Setting up parameter for arc welding machine

Objectives: At the end of this lesson you shall be able to
- **select and set the electrode and current according to the plate thickness.**

Electrode size and AMPS used

The following will serve as a basic guide of the amp range that can be used for different size electrodes. Note that these ratings can be different between various electrode manufactures for the same size rod. Also the type coating on the eletrode could effect the amperage range. When possible, check the manufactures info of the electrode you wil be using for their recommended amperage settings.

Electrode Table

Electrode	AMP	Plate
1/16"	20 - 40	Up to 3/16"
3/32"	40 - 125	Up to 1/4"
1/8	75 - 185	Over 1/8"
5/32"	105 - 250	Over 1/4"
3/16"	140 - 305	Over 3/8"
1/4"	210 - 430	Over 3/8"
5/16"	275 - 450	Over 1/2"

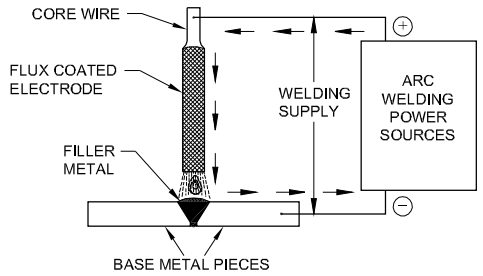
Note : The thicker the material to be welded, the higher the current needed and the larger the electrode needed.

Arc welding electrodes

Objectives: At the end of this lesson you shall be able to
- **explain arc welding electrode**
- **state the types of electrodes**
- **explain the coating factor**
- **describe the characteristics of flux coating on electrode**
- **explain the functions of flux coating during welding.**

Introduction: An electrode is a metallic wire of standard size and length, generally coated with flux (may be bare or without flux coating also) used to complete the welding circuit and provide filler material to the joint by an arc, maintained between its tip and the work. (Fig 1)

Fig 1



FLUX COATED METALLIC ELECTRODE IN THE WELDING CIRCUIT

Different types of electrodes used are given in the Electrode chart.

Method of flux coating:

– Dipping

– Extrusion

Dipping method: The core wire is dipped in a container carrying flux paste. The coating obtained on the core wire is not uniform resulting in non-uniform melting; hence this method is not popular.

Extrusion method: A straightened wire is fed into an extrusion press where the coating is applied under pressure. The coating thus obtained on the core wire is uniform and concentric, resulting in uniform melting of the electrode. (Fig 2) This method is used by all the electrode manufacturers.

Coating factor (Fig 3): The ratio of the coating diameter to the core wire diameter is called the coating factor.

$$\text{Coating factor} = \frac{\text{Coating dia of electrode}}{\text{Core wire dia. of electrode}}$$

It is 1.25 to 1.3 for **light coated,**

1.4 to 1.5 for **medium coated,**

Fig 2

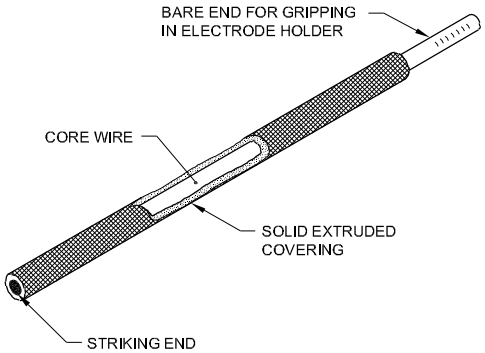
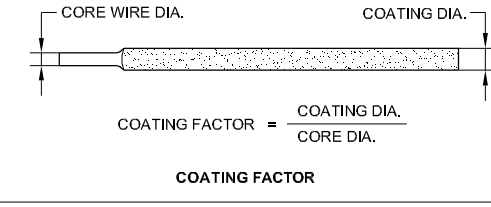


Fig 3



1.6 to 2.2 for **heavy coated,** and above 2.2 for super heavy coated electrodes.

Types of flux coating

– Cellulosic

– Rutile

– Iron powder

– Basic coated

Cellulosic electrode: Cellulosic electrode coatings are made of materials containing cellulose, such as wood pulp and flour. The coating on these electrodes is very thin and the slag in easily removed from deposited welds. The coating produces high levels of hydrogen and is therefore not suitable for high-strength steels. This type of electrode is usually used on DC+ and suited to vertical down welding.

Rutile electrodes: Rutile electrodes, are general-purpose electrodes have coatings based on titanium dioxide. These electrodes are widely used in the fabrication industry as they produce acceptable weld shape and the slag on deposited welds is easily removed. Strength of deposited welds is acceptable for most low-carbon steels and the majority of the electrodes in this group are suitable for use in all positions.

