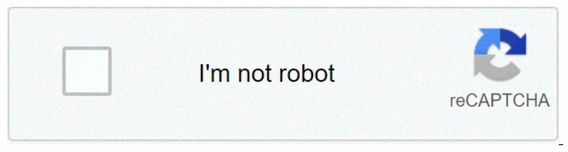

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Welding electrode selection guide

The selection of the right welding electrodes or filler wire is an expert task performed by Welding Engineers based on factors:Base material types, grade e.g. Stainless steel or carbon steel, SS316, ASTM A106, etc.Similar material welding or dissimilar welding.Joining or weld overlay application.Metallurgy of the material, its physical, and chemical properties.Service conditions e.g. room temperature elevated temperature, deep-sea, etc.Type of available welding process.Availability of welding consumables in the market.Type of welding joint and applicable welding stresses.The thickness of the base metals to be joinedAnticipated cost, and quality requirements.Click here to download a pdf copy for a detailed electrode selection chart sheet for the most commonly used materials.These are the main summary of the points to be considered for choosing a welding electrode although there are various other associated factors that need to be considered too.An easy way to find an electrode for a known type of material is via ASME Section IIC. ASME IIC contains 36 SFA from SFA 5.1 to SFA 5.36. A summary of these SFA numbers and their material types is shown in the below table.Click here, For the Aluminum Welding Selection chart & guide.Use these charts to easily locate matching, suitable electrode or filler wire for welding to join various similar and dissimilar welding.Welding electrode selection for carbon steel to carbon steel, C-Mo, Cr-Mo & Nickel steels are given in the below chart. Most of the carbon steel is welded using an E7018 stick rod or ER70S-6 TIG/ MIG filler.These electrode's deposit strength is higher than most commonly used carbon steel such as ASTM A36, ASTM A 516, S275 or S375, ASTM 105, A106, etc.Refer to the below chart to find dissimilar weld combinations also.

For example, if you wish to weld Carbon steel to 5Cr-1/2Mo, you can use E7018, E8018-B2, or E8018-B3 Stick rod or their equivalent TIG/ MIG filler such as ER70S-6, ER80S-B2 or ER80SB-3.The below chart gives very detailed guidelines for stick welding (SMAW) or equivalent TIG/MIG filler wires for different types of stainless steel welding.In these consumables, XX means -15/ -16 or -17 type. For example, E309L-XX, you can use either E309L-15 or E309L-16, or E309-17.Click here to learn the difference between -15, -16, or -17 type electrodes.When choosing stainless steel electrodes, it is very essential to consider the matching electrodes to ensure the right corrosion protection properties of the weldment.Use this chart to find welding electrodes for welding duplex stainless steel, Super Duplex stainless steel, and welding Duplex stainless steel to Carbon steel, stainless steel, and Nickel alloys.TIG/ MIG equivalent of these given stick electrodes/ SMAW Electrodes are:E2209 = ER2209E2553 = ER2553E2594 = ER2594E309L, E309LMo = ER309L/ ER309LMoENiCrMo10/ ENiCrMo14 =ERNiCrMo-10/ ERNiCrMo-10Click here for Aluminum filler metal selection chart.Further resources: The selection of right welding electrodes is a quite challenging job because we need to consider many factors while choosing the best alternative. In this article, we will discuss the various factors responsible for choosing the right welding electrode for the Shielded Metal Arc welding Process (SMAW) for Carbon steels.

The Shielded metal arc welding electrodes are always covered by flux and the electrode's name starts with E followed by either a four-digit number or a five-digit number for example E7018, E6010, E6013, E10018, etc. Each letter and digit has a specific meaning, for example: in E7018 the letter 'E' stands for Electrode, '70' denotes the minimum tensile strength i.e. 70 Ksi (or 70000 Psi) for this case, the second last digit i.e. '1' indicates the position in which the electrode can be used.

