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Electrode evolution

The development of low-manganese flux-cored electrodes benefits welders exposed to fumes

Welders who are exposed to welding fumes may potentially be at risk for various short-term or long-term health issues. In particular, there are concerns about potential neurological effects associated with exposure to manganese emissions in welding fumes. This is part of the reason for the push to develop rutile-coated and basic-coated welding electrodes with a significant reduction of manganese.

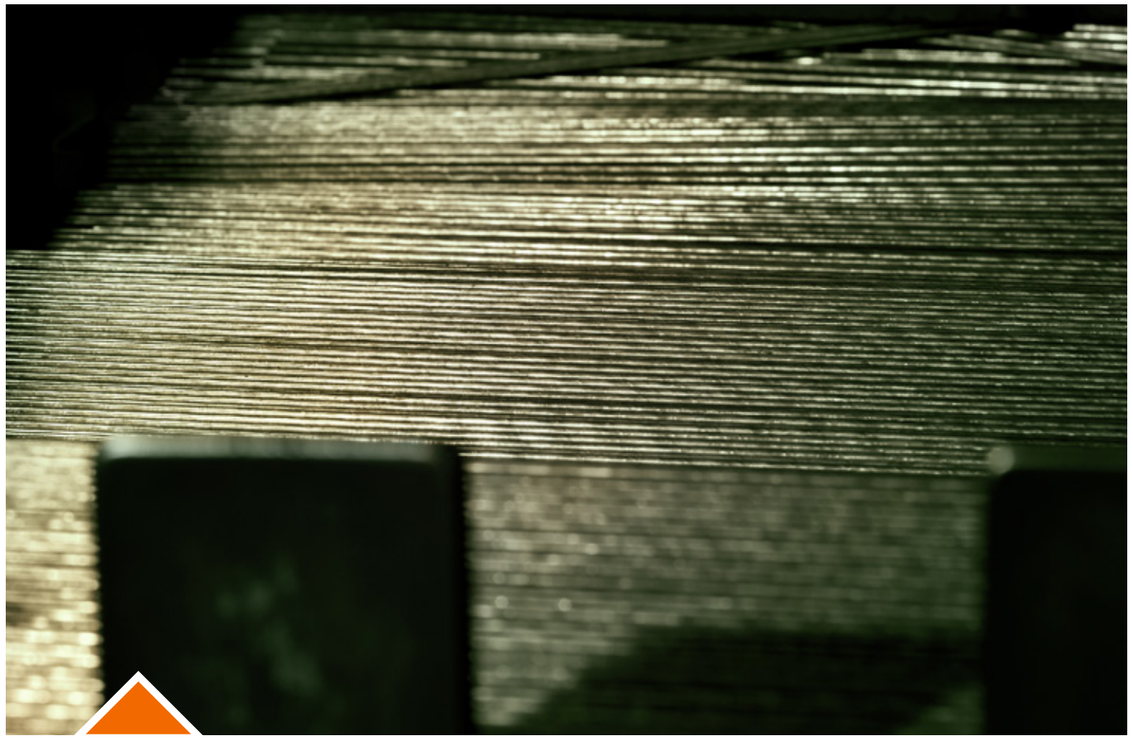
In response, Weldcote developed low-manganese rutile-coated E6013 and basic-coated E7018 electrodes that reduce a welder's exposure to hazardous manganese emissions. The new patented Weldcote line has a flux composition that supplies base metal with significantly lower manganese content, decreasing manganese vapor emissions by as much as 60 percent in comparison to standard electrodes. Additionally, the new electrodes meet and exceed the required mechanical properties and the requirements of international standards.

The most commonly used material in general construction is low-carbon steel. Steel is an iron-based alloy that contains the alloy elements carbon, manganese and silicon, at minimum.

Rutile-coated E6013 and basic-coated E7018 electrodes typically are used for manual welding of low-carbon steel by the shielded metal arc welding (SMAW) method, a process that is accompanied by fume emissions. Welding fumes are a complex mixture of metallic oxides, silicates and fluorides. They are formed when a metal is heated above its boiling point and its vapors condense into very fine solid particulates.

