For Mild Steel and 490MPa High Tensile Strength Steel

A guide for selecting the type of welding consumable [1]

Type of covering per AWS standard		High titania E6013	Low hydro-gen E7016	Ilme-nite [2] E6019	High cellulose E6010	Lime titania [3] E6013	Iron-powder iron-oxide E6027	Iron-powder titania E7024
Weldability								
▪Crack resistant		△	◎	○	○	○	△	△
▪X-ray soundness		△	◎	○	△	○	△	△
▪Impact value		△	◎	○	○	○	△	△
Usability								
▪Suitability for particular welding positions	F	◎	○	◎	△	◎	-	-
	F, HF	◎	○	◎	△	◎	◎	◎
	VU	△	◎	◎	○	◎	--	-
	VD	○	-[4]	-	◎	△	-	-
	OH	△	◎	◎	○	◎	-	-
▪Bead appear-ance	F	◎	△	○	△	◎	-	-
	F, HF	◎	△	○	△	◎	◎	◎
	V, OH	◎	◎	○	○	◎	-	-
▪Penetration		△	○	◎	◎	○	△	△
▪Spatter		◎	○	○	△	○	○	○
▪Slag removal		◎	△	○	○	○	◎	◎
▪Travel speed		○	△	○	△	◎	◎	◎
▪Suitability for thin metal		◎	△	○	△	◎	○	○

Note (1) ◎: Excellent, ○: Good, △: Fair
F: Flat butt welding, F, HF: Flat and horizontal fillet welding, VU: Vertical-up welding, VD: Vertical-down welding, OH: Overhead welding, V, OH: Vertical and overhead welding
(2) The ilmenite type corresponds to the iron-oxide titania potassium type per the AWS standard.
(3) The lime titania type is not specified by the AWS standard, but exact brands fall in the range of AWS E6013.
(4) Some low-hydrogen electrodes classified as E7048 are suitable exclusively for vertical-down welding.

Tips for better welding results

(1) Slag and fumes on tack weld beads absorb moisture; therefore, they must be removed right after tack welding to prevent adverse effects on the subsequent main welding.

(2) When wind velocity is more than 3m/sec in field welding, use a wind screen, or nitrogen in the wind decreases impact value and X-ray soundness of the weld.

(3) In welding medium and heavy thick mild steels by using non-low-hydrogen electrodes, keep the work at appropriate preheat and interpass temperature to remove diffusible hydrogen and thereby prevent cracking in the weld.

(4) In order to get better impact values, it is effective to lay each weld layer as thin as possible.

(5) Many brands of covered electrodes can be used with both AC and DC power sources. Low-hydrogen type electrodes, however, should be tested on mechanical properties beforehand, because DC current causes a little lower strength of the weld metal.

(6) Low-hydrogen type electrodes are more suitable for surface finishing and repair welding of gas shielded metal arc and self-shielded metal arc welded deposits in order to prevent pits and blowholes.

How to keep covered electrodes in good condition

(1) Store covered electrodes in a warehouse where the humidity is low.

(2) Low-hydrogen type electrodes should be stored in an oven (100-150°C) placed near the welding area after re-drying was finished so that welders can take out the electrodes little by little. This manner is good for preventing the electrodes from moisture pick up and thereby decrease the diffusible hydrogen content of the weld metal.

(3) A change of the color of the flux coating to become darker, much more spatter, stronger arc, and irregular slag-covering are signs that the electrodes picked up moisture excessively. In such a case, re-drying is effective even for non-low-hydrogen electrodes to improve usability and X-ray soundness. But excessive drying for long hours at high temperatures deteriorates X-ray soundness of the weld metal.

(4) Welders should bring an appropriate amount of electrodes for half-a-day use at sites in order to prevent electrodes from excessive moisture pick up.