Basic or hydrogen-controlled electrodes: Basic or hydrogen controlled electrode coatings are based on calcium fluoride or calcium carbonate. This type of electrode is suitable for welding high-strength steels without weld cracks and the coatings have to be dried. This drying is achieved by backing at 450^0C holding at 300^0C and storing at 150^0C until the time of use. By maintaining these conditions it is possible to achieve high strength weld deposits on carbon, carbon manganese and low alloyed steels. Most electrodes in this group deposit welds with easily removable slags, producing acceptable weld shape in all positions. Fumes given off by this electrode are greater than with other types of electrodes.

Iron powder electrodes: Iron powder electrodes get their name from the addition of iron powders to the coating which tend to increase efficiency of the electrode. For example, if the electrode efficiency is 120%, 100% is obtained from the core wire and 20% from the coating. Deposited welds are very smooth with an easily removable slag; welding positions are limited to horizontal, vertical fillet welds and flat or gravity position fillet and butt welds.

Composition/characteristics flux: The coating of the welding electrodes consists of a mixture of the following substances.

Alloying substances: These substances compensate for the burning of manganese, ferro-silicon. The alloying substances are:

- ferro-manganese
- ferro-silicon
- ferro-titanium.

Arc stabilising substances: These are carbonates known as chalk and marble. These are used for the stabilisation of the arc.

Deoxidizers: These substances prevents porosity and make the welds stronger. The deoxidising substances are iron oxide, lamitite, magnetite.

Slag forming substances: These substances melt and floats over the molten metal and protect the hot deposited weld metal from the atmospheric oxygen and nitrogen. Also due to the slag covering the weld metal is prevented from fast cooling. The slag forming substances are clay, limestone.

Fluxing/cleaning substances: These substances remove oxides from the edges to be welded and controls the fluidity of the molten metal. The cleaning substances are lime stone, chlorides, fluorides.

Gas forming substances: These substances form gases which aid the transfer of metal. They also shield the welding arc and weld pool. The substances are wood flour dixtorine and cellulose.

Binding and plasticizing substances: These substances help the applied coating to grip firmly around the core wire of the electrode.

These are sodium and potassium silicates.

Purpose or function of flux coating: During welding, with the heat of the arc, the electrode coating melts and performs the following functions.

- It stabilizes the arc.
- It forms a gaseous shield around the arc which protects the molten weld pool from atmospheric contamination.
- It compensates the losses of certain elements which are burnt out during welding.
- It retards the rate of cooling of the deposited metal by covering with slags and improves its mechanical properties.
- It helps to give good appearance to the weld and controls penetration.
- It makes the welding in all positions easy.
- Both AC and DC can be used for the welding.
- Removes oxide, scale etc. and cleans the surfaces to be welded.
- It increases metal deposition rate by melting the additional iron powder available in the flux coating

Types of electrodes for ferrous and alloy metals

Mild steel electrode: Mild steel is characterized by carbon content not exceeding 0.3%. Mild steel electrode core wire contains various alloying elements.

Carbon 0.1 to 0.3%
(Strengthening agent)

Keep carbon as low as possible.

Silicon above 0.5%
(Deoxidizes, prevents weld metal porosity.)

Manganese 1.65%
(Increases strength and hardness.)

Nickel
(Increases strength and notch toughness.)

Chromium
(Increases tensile strength and hardness. Lowers the ductility.)

Molybdenum 0.5%
(Increases hardness and strength.)

Indian Standard System laid down in IS:814-1991 a classification and coding of covered electrodes for metal arc welding of mild steel, and low alloy high tensile steel. Mild steel and low alloy high tensile steel electrodes are classified into seven recognised groups, depending upon

the chemical composition of the flux coating.

Stainless steel electrodes: Selecting proper electrodes depends primarily on the composition of the base metal to be welded.

These electrodes are available with either lime or titanium coatings. The lime coated electrode is used only with DC reverse polarity. Titanium coated electrodes can be used in AC and DC reverse polarity, and will produce smoother and stable arc.

The coding system for stainless steel electrodes differs somewhat from that for the M.S. electrode. The I.S.5206 - 1969 specification for corrosion-resisting chromium and chromium-nickel steel covered electrodes will give full details.

During welding, the electrode will tend to get red hot quickly. To avoid this, 20 to 30% lower current than what is used for ordinary M.S. electrode is recommended.

Special purpose electrodes:

– Deep penetration electrodes
– Contact electrodes or iron powder electrodes
– Cutting and gouging electrodes
– Underwater welding and cutting electrodes
– Low hydrogen electrodes.

Deep penetration electrodes: These electrodes are used to get deep penetration in the joints. Deep penetration occurs because of the very strong stream of gas produced by the burning of the cellulosic materials in the flux coating.

Butt joints on heavy sections are welded without edge preparation using these electrodes.

The depth of the penetration will be more than to the core wire diameter of the electrode used.

Contact electrodes (Iron powder): These electrodes contain a large amount of iron powder in their coatings. Therefore the arc ignites very easily. These electrodes are also called 'touch type' electrodes. While using this type of electrodes a large amount of weld metal is deposited per unit time.

