4

Base and Filler Metal Classification

Objectives

Students will be able to:

- List and describe the different types of steel.
- Define the different classification systems for ferrous metals.
- Explain the techniques used to identify types of steel.
- Compare and contrast carbon steel covered and stainless steel electrodes.
- Identify the correct filler metal combination with base metal.

Orienting Questions

- ✓ What are the types of steel and how are they different?
- ✓ What classification systems are used to identify steel?
- ✓ What techniques are used to determine types of steel?
- ✓ How are carbon steel covered and stainless steel electrodes identified?
- ✓ How are the appropriate filler metal and electrode determined?

Keys for success

- ☐ Read and review required text along with this module
- ☐ Review key terms
- ☐ Do each and every activity in the module

Helpful Tips

- ✓ You can select the **BLUE TERMS** to learn more.
- ✓ If needed, there are **CLOSED CAPTION** buttons CC on the YouTube videos that will enable you to read along while you watch. The Closed Caption buttons are located bottom right of the video screen.
- ✓ Anytime you see **EXPLORE** click on link or image to learn about the subject.
- ✓ Anytime you see me  click my image and let me read the text to you!
- ✓ When you see this book icon  it is alerting you to a reading assignment. Information will be provided by your instructor on the reading materials.
- ✓ Anytime you see this icon,  click on the image to watch a video about the module subject.

INTRODUCTION

Module four will focus on different base metal classification systems for ferrous metal. Not only will we discuss the classification systems, we will also discuss the different physical characteristics that will aid us in material identification. We will look at different techniques to aid in material identification and tools that are available on the market. We will also discuss the AWS filler classifications for solid wire, flux cored wire, and flux coated electrodes along with factors that need to be considered in selecting the correct product.

4.1 BASE METAL CLASSIFICATION FOR FERROUS METALS

Read Chapter 26 in *Welding Principles and Applications,* Larry Jeffus, 7th edition.

A **Base Metal** is the metal or alloy to be welded, brazed, soldered, or cut. Ferrous metals are base metals that contain iron. They can be pure iron, like wrought iron, or they may be an alloy of iron and other elements. An **Alloy**, as defined by the American Welding Society, is a substance with metallic properties and composed of two or more chemical elements of which at least one is a metal. Stainless steel is an example of an iron alloy.

4.1.1 GRADES OF STEEL

Modern-day steel is an alloy. Steel is a combination of iron ore, carbon, and additional elements. The type and amount of elements in the steel depends on which type of steel is created. The amount of carbon in steel has a large effect on the hardness, strength, and other characteristics of the steel but the additional alloying elements also effect the steel's characteristics. In this section we will discuss basic carbon steel and how the varying levels of carbon changes the characteristics of steel.

LOW CARBON (MILD STEEL)

Low carbon steel or commonly known as mild steel, are considered to have less than .30% of overall carbon content. This type steel is easy to fabricate and weld, and is generally easy to work with as far as most general applications.

MEDIUM CARBON STEEL

Medium carbon steels are considered to have more than .30% of carbon but less than .50%. The increased carbon content in the steel can require a minimal amount of preheating prior to welding. It is also less likely to be bent or formed due to the increased hardness but can still be welded without too much additional preparation work. It is not uncommon when SMAW welding medium carbon steel, to use low hydrogen electrodes to avoid hydrogen induced cracks or cold cracks.

HIGH CARBON STEEL

High carbon steels are considered to have between .50% and .90% of carbon content. High carbon steels are much more difficult to work with due to their increased hardness and strength. The increased hardness carries with it the characteristic of brittleness which means hard carbon steels are much more prone to cracking. Arc welding high carbon steel can require a considerable amount of preheating prior to the weld in order to limit the likelihood of cracking.

TOOL STEEL

Tool steel has a carbon content between .80% and 1.50%. The high carbon content makes this material very difficult to weld. While steel with a low amount of carbon is possible to gas weld with proper technique and handling, arc welding requires a great deal more work. If a tool steel part is arc welded, it is recommended that the part be annealed, softened, and reheated again to regain the hardness and strength after welding is completed.

HIGH MANGANESE STEEL

High manganese steel contains 12% or more manganese content along with a carbon content between 1% and 1.4%. High manganese steels are used in wear resistant applications or where sudden impact can be a factor. An example of such an application is earthmoving equipment. Earthmoving equipment, such as bulldozers, experience constant abrasion and impact due to their work environment. The bulldozer bucket (see Figure 1) is made of high manganese steel due to the constant friction caused by pushing dirt and the impact with materials such as the rocks or stumps that it comes in contact with along the way. Certain materials will wear down over time and need to be resurfaced or hard-faced. This process is where layers of arc welded beads are stacked, usually in 90° alternating layers, to rebuild the worn surface. The electrodes used for this process are specially designed and are also considered to be wear resistant like the base

Figure 1. Bulldozer Bucket
(by Peter Griffin, Public Domain)

STAINLESS STEEL

Stainless steel, also an iron-based ferrous metal, is an alloy that includes chromium and nickel which give it corrosion resistant properties.

There are four basic stainless steels alloy groups:

Ferritic – These steels contain less than 0.10% carbon and are magnetic. The fact that they can't be hardened via heat treatment and don't weld to a high standard limits the use of these metals somewhat, but they are still suitable for a wide range of applications.

Austenitic – This is the most common type of stainless steel, accounting for up to 70% of all stainless steel production. Its versatility is in large part down to the fact that it can be formed and welded with successful results.

Martensitic – This type of steel shares some characteristics with ferritic, but boasts higher levels of carbon, up to a full 1%. This means that they can be tempered and hardened and are thus highly useful in situations where the strength of the steel is more important than its resistance to corrosion.

Precipitation Hardening –after a special heat treatment technique that is used to increase the yield strength of malleable materials, these steels become extremely strong. They can be machined and worked into a wide variety of shapes without becoming distorted and, in terms of corrosion, have the same resistance levels as austenitic steels.

Stainless steel is fairly easily welded but does require extra attention to heat input and proper shielding from atmospheric gases. If the heat input is too high and the metal is allowed to cool too fast, carbide precipitation may result. If atmospheric gases are allowed to get to the molten weld puddle, sugaring or oxidizing of the weld may occur. Sugaring or oxidizing of the weld will look like burnt sugar, almost lava rock like in appearance, very porous and coarse.

CAST IRON

Cast-iron is a material widely used in such things as engine blocks, cylinder heads and other engine components. It also exists in many other products that we use each day such as cookware (see Figure 2), furniture, grills, etc. Cast-iron is an iron base material as the name infers and will have 1.7% up to 4% of carbon content. This high level of carbon content makes the material extremely hard and very brittle.

Figure 2. Cast Iron Cookware
(by Evan-Amos, Public Domain)

There are five different types of cast-iron:

Gray cast-iron - the most common type of cast-iron that is easily welded but tends to have a very porous structure which allows it to absorb oils and foreign materials that must be baked out or cleaned away before welding.

White cast-iron - is the hardest and most difficult to weld because it is prone to fractures due to the high carbon content and hardness.

Malleable cast-iron - is cast-iron that has gone through a heat treating process to remove some of the brittleness properties. It can also be welded fairly easily and as long as we keep it underneath the threshold of 1200°F,it stays in the malleable cast-iron state without returning to the white cast-iron that we find above 1700°F.