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A guide for selecting filler metals for API grade pipes and comparison of welding procedures (1)

API 5L pipe grade	Welding pass	With high cellulose electrodes	With low hydrogen electrodes		
		Downhill welding process	Uphill welding process	Downhill welding process	
				With only low hydrogen electrodes	With a combination of high cellulose and low hydrogen electrodes
A25 A, B X42 X46 X52	Root	KOBE-6010 KOBE-7010S	LB-52U	LB-78VS	KOBE-6010 KOBE-7010S
	Hot		LB-47 LB-52 LBM-52 LB-52-18		
	Filler and cap				LB-78VS
X56	Root	KOBE-6010 KOBE-7010S	LB-52U	LB-78VS	KOBE-6010 KOBE-7010S
	Hot		LB-52 LBM-52 LB-52-18		
	Filler and cap	KOBE-7010S			LB-78VS
X60	Root	KOBE-6010 KOBE-7010S	LB-52U	LB-78VS LB-88VS	KOBE-6010 KOBE-7010S
	Hot		LB-52 LBM-52 LB-52-18		
	Filler and cap	KOBE-7010S KOBE-8010S			LB-78VS LB-88VS
X65	Root	KOBE-7010S KOBE-8010S	LB-52U	LB-88VS	KOBE-7010S KOBE-8010S
	Hot		LB-57 LB-62 LB-62D		
	Filler and cap	KOBE-8010S			LB-88VS
X70	Root	KOBE-7010S KOBE-8010S	LB-62U	LB-88VS	KOBE-7010S KOBE-8010S
	Hot		LB-62 LB-62D		
	Filler and cap	KOBE-8010S			LB-88VS
X80	Root	-	LB-62U	LB-98VS	KOBE-7010S KOBE-8010S
	Hot		LB-65D		
	Filler and cap				LB-98VS
Weldability					
▪Stability of root pass		○	◎	△	○
▪Weld soundness		○	◎	○	○
▪Crack resistance		△	◎	◎	○
Welding efficiency		◎	△	○	◎
Groove size tolerance		○	◎	△	○

Note (1) ◎: Excellent, ○: Fair, △: Inferior

Tips for better welding results

1) Sizes and tolerances of welding grooves

In one-side butt welding of pipes, it is important to make sound root pass welds without incomplete joint penetration and other discontinuities. For this, it is essential to prepare welding grooves suitable for individual welding procedures. Refer to the recommended sizes and tolerances of the grooves shown in the table below.

Welding consumable	Welding process	Recommendation and tolerance	Groove angle (deg.)	Root face (mm)	Root gap (mm)	Misalignment (mm)
High cellulose electrodes	Downhill welding	Recommendation	60-70	1.2-2.4 (1.2-2.0)	1.2-2.0	≦0.8
		Tolerance	50-75	0.8-2.4	0.8-2.4	≦1.6
Low hydrogen electrodes	Uphill welding	Recommendation	60-80 (70-80)	0.4-2.0	2.0-3.2 (2.0-2.6)	≦1.6 (≦0.8)
		Tolerance	55-90	0.4-2.4	1.6-3.6	≦2.0
	Downhill welding	Recommendation	60-80	1.2-2.0	2.6-3.4 (2.6-3.2)	≦0.6
		Tolerance	55-90	1.0-2.0	2.5-3.5	≦1.0

Note: Recommended ranges in parentheses are suitable for small diameter tubes with an approximate thickness of 7mm or less.

2) How to proceed root pass welding

(1) Downhill welding should be started at the 11 to 1 o'clock position of a pipe, whereas uphill welding should be started at the 5 to 7 o'clock position in common procedures. However, welding should be started at where there is a narrower root opening.

(2) It is recommended to strike an arc on the groove face and transfer the arc to the root of the groove, maintaining the arc in stable condition.

(3) Joint penetration can be adjusted by controlling the shape of a keyhole molten crater by adjusting welding current, electrode holding angle, the extent of sticking an electrode into the root opening, and weaving width. Control the penetration more strictly particularly at the 12 o'clock position where reverse side bead extrusion tends to be excessive and the 6 o'clock position that tends to cause a concave reverse side beads.

(4) Before joining beads particularly with low hydrogen electrodes, the end of the preceding bead should be tapered by grinding.

(5) After the completion of root pass welding, remove slag and unacceptable portion of beads, and shape the beads along the entire circumference of the pipe by grinding. Particularly, where the weld surfaces contain deep undercut, the shaping should be conducted more carefully.

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Types and features of flux-cored wires

There are two types of flux cored wires: DW series rutile type and MX series metal type. Both DW and MX series include a variety of wires that use either CO_2 or Ar-CO_2 admixture shielding gas. The following paragraphs describe essential characteristics of both types of flux-cored wires to provide users with a useful guide.

DW series:
DW series is the most popular type of flux-cored wire, most of which contains rutile flux. This series offers excellent weldability with good arc stability and very low spatter generation. With CO_2 or Ar-CO_2 admixture shielding gas, DW wires show good slag removability and smooth, glossy bead appearance. Because of high deposition rates, highly efficient welding can be conducted. DW series includes those suitable for out-of-position welding and those suitable for horizontal fillet welding for a variety of applications.