Cutting and gauging electrodes: The cutting electrodes are of a tubular type. While cutting, air is sent through the centre at high pressure to cut ferrous metals. The gouging electrodes can make 'U' grooves on the ferrous metals.

Underwater welding and cutting electrodes: These electrodes are used to cut and weld metals under the water. The coating having an external coating of varnish by 'lacquer' polishing or 'celluloid ' helps to insulate and protect the electrodes when immersed in water for welding or cutting purpose.

Low hydrogen electrodes: Hydrogen controlled electrodes shall be such that the diffusible hydrogen content of the deposited metal will be low. This electrode is used with DC reverse polarity and can be used in all welding positions. These electrodes help to get a weld without cracks.

Coding of electrodes

Objectives: At the end of this lesson you shall be able to
- **explain the necessity of coding electrodes**
- **describe the electrode coding as per BIS, AWS and BS.**

Necessity of coding electrodes: Electrodes with different flux covering gives different properties to the weld metal. Also electrodes are manufactured suitable for welding with AC or DC machines and in different positions. These conditions and properties of the weld metal can be interpreted by the coding of electrodes as per Indian Standards.

The chart shown at the end of this lesson gives the specification of a particular electrode and also shows what each digit and letter in the code represents. By referring to this chart any one can know whether an electrode with a given specification can be used for welding a particular job or not.

Classification of electrodes shall be indicated by the IS: 814-1991 coding system of letters and numerals to indicate the specified properties or characteristics of the electrode.

Main coding: It consists of the following letters and numerals and shall be followed in the order stated:

a) a prefix letter 'E' shall indicate a covered electrode for manual metal arc welding, manufactured by extrusion process;

b) a letter indicating the type of covering;

c) first digit indicating the ultimate tensile strength in combination with the yield stress of the weld metal deposit;

d) second digit indicating the percentage elongation in combination with the impact values of the weld metal deposited;

e) third digit indicating welding position(s) in which the electrode may be used and

f) fourth digit indicating the current condition in which the electrode is to be used.

Additional coding: The following letters indicating the additional properties of the electrodes may be used, if required:

a) letters H_1, H_2, H_3 indicating hydrogen controlled electrodes

b) letters J, K and L indicating increased metal recovery as 'Effective Electrode Efficiency' as per IS:13043:91. Specification in the followings range:

J = 110 - 129 percent;
K = 130 - 149 percent; and
L = 150 percent and above.

c) letter 'X' indicating the radiographic quality

Different standards used in coding of electrodes

They are:

1 I.S. (814 - 1991)
2 A.W.S.
3 B.S.

Indian system of coding of electrodes according to IS : 814-1991

Type of covering: The type of covering shall be indicated by the following letters.

A - Acid

B - Basic

C - Cellulosic

R - Rutile

RR - Rutile, heavy coated

S - Any other type not mentioned above

Strength characteristics: The combination of the ultimate tensile strength and the yield strength of the weld metal deposited shall be indicated by the digits 4 and 5. (See Table 1.)

Table 1

Designation of strength characteristics

(Clauses 5.2 and 5.3)

Designating digit	Ultimate tensile strength N/mm²	Yield strength Min N/mm²
4	410-510	330
5	510-610	360

Elongation and impact properties: The combination of percentage elongation and impact properties of all weld metal deposited for the two tensile ranges (See Table 1) shall be as given in Table 2.

Table 2

Combination of percentage elongation and impact strength

(Clause 5.3)

Designation digit	Percentage elongation (Min) on 5.65/So	Impact strength in joules (Min)/at °C
(For tensile range 410-510 N/mm²)		
0	No elongation and impact requirements	
1	20	47J/+27°C
2	22	47J/+0°C
3	24	47J/-20°C
4	24	27J/-30°C
(For tensile range 510-610 N/mm²)		
0	No elongation and impact requirements	
1	18	47J/+27°C
2	18	47J/+0°C
3	20	47J/-20°C
4	20	27J/-30°C
5	20	27J/-40°C
6	20	27J/-46°C

Welding position: The welding position or positions in which the electrode can be used as recommended by the manufacturer shall be indicated by the appropriate designating digits as follows.

1 All positions

2 All positions except vertical down

3 Flat butt weld, flat fillet weld and horizontal/vertical fillet weld

4 Flat butt weld and flat fillet weld

5 Vertical down, flat butt, flat fillet and horizontal and vertical fillet weld

6 Any other position or combination of positions not classified above

Where an electrode is coded as suitable for vertical and overhead position it may be considered that sizes larger than 4 mm are not normally used for welding in these positions.

An electrode shall not be coded as suitable for a particular welding position unless it is possible to use it satisfactorily in the position to comply with test requirements of this code.

Welding current and voltage conditions: The welding current and open circuit voltage conditions on which the electrodes can be operated as recommended by the manufacturer shall be indicated by the appropriate designating digits as given in Table 3.

