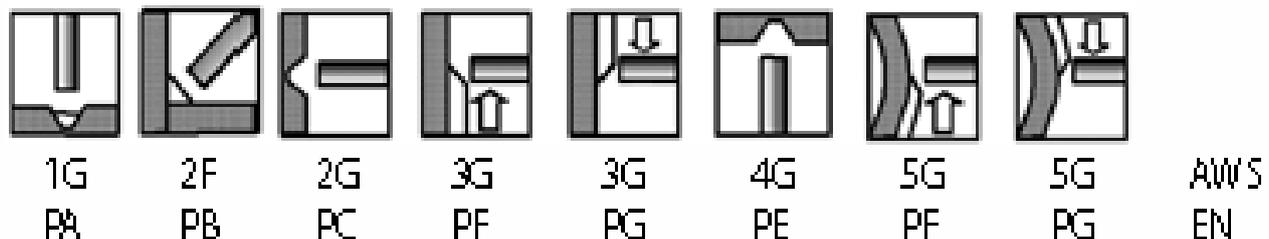
- it is a slag less metal powder tubular cored wire with outstanding welding properties in the short-arc and spray-arc ranges.
- almost splatter free when welding in the spray-arc range.

- provides good restriking, even with a cold the wire tip, thus being suitable for a robot applications.

Characteristics that recommend this type of wire for FCAW are: high deposition rate and welding speed, good wall fusion, finely rippled welds, without undercutting into the base metal, not even on contaminated or corroded metal surfaces.

Main applications are for this type of wire are: shipbuilding; rolling stock construction; structural steelwork, boiler-works; bridge cranes, cranes, earth moving machines.

Welding positions that are recommended for this type of wire are presented in figure 2. Technical data include: current: DC+, gas: M21 (Ar/CO<sub>2</sub>, Diffusible H<sub>2</sub>: 3 ml/100 g max.) [10].



**Fig. 2 Recommended welding positions for T 42 3 M M 1 H5 wire [10]**

Deposited metal submitted to chemical analysis gives results presented in table 3, while mechanical characteristics are presented in table 4.

**Table 3 Chemical analysis results for the deposited metal [10]**

Gas	C	Mn	Si	S	P
Ar-CO <sub>2</sub>	0.02	1.6	0.8	≤0.005	≤0.013

**Table 4 Mechanical properties of the deposited metal [10]**

Gas	Heat treatment	Rm, N/mm <sup>2</sup>	Rs, N/mm <sup>2</sup>	E, %, 5d	Kv, J, at -20°C
CO <sub>2</sub>	As welded	510-600	≥420	≥24	≥50

The practical data presented in these tables, justifies the quality of deposited metal using the low fumes tubular wires.

## 5.2 Case study 2

„Low fume” tubular wire, Stardual 100 HP, T 42 2 P C 1 H5 according to EN ISO 17632-A, that generates less fume than similar standard products. It enables fume emission rate reduction of up to 30% (standard shielding gas C1).

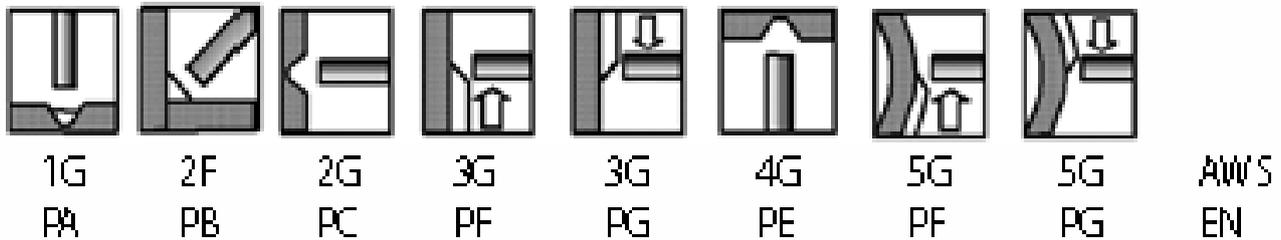
Other advantages include:

- it is a rutile tubular cored wire with enhanced filling degree.
- due to its easily controllable weld pool, it possesses outstanding welding properties.
- It can be welded in all positions with only one setting of parameters (24 V, wire feed 9 m/minute, diameter 1.2 mm).
- the enhanced filling degree results in increased current carrying capacity and deposition rate, thus essentially increasing welding speed and leading to a saving of time and costs.

- low spatter loss, easy slag rem.

Main applications for this type of wire include: shipbuilding; rolling stock construction, agriculture machines, bridge cranes, cranes, earth moving machines.

Welding positions that are recommended for this wire are presented in figure 3. Technical data include: current: DC+, gas: CO<sub>2</sub>, diffusible H<sub>2</sub>: 5 ml/100 g max.) [10].



**Fig. 3 Recommended welding positions for T 42 2 P C 1 H5 wire [10]**

Deposited metal submitted to chemical analysis gives results presented in table 5, while mechanical characteristics are presented in table 6.

**Table 5 Chemical analysis results for the deposited metal [10]**

Gas	C	Mn	Si	S	P
CO <sub>2</sub>	0.03	1.5	0.6	≤0.020	≤0.020

**Table 6 Mechanical properties of the deposited metal [10]**

Gas	Heat treatment	Rm, N/mm <sup>2</sup>	Rs, N/mm <sup>2</sup>	E, %, 5d	Kv, J, at -20°C
CO <sub>2</sub>	As welded	510-610	≥420	≥24	≥50

The quality of depositions made using this types are wires are certified by the data presented above.

## 6. CONCLUSIONS

6.1 The advantages of using flux cored arc welding (FCAW) are presented, as well as potential applications of this method, with distinct activity fields, such as: industrial construction, naval, chemistry, petrochemistry etc.

6.2 The main disadvantages of the FCAW process are presented, consisting in the noxes emitted by the process, which impose mechanical and forced local ventilation of the environment, working in open spaces, usage of welding guns with noxes absorption systems, as well as new types of tubular wires, with low fume emissions.

6.3 Problems regarding noxes, their effect, "in-situ" measurements as well as permissive exposure limits according to OSHA are presented also.

6.4 Case studies presenting last generation tubular wires explain cases of such new tubular wires that are manufactured.

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