Lesson 3: Selecting and Maintaining Electrodes and Safety Lenses

Arc welding electrodes are available in a variety of sizes and flux coatings. They are designed for use in certain welding positions and with certain electrical currents. Selecting the right electrode for the job depends on the properties of the electrode and the workpiece. In turn, the diameter of the electrode is a useful guide for choosing the correct filter lenses to protect the eyes from the harmful light of the welding arc. Proper eye protection is essential during welding. This lesson discusses the factors to consider when selecting electrodes and safety lenses for welding.

Electrode Parts and Functions

To review, an electrode is a metal rod that a welder uses to establish an arc between the electrode and the metal. The two parts of an electrode are (1) a solid metal core and (2) a flux coating. The solid metal core provides filler metal to the weld as it melts.

Depending on the type of electrode, the flux coating does any or all of the following:

- Adds filler metal to the weld
- Stabilizes the arc
- Produces a gas shield that protects the weld
- Adds flux to the weld, which removes impurities that rise to the surface of the weld and promotes the formation of slag, the protective layer over the weld
- Adds alloying elements to improve the weld
- Determines the polarity (positive or negative) of the electrode

Factors to Consider When Choosing an Electrode

To produce a good-quality weld, it is important to use the right electrode for the job. With some welding tasks, there may be specifications for the electrode to be used. With others, there may not be any specifications for the type of electrode. In such situations, many factors must be taken into consideration when choosing the electrode or combination of electrodes. Some, but not all, of these factors are described below.

- Type of metal being welded and its tensile strength: Tensile strength is the amount of stress the metal can withstand. Electrodes are designed to fuse specific types of metal. The tensile strength of the electrode filler metal should be at least as strong as that of the metal being welded.
- Thickness of the metal: The thickness of the metal affects the number of passes required, the width of the bead, and, thus, the diameter of the electrode chosen. In addition, thicker metals may require deeper penetration, which can be another factor in choosing an electrode.
- Condition of the base metal: Some electrodes work better than others on surfaces that are dirty, rusty, greasy, etc.
- Weld position (flat, vertical, horizontal, and overhead): Weld position mainly becomes important when welding is performed in the overhead position. A smaller diameter electrode is preferred when the weld position is overhead. Because gravity causes the molten metal to fall from an overhead weld, a smaller diameter electrode is preferred to reduce the droplets of molten metal. This factor is not an issue when welding is performed in the flat position.
- Experience of the welder: An experienced welder is capable of using a larger diameter electrode at a higher current setting without overwelding or overheating the base metal.
- Rate at which the filler should be added: Some electrodes are designed to deposit more filler metal in a shorter length of time.
- Design or alignment of the joint: Depending on the design of the joint, a combination of electrode sizes may be required to make a good weld. Some electrodes are designed to fill large gaps in joints with poor alignment.
- Properties of the alloying elements in the flux coating: The alloys in some electrode coatings can affect the quality of the weld, such as its strength and rust resistance.
- Type of electric current being used: Electrodes are designed for use with specific currents, such as alternating current, direct current electrode negative, and direct current electrode positive. The type of electric current produced by the welding machine must be known in order to choose the correct electrode.

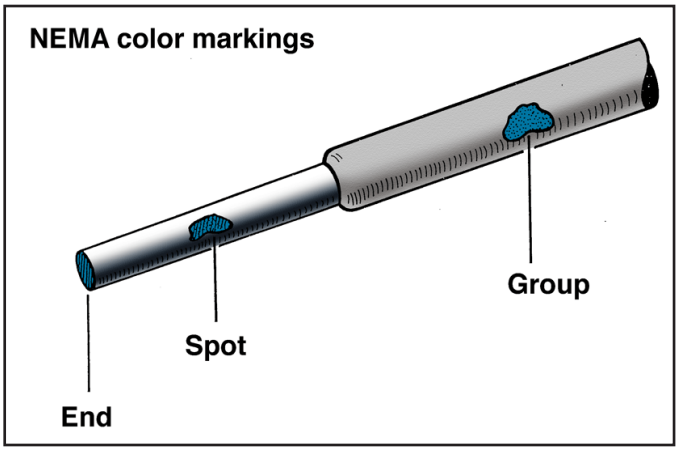
Identifying Electrodes

Electrode manufacturers classify electrodes by using one of two systems. One method is the color-coding system developed by the National Electrical Manufacturers Association (NEMA) and the other is the letter-and-number system developed by the American Welding Society (AWS).