MX series:
MX series is metal type flux-cored wire. Due to high deposition rates, highly efficient welding can be conducted. MX wires offer excellent weldability with good arc stability and low spatter generation. With some brands of wires, the amount of slag is as little as in gas metal arc welding with solid wires; therefore, multi-pass welding can continuously be conducted without removing the slag on each pass. A variety of MX wires are available to cover wide applications of thin plate, medium and thick plate, and primer-coated plates.

Deposition rate:
Compared at the same welding current, the deposition rates of flux-cored wires are higher by 50 - 60% relative to stick electrodes and 10 - 20% higher than solid wires. Spatter generation in use of flux-cored wires is much lower than in use of solid wires.

Tips for better welding results

In addition to the tips for gas metal arc welding with solid wires, the following tips especially for flux-cored wires are essential to use the excellent features of the wires.

(1) Because the wire is softer than solid wire, do not excessively tighten the pressure roller of the wire feeder so as not to cause the deformation of the wire.
(2) In flat butt welding, backhand technique is better for stable penetration. In horizontal and overhead fillet welding, forehand technique is better for flat bead appearance.
(3) In vertical down fillet welding, the first layer run should be straight and keep the welding speed faster to avoid slag inclusions and to get better penetration. For the 2nd and subsequent layers, remove the slag of preceding beads and avoid weaving.
(4) In one-side welding, welding parameter should carefully be selected to prevent welding defects such as hot cracking.
(5) In horizontal fillet welding of primer-coated plates, porosity defects such as pit and gas hole are apt to occur; therefore, the selection of proper wires and welding parameters suitable for welding primer-coated plates are essential. Figure 1 shows the relationship between welding speed and the number of pits occurred in the weld metal. Figure 2 shows proper welding speeds related to fillet leg lengths.

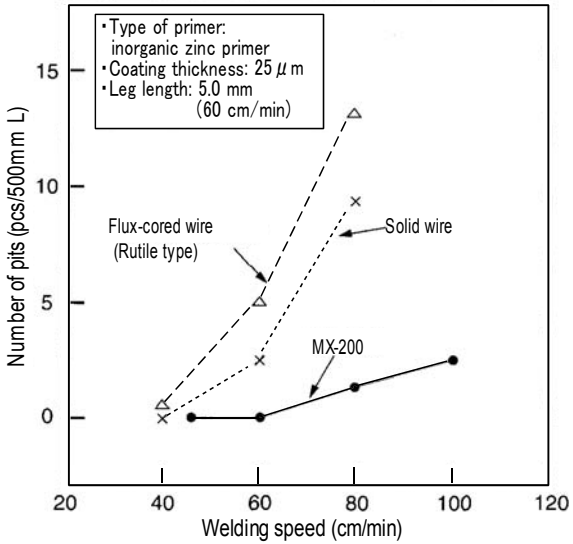

Fig. 1 Porosity resistance to primer

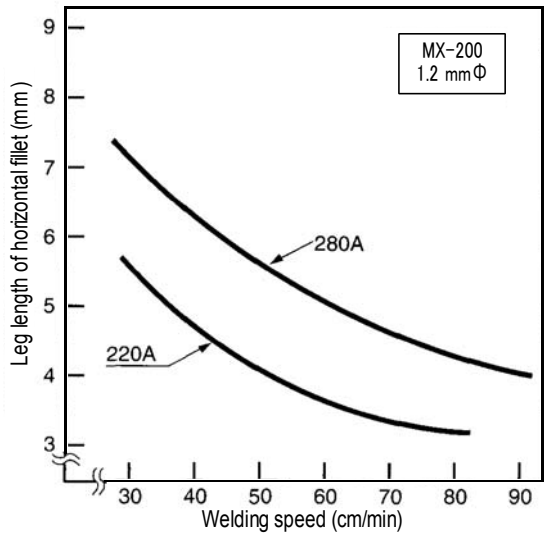

Fig. 2 Horizontal fillet leg length vs. welding speed

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Tips for better welding results in Gas Metal Arc Welding