Base Metal Type	Thickness Range	Desired Results	Welding Current	Electrode Type	Color Tips	Shield Gas	Tungsten Performance Characteristics
Aluminum Alloys and Magnesium Alloys	All	General purpose	ACHF	Pure (EW-P)	Green(WP)	Argon	Balls easily, low cost, tends to spit at higher currents, used for non-critical welds only.
				2% Thoriated(EW-Th2)	Red(WT20)	75% Argon 25% Helium	Higher current range and stability, better arc starts, with lower tendency to spit, medium erosion.
	Only thin sections	Control penetration	DCRP	2% Ceriated(EW-Ce2)	Gray(WC20)	Argon Helium	Lowest erosion rate, widest current range, AC or DC, no spitting, best arc starts and stability.
	Only thick sections	Increase penetration or travel speed	DCSP	2% Thoriated(EW-Th2)	Red(WT20)	75% Argon 25% Helium	Best stability at medium currents, good arc starts, medium tendency to spit, medium erosion rate.
				2% Ceriated(EW-Ce2)	Gray(WC20)	Helium	Low erosion rate, wide current range, AC or DC, no spitting, consistent arc starts, good stability.
Copper Alloys, Cu-nialloys and Nickel Alloys	All	General purpose	DCSP	2% Thoriated(EW-Th2)	Red(WT20)	75% Argon 25% Helium	Best stability at medium currents, good arc starts, medium tendency to spit, medium erosion rate.
				2% Ceriated(EW-Ce2)	Gray(WC20)	75% Argon 25% Helium	Low erosion rate, wide current range, AC or DC, no spitting, consistent arc starts, good stability.
	Only thick sections	Increase penetration or travel speed	DCSP	2% Ceriated(EW-Ce2)	Gray(WC20)	75% Argon 25% Helium	Low erosion rate, wide current range, AC or DC, no spitting, consistent arc starts, good stability.
Mild Steels, Carbon Steels Alloy Steels Stainless Steels and Titanium Alloys	All	General Purpose	DCSP	2% Thoriated(EW-Th2)	Red(WT20)	75% Argon 25% Helium	Best stability at medium currents, good arc starts, medium tendency to spit, medium erosion rate.
				2% Ceriated(EW-Ce2)	Gray(WC20)	75% Argon 25% Helium	Low erosion rate, wide current range, AC or DC, no spitting, consistent arc starts, good stability.
				2% Lanthanated (EWG-La2)	Blue(WL20)	75% Argon 25% Helium	Lowest erosion rate, highest current range on DC, no spitting, best DC arc starts and stability.
	Only thick sections	Increase penetration or travel speed	DCSP	2% Ceriated (EW-Ce2)	Gray(WC20)	75% Argon 25% Helium	Low erosion rate, wide current range, no spitting, consistent arc starts, good stability.
				1.5% Lanthanated (EWG-La2)	Gold(WL15)	Helium	Lowest erosion rate, highest current range, no spitting, best DC arc starts and stability.

In particular, the letter '1' depicts all position and the last two digits together shows the polarity and the flux composition of the electrode. To read more about the electrode symbols and their meaning please read this article: As discussed earlier, we need to consider various factors before choosing an electrode.

Type	AWS Class	Current Type	Welding Position	Weld Results
Mild Steel	E6010 E6011	DCR DCR, AC	F, V, OH, H F, V, OH, H	Fast freeze, deep penetrating, flat beads, all- purpose welding
	E6012 E6013 E6014	DCS,AC DCR,DCS,AC DCS,AC	F, V, OH, H F, V, OH, H F, V, OH, H	Fill-freeze, low penetration, for poor fit-up, good bead contour, minimum spatter
	E6020 E6024	DCR,DCS,AC DCR,DCS,AC	F, H F, H	Fast-fill, high deposition, deep groove welds, single pass
	E6027	DCR,DCS,AC	F, H	Iron powder, high deposition, deep penetration
	57014	DCR,DCS,AC	F, V, OH, H	Iron powder, low penetration, high speed
	E7024	DCR,DCS,AC	F, H	Iron powder, high deposition, single and multiple pass
Low Hydrogen	E6015 E6016 E6018 E7016 E7018 E7028	DCR DCR,AC DCR,AC DCR,AC DCR,AC DCR,AC	F, V, OH, H F, V, OH, H F, V, OH, H F, V, OH, H F, V, OH, H F, H	Welding of high-sulphur and high-carbon steels that tend to develop porosity and crack under weld deposit
Stainless Steel	E308-15,16	DC, AC	F, V, OH, H	Welding stainless steel 301, 302, 303 304, 308
	E309-15,16	DC, AC	F, V, OH, H	Welding 309 alloy at elevated temperature application and dissimilar metals
	E310-15,16	DC, AC	F, V, OH, H	Welding type 310 and 314 stainless steel where high corrosion and elevated temperatures are required
	E316-15,16	DC, AC	F, V, OH, H	Welding type 316 stainless steel and welds of highest quality. Contains less carbon to minimize carbon transfer in the weld. Type 316 reduces pitting corrosion
	E347-15,16	DC, AC	F, V, OH, H	For welding all grades of stainless steels
Low Alloy	E7011-A1 E7020-A1	DCR, AC DCR, DCS, AC	F, V, OH, H F 2	For welding carbon moly steels
	E8018-C3	DCR, AC	F, V, OH, H	For low alley, high-tensile strength
	E10013-G	DCS, AC	F, V, OH, H	For low alloy, high-tensile steels
DCR – Direct Current Reverse Polarity DCS – Direct Current Straight Polarity			AC – Alternating Current F – flat, V-vertical, OH – overhead, H-horizontal	

These factors are as under; 1. Base metal or Parent Metal 2. Welding Position 3.