NEMA System

The NEMA color-coding system classifies electrodes by using color markings on the end (end marking), the bare metal core (spot marking), and the flux coating (group marking) of the electrode. See Figure 3.1. Some manufacturers may use their own trademark or coating colors, which should not be confused for NEMA markings.

Figure 3.1 – Placement of NEMA Color Codes on an Electrode



AWS System

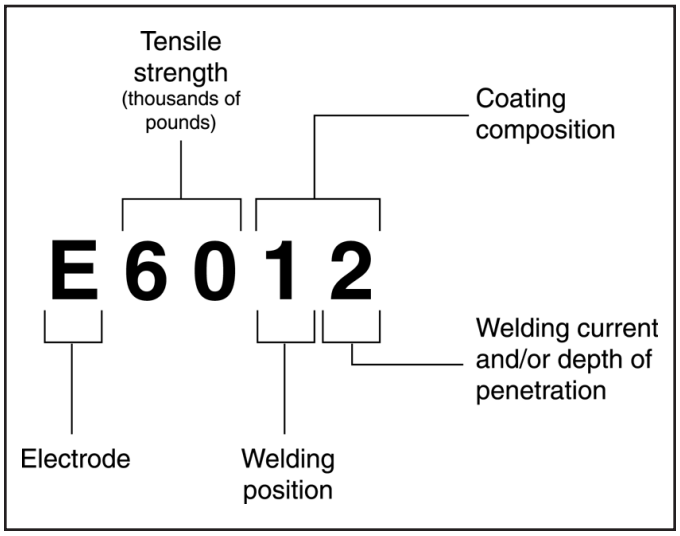
The AWS classification for electrodes is the most frequently used system. It uses a series of letters and numbers that provide important information about the properties of an electrode. The AWS code is stamped on the side of the electrode, near the bare end. See Figure 3.2. Some of the information in the AWS classification is explained below.

Figure 3.2 – Placement of AWS Code on Electrode

Characters in the AWS Classification System

To understand the meaning of the AWS electrode classification, the letters and numbers in the code must be broken down and examined separately. The classification code begins with a letter prefix followed by four or five numbers. With some electrodes, a letter-and-number suffix is placed at the end of the series of numbers. See Figure 3.3 for the breakdown of a typical AWS classification number.

Figure 3.3 – Breakdown of AWS Code



Letter prefix: The prefix letter or letters provide information about which welding process can be used. An "E" indicates that the electrode is used in arc welding. Another prefix example is "RG," which indicates it is a rod used in oxyfuel welding.

First two digits or the first three digits: The first two digits of a four-digit number or the first three digits of a five-digit number indicate the minimum tensile strength of the filler metal. Minimum tensile strength is expressed in pounds per square inch (psi) or kilopounds per square inch (ksi). For example, a 60-series electrode has a minimum tensile strength of 60,000 psi and a 100-series electrode indicates a minimum tensile strength of 100,000 psi. Minimum tensile strength can be defined as that following postheating treatment (the stress-relieved state) or that without postheating (the as-welded state). The electrode manufacturer's specifications explain under which condition minimum tensile strength has been determined for an electrode.

Second digit from the right: The second digit from the right indicates the recommended welding position for the electrode. The number "1" indicates the electrode can be used in all positions: flat (F), vertical (V), overhead (OH), and horizontal (H). The number "2" indicates the electrode can be used in flat and horizontal positions. A "3" is no longer used as a code number for weld position. It formerly meant that the electrode was used in flat position. It may still appear in some reference books. The number "4" indicates the electrode can be used in flat, horizontal, overhead, and vertical-down positions.