COMMON KNOWLEDGE

Manganese is an essential alloying element in steel. Together with carbon, manganese improves the hardness and strength of steel. In addition, manganese significantly improves the plasticity and toughness of steel and also works as a deoxidizer and desulfurizer. There is no structural steel that does not contain manganese.



Weldcote's low-manganese product line is available in three AWS classifications: E6011, E6013 and E7018.

In coated consumable electrodes for SMAW, manganese is found in the metal core and in the flux. Typical manganese content in the metal core is 0.35 to 0.50 weight-percent; the rest of the manganese comes from the flux coating. The manganese element appears in the flux as ferromanganese powder or as a pure electrolytic metal.

Due to manganese's high vapor pressure, its transferring efficiency to base metal is low. Thus, its concentration must be high and, therefore, welders are subjected to serious exposure.

DEFINING THE PROBLEM

During the arc welding process, manganese is transferred from the consumable electrode to the base metal. Transferring occurs through the state of liquid phase. In this state, vapor pressure of manganese

Table 1. Manganese content in standard electrodes and Weldcote's low-manganese electrodes.

Type of coating	Typical Fe-Mn content in flux (weight-percent)	Typical content in weld (weight-percent)
Rutile E6013	9-10	0.4-0.5
Basic E7018	5-6	1.0-1.1
Weldcote rutile E6013	5-6	0.24-0.28
Weldcote basic E7018	3	0.6-0.7

Table 2. Typical chemical composition of base metal (weight-percent) for Weldcote's low-manganese (LMn) electrodes.

Type	C	Mn	Si	P	S	Ni	Cr	Mo	V
Z11-LMn E6013	0.07	0.25	0.18	0.016	0.007	0.24	0.07	0.002	0.014
Z4-LMn E7018	0.06	0.65	0.38	0.018	0.005	0.18	0.14	0.008	0.05

C = carbon, Si = silicon, P = phosphorus, S = sulfur, Ni = nickel, Cr = chromium, Mo = molybdenum and V = vanadium

is higher than the vapor pressure of the other elements present. Therefore, it is subjected to stronger vaporization. This explains why there is such a low efficiency of manganese transferring from one solid state in the consumable electrode through liquid phase to another solid state in the base metal.

Manganese transferring efficiency is particularly low for rutile-coated electrodes. Thus, evaporated manganese compounds exist in the work area of the welder in relatively high concentration.

Common solutions to this problem are ventilation and exhaust systems.

However, these solutions only partially solve the problem.

Another existing solution is to use low-manganese flux-cored electrodes, which significantly reduce a welder's exposure to manganese. These types of electrodes are offered by several welding equipment manufacturers, including Weldcote.

The low-manganese product line is available in three AWS classifications: E6011, E6013 and E7018.

- E6011 is an all-position, AC/ DC electrode for deep weld penetration for root passes for welding pipes and general structural welding.
- E6013 is an all-position, AC/DC electrode typically used for welding cleaner steel.
- E7018 H4R is a low-hydrogen, humidity-resistant, usually DC, all-position, versatile electrode used for many metals, including structural. It has the capability of producing more uniform base metal.

Weldcote developed low-manganese electrodes that reduce a welder's exposure to hazardous manganese emissions.

The flux composition in Weldcote's low-manganese electrodes provides micro alloying and purifying of the base metal, which are necessary to achieve the required mechanical properties.

All three are characterized by a stable and smooth arc, easy slag detachability and excellent weld bead appearance.

TECHNICAL CHALLENGES

Because of high manganese vapor pressure, the only way to reduce its emission during the welding process is to decrease manganese content in the consumable electrode, mainly in the flux coating. This will reduce manganese content in the base metal, leaving the main challenge to be achieving the required mechanical properties for the base metal.

The precise composition of flux is proprietary for each manufacturer, and therefore, the formulas are unknown. Information about typical manganese content in Weldcote's low-manganese electrodes is, however, available (see Table 1).

Ferromanganese powder content in the flux coating was reduced almost by half. The significant reduction of manganese will drop the amount of manganese that evaporates during welding.