Base Material (see Notes 1, 2, and 4)	Carbon Steel	Carbon-molybdenum Steel	1 and 1 ¼ Cr-½ Mo Steel	2 ¼ Cr-1 Mo Steel	5 Cr-½ Mo Steel	9 Cr-1 Mo Steel	3 ½ Nickel Steel	2 ½ Nickel Steel	9 ¼ Nickel Steel
Carbon steel	All (see Note 3)	AC	AD	ADE	ADEF	ADEFH	AJ	AK	*
Carbon-molybdenum steel		C	CD	CDE	CDE	CDEFH	*	*	*
1 and 1 ¼ Cr-½ Mo steel			D	DE	DEF	DEFH	*	*	*
2 ¼ Cr-1 Mo steel				E	EF	EFH (see Note 4)	*	*	*
5 Cr-½ Mo steel					F	FH	*	*	*
9 Cr-1 Mo steel						H (see Note 4)	*	*	*
2 ½ nickel steel							J	JK	LM
3 ½ nickel steel								K	LM
9 ¼ nickel steel									LM

Key
A ASME/AWS SFA/A 5.1, Classification E7XXX low hydrogen (see Note 5).
B ASME/AWS SFA/A 5.1, Classification E6010 for root pass (see Note 5).
C ASME/AWS SFA/A 5.5, Classification E7XXX-A1, low hydrogen.
D ASME/AWS SFA/A 5.5, Classification E7XXX-B2L (see Note 6) or E9XXX-B2, low hydrogen.
E ASME/AWS SFA/A 5.5, Classification E9XXX-B3L (see Note 6) or E9XXX-B3, low hydrogen.
F ASME/AWS SFA/A 5.5, Classification E9XXX-B9 or E9XXX-B9L (see Note 6), low hydrogen.
G ASME/AWS SFA/A 5.5, Classification E9XXX-B9 or E9XXX-B9L (see Note 6), low hydrogen.
H ASME/AWS SFA/A 5.5, Classification E9XXX-C1 or E7XXX-C1L, low hydrogen.
I ASME/AWS SFA/A 5.5, Classification E9XXX-C2 or E7XXX-C2L, low hydrogen.
J ASME/AWS SFA/A 5.11, Classification ENiCrMo-3.
K ASME/AWS SFA/A 5.11, Classification ENiCrMo-6, ENiCrFe-4, ENiCrFe-5, ENiCrMo-3, ENiCrMo-4, ENiCrMo-10, ENiMo-6, or ENiMo-9.

Power Supply 4. Joint Preparation 5.

Welding Quality/Weld finish 6. Welding Cost We will discuss these factors one by one. Please note that a selection chart for choosing the correct welding electrode based on the parent material (in PDF format) is given at the end of this article. 1. Base Metal or Parent Metal: Base Metal or Parent Metal is one of the most important factors to be considered while selecting an electrode. We need to take into consideration three following parameters; a. Base metal mechanical properties: The mechanical properties especially the tensile strength of the electrode and that of the base metal should be similar or as close as possible. In case of wide differences in tensile strength between the welding electrode and the base metal, there will always be chances of cracking and other welding discontinuities. Hence to prevent cracking and other welding discontinuities we should always choose an electrode having minimum tensile strength equivalent to the parent metal being welded. b. Base metal chemical properties: The chemical properties shall also be checked before choosing an electrode. The chemical composition of the electrode should match the chemical composition of the base metal, especially the carbon percentage. However, practically it's not possible to match every parameter of an electrode with the base metal. Hence we need to choose an electrode having chemical properties as close as possible with the parent metal. c. Base metal thickness: Base metal thickness is very important while choosing an electrode. For thinner materials, an electrode with soft arc and less penetrating power can give good results but for thicker material we need and electrode with digging arc for deep penetration, maximum ductility, and low hydrogen for defect-free welding. We should always keep in mind that the electrode size (diameter) should not be more than the thickness of the parent metal. 2. Welding Position: The second factor is the welding position. Each electrode is meant for welding at some particular position. Hence we need to choose electrode as per the position of our job.