Alloy cast-iron - has additional elements added such as chromium, copper, manganese, molybdenum, and even nickel to manipulate the physical characteristics of this material. Most types of alloy cast-iron are easily welded when proper preheating procedures are followed.

Nodular cast-iron - also known as ductile cast iron. It has greater tensile strength than gray cast-iron but maintains the corrosion resistance we find with gray cast-iron. Nodular cast-iron also requires proper preheating and post weld cooling, in order to stress relieve and fight cracking tendencies.

Cast-iron in general can be difficult to work with. Many of the older cast iron parts weld fairly easily with minimal trouble or special consideration. Modern-day cast iron can be very difficult because imported components are not heavily regulated therefore the quality of the castings suffers. The inconsistency of the chemistry and the lack of control with the imported components, leads to very temperamental material that does not lend itself to welding most of the time. Another challenge with all cast iron is it is normally fairly porous which allows it to absorb oils and contaminants from the surface. When these portions of porosity are welded, the contaminants will boil out the weld. This will require grinding the work piece to remove the imperfect weld until we reach sound material without contaminants.

Some special tricks of the trade when working with cast-iron and trying to minimize crack repair is to drill a hole at each end of the crack to keep the crack from spreading. By doing this you can begin repairing the crack based on what would be most appropriate for that particular type of material.

Another common practice in working with cast iron is to preheat the cast iron to a few hundred degrees and then post heat it after the weld, thus controlling the rate at which it cools. This is needed because of the risk if it cools too fast it might crack again or even crack the surrounding areas.

An additional technique is to peen the material after welding as a form of stress relieving. Peening can be as simple as using a ball peen hammer (see Figure 3) and tapping the material repeatedly around the weld for a duration of time while it cools. This peening acts as a stress relieving measure and can aid the material in making it less likely to crack. A general rule, when working with cast-iron, is to take your time and spread out the heat input and give it adequate time to cool without overheating the material.

Figure 3. Peening Hammer (by Securiger, CC BY-SA 3.0)

MODULE ACTIVITY 1

Choose the correct answer.

1. A base metal is the metal or alloy to be welded, brazed, soldered, or cut. T/F
2. An alloy is a substance with metallic properties and composed of two or more chemical elements of which at least one is a nonmetal. T/F
3. ____________ (low carbon steel, high carbon steel) is hard and brittle.
4. The type of cast iron most difficult to work with is
    a. White
    b. Malleable
    c. Alloy
    d. Nodular
5. A good rule when working with cast iron is to take your time and pay special attention to heating and cooling techniques. T/F

4.1.2 CLASSIFICATION SYSTEMS FOR FERROUS METALS

There are a number of different classification or numbering systems that have been developed over the years in reference to the different grades of steel. The professional societies, listed in Figure 4, are responsible for creating different steel classification systems.

AISI – American Iron and Steel Institute

SAE – Society of Automotive Engineers

ASME – American Society of Mechanical Engineers

ASTM - American Society for Testing of Materials

UNS – Unified Numbering System

Figure 4. Professional Societies Related to Steel Classification (by Paul Phelps, CC BY 4.0)

The two most common systems, AISI and SAE, have merged into one similar system. This system uses a 4 to 5 digit numbering system. As seen in Figure 5, the first digit refers to the basic alloy group as noted in the table below. The second digit refers to the sub alloy group. The last two digits refer to the permissible carbon content.

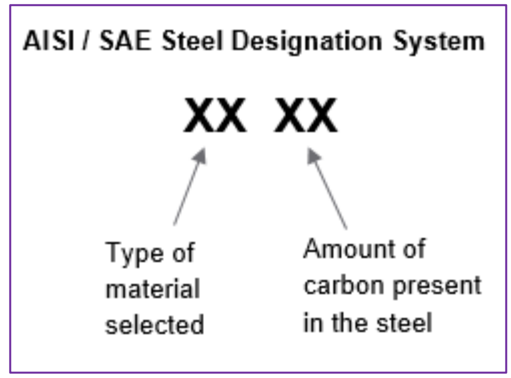


Figure 5. Steel Classification Nomenclature
(by Paul Phelps, CC BY 4.0)

10XX	Carbon steels	Plain carbon, Mn 1.00% max
11XX		Resulfurized free machining
12XX		Resulfurized / rephosphorized free machining
15XX		Plain carbon, Mn 1.00-1.65%
13XX	Manganese steel	Mn 1.75%
23XX	Nickel steels	Ni 3.50%
25XX		Ni 5.00%
31XX	Nickel-chromium steels	Ni 1.25%, Cr 0.65-0.80%
32XX		Ni 1.75%, Cr 1.07%
33XX		Ni 3.50%, Cr 1.50-1.57%
34XX		Ni 3.00%, Cr 0.77%
40XX	Molybdenum steels	Mo 0.20-0.25%
44XX		Mo 0.40-0.52%
41XX	Chromium-molybdenum steels	Cr 0.50-0.95%, Mo 0.12-0.30%
43XX	Nickel-chromium-molybdenum steels	Ni 1.82%, Cr 0.50-0.80%, Mo 0.25%
47XX		Ni 1.05%, Cr 0.45%, Mo 0.20-0.35%
46XX	Nickel-molybdenum steels	Ni 0.85-1.82%, Mo 0.20-0.25%
48XX		Ni 3.50%, Mo 0.25%
50XX	Chromium steels	Cr 0.27-0.65%
51XX		Cr 0.80-1.05%
50XXX		Cr 0.50%, C 1.00% min
51XXX		Cr 1.02%, C 1.00% min
52XXX		Cr 1.45%, C 1.00% min
61XX	Chromium-vanadium steels	Cr 0.60-0.95%, V 0.10-0.15%
72XX	Tungsten-chromium steels	W 1.75%, Cr 0.75%
81XX	Nickel-chromium-molybdenum steels	Ni .30%, Cr 0.40%, Mo 0.12%

86XX		Ni .55%, Cr 0.50%, Mo 0.20%
87XX		Ni .55%, Cr 0.50%, Mo 0.25%
88XX		Ni .55%, Cr 0.50%, Mo 0.35%
92XX	Silicon-manganese steels	Si 1.40-2.00%, Mn 0.65-0.85%, Cr 0-0.65%
93XX	Nickel-chromium-molybdenum steels	Ni 3.25%, Cr 1.20%, Mo 0.12%
94XX		Ni 0.45%, Cr 0.40%, Mo 0.12%
97XX		Ni 0.55%, Cr 0.20%, Mo 0.20%
98XX		Ni 1.00%, Cr 0.80%, Mo 0.25%

Figure 6. AISI/SAE Steel Classification System (by Unknown, Public Domain)

For example, with a 1020 steel, the first digit of one signifies it is a carbon steel, the second digit of zero signifies there is no additional alloy, and the last two digits show us that it has a .20% of carbon allowable to be classified is a 1020 carbon steel. This system is very useful in understanding which alloy elements are in steel as well as its carbon content.

Not all of the steel classification systems contain as much detail as the AISI/SAE system. The ASME material classification system and the ASTM use similar systems with a letter identifier used to show of its ferrous or metric or some other type of specific information followed by an arbitrarily assigned material number. Within these two standards you find materials identified in the form an application such as some materials are identified welded pipe, seamless pipe, bars or shapes, or other specific types of applications or forms. With these two types of systems is very important to have access to the material database documents which details the specifics of a particular type of metal such as chemical composition, and characteristics.