For the purpose of coding an electrode, for any of the current conditions under 5.5 shall be of size 4 mm or 5 mm and shall be capable of being operated at that condition satisfactorily within the current range recommended by the manufacturer.

Hydrogen controlled electrodes: The letters H_1, H_2 and H_3 shall be included in the classification as a suffix for those electrodes which will give diffusible hydrogen per 100 gm when determined in accordance with the reference method given in IS: 1806:1986 as given below.

H_1 - Up to 15 ml diffusible hydrogen
H_2 - Up to 10 ml diffusible hydrogen
H_3 - Up to 5 ml diffusible hydrogen

Table 3

Welding current and voltage conditions
(Clause 5.5)

Digit	Direct current: recommended electrode polarity	Alternating current: open circuit voltage, V, Min
0	–	Not recommended
1	+ or –	50
2	–	50
3	+	50
4	+ or –	70
5	–	70
6	+	70
7	+ or –	90
8	–	90
9	+	90

1 Symbol 0 reserved for electrodes used exclusively on direct current,

2 Positive polarity +, Negative polarity –.

The frequency of the alternating current is assumed to be 50 or 60 Hz. The open circuit voltage necessary when electrodes are used on direct current is closely related to the dynamic characteristics of the welding power source. Consequently no indication of the minimum open circuit voltage for direct current is given.

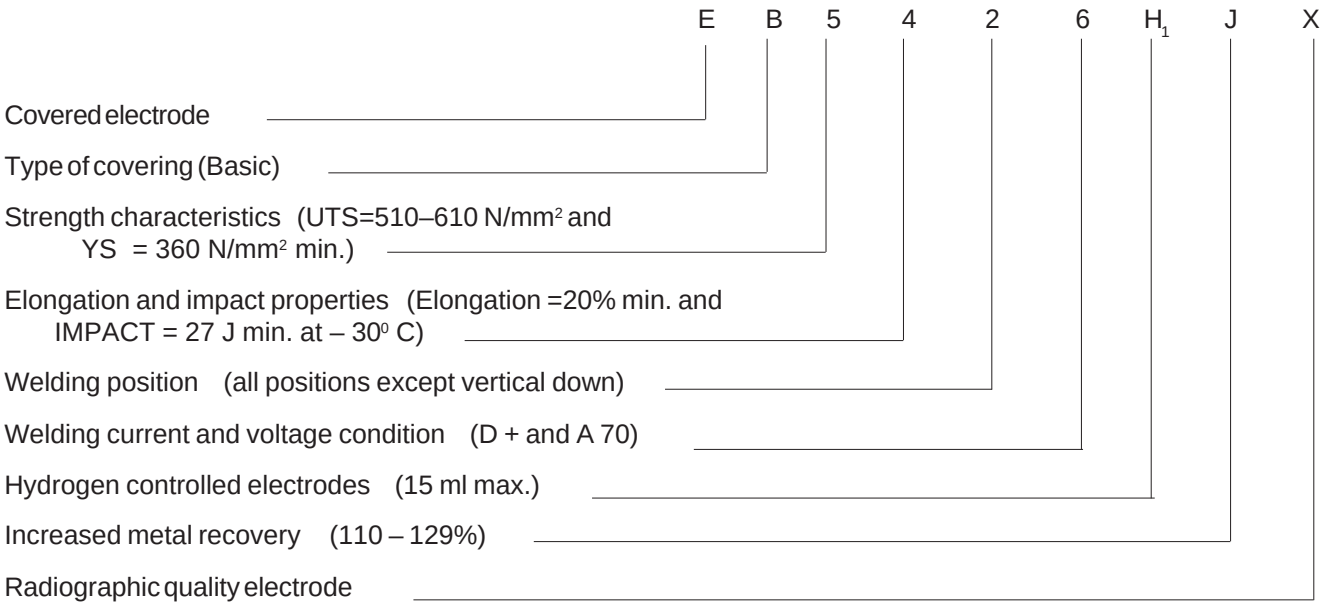
Increased metal recovery: The letters J, K and L shall be included in the classification as a suffix for those electrodes which have appreciable quantities of metal powder in their coating and give increased metal recovery with respect to that of core wire melted, in accordance to the range given in 5.0.2 (b).

The metal recovery shall be determined as 'Effective Electrode Efficiency (E_E) as per the method given in IS 13043:1991.

Radiographic quality electrodes: The letter 'X' shall be included in the classification as a suffix for those electrodes which deposit radiographic quality welds.