Last digit on the right: This digit provides operating characteristics, such as the proper welding current and/or depth of penetration of the filler metal. The currents include alternating current (ac), direct current electrode negative (dcen), and direct current electrode positive (dcep). Formerly referred to as direct current straight polarity (dcsp), dcen means that the electrode is the negative pole and the work is positive. Formerly referred to as direct current reverse polarity (dcrp), dcep means the electrode is positive and the work is negative.

Last two digits on the right combined: The last two digits on the right together provide information such as the coating composition and proper application. For example, the coating of an electrode with a code number ending in "10" is composed of high-cellulose sodium and one ending in "11" is composed of high-cellulose potassium.

Letter-and-number suffix: Some less common electrodes have additional designators (suffixes) after the four- or five-digit number to indicate other specifications. See Figure 3.4.

See Table 1 for AWS classifications of 60- and 70-series electrodes.

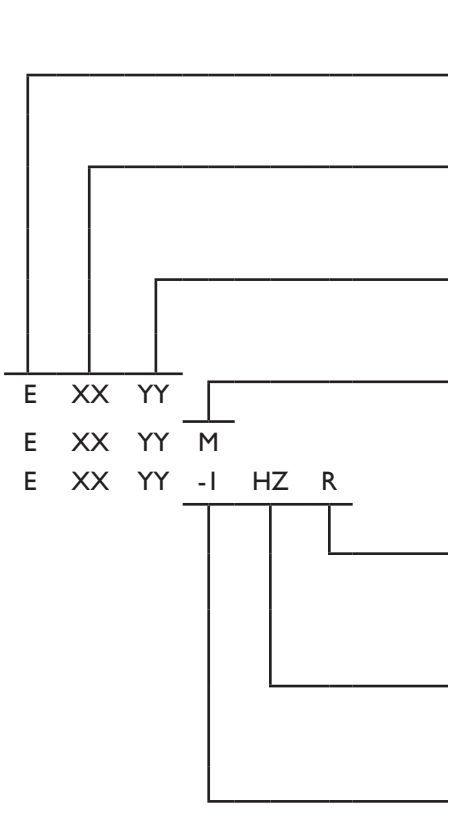
Care and Storage of Electrodes

Proper care and storage of electrodes will save time, avoid lost time on the job, and help prevent defective welds. It is essential that electrodes be kept dry in a waterproof container. A moist electrode can produce steam, which can carry away the shielding gases that protect the weld. Damp electrodes can also cause such problems as increased spatter and poor slag removal. Hydrogen from water can be added to welds and weaken them. Welds that are made with damp electrodes may be porous and may crack. Such faulty welds could be a safety threat if they go undetected and subsequently fail under stress.

Knowing the manufacturer's specifications for the moisture-pickup time period for an electrode is key to preventing damage from moisture. The time it takes for an electrode to pick up moisture from the air is called the moisture-pickup time period. To minimize exposure to moisture in the air or from other sources, it is important to take only the number of electrodes needed for a job or only the number that can be used within the moisture pickup period. Electrodes should be kept in their original package before use. Special waterproof dispensers are available for on-the-job storage to help keep electrodes dry. If moisture exposure occurs, electrodes should be dried in an electrode drying oven before they are used.

Electrodes should be handled carefully to avoid damaging the flux coating. Proper storage prevents electrodes from being bent, which causes chips and cracks in the flux coating. Many welding procedures do not allow the use of electrodes with a chipped or cracked coating.

Figure 3.4 – Explanation of Each Part of the AWS Code



Mandatory Classification Designators: *

Designates an electrode. This designator may be deleted from the product imprint required for identification of the electrode.

Designates the tensile strength (minimum), in ksi, of the weld metal when produced in accordance with the test assembly preparation procedure of this specification.

Designates the welding position in which electrodes are usable, the type of covering, and the kind of welding current for which the electrodes are suitable. See Table 1.

Designates an electrode (E7018M) intended to meet most military requirements (greater toughness, lower moisture content — both as-received and after exposure — and mandatory diffusible hydrogen limits for weld metal).

Optional Supplemental Designators:

Designates that the electrode meets the requirements of the absorbed moisture test (an optional supplemental test for all low hydrogen electrodes except the E7018M classification, for which the test is required).