EXPLORE: ASTM Designation System

The UNS system was developed to create a common classification system with the idea of it replacing all other systems with just one. The UNS classification system is similar in concept to that of the ASTM/ASME systems, in that we find a letter prefix used to group similar types materials such as “A” for aluminum, or “W” for welding filler metals and an arbitrarily assigned material identification number.

EXPLORE: Unified Numbering System

In the AISI material identification system, we find stainless steels identified by a three digit number. Similar types of stainless steel are grouped in different series of numbers, such as the 300 series being austenite stainless steel. Stabilizing elements that are added to different chemistries, will be noted as suffixes. In the example of a 304L stainless steel, the L signifies a low carbon material.

MODULE ACTIVITY 2

Choose the correct answer.

6. The steel classification system is a combination of the AISI and ASTM classification systems. T/F
7. Steel classification nomenclature uses a ___________ (two to three, four to five) digit numbering system.
8. Which statement is not part of steel classification:
   a. The last two digits refer to the permissible carbon content.
   b. The first digit refers to the basic alloy group.
   c. The third digit refers to the type of electrode needed.
   d. The second digit refers to the sub alloy group.

4.1.3 MATERIAL IDENTIFICATION TECHNIQUES

Understanding the classifications and general characteristics of all the available materials is essential to identify or verify the proper materials to use on a job. If we work with material other than what is specified in the plans or blueprints, it can be a very costly error due to wasted time and materials and possibly compromise the integrity of the component.

In the course of a day in modern manufacturing, it is not uncommon to come across multiple types of materials. Some of these materials will share similar characteristics and be difficult to identify without understanding those characteristics. Some facilities have extremely large material bays with stacks and stacks of different types of material in varying thicknesses, grades, sheet sizes, and classification. Therefore, we have to rely on what we know of the material to select the needed piece.

	Carbon Steel CRS	Carbon Steel HRS	Stainless Steel	Titanium	Aluminum	Magnesium	Cast Iron
Size	Accurate	Oversized	Accurate	Accurate	Accurate	Accurate	Formed to the part
Color	Dull Grey	Black / Dark Grey	Bright / Silvery with Tan tint	Bright / Silvery with Tan tint	Silver / White	Silver / White	Dull grey
Shape / edges	Square	Rounded	Both	Both	Both	Both	according to form
Texture	Med Coarse to Smooth	Mill Scale	Polished or Smooth or Coarse	Polished or Smooth or Coarse	Polished or Smooth or Coarse	Polished or Smooth or Coarse	Coarse according to mold
Magnetism	Yes	Yes	Some grades	No	No	No	Very
Weight	Heavy	Heavy	Heavy	Light	Light	Light	Very Heavy
Flammable	No	No	No	No	Dust / Yes	Yes	No
Reaction to direct flame / heat source	Stays Centralized to location of where heat was applied	Stays Centralized to location of where heat was applied	Stays Centralized to location of where heat was applied	Stays Centralized to location of where heat was applied	High Thermal conductivity / absorbs heat and spreads out	High Thermal conductivity / absorbs heat and spreads out	Stays Centralized to location of where heat was applied
Color from applied flame / heat	Red	Red	Rainbow	Rainbow	None	None	Red
Spark Test	Long Carrier Lines	Long Carrier Lines	Form close to wheel, short	Bright White	None / Dust only	None / Dust only	Red Carrier Lines
Hardness Test	Soft / Med / Hard	Soft / Med / Hard	Hard	Hard	Soft / Med	Soft / Med	Hard

Figure 7. Physical Characteristics of Different Types of Steel (by Paul Phelps, CC BY 4.0)

In Figure 7 above, you see a general breakdown of some different physical characteristics and what can be expected of that characteristic for each material type.

There are different techniques that can be used to quickly and easily identify a type of material by major categories. As we review these different characteristics for each material, you will find an overlap, with many of the materials sharing similar characteristics. As a result of this, it will be important to consider more than one characteristic of a material to truly be able to determine what it is.

APPEARANCE

- Dimensions – This can be a quick and easy way to evaluate a material. Cold rolled steels will be very accurate in dimension with squared off edges, while hot rolled steel will be oversized and have rounded edges as part of the forming process. Other materials, such as stainless steel, titanium, aluminum, and magnesium typically are very accurate in size with squared edges, very similar to cold rolled steel. So if the material is oversized or an uneven or fractional number, we consider it to be hot rolled steel. For example, if we order a 4' x 8' piece of cold rolled steel, the material will be just as ordered, 4' x 8'. If it is hot rolled steel, we would find it to be 4 foot 2" x 8' 2 inches or not a specific oversized dimension. Due to the forming process, the hot rolled steel requires much work to produce and will be cheaper.

- Color - Another factor when considering appearance will be color. Cold rolled steel will be a dull matte grey or silver in appearance, while hot rolled steel will be very dark, like black or dark gray and have a mill scale finish on the surface. This mill scale is naturally forming as a material is produced, and acts as a protective barrier on the surface the material as it goes through the fabrication process. Stainless steels will be bright and silvery and you build and see a slight tan tint in the color. Titanium is very similar in color to stainless steel. Aluminum and magnesium will be much whiter to silver in color. Cast-iron can vary depending on the type, but normally it will be a dark to dull gray in appearance.

- Texture - One additional factor when considering appearance will be the surface texture of the material. Texture can be very different depending on the thicknesses of the material itself. When looking at cold rolled steel, you will find the surface texture ranges from medium coarseness to smooth in appearance or texture. Hot rolled steel will be rather course where you find the mill scale. Stainless steel will have a near polish or high-gloss smooth finish. As you get into the thicker materials, you find the surface to be much more course. The same is true when looking at titanium. Aluminum and magnesium have the same texture when in a polished state. Coarser textures are usually found in the thicker materials. Cast-iron will take its texture from the mold that was used. Many times the mold will include the part number or other details.

MAGNETISM

Magnetism may seem to be an easily detected characteristics. There are some factors that need to be explored regarding magnetism. Steels in general, whether cold rolled or hot rolled, are generally very magnetic due to the carbon content. Most people think stainless steels are non-magnetic. This is not always true. Certain grades of stainless steel have a higher carbon content and therefore will have magnetic properties. Therefore, magnetism cannot be used as the sole reason for determining the material is or is not stainless steel. As previously stated, we need to consider all the characteristics of a material to identify it. Titanium, aluminum, magnesium all are nonmagnetic. Cast-iron will be very magnetic since it typically has a much higher carbon content than cold rolled or hot rolled steel.

CHISEL / FRACTURE / FILE (HARDNESS TEST)

A chisel, fracture, or file test will evaluate the level of hardness for a material. Hardness is considered to be a measurement of a material's resistance to penetration. A quick hardness test can be accomplished by using a file to see how easily it cuts into the material. We can also look at how a chisel may dig into the material or how easily the chisel can cause a piece of the material to fracture or splinter off.

The grade of steel will cause varying degrees of hardness. Medium and high carbon steels are going to be much harder because of the higher carbon content and therefore much resistant to the cutting action of a file or chisel. Low carbon steels will be fairly soft, medium carbon steels are medium hard, and higher carbon steels are the hardest in overall makeup. Stainless steels are typically harder due to the elements that make it stainless, the chromium and nickel. Compared to carbon steel, stainless steel is closer to a medium carbon steel in hardness. Titanium will be very much like stainless steel with regard to hardness. Aluminum and magnesium are usually considered soft materials but depending on the alloy and heat treating process, one can find very hard grades of each. Cast-iron, due to the high carbon content, will be very hard and as result, very brittle. Therefore it would be very possible to fracture a piece off, due to its brittle nature.