However, at the same time, chemical composition of base metal will be influenced and the content of manganese will drop (see Table 2). Despite the low manganese content

Table 3. Typical mechanical properties and their comparison to international standards requirements.

Type	Yield point (MPa)	UTS (MPa)	Elongation (percent)	V-charpy impact energy (J)
Z11-LMn E6013	440	500	25	65 @0C°
AWS A5.1 E6013 Req.	>330	>430	>17	-
EN ISO 2560-A E 38 0 R R 1 2 Req.	>380	470-600	>20	>47 @ 0 C°
Z4-LMn E7018	520	570	27	130 @-30 C°
AWS A5.1 E7018 H4R Req.	>400	>490	>22	>27 @-30 C°
EN ISO 2560-A E 46 3 B 3 2 H5 Req.	>460	530-680	>20	>47 @-30 C°

Table 4. Preliminary results of welder's exposure to manganese rutile-coated E6013 and manganese basic-coated E7018.

Type	Welder's exposure (mg/m³)
Rutile Z11 E6013	0.007
Rutile E6013 (competitor 1)	0.008
Weldcote rutile 11 LMn	0.003
Basic E7018-1 H4R (competitor 2)	0.013
Weldcote basic Z4-LMn E7018 H4R	0.0067

Table 5. Preliminary results of manganese emission - rutile-coated E6013.

Electrode type	Z-11 E6013	Weldcote – 11 LMn E6013	E6013 (competitor 1)	E6013 (competitor 2)
Number of test				
1	0.99	0.31	0.51	0.48
2	0.67	0.32	0.72	0.52
3	0.62	0.26	0.47	0.47
4	0.82	0.31	0.54	0.61
5	0.77	0.32	0.55	0.54
Mean	0.77	0.30	0.56	0.52
Variance	0.02083	0.00063	0.0092	0.0031
Observations	5	5	5	5
Pearson correlation	0.46		0.212	
Hypothesized mean difference	0		0	
Df	4		4	
t Stat	7.80		0.76	
P(T<=t) one-tail	0.0007		0.25	
t Critical one-tail	2.13		2.13	
P(T<=t) two-tail	0.0015		0.49	
t Critical two-tail	2.78		2.78	

Because of high manganese vapor pressure, the only way to reduce its emission during the welding process is to decrease manganese content in the consumable electrode, mainly in the flux coating.

in the base metal, the unique flux formula produces proper mechanical properties of base metal (see Table 3).

MAKING MEASUREMENTS

Measurement of manganese emission in the welding fume was done in two different ways. First, the welder's exposure to manganese fume was tested during a prolonged period of welding plate for examination of mechanical properties according to the AWS A5.1 standard.

Ventilation conditions in the welding laboratory were near ideal and two ventilation systems were working during the experiment. Welding time was approximately six hours. The results are presented in Table 4.

Second, the welder's exposure to manganese fume was tested using a specially prepared chamber (see Figure 1). The top of the chamber was connected by a flexible hose to the exhaust pumping system, extracting

The new Weldcote low-manganese electrodes decrease manganese vapor emissions by as much as 60 percent in comparison to standard electrodes.

all the produced fumes. The cyclone with the cellulosic filter was placed on the neck of the funnel and the filter was connected with a tube to a precise lab pump. In this configuration, most of the fumes passed through the cellulosic filter. The results are shown in Tables 5 and 6.

The result, from a technical standpoint, it that it is possible to achieve the required mechanical properties of base metal with E6013 and E7018 SMAW electrodes while manganese content is decreased by at least 40 percent. The unique flux composition provides micro alloying and purifying of the base metal, which are necessary to achieve the required mechanical properties.

Clear correlation was observed between the two exposure measurements methods. As expected, there is strong correlation between manganese content in the consumable electrode and the manganese emissions in the welding fumes.

Reducing manganese content in the flux coating by approximately

Table 6. Preliminary results of manganese exposure, basic-coated E7018 – welding chamber.