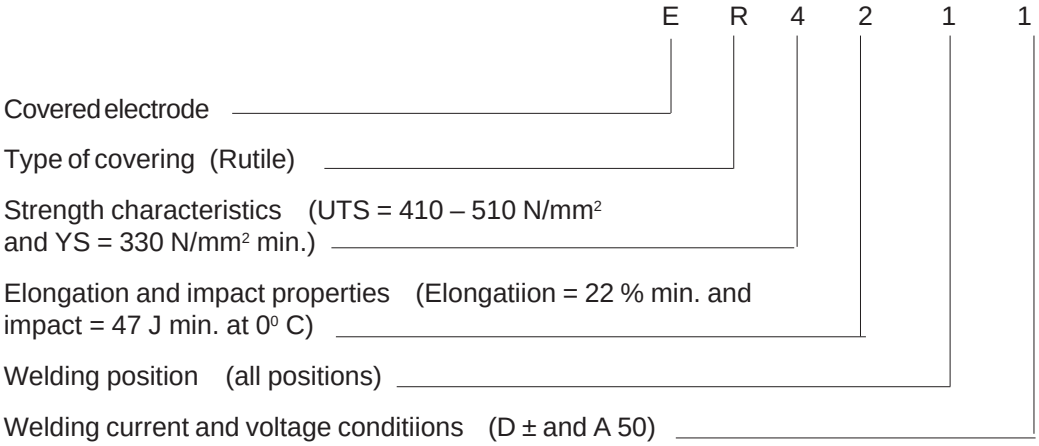
Example 1

The classification for the electrode EB 5426H1JX



Example 2

The classification for the electrode ER 4211



AWS codification of carbon steel and low alloy steel coated electrodes

Chart - 1 shows the details of AWS coding of an electrode.

In the chart , E stands for electrode. It means that it is a stick electrode.

The first two digits are very important. They designate the minimum tensile strength of the weld metal that the electrode will produce.

The third digit indicates the welding positions.

The last digit in the code indicates the kind of flux coating used.

BS codification of carbon steel and low alloy steel covered electrodes (BS 639 : 1976 equivalent to ISO 2560)

As shown in chart 2, E stands for covered MMA electrode.

The first two digits indicate tensile strength and yield stress.

The next two digits indicate elongation and impact strength.

The letter after the first 4 digits indicates the type of covering.

The first 3 digits after the letter indicating the type of covering shows electrode efficiency.

The fourth digit after the letter indicating the type of covering shows the welding position.

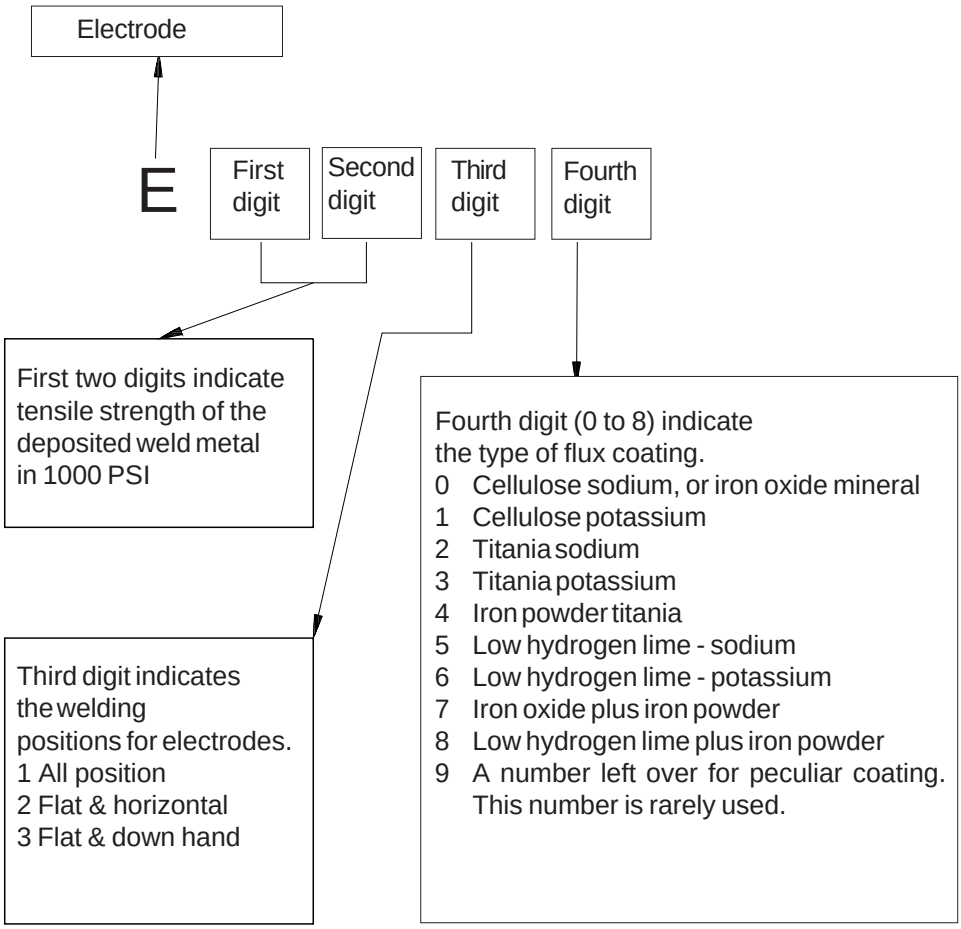
The fifth digit after the letter indicating the type of covering indicates current and voltage.