WEIGHT TO SIZE COMPARISON

Weight is an additional characteristic to consider when trying to separate different types of material. Steels and stainless steels are characteristically heavy in physical weight when compared to their size and as expected we will find aluminum's and magnesium is to be fairly light in comparison. Titanium is much different as it has the same strength or higher strength characteristic as steel but at a fraction of the weight. Cast-iron is very similar to steels in that they are very heavy compared to their overall size.

FLAME / REACTION TO DIRECT HEAT

Different materials have different reactions when a direct flame is applied to the surface of the material. Applying a direct flame will allow us to visibly see different colors and reactions to the heat input, along with how the material absorbs the heat. With steels, the heat will stay fairly centralized where applied and it will be a cherry red color at the location where the heat is applied. With stainless steels and titanium, the heat will remain fairly centralized where applied and it will turn cherry red color but once the heat is removed, you will see a rainbow colored ring around where the heat was applied. This rainbow color spectrum will make it obvious whether the material is stainless steel or titanium.

Aluminum and magnesium will have a much different reaction to heat input with the direct flame. With these steels, there will have no visible change in color when direct flame is applied to the base metal. As they are heated and get closer to their melting points, we will see a phase change from a solid to a liquid state. One factor we need to take note of is the fact that magnesium is combustible/flammable. Magnesium burns at an extremely high temperature and does not require oxygen to burn. Therefore, once magnesium catches on fire, it will be very difficult to deal with and put out, so heating it to its melting point could be very dangerous. Aluminum, in its solid-state, is not dangerous to heat up to the melting point. One thing that is different with aluminum is that the heat is evenly distributed throughout the piece when a direct flame is applied, like with carbon steels and stainless steels. This is why aluminum is the desired choice for a frying pan since heating one area makes the whole piece become heated. This is known as thermal conductivity. Another characteristic of aluminum is that in solid-state, it is not flammable but aluminum grinding dust is very flammable/combustible. Therefore, in a welding facility, we must be very careful in the collection and disposal of aluminum grinding dust.

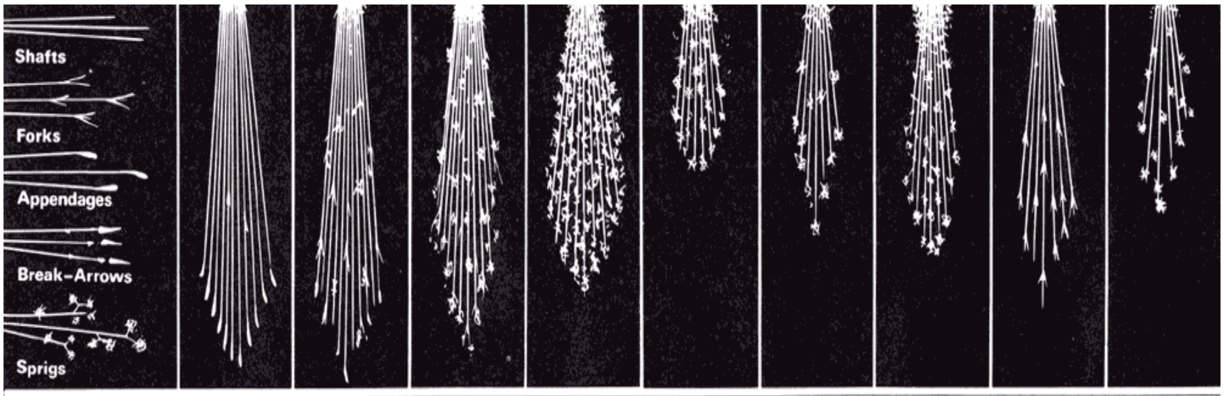
Cast-iron will be very similar to how carbon steels react to heat in the fact that the heat stays fairly centralized where it is applied. Where the heat is being applied it will be cherry red in color, but once the flame is removed, it will return back to its normal color with a slight burn mark.

SPARK

The spark test is a common, old-school technique but also a very effective test. Spark testing requires us to have an abrasive grinding device such as a bench grinder or an angle grinder. When we place the material to be tested against the grinding wheel, it will give off a spark. Depending on the chemistry of the base metal, the spark will have different shape lengths and visual characteristics. Some materials will have a very obvious change in color. One example of an obvious change is with titanium. It throws off a very bright white spark when grinded. Aluminum and magnesium do not spark as they are nonferrous, but they will give off a dust rather than spark.

Stainless steels, steels, and cast-iron will all give off varying spark patterns according to their chemistry. When evaluating the spark pattern, you have to look at the carrier lines as a spark flies away from the brace to fully evaluate that spark pattern. Some of the differences can be very subtle and hard to distinguish but over time and with experience it can become easier. If you are going to use the spark test on a regular basis, get different samples of materials that you know what they are and look at the spark pattern for that type of material, making note of what you see. This will give you a frame of reference when evaluating unknown materials.

EXPLORE: Spark Test



CHARACTERISTICS OF SPARK TEST	LOW C. STEEL (0.1%C)	MILD STEEL (0.25%C)	MED. C. STEEL (0.4%C)	HIGH C. STEEL (0.7%C)	GREY CAST IRON	MALLEABLE CAST IRON	AUSTENITIC MANG. STEEL	HIGH ALLOY STEELS 18/18 Stain	Die Steel
Volume of Stream	Large	Large	Large	Med. Large	Small	Moderate	Mod. Large	Moderate	Small
Relative Length	1.6m	1.8m	1.6m	1.4m	0.6m	0.75m	1.1m	1.3m	0.9m
Colour at Wheel	Straw	White	White	White	Red	Straw	White	Straw	Red
Colour at end	Straw-white	White	White	White	Straw	Straw	White	White	
DESCRIPTION OF SPARK STREAM (COMPARE WITH KNOWN SAMPLES)	As carbon increases in iron, spark changes from long straw shafts with appendages to forked shafts and some sprigs, number of sprigs increasing with carbon content.			Mass of small fine repeating sprigs.	Many small repeating sprigs.	Longer shaft than grey iron, small repeating sprigs.	Many fine repeating sprigs.	Alloys reduce spark length of comparable carbon steel.	

CHIP AND FRACTURE
White Cast Iron: Brittle hard small fragments, silvery fracture.
Grey Cast Iron: Small chips, smooth groove, dark grey fracture can mark finger on paper.
Malleable Cast Iron: Tough rough chips larger than Grey Iron.
Cast Steel: Chips easily to continuous smooth groove, coarser crystalline fracture than rolled steel.
High Carbon Steel: Chips hard than MS with lighter coloured edges, very light fine fracture.
Aluminium, Copper, Bronzes: Smooth easily produced chips leaving saw edged groove.

MAGNETISM
The following reactions to a magnet are useful for separation.
Magnetic: Nickel, Mild Steel, Carbon and Low Alloy Steels, Grey Iron, Malleable Irons, Straight Chromium Steels.
Non-Magnetic: Austenitic Manganese or Austenitic Stainless Steels and all non-ferrous metals.
Slightly Magnetic: Monel 4, Work-Hardened Aust. Mang. Steel and Work-Hardened Stainless Steels.