Classification	Welding Current	Arc	Penetration	Coating/Slag	Iron Powder
EXX10	DC+	Digging	Deep	Cellulose-Sodium	0-10%
EXXX1	AC, DC+	Digging	Deep	Cellulose-Potassium	0%
EXXX2	AC, DC-	Medium	Medium	Titania-Sodium	0-10%
EXXX3	AC, DC-, DC+	Soft	Light	Titania-Potassium	0-10%
EXXX4	AC, DC-, DC+	Soft	Light	Titania-Iron Powder	25-40%
EXXX5	DC+	Medium	Medium	Low Hydrogen-Sodium	0%
EXXX6	AC,DC+	Medium	Medium	Low Hydrogen-Potassium	0%
EXXX8	AC, DC+	Medium	Medium	Low Hydrogen-Iron Powder	25-40%
EXX24	AC, DC-, DC+	Light	Light	Titania-Iron Powder	50%
EXX28	AC, DC+	Medium	Medium	Low Hydrogen-Iron Powder	50%

The welding position is specified in the electrode name itself i.e the second last digit gives the position for example: in the E7018 electrode, the second last digit i.e. 1 give the position for which the electrode can be used. A general summary of the welding position for electrodes are given below (Table 1); Table 1 Welding electrode position table for selection of an electrode 3. Power Supply: Some electrodes can be used with alternating Power (AC) supply, some can be used with direct current power (DC) supply and Some electrodes work well with both AC as well as DC. Hence, depending upon the power output of the welding machine we can choose the electrode. For example, if the machine is capable of giving only AC output, then we will not be able to use the electrodes which are not meant for AC. However, if the welding machine is capable of both AC as well as DC output then we can choose from a broader range of electrodes. When using Direct Current (DC) power supply, if the electrode is connected with the positive terminal of the machine then it is known as Direct current electrode positive (DCEP) or reverse polarity and, if the electrode is connected with the negative terminal of the machine then it is known as Direct current electrode negative (DCEN) or straight polarity.

DCEP is the preferred polarity for most of the Shielded metal arc welding (SMAW) operations. However please refer to Table-2 for the correct polarity in which welding electrodes can be used. The last two digits of the electrode name denotes the polarity as well as the flux of the electrode. Please see the table given below (Table 2) for a summary of electrodes and the polarity in which they can be used. Table 2 Table for the polarity of arc welding electrodes, to be considered while choosing an electrode 4. Joint Preparation: The fourth factor to be considered while selecting an electrode is the joint preparation or groove configuration.

It there is a tight fit-up or unbevelled root face then an electrode with a digging arc can be used, which can provide deeper penetration. Electrodes such as E6010 or E6011 can be used for this purpose. If there is sufficient root gap and beveled root face, then we can use electrodes which can give shallow to moderate penetration such as E6013 or E7018.