Designates that the electrode meets the requirements of the diffusible hydrogen test (an optional supplemental test of the weld metal from low hydrogen electrodes, as-received or conditioned — with an average value not exceeding "Z" mL of H_2 per 100g of deposited metal, where "Z" is 4, 8, or 16).

Designates that the electrode (E7016, E7018, or E7024) meets the requirements for improved toughness — and ductility in the case of E7024.

* Note: The combination of these designators constitutes the electrode classification.

Source: American Welding Society (AWS) Committee on Filler Metal, 1991, Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding, ANSI/AWS A5.1-91, Miami: American Welding Society, Figure 16.

Choosing Safety Lenses

As discussed in the lesson on arc welding safety, light from the welding arc can injure the eyes. Arc rays can damage the retina (back of the eye) and cause loss of vision. Light from the arc can also cause painful burns of the conjunctiva (whites of the eyes). These burns can easily become infected and cause even more problems. Eye burns can be prevented with good-quality filter lenses that shield the eyes from harmful arc rays. Good lenses filter out about 99.5% of the infrared rays and 99.75% of the ultraviolet rays produced by the welding arc.

The right filter lens must be selected for the welding job. See Figure 3.5. Lenses with shade numbers 10, 12, and 14 are usually worn in arc welding. As a general rule, the larger the diameter of an electrode, the brighter the arc it produces. The brighter the arc is, the greater the

Table 1
Electrode Classification

AWS Classification	Type of Covering	Welding Position[A]	Type of Current[B]
E6010	High cellulose sodium	F,V,OH,H	dcep
E6011	High cellulose potassium	F,V,OH,H	ac or dcep
E6012	High titania sodium	F,V,OH,H	ac or dcen
E6013	High titania potassium	F,V,OH,H	ac, dcep, or dcen
E6019	Iron oxide titania potassium	F,V,OH,H	ac, dcep, or dcen
E6020	High iron oxide	H-fillets F	ac or dcen ac, dcep, or dcen
E6022[C]	High iron oxide	F,H	ac or dcen
E6027	High iron oxide, iron powder	H-fillets F	ac or dcen ac, dcep, or dcen
E7014	Iron powder, titania	F,V,OH,H	ac, dcep, or dcen
E7015	Low hydrogen sodium	F,V,OH,H	dcep
E7016	Low hydrogen potassuim	F,V,OH,H	ac or dcep
E7018	Low hydrogen potassium, iron powder	F,V,OH,H	ac or dcep
E7018M	Low hydrogen iron powder	F,V,OH,H	dcep
E7024	Iron powder, titania	H-fillets, F	ac, dcep, or dcen
E7027	High iron oxide, iron powder	H-fillets F	ac or dcen ac, dcep, or dcen
E7028	Low hydrogen potassium, iron powder	H-fillets, F	ac or dcep
E7048	Low hydrogen potassium, iron powder	F,OH,H,V-down	ac or dcep

Notes:
A. The abbreviations indicate the welding positions as follows:
F = Flat
H = Horizontal
H-fillets = Horizontal fillets
V-down = Vertical with downward progression