RELATIVE WEIGHTS
Approximate kilograms per cubic metre are shown for various metals and alloys:

1.74×10^3	Magnesium
2.70×10^3	Aluminium and its alloys
7.20×10^3	Cast Iron, Tin, Zinc
7.85×10^3	Steel, Stainless Steel
8.85×10^3	Copper, Nickel, Monel, Brass
11.35×10^3	Lead
15.20×10^3	Sintered Tungsten Carbides

Figure 8. Overview of the Spark Test (by Zeolite, Public Domain)

ALLOY ANALYZER

With the technology present in the modern day, there are a number of tools that can aid us in material identification. One such piece of equipment is known as an alloy analyzer. An alloy analyzer can be handheld or benchtop in design and is capable of taking a sample of the material using extra technology and doing a full chemical analysis of the material. Current models on the market will have a built-in database which then the analysis will be compared against and if there is a match it will identify the type of material that it is. If it is not an exact match it gives the chemical analysis and the percentage that it is off of the desired chemistry. With so many different materials on the market in advance chemistries certain factors can limit

Figure 9 Alloy Analyzer
(by Unknown, Public Domain)

this piece of equipment's ability to accurately identify the material. It is a very nice tool but in my personal experience when you get into the more advanced alloys it can be challenged. Two main limiting factors will be the light elements such as aluminum and magnesium. Because of their low atomic weight it has difficulty in separating out those particles and measuring exactly the content but because of the other alloys in the mix even the older piece of material do a fair job in identifying material.

Advancements have been made in current technology has a much better ability to separate out these light elements and give you accurate measurements for the. The other main limiting factor it cannot do is tell us how much carbon is in the overall makeup of the material. And as you can see with our different materials carbon content can be a very critical factor. So a **Carbon Equivalent** mathematical formula has been developed where we can take the chemical analysis information and plug it into the mathematical formula to estimate the carbon content. The link below takes you to the Wikipedia site which details this mathematical formula for your review.

EXPLORE: Alloy Analyzers

EXPLORE: Equivalent Carbon Content

MODULE ACTIVITY 3

Choose the correct answer.

9. Dimensions, color, and texture are ways to identify a material. T/F
10. Stainless steel is non-magnetic. T/F
11. ____________ (cold rolled steel, hot rolled steel) will be very accurate in dimensions.
12. A steel that is bright and silvery in appearance is
    a. Cast iron
    b. Titanium
    c. Aluminum
    d. Stainless
13. Which answer is not a technique to identify materials?
    a. Hardness test
    b. Weight to size comparison
    c. Melting test
    d. Spark test
14. A full chemical analysis of a material can be done by a/an
    a. Acid test
    b. Alloy analyzer
    c. X-ray
    d. Spark test

Video 1 – Click on the video icon to watch a video about material identification techniques. (Paul Phelps, Standard YouTube License)

Video 2 - Click on the video icon to watch a video about additional material identification techniques. (Paul Phelps, Standard YouTube License)

Video 3 - Click on the video icon to watch a video about additional material identification techniques. (Paul Phelps, Standard YouTube License)

4.2 FILLER METAL CLASSIFICATION

Read Chapter 27 in *Welding Principles and Applications,* Larry Jeffus, 7th edition.

Filler metal selection can be influenced by a number of different factors such as:

- type of electrode to be used
- welding current and power range the welding power source can supply
- mechanical properties of the weld
- the type and thickness of base metal
- welding positions
- joint design
- surface condition
- number of passes to be welded and quantity of welds
- amount of distortion
- preheating and post heating temperatures
- fabrication considerations
- amount of post weld cleanup
- welding environment (shop versus field)

Considering these factors and more will help guide us through the complex process of selecting the weld process and filler metal to be used for the given project. Choosing the best Filler Metal and Electrode is complicated. Some electrodes have more than one application, many welding electrodes may be used for the same type of work, and you may need to choose more than one type of electrode.

Before we proceed, we need to discuss the American Welding Society's electrode classification system. The AWS system is considered the main classification system. Each AWS electrode has its own welding classifications. On the electrode label, you may find multiple numbers but you can easily identify the AWS classification and specification number. The specifications reference the standard that the electrode characteristics are measured against and must be adhered to be considered AWS qualified.

The AWS classification system uses a series of letters and numbers in a code that gives the important information about the filler metal. With AWS, we find a number of prefixes that we must understand when looking at the classification systems. The prefix letter is used to indicate the filler's form, a type of process the filler is to be used with, or both. The prefix letters and their meanings are as follows:

E – Electrode, signifying a current carrying electrode as we see with stick welding (SMAW)

R – Rod, a filler wire to be heated or melted by separate means such as wired used for TIG welding or Oxy-fuel welding

ER – electrode or Rod, a filler metal that is capable of being supplied in broad or electrode form being that is current caring award noncurrent caring such as we find with MIG welding, TIG welding, or Oxy-fuel welding

EC – composite electrode, typically used for SAW submerged arc welding which we find specialty alloyed electrode which uses an additional external flux matched to the electrode and the required welding characteristics

B – Brazing, used for brazing process commonly comes in a rod form but can be found also in the form of sheets, washers, and rings

RB – Rod brazing, a current caring brazing electrode commonly used when arc brazing

RG – Rod gas, filler wire designed to work with an oxygen-based process such as Oxy-fuel or Oxy-acetylene welding

IN – consumable insert, normally used for pipe, they are specially designed rings to be placed in between two piece of pipe and welded over as part of the joining process where this ring becomes consumed in acts as the filler material for the root pass

EW – Tungsten electrodes, current carrying non consumable electrode used for TIG welding

F – **Flux**, used for SAW submerged arc welding

In addition to the prefix, there are some suffix identifiers that are used to indicate a change in the alloy in a covered electrode or the type of welding current to be used with stainless steel-covered electrodes.

EXPLORE: Classification of Welding Electrodes

MODULE ACTIVITY 4

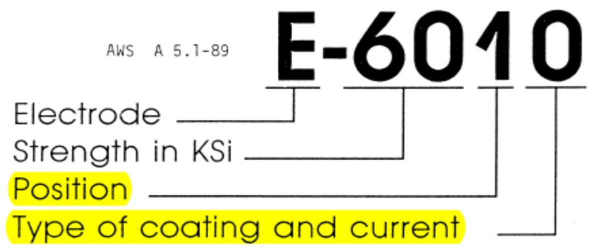
Choose the correct answer.

15. Choosing the best filler metal and electrodes is a simple process. T/F
16. Each welding electrode has its own welding classification. T/F
17. Which answer is not a prefix in the AWS electrode classification system?
    a. E
    b. RB
    c. EW
    d. ET

4.2.1 ARC WELDING ELECTRODE CLASSIFICATION

CARBON STEEL COVERED ELECTRODES

Carbon steel covered electrodes are used in stick welding. Figure 10 shows how one type of carbon steel covered electrode is identified. The prefix E represents a current carrying electrode. The first two numerical digits signify the tensile strength of the weld deposit. The third digit signifies position according to the table shown below. The fourth digit signifies type of coating and welding current to be used for this electrode per the table below. As a welder on the job site, the most critical piece of information is the current required to ensure proper setup for using the welding electrode.