TUNGSTEN ELECTRODE SELECTION CHART

Type of Tungsten	Sizes	Current	Materials Welded
2% Thoriated Tungsten (EwTh2) - Red Tip			
Offers good arc stability and is ideal for DC high current requirements.	0.04" x 7" 1/16" x 7" 3/32" x 7" 1/8" x 7" 5/32" x 7"	DC	Carbon Steel Stainless Steel Nickel Alloys Titanium Cooper
1.5% Lanthanated Tungsten (EWLa1.5) - Gold Tip			
Provides excellent arc starting, arc stability and re-ignition, and less prone to tip wear. Best used in DC applications	0.04" x 7" 1/16" x 7" 3/32" x 7" 1/8" x 7" 5/32" x 7"	DC AC	Carbon Steel Stainless Steel Nickel Alloys Titanium Aluminum Magnesium
2% Lanthanated Tungsten (EWLa2) - Blue Tip			
Provides excellent arc starting, arc stability and re-ignition, and less prone to tip wear. Performs exceptionally well in both AC & DC	0.04" x 7" 1/16" x 7" 3/32" x 7" 1/8" x 7" 5/32" x 7"	DC AC	Carbon Steel Stainless Steel Nickel Alloys Titanium Aluminum Magnesium
2% Ceriated Tungsten (EWCe2) - Grey Tip			
Performs well in DC welding and arc starting at low current settings. Can be used proficiently in AC processes.	0.04" x 7" 1/16" x 7" 3/32" x 7" 1/8" x 7" 5/32" x 7"	DC AC	Carbon Steel Stainless Steel Nickel Alloys Titanium Aluminum Magnesium
0.3% Zirconiated Tungsten (EWZ3) - Brown Tip			
Bears a fine performance in AC welding. Produces an extremely stable arc, retains a balled tip, and shows a high resistance to contamination. Great current carrying capability	0.04" x 7" 1/16" x 7" 3/32" x 7" 1/8" x 7" 5/32" x 7"	AC	Aluminum Magnesium
0.8% Zirconiated Tungsten (EWZ8) - White Tip			
Bears a fine performance in AC welding. Produces an extremely stable arc, retains a balled tip, and shows a high resistance to contamination. Great current carrying capability	0.04" x 7" 1/16" x 7" 3/32" x 7" 1/8" x 7" 5/32" x 7"	AC	Aluminum Magnesium
Pure Tungsten (EWP) - Green Tip			
Forms a clean, balled end when heated and provides good arc stability for AC welding.	0.04" x 7" 1/16" x 7" 3/32" x 7" 1/8" x 7" 5/32" x 7"	AC	Aluminum Magnesium
TRI-Element Tungsten (EWG) - Purple Tip			
Combines the best of all alloying elements and provides excellent arc stability in AC and DC welding	0.04" x 7" 1/16" x 7" 3/32" x 7" 1/8" x 7" 5/32" x 7"	DC AC	Carbon Steel Stainless Steel Nickel Alloys Titanium Aluminum Magnesium

Depending upon the operating characteristics, Grouping of SMAW electrodes can be done in the following ways; Fast-Freeze electrodes Fast-Fill electrodes Fill-Freeze electrodes Low Hydrogen electrodes Fast-Freeze electrodes (EXX10/EXX11) are those which can solidify quickly and are capable of giving forceful arc which helps in deep penetration and slag formation is quite low. Whereas The Fast-Fill electrodes (EXX22/EXX24/EXX24/EXX27/EXX28) can be melted very quickly with a high deposition rate and travel speed is also very high. However, these electrodes produce heavy slag. The third type of electrodes i.e. Fill-Freeze electrodes (EXX12/EXX13/EXX14) is a compromise between the fast-freeze electrodes and fast-fill electrodes, hence the Fill-Freeze electrodes possess characteristics in-between the Fast-fill and the Fast freeze electrodes. These electrodes are having medium penetration and medium deposition rate hence very useful for Thin/Sheet metal welding. The fourth type of electrodes is Low Hydrogen Electrodes (EXX15/EXX16/EXX18). Some Low Hydrogen Electrodes are having characteristics similar to fast-fill and some are having similar to Fill-Freeze. But they have been grouped separately because of their Low Hydrogen properties. These electrodes produce excellent welding with high ductility and good notch toughness. In case of a low diameter pipe, back-chipping and welding from the other side (ID side) can,t be done due to inaccessibility, hence a deeper penetration is always required. Hence we can select Fast-Freeze electrodes like E6010 for that case. To weld Sheet Metal or material with very low thickness, we can choose Fill-Freeze electrodes like E6013, because of it's medium penetration characteristics. Hence Selection of electrodes can be done in this way too. 5. Welding Quality/Weld finish: The required quality and the weld finishing is also an important factor to be considered before selecting an electrode. Electrodes can be chosen depending upon the final finishing requirement for example Flat weld bead, concave weld bead, or convex weld bead.

The quality of the weld must suit the service requirements of the job. For example, to weld cryogenic vessel parts that are supposed to work at very extreme temperature and pressure with high impact loading or parts that are subjected to a corrosive atmosphere, we need a low hydrogen electrode such as E7018, which can produce very sound welding with higher ductility. So the chances of getting any weld defect during operation will be minimized. Table 3 gives a summary of the features of welding electrodes, which you may find useful while selecting an electrode for a particular job. Table 3 6. Welding Cost: Finally, the cost of the electrode should be considered according to your project requirement.

We cannot choose a costly electrode for a low budget project. Similarly, for critical jobs where quality needs to be given utmost care a low hydrogen electrode with higher ductility such as E7018 can be considered to meet the quality requirements. Hence, While selecting the welding electrodes the above factors can be considered to get the required result.

To download the Welding electrode selection chart/guide according to the base metal (in pdf format), please click on the below link; Electrode Selection guide as per parent metal Equipment Filler Metals Automation Safety/PPE Weld Fume Control Accessories, Tools, Software New and Featured Buy Red Save Green Rebate In Stock Now Popular Products