(1) Use a CO_2 shielding gas corresponding to ANSI/AWS A5.32/A5.32M SG-C or an equivalent CO_2 gas purified for welding.
(2) Control the mixing ratio of Ar and CO_2 in an Ar-CO_2 admixture shielding gas because fluctuation of the mixing ratio affects the usability of a solid wire.
(3) Adjust the shielding gas flow rate in the 20 to 25 l/min range.
(4) Use a wind screen in welding in a windy area because a strong wind causes blowholes.
(5) Use a proper ventilation system at where general ventilation is inadequate.
(6) Keep the tip-to-work distance at around 15 mm with welding currents less than 250A and at around 20 to 25 mm with welding currents over 250A.
(7) The use of an excessively low arc voltage may generate a large sound in spray arc welding with an Ar-CO_2 shielding gas. In such a case increase the arc voltage to prevent blowholes.
(8) Torch angle, welding speed, wire diameter, and welding current markedly affect bead appearance and penetration; therefore, adjust such welding parameters according to the application.

Tips for better welding results in Gas Tungsten Arc Welding

(1) Welding power source:
Use the DC-EN connection with the constant current or drooping characteristic DC power source in general applications.
(2) Shielding gas:
Use an argon gas with a high purity equivalent to that of JIS K1105, in order to prevent pits and blowholes in the weld metal and decrease consumption of the tip of a tungsten electrode. When the length of the Ar gas piping is long, use metal pipes or Teflon tubes to prevent porosity in the weld metal, because moisture can permeates into the Ar gas through the wall of a rubber hose and thereby causes porosity. Adjust the shielding gas flow rate in the 12-18 l/min range.
(3) Tungsten electrode:
A 1-2% thoriated tungsten electrode is suitable. The tip of the tungsten electrode must be kept sharp in order to maintain the arc stable.
(4) Tungsten electrode extension length and arc length:
In order to keep the shielding of molten weld pool in good condition, the extension of a tungsten electrode from shielding nozzle should be approx. 5 mm. Maintain the arc length at 1-3 mm. The use of an excessively long arc length can deteriorate the shielding effect and causes undercut.
(5) Cleaning of welding groove:
Because the quality of gas tungsten arc welds is markedly affected by dirt on groove surfaces, scale, rust, water and oil must be removed before welding because they can cause pits, blowholes and unstable arcs.
(6) Wind protection and ventilation:
Use a wind screen in a windy site to maintain the shielding gas in good condition. Use an appropriate ventilation system where welding is carried out in a confined area to prevent welders from oxygen deficiency.

Tips for better welding results in Submerged Arc Welding

(1) Accuracy of groove sizes:
The accuracy of root gap and groove angle affects the quality of welds much more than with other welding processes; where the accuracy is poor, burn-through, lack of penetration, excessive or insufficient reinforcement can occur.
(2) Surface of groove:
Rust and oil in the groove must be removed before welding to prevent pits and blowholes.
(3) Distribution and circulation of flux:
Where a flux is supplied excessively on the base plate, the bead appearance becomes irregular particularly in use of melted fluxes. In case where a flux is used repetitively by means of a circulation system, the flux can be contaminated with scale and dust and its grain size distribution can be varied; therefore, add new flux occasionally to maintain good performances of the flux.
(4) Grain size of flux:
A few gain sizes of a certain brand of melt flux are available. The most proper size depends on welding currents to be used. The use of high currents with a coarse grain size flux can deteriorates bead appearance; in contrast, the use of low currents with a fine grain size flux can cause pock marks because of poor degassing.
(5) Welding condition and penetration:
Submerged arc welding can use a wide range of parameters such as wire diameter, welding current, arc voltage and welding speed; however, erroneous setting of the parameter causes burn-through, and insufficient or excessive penetration and reinforcement. The bead shape can be affected by the travel angle of a wire; that is, where the wire is leaned to the direction of welding (backhand welding), the bead shape becomes narrower with comparatively deep penetration. In contrast, where the wire is leaned to the opposite direction of welding (forehand welding), the bead shape becomes wider with shallower penetration.

A guide for selecting welding consumables for pipe welding

1. Welding consumables for straight pipe seam welding

API pipe grade	Flux/Wire	Application
X42, X46 X52, X56 X60	MF-38/US-36 or US-49	General applications
	MF-100N/US-36 or US-40	Low temperature applications

2. Welding consumables for spiral pipe welding

API pipe grade	Flux/Wire	Application
X42, X46	G-50/US-36 or US-40	General applications
X52, X56 X60, X65	G-60/US-36 or US-40	High speed welding
X70	MF-100N/US-36 or US-40	Low temperature applications