Position

1.	Flat, Horizontal, Vertical, Overhead
2.	Flat and Horizontal only
4.	Flat, Horizontal, Vertical Down, Overhead

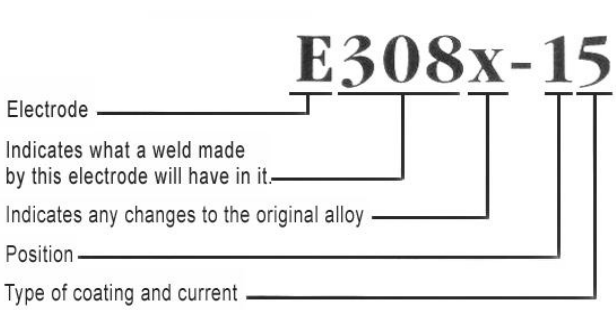
Types of coating and current

Digit	Type of Coating	Welding Current
0	cellulose sodium	DCEP
1	cellulose potassium	AC or DCEP or DCEN
2	titania sodium	AC or DCEN
3	titania potassium	AC or DCEP
4	iron powder titania	AC or DCEN or DCEP
5	low hydrogen sodium	DCEP
6	low hydrogen potassium	AC or DCEP
7	iron powder iron oxide	AC or DCEP or DCEN
8	iron powder low hydrogen	AC or DCEP
E6020	iron oxide sodium	AC or DCEP

DCEP — Direct Current Electrode Positive
DCEN — Direct Current Electrode Negative

Figure 10. Explanation of Carbon Steel Covered Electrode Classification (by Abdel Halim Galala, Public Domain)

STAINLESS STEEL ELECTRODES AND FILLER WIRE



Stainless steel covered electrodes, used in the SMAW welding process, follow the same designation as the base metal with the AISI three-digit stainless steel numbering system to identify the alloy. The general rule, when selecting a stainless steel electrode, is to match the base metal alloy when possible. At times you will not be able to match the base metal alloy and the welding alloy because an exact match does not exist. The common practice is to go to the next highest alloy number closest to the base metal alloy.

Figure 11. Explanation of Stainless Steel Covered Electrode Classification (by Unknown, Public Domain)

As in Figure 11 to the right, after the three digit alloy classification, you can find different suffixes, such as L, which signifies a low carbon material. Figure

12 below is the table for additional suffixes. In the event you find a dash plus a number after the suffix, this is used to reference the type of coating and current required to weld with this electrode.

Suffix	Changes made or additional Requirements
L	Has a lower carbon content.
H	Limited to upper range on the carbon content.
Mo	Molybdenum - pitting resistance, creep strength, ferrite increase.
Nb	Niobium added- prevents corrosion just outside of the weld bead.
Ni	Nickel added- high temperature strength, corrosion resistance, added toughness
LR	Low Residuals- lower range for C, Si, P, S,- narrower range: Cb and Mn.

Dash No.	Out of position	Bead ripple	Slag removal	Spatter level	Transfer type	Operating current	Bead profile
-x5	1(5/32')	3	3	3	Globular	DC(+)	Convex
-x6	2(5/32')	2	2	2	Globular	AC/ DC(+)	Flat
-x7	3(3/16')	1	1	1	Spray	AC/ DC(+)	Concave

Figure 12. Explanation of Stainless Steel Electrodes Classification Suffixes
(by Unknown, Public Domain)

MODULE ACTIVITY 5

Choose the correct answer.

18. Carbon steel covered electrodes are used in the SMAW welding process and .stainless steel electrodes in stick welding. T/F
19. The prefix _____________ (E, X) is used in both carbon steel and stainless steel electrode designation.
20. What is the most critical piece of information for using a welding electrode?
    a. Filler metal
    b. Tensile strength
    c. Current
    d. Position
21. When a match is not available for a base metal alloy and the welding alloy, the common practice is to use the next highest alloy number closest to the base metal alloy. T/F

4.2.2 FILLER WIRE CLASSIFICATION

GMAW and GTAW, a.k.a. MIG and TIG welding, use the same classifications system. We must find the correct product type to match the process, whether it is a spooled wire for MIG welding or a rod cut to length like we find with TIG welding.

SOLID WIRE CLASSIFICATION

The classification system for a solid wire (see Figure 13) uses an ER prefix as this filler metal is supplied for use in either an electrode or rod form. The first two numerical digits signify the tensile strength of the weld deposit. The "S" signifies that it is a solid wire. The dash followed by a number indicates specific chemistry differences that affect the weld mechanical properties. Some of the more common chemistry differences are noted by – 2, which indicates a lower level of silicone content that reduces its ability to weld over slightly contaminated or rusted materials. Another common type of chemistry is – 6, which indicates a higher level of manganese and silicone, which gives it greater cleaning action and ability to weld over contaminants without affecting weld quality. This results in the welder having a better flow of the molten puddle.

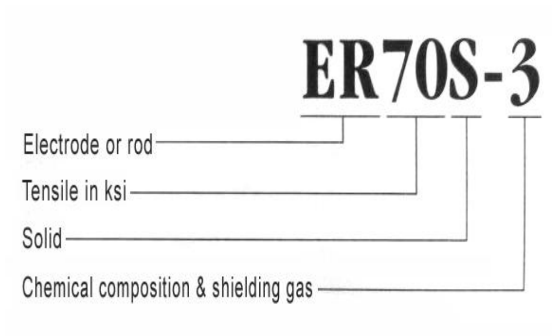


Figure 13. Explanation of Solid Wire Classification (by unknown, Public Domain)

Electrode	Shielding gas	Polarity	CVN Toughness	Wire chemical composition					
				C	Mn	Si	Ti	Zr	Al
ER70S-2	CO2	DCEP	27J @-29°C / (20ft-lbf @ -20°F)	0.07	0.90-1.40	0.40-0.70	0.05-0.15	0.02-0.12	0.05-0.09
ER70S-3	CO2	DCEP	27J @-18°C / (20ft-lbf @ 0°F)	0.06-0.15	0.9-1.40	0.45-0.70	-	-	-
ER70S-4	CO2	DCEP	not required	0.07-0.15	1.00-1.50	0.65-0.85	-	-	-
ER70S-5	CO2	DCEP	not required	0.07-0.19	0.90-1.40	0.30-0.60	-	-	0.05-0.09
ER70S-6	CO2	DCEP	27J @-29°C / (20ft-lbf @ -20°F)	0.07-0.15	1.40-1.85	0.80-1.15	-	-	-

ER70S-7	CO_2	DCEP	27J @-29℃ / (20ft-lbf @ -20°F)	0.07-0.15	1.50-2.00	0.50-0.80	-	-	-
ER70S-G	as agreed		as agreed	No requirements					
E70C-3C	CO_2	DCEP	27J @-18℃ / (20ft-lbf @ 0°F)						
E70C-3M	75-80%Ar, bal. CO_2	DCEP	27J @-18℃ / (20ft-lbf @ 0°F)						
E70C-6C	CO_2	DCEP	27J @-29℃ / (20ft-lbf @ -20°F)						
E70C-6M	75-80%Ar, bal. CO_2	DCEP	27J @-29℃ / (20ft-lbf @ -20°F)						
E70C-G(X)	as agreed								

Figure 14. Solid Wire Classification System (by Unknown, Public Domain)

TUBULAR WIRE CLASSIFICATION

FCAW, flux cored arc welding is a wire fed process that uses a certain wire type and lacks a shielding gas. This filler metal classification system is fairly simple and easily identified by a T in the third position of the system. The capital T indicates a tubular wire. Flux cored arc welding wire begins as a flat sheet that is then formed into a tube, very small in diameter, with powdered metallic flux inside. This flux functions in very much the same way as the flux on the outside of a stick electrode.