Electrode type	Z-4 E7018 regular	Z-4 LMn E7018 H4R	E7018-1 H4R (competitor)
Number of test			
1	1.11	1.09	1.40
2	1.31	1	1.09
3	1.08	0.64	0.91
4	1.2	1.04	1.37
5	2.1	0.85	1.31
6	1.05	0.9	
7	1.11	0.74	
Mean	1.28	0.89	1.22
Variance	0.1384	0.027	0.21
Observations	7	7	5
Pearson correlation	-0.0063		
Hypothesized mean difference	0		
Df	6		
t Stat	2.50		
P(T<=t) one-tail	0.023		
t Critical one-tail	1.94		
P(T<=t) two-tail	0.046		
t Critical two-tail	2.45		

Reducing manganese content in the flux coating by approximately 40 percent results in an even more effective effort in lowering a welder's exposure to manganese emissions.

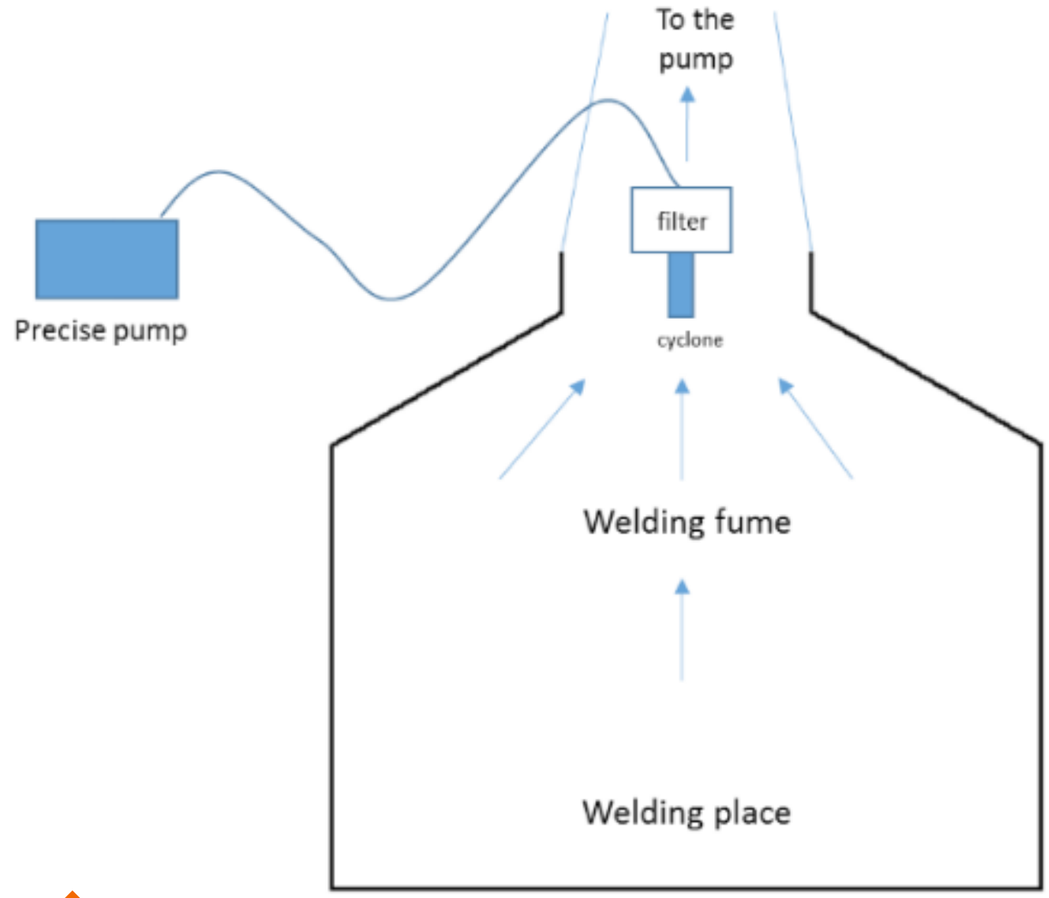


Figure 1. Schematic view of welding chamber for manganese exposure measurement.

40 percent results in an even more effective effort in lowering a welder's exposure to manganese emissions. Use of Weldcote's low-manganese electrodes reduced exposure to manganese in comparison with Weldcote's regular electrodes, along with competitors' electrodes. ■

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