In the case of rutile covered electrodes, the digits indicating the electrode efficiency after the letter indicating the types of covering will not be given as shown in chart 1.

Chart 2 shows an electrode coding with electrode efficiency.

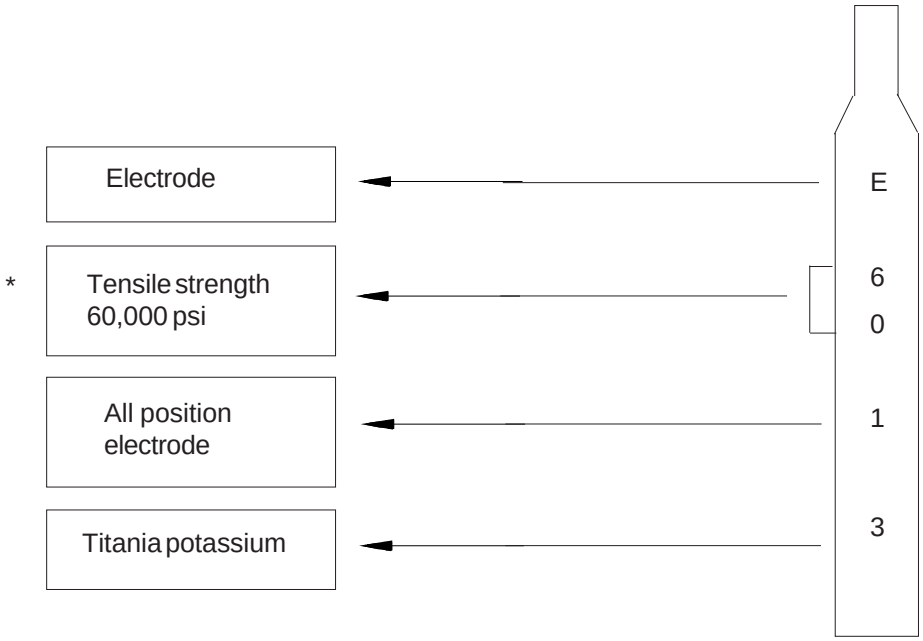
CHART 1

AWS CODIFICATION OF CARBON STEEL AND LOW-ALLOY STEEL COATED ELECTRODES

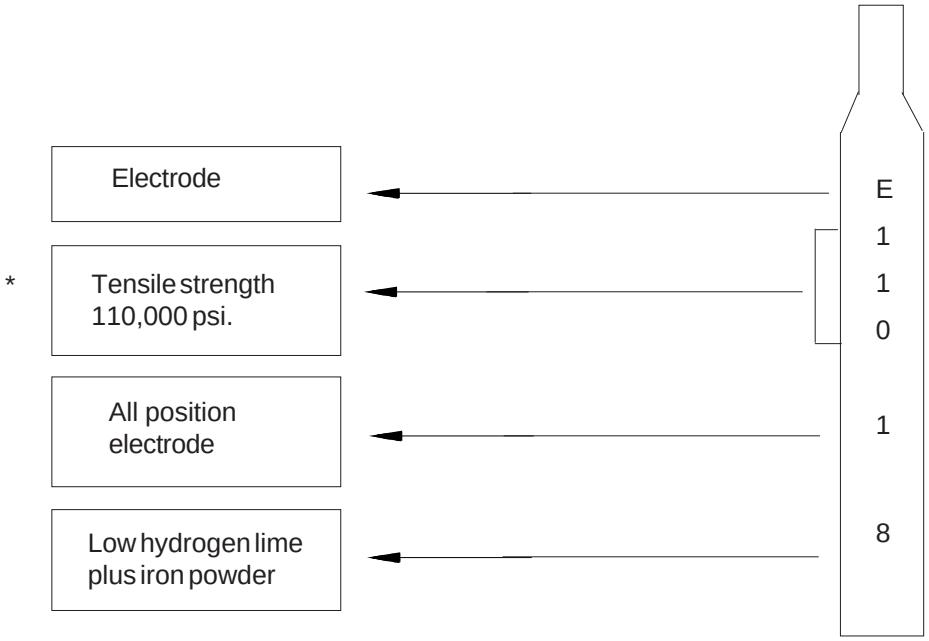


FOUR DIGITS CODIFICATION

EXAMPLE : AWS – E 6013.



FIVE DIGITS CODIFICATION



* To get the tensile strength of the weld in p.s.i., the number given here should be multiplied by 1000.