We have two major types of FCAW processes: self-shielded, where only the burning of the wire and internal flux protects the weld from external gases; or dual shielded, where we use the addition of an external shielding gas, along with the flux within the wire, to give additional protection to the weld puddle.

When looking at the weld wire classification for FCAW, we find a capital E signifying it is a current caring electrode. In the next location is a single-digit, which is an indication of tensile strength measured in 10 times KSI. For example, in Figure 15 below, the number eight it indicates that it has an 80,000 pounds per square inch of tensile strength. The next digit indicates the wire position. A number one signifies the wire can be used in all positions, while a zero indicates it is only to be used in flat or horizontal position. Next, we find the T, indicating that it is a tubular wire. The next remaining positions indicate the filler metals usability and performance capabilities. For example, a – 1 indicates use of an external shielding gas and its ability to be used as a single pass weld wire or for a multilayer weld as required. If a – 2 is present we find it to be ideal for single pass welds only with use of an external shielding gas. When we see a –4 it indicates it is a self-shielded wire which works well producing a large molten weld puddle which equates to high deposition rates. In the event we see a –7 in indicates it is a self-shielded while capable of all position welding can be used for single or multi pass welds.

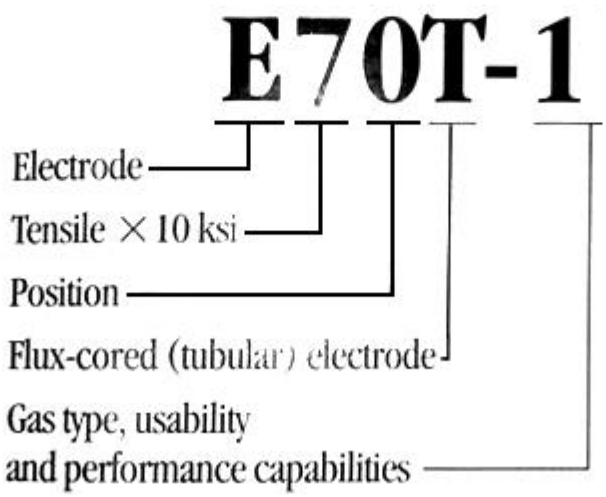


Figure 15. Explanation of Tubular Wire Classification (by Unknown, Public Domain)

POSITION, SHIELDING, POLARITY, APPLICATION REQUIREMENT

AWS	position	shielding	current	App.	AWS	position	shielding	current	App.
E70T-1	H, F	CO2	DC(+)	M	E70T-9	H, F	CO2	DC(+)	M
E70T-1M	H, F	Mix Gas*	DC(+)	M	E70T-9M	H, F	Mix Gas*	DC(+)	M
E71T-1	H,F,VU.OH	CO2	DC(+)	M	E71T-9	H,F,VU.OH	CO2	DC(+)	M
E71T-1M	H,F,VU.OH	Mix Gas*	DC(+)	M	E71T-9M	H,F,VU.OH	Mix Gas*	DC(+)	M
E70T-2	H, F	CO2	DC(+)	S	E70T-10	H, F	Mix Gas*	DC(-)	S
E70T-2M	H, F	Mix Gas*	DC(+)	S	E70T-11	H, F	Mix Gas*	DC(-)	M
E71T-2	H,F,VU.OH	CO2	DC(+)	S	E71T-11	H,F,VD.OH	Mix Gas*	DC(-)	M
E71T-2M	H,F,VU.OH	Mix Gas*	DC(+)	S	E70T-12	H, F	CO2	DC(+)	M
E70T-3	H, F	Mix Gas*	DC(+)	S	E70T-12M	H, F	Mix Gas*	DC(+)	M
E70T-4	H, F	Mix Gas*	DC(+)	M	E71T-12	H,F,VU.OH	CO2	DC(+)	M
E70T-5	H, F	C02	DC(+)	M	E71T-12M	H,F,VU.OH	Mix Gas*	DC(+)	M

E70T-5M	H, F	Mix Gas*	DC(+)	M	E61T-13	H,F,VD.OH	NONE	DC(-)	S
E71T-5	H,F,VU.OH	CO2	DC(+,-)	M	E71T-13	H,F,VD.OH	NONE	DC(-)	S
E71T-5M	H,F,VU.OH	Mix Gas*	DC(+,-)	M	E71T-14	H,F,VD.OH	NONE	DC(-)	S
E70T-6	H, F	NONE	DC(+)	M	EX0T-G	H, F	Not specified		M
E70T-7	H, F	NONE	DC(-)	M	EX1T-G	ALL	Not specified		M
E71T-7	H,F,VU.OH	NONE	DC(-)	M	EX0T-GS	H, F	Not specified		S
E70T-8	H, F	NONE	DC(-)	M	EX1T-GS	ALL	Not specified		S
E71T-8	H,F,VU.OH	NONE	DC(-)	M					

Figure 16. Tubular Wire Classification System (by Unknown, Public Domain)

EXPLORE: UNDERSTANDING LOW-ALLOY-STEEL

MODULE ACTIVITY 6

Choose the correct answer.

22. The classification system for a solid wire uses an ER prefix. T/F
23. The first two numerical digits for both solid and tubular wire classification refer to the tensile strength of the weld. T/F
24. Tubular wire classification always has this in the fourth position of the system.
    a. E
    b. T
    c. 1
    d. 7

4.2.3 ELECTRODE MANUFACTURER SUPPLIED DATA

When it comes to high-quality welding, the welding codes are referenced to ensure the quality and consistency of the work. The American Welding Society (AWS) D1 .1 structural steel welding code is commonly referred to as a reference in many other codes. As we refer to our codes to determine how we need to approach a welding task, we need to refer back to electrode codes of the manufacturer of the electrode for the specifics of amperage voltage and ideal set up and use. It is best that we get the information directly from the manufacturer for the simple reason that the manufacturer supplied data is going to be the best chance of getting the best results from that product. The manufacture wants their product to perform at its peak and will provide the parameters to do so. With so many different manufacturers in the market, each one puts a slightly different spin on their product and its chemistry, to give them an edge over the competition. Therefore, to find the ideal parameters for that product, it only makes sense that we get it specifically from the manufacture of the electrode.

Each manufacturer tends to make multiple versions of a particular product, such as an E7018. This is a very common electrode, but by manipulating the chemistry, they can alter the way it performs and acts in different applications and welding positions. The AWS, through their electrode specifications, outlines exactly what is required for an electrode and its performance and strength characteristics to be considered a 7018 electrode, but there is enough variance allowed so the manufacturers can tweak the chemistry according to what they want to achieve. With each of these versions, it is common to find different trade names given to the different version. To avoid being confused by all the different trade names, we need to refer back to the AWS classification system for the number, which identifies exactly what type of electrode it is. We can then reference specific data from the manufacture for their specialty line to determine the electrode's intended application.

Additional information we can gain from the electrode manufacturer will be:

- number of welding electrodes per pound
- number of inches of weld per welding electrode
- welding amperage range setting for each size of welding electrode
- manipulation techniques ideal for the electrode
- welding positions this electrode is suited for
- welding codes this electrode is qualified to work under
- different types of base metals that be welded
- how it reacts to surface contaminants, such as rust, oil, or paint
- characteristics of the weld's penetration into the joint
- requirements for preheating or post heating
- hard data from the lab concerning physical strengths such as ultimate strengths, tensile, yield point, yield strengths, elongation, and impact strengths
- chemistry

All of this information can be very important throughout the process for the welder, manufacturer, fabricator, estimator, and purchasing agent. With this data, they can determine quantities of product required for a particular job or component as well as what this electrode will produce and what to expect out of its performance. We can also plan the work around such things as surface cleanliness required, requirements for post weld cleanup to remove spatter or burn marks, or slag depending on the process. If we are to adhere to code quality, we must adhere to the manufacturer's recommended parameters regarding voltages, amperage, wire feed speeds, and travel speeds.