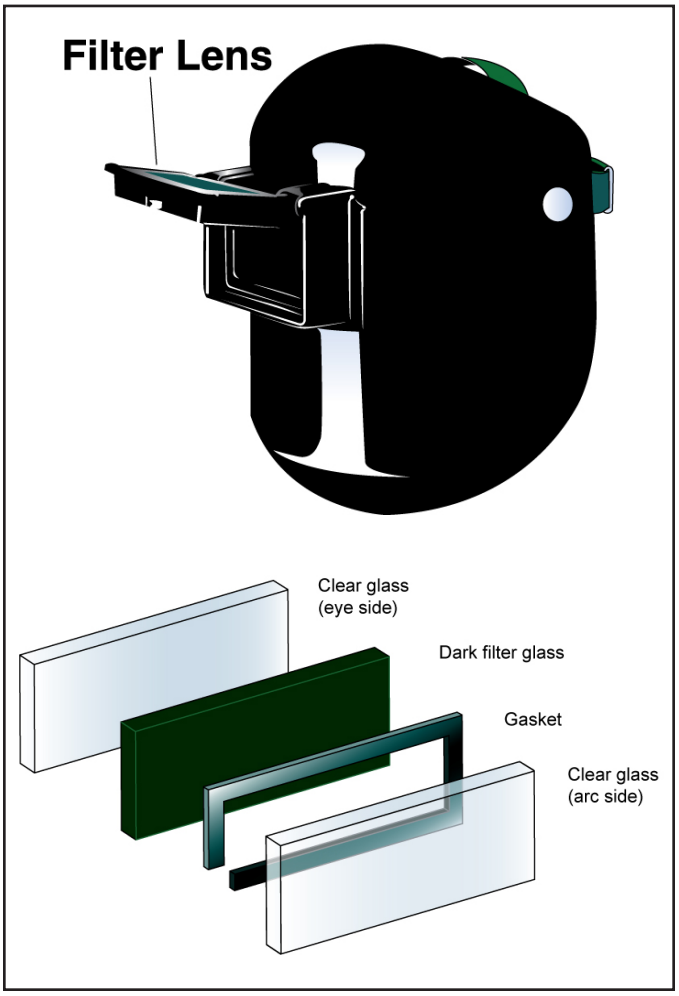
V = Vertical, OH = Overhead } { For electrodes 3/16 in. (4.8 mm) and under, except 5/32 in. (4.0 mm) and under for classifcations E7014, E7015, E7016, E7018, and E7018M.

B. The term "dcep" refers to direct current electrode positive (dc, reverse polarity). The term "dcen" refers to direct current electrode negative (dc, straight polarity).

C. Electrodes of the E6022 classification are intended for single-pass welds only.

Source: American Welding Society (AWS) Committee on Filler Metal, 1991, Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding, ANSI/AWS A5.1-91, Miami: American Welding Society, Table 1.

Figure 3.5 – Filter Lens on an Arc Welding Helmet



degree of darkness required in the filter lens. Common electrode sizes and the recommended safety lenses to use with them are as follows:

- Electrodes with a diameter of up to 5/32 in. – no. 10 shade
- Electrodes with a diameter of 3/16 in. to 1/4 in. – no. 12 shade
- Electrodes with a diameter of 5/16 in. to 3/8 in. – no. 14 shade

It is important to check with the instructor or the manufacturer's guidelines to make sure that the shade of filter lens is right for the job. Too dark of a lens can cause eyestrain. If the work cannot be seen comfortably through the lens when the arc is struck, the lens is probably too dark.

In addition to filter lenses, safety glasses must also be worn to protect the eyes. If the welding helmet is not equipped with safety glass under the filter lenses, a pair of safety glasses must be worn under the helmet. Safety glasses should be kept on during the entire welding process, especially when chipping slag. Others in the welding area should also wear eye protection, such as flash glasses, to avoid injury from reflected light.

Care of Filter Lenses and Welding Helmets

Filter lenses and welding helmets need care to keep them in good condition. Unprotected filter lenses can be spattered with molten metal during welding. A clear outer lens of glass or plastic should be used to protect the filter lens from damage and avoid costly replacement. Filter lenses should be inspected for cracks or other damage to make sure no arc rays can leak through to the eyes. Another area of potential leakage is the lens gasket. It should be inspected to make sure all parts of the lens assembly are installed correctly. The shade number should be marked on the filter lens and on its storage container for easy identification.

Before a welding helmet is used, it must be inspected for wear, cracks, and other damage. A damaged helmet must be repaired or replaced. For storage, a welding helmet should be hung or kept in a place where it is protected from impact and other sources of damage.

Summary

The diameter of the electrode, the type of flux coating, and many other factors must be considered when selecting an electrode for arc welding. The two methods of electrode classification are the NEMA color-coding system and the AWS letter-and-number system. Understanding the meaning of the AWS code helps in the selection of the right electrode for the job. Proper care and storage of electrodes protects the coating from moisture, cracking, and chipping. The diameter of the electrode can be used as a guide for selecting filter lenses with the correct shade number. A filter lens should be protected from metal spatter by a clear outer safety glass. Filter lenses and welding helmets should be inspected for damage before use and stored where they are protected from damage.

Credits

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