CHART 2 (BS 639 : 1976 equivalent to ISO 2560)

COVERING (4)

A	Acid (iron oxide)
AR	Acid (rutile)
B	Basic
C	Cellulosic
O	Oxidising
R	Rutile (medium coated)
RR	Rutile (heavy coated)
S	Other types

ELECTRODE EFFICIENCY (5)

% recovery to nearest 10% (> 110)

STRENGTH (2)

Electrode designation	Tensile strength N/mm²	Minimum yield stress. N/mm²
E43	430.550	330
E51	510.650	360

(H) (8)

Indicates hydrogen controlled (> 15mg/100g)

Example (b)

E 51 33 B 160 2 0 (H)

1 2 3 4 5 6 7 8

PROCESS (1)

Covered MMA electrode

WELDING POSITION (6)

1	All positions
2	All positions except vertical down
3	Flat and, for fillet welds, horizontal vertical
4	Flat
5	Flat, vertical down and, fot fillet welds, horizontal vertical
6	Any position or combination of positions not classified above.

ELONGATION (3)

First Digit	Minimum elongation, %		Temperature for impact value of 28J, ⁰C
	E43	E51	
0	Not specified		Not specified
1	20	18	+ 20
2	22	18	0
(3)	24	20	-20
4	24	20	-30
5	24	20	-40

CURRENT / VOLTAGE (7)

Code	Direct current	Alternating current
	Recommended electrode polarity	Minimum open circuit voltage, V.
0	Polarity as recommended by manu-facturer	Not suitable for use on A C
1	+ or -	50
2	-	50
3	+	50
4	+ or -	70
5	-	70
6	+	70
7	+ or -	90
8	-	90
9	+	90

IMPACT (3)

Second digit	Minimum elongation, %		Impact properties		
			Impact value, J		Tempera-
	E43	E51	E43	E51	ture ⁰ C
0	Not specified		Not specified		
1	22	22	47	47	+20
2	22	22	47	47	0
(3)	22	22	47	47	- 20
4	Not	18	Not	41	- 30
6	relevant	18	relevant	47	- 50

Example (1) Covered electrode for manual metal arc welding having a rutile covering of medium thickness and depositing weld metal with the following minimum mechanical properties. (BS 639)

Tensile Strength : 500 N/mm ^{2}

Elongation : 23 %

Impact strength : 71J at + 20 ^{0} C, 37 J at 0 ^{0} C, 20 J at -20 ^{0} C.

It may be used for welding in all positions. It welds satisfactorily on alternating current with a minimum open-circuit voltage of 50 V and on direct current with positive polarity.

The complete classification for the electrode would therefore be E 43 21 R 1 3

and the compulsory part would be E 43 21R.

Covered electrode for manual metal arc welding — E

Tensile strength — 43

Elongation and impact strength — 21

Covering — R

Welding positions — 1

Current and voltage — 3

Example (2) An electrode for manual metal arc welding having a basic covering, with a high efficiency and depositing weld metal containing 8 ml of diffusible hydrogen per 100 g of deposited weld metal with the following minimum mechanical properties.

Yield stress: 380 N/mm^2

Tensile strength : 560 N/mm^2

Elongation : 22 % Also a minimum elongation of 20%

Impact strength : 47 J at -20 ^{0} C with an impact value of 28 J at -20 ^{0} C

Nominal efficiency : 158%

It may be used for welding in all positions except vertical down, direct current only.

The complete classification for the electrode would, therefore, be E 51 33 B 160 2 0 (H)

and the compulsory part would be E 51 33 B..

Covered electrode for manual metal arc welding — E

Tensile strength and yield stress — 51

Elongation and impact strength — 33

Covering — B

Efficiency — 160

Welding positions — 2

Current and voltage — 0

Hydrogen controlled — (H)

Selection and storage of electrodes

Objectives: At the end of this lesson you shall be able to
- **select a suitable electrode to weld a particular job**
- **state the necessity of baking a coated electrode**
- **store and handle the electrode properly for better weld quality.**

Selection/choice of electrodes

Selection of an electrode is very important in order to get a joint welded with the required strength.

Selection factors

Properties of base metal: Top quality weld should be as strong as the base metal.

Select an electrode that is recommended as per the properties of the base metal. (Fig 1)

Fig 1

BASE METAL	ELECTRODE SELECTED
MILD STEEL	MEDIUM COATED RUTILE M.S. ELECTRODE
MEDIUM CARBON STEEL	HEAVY COATED LOW HYDROGEN M.S. ELECTRODE
STAINLESS STEEL	COLUMBIAM BASED STABILISED STAINLESS STEEL ELECTRODE
COPPER	HEAVY COATED BRONZE ELECTRODE

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The size of the electrode depends on:

– thickness of metal to be welded
– edge preparation of joints
– root run, intermediate or covering run
– welding position
– welder's skill.