MODULE ACTIVITY 7

Choose the correct answer.

25. It is important to refer to the manufacturers electrode data. T/F
26. The AWS does not have electrode specifications that outline electrode performance and strength requirements. T/F

MAJOR CONCEPTS

KEY CONCEPTS

- The amount of carbon in steel has a large effect on the hardness, strength, and other characteristics of the steel which determines the specific type of steel.
- There are a number of different classification or numbering systems that have been developed over the years in reference to the different grades of steel.
- There are different techniques that can be used to quickly and easily identify a type of material by major categories
- Carbon steel covered electrodes are used in stick welding. Stainless steel covered electrodes, used in the SMAW welding process. Each type of electrode has its own classification system.
- The appropriate filler wire must match the chosen welding process, whether it is a spooled wire for MIG welding or a rod cut to length for TIG welding, by using the filler wire classification system.
- It is best to consult the manufacturer's product information for an electrode to get the best results from the electrode. The manufacture wants their product to perform at its peak and will provide the parameters to do so.

KEY TERMS

Alloy
Carbon
Equivalent
Electrode
Flux
Filler
Metals
Base
Metal

MODULE REINFORCEMENT

ASSESSMENT

True/False: Indicate whether the statement is true or false.

____ 1. SAE stands for the Society of Automotive Engineers.
____ 2. Some types of steel are determined by the amount of carbon in them.
____ 3. The most widely used filler metal numbering and lettering system was developed by ASTM.
____ 4. Carbon equivalence can be used to determine whether special procedures are needed to make an acceptable weld.
____ 5. It is important to refer to the manufacturer's electrode data.

Multiple Choice: Identify the choice that best completes the statement or answers the question.

____ 1. The classification system for ferrous metals combines the ____ and ___ systems.
a) SAE, UNS
b) ASTM, ASME
c) SAE, AISI
d) ASME, SAE

____ 2. A ____ steel has a carbon content of less than 0.30%.
a) Mild carbon
b) Medium carbon
c) High carbon
d) Tool

____ 3. A ____ of carbon content makes a material hard and brittle.
a) High level
b) Medium level
c) Low level
d) Extremely low level

____ 4. ____ is the most common type of stainless steel.
a) Ferritic
b) Austenitic
c) Martenitic
d) Precipitation Hardening

____ 5. ____ cast iron requires proper preheating and postweld cooling temperatures and rates must be maintained to retain its properties.
a) Alloy
b) Malleable
c) Nodular
d) Gray

____ 6. The spark test is used to ____.
a) Determine the carbon content of a metal
b) Determine the brittleness of a metal
c) Identify the alloy in a metal
d) Identify a metal

____ 7. Which statement best describes a 1020 steel?
a) The first digit of one signifies it is a carbon steel
b) The second digit of zero signifies there is no additional alloy
c) The last two digits signifies it has .20% carbon
d) All the above

____ 8. Filler metal selection can be influenced by ____.
a) Type of current
b) Joint design
c) Surface condition
d) All of the above

____ 9. In E-6010, the one signifies ____.
a) Tensile strength
b) Type of coating and current
c) Welding position
d) Electrode

____ 10. With stainless steel electrodes, the three digit number following the initial letter prefix represents the ____.
a) Tensile strength
b) Stainless steel
c) Welding current
d) Shielding gas

Completion: Complete each statement.

1. ER70S-3 is a classification for ___________________.

2. In E70T-1, the T signifies ____________________.

Short Answer: Give a brief answer for each question below.

1. Why are high carbons steels preheated before welding?

2. Explain the steel classification number 1030.

ANSWER KEY TO MODULE ACTIVITIES

ACTIVITY 1

1. T

2. F
3. High carbon steel
4. a
5. T

ACTIVITY 2

6. F
7. Four to five
8. c

ACTIVITY 3

9. T
10. F
11. Cold rolled steel
12. d
13. c
14. b

ACTIVITY 4

15. F
16. T
17. d

ACTIVITY 5

18. F
19. E
20. c
21. T

ACTIVITY 6

22. T
23. F
24. b

ACTIVITY 7

25. T

26. F

ANSWERS TO ASSESSMENT QUESTIONS

TRUE/FALSE (textbook page reference)

1.	ANS:	T	PTS:	1	REF:	671
2.	ANS:	T	PTS:	1	REF:	671
3.	ANS:	F	PTS:	1	REF:	689
4.	ANS:	T	PTS:	1	REF:	691
5.	ANS:	T	PTS:	1	REF:	690

MULTIPLE CHOICE

1.	ANS:	c	PTS:	1	REF:	671
2.	ANS:	a	PTS:	1	REF:	671
3.	ANS:	a	PTS:	1	REF:	673
4.	ANS:	b	PTS:	1	REF:	674-675
5.	ANS:	c	PTS:	1	REF:	676
6.	ANS:	d	PTS:	1	REF:	683
7.	ANS:	d	PTS:	1	REF:	671
8.	ANS:	d	PTS:	1	REF:	693
9.	ANS:	c	PTS:	1	REF:	696
10.	ANS:	b	PTS:	1	REF:	701

COMPLETION

1. ANS: Solid wire filler metal

PTS: 1 REF: 699

2. ANS: Tubular wire

PTS: 1 REF: 700

SHORT ANSWER

1. ANS: To prevent the heat-affected zone from becoming very hard and brittle martensite.
PTS: 1 REF: 673

2. ANS: A carbon steel with no additional alloy that has .30% carbon
PTS: 1 REF: 671

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Paul Phelps	Video 1. Material Identification Techniques 1	http://youtu.be/1TKN8I7P8qc	CC BY-SA 4.0
Paul Phelps	Video 2. Material Identification Techniques 2	https://youtu.be/D2Y8XuYyt1U	CC BY-SA 4.0
Paul Phelps	Video 3. Material Identification Techniques 3	https://youtu.be/bf_8fuQ9bz8	CC BY-SA 4.0
Abdel Halim Galala	Figure 10. Explanation of Carbon Steel Covered Electrode Classification	http://cr4.globalspec.com/thread/50732/welding-electrodes	Public Domain
Unknown	Figure 11. Explanation of Stainless Steel Covered Electrode Classification	http://www.hkweld.com/sdp/170755/4/cp-1009246/0.html	Public Domain
Unknown	Figure 12. Explanation of Stainless Steel Electrodes Classification Suffixes	http://www.hkweld.com/sdp/170755/4/cp-1009246/0.html	Public Domain
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Unknown	Figure 14. Solid Wire Classification System	http://www.hkweld.com/sdp/170755/4/cp-1009246/0.html	Public Domain

Unknown	Figure 15. Explanation of Tubular Wire Classification	http://www.hkweld.com/sdp/170755/4/cp-1009246/0.html	Public Domain
Unknown	Figure 16. Tubular Wire Classification System	http://www.hkweld.com/sdp/170755/4/cp-1009246/0.html	Public Domain

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