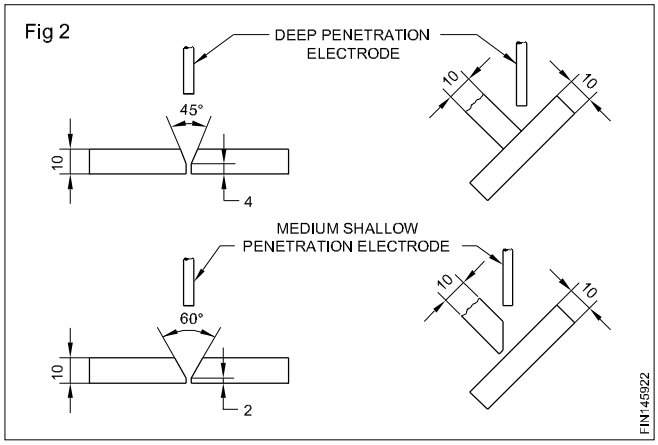
Never use a larger dia. electrode than the thickness of base metal.

Joint design and fit up

Select:

– deep penetration electrodes for insufficiently bevelled joints
– medium penetration electrodes for open and sufficiently bevelled joints. (Fig 2)

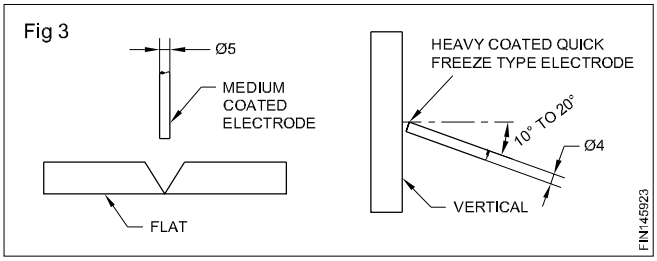
Fig 2



Welding position: Electrodes are manufactured for different positions, to produce better welds.

Select an electrode as per the welding position. (Fig 3)

Fig 3



Welding current: Electrodes are available for use with:

– AC or DC (straight or reverse polarity)
– AC and DC (both).

Select as per the availability of the welding machine.

Production efficiency: The deposition rate of electrode is important in production work. So select an iron powder electrode for production work.

Faster the weld, lower the cost.

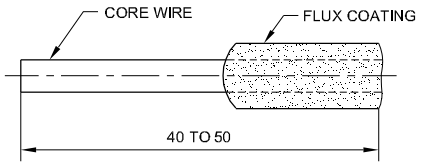
Select the electrode, which is designed for the particular production work.

Usage and storage of electrodes

Electrodes are costly, therefore, use and consume every bit of them.

Do not discard STUB ENDS more than 40-50 mm length. (Fig 4)

Fig 4



STUB END

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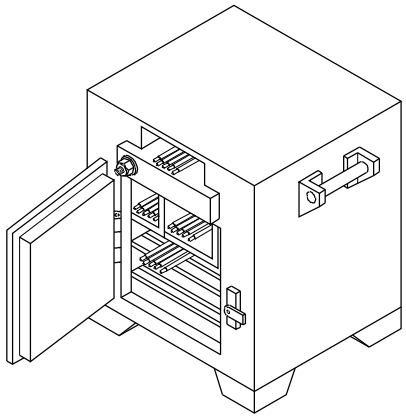
Electrode coating can pick up moisture if exposed to atmosphere.

Store and keep the electrodes (air tight) in a dry place.

Heat the moisture affected/prone electrodes in an electrode drying oven at 110 - 150° C for one hour before using. (Fig 5)

Fig 5



ELECTRODE DRYING OVAN

FIN145925

Remember a moisture-affected electrode:

– has rusty stub end
– has white powder appearance in coating
– produces porous weld.

Always pick up the right electrode that will provide:

– good arc stability
– smooth weld bead
– fast deposition
– minimum spatters
– maximum weld strength
– easy slag removal.

Storage of electrodes: The efficiency of an electrode is affected if the covering becomes damp.

– Keep electrodes in unopened packets in a dry store.
– Place packages on a duckboard or pallet, not directly on the floor.
– Store so that air can circulate around and through the stack.
– Do not allow packages to be in contact with walls or other wet surfaces.
– The temperature of the store should be about 5^0C higher than the outside shade temperature to prevent condensation of moisture.
– Free air circulation in the store is as important as heating. Avoid wide fluctuations in the store temperature.
– Where electrodes cannot be stored in ideal conditions place a moisture-absorbent material (e.g silica-gel) inside each storage container.

Drying electrodes: Water in electrode covering is a potential source of hydrogen in the deposited metal and thus may cause:

– Porosity in the weld
– Cracking in the weld.

Indications of electrodes affected by moisture are:

– White layer on covering.
– Swelling of covering during welding.
– Disintegration of covering during welding.
– Excessive spatter.
– Excessive rusting of the core wire.

Electrodes affected by moisture may be dried before use by putting them in a controlled drying oven for approximately one hour at a temperature around 110 - 150^0C. This should not be done without reference to the conditions laid down by the manufacturer. It is important that hydrogen controlled electrodes are stored in dry, heated conditions at all times.

Warning: Special drying procedures apply to hydrogen controlled electrodes. Follow the manufacturer's instructions.