Material Science in Welding

Objective:

1. Define metallurgy terms.
2. Compare and contrast ferrous and nonferrous metals.
3. Describe three physical properties of metals.
4. Describe five mechanical properties of metals.
5. Compare and contrast different types of ferrous metals based on carbon content and uses.

Terms:

alloy: A material having metallic characteristics and made up of two or more elements, one of which is a metal.

brittleness: The tendency of a material to fail suddenly by breaking when stressed, without permanent deformation of the material before failure.

coefficient of thermal expansion/contraction: The ratio showing how much any dimension of a given material (including metal) changes as temperature changes (measurement of expansion and contraction per heat transfer). For example, when a material is heated, it either expands or contracts. The amount this occurs within a given temperature range is called the coefficient of expansion.

compressive strength: A metal's ability to resist forces that attempt to squeeze or crush it.

distortion: The undesired alteration of a part usually caused by mechanical or thermal means; may also be applied to wave forms.

ductility: The tendency of a material to physically deform under an applied mechanical stress.

electrical conductivity: The rate at which electric current will flow through the metal.

ferrite (Fe): Pure iron crystal structure.

ferrous metals: Metals that contain iron as the primary element. Ferrous metals are the most common type of welded metal.

hardness: The ability of a material to resist indentation, penetration, abrasion and/or scratching.

heat affected zone (HAZ): The portion of the base metal that has not been melted but whose mechanical properties have been altered by the heat of welding.

Terms Cont'd.:

magnetic: A material that can be attracted to magnets; magnetic forces can be used to weld workpieces together.

melting point: The temperature at which a solid becomes a liquid. Welding requires metals to reach their melting points.

modulus of elasticity: The ratio of tensile stress to the strain it causes, within that range or elasticity where there is a straight-line relationship between stress and strain. The higher the modulus, the lower the degree of elasticity.

nonferrous metal: A metal that does not contain iron. Nonferrous metals are more difficult to weld than ferrous metals.

shear strength: The ability of a material to withstand opposing forces.

specific heat: The quantity of heat necessary to raise a unit mass of a substance by one degree Celsius (1.8°F). If twice as much energy is added to a substance, its temperature should increase by twice as much. Specific heat is usually expressed in joules.

tensile strength: The ability of the metal to resist forces that attempt to pull it apart or stretch it. thermal conductivity: The rate at which heat flows through metal.

thermal conductivity: The rate at which heat flows through metal.

thermal expansion: The increase in the dimensions of a metal due to an increase in its temperature.

torsional strength: The ability of a material to withstand twisting forces (torque).

yield strength: The ability of a metal to tolerate gradual progressive force without permanent deformation.

Introduction

We use a wide variety of metals, including steel, cast iron, aluminum and stainless steel, to build things. Not surprisingly, different metals react to the welding process in different ways. In addition, differences in their chemical properties make some metals more suitable than others are for specific applications. For example, some metals are excellent conductors of heat and electricity, some are used to coat other metals, and still others are used in the food industry. Welders must be very familiar with the wide range of properties of metals in order to create the best weld possible.

Types of Metal

There are two primary classifications of metals, *ferrous* and *nonferrous*.

Ferrous Metals: The primary element in ferrous metals is iron. Chemical terms for iron, such as the chemical symbol (Fe) and the names of iron compounds, come from the Latin word for iron, ferrum. *Ferrite* is the form of pure iron found at room temperature.

Nonferrous: The primary elements in nonferrous metals are not iron. Table 1 lists a variety of common nonferrous metals.

Table 1. Nonferrous Metals

1.	13 Aluminum **Al** 26.982	Lightweight, good conductor of heat and electricity
2.	29 Copper **Cu** 63.546	Excellent conductor of heat and electricity, resistant to corrosion
3.	12 Magnesium **Mg** 24.305	Lightweight, lighter than aluminum; used to build lightweight components to save energy; will burn violently and produces toxic magnesium oxide smoke.
4.	28 Nickel **Ni** 58.69	Used as an alloy with iron to produce nickel steel and stainless steel; produces tough, higher-strength materials.
5.	50 Tin **Sn** 118.71	Used in the food and agricultural industries to protect products as a coating or plating

Table 1, Cont'd. Nonferrous Metals		
6.		Common use is to coat metallic materials like sheets of steel, to prevent corrosion (rust); galvanized steel has a zinc coating. Toxic to weld.
7.		Lightweight, high-strength metal; used to save energy by reducing material weight.

All ferrous metals are iron-based, and therefore it is common for these types of iron and steel to be strongly *magnetic*. However, nonferrous metals contain no iron, and therefore, most have very weak to no magnetic properties. Alloys are metals made of a combination of metals and other elements that substantially change their physical and mechanical properties. An example is stainless steel, an alloy made of iron, nickel and chromium.

Physical Properties of Metal

The physical properties of metals are characteristics observed when some form of energy changes the metal.

Examples of physical properties:

- Magnetic: having the tendency to react to magnetism; magnetic forces can be used to weld workpieces together.
- *Melting point*: the temperature at which metals transform from solid to liquid.
- *Thermal conductivity*: the rate at which heat moves through the metal; aluminum is a very good thermal conductor.
- *Electrical conductivity*: the rate at which electricity conducts through metal; copper is a very good conductor of electricity.

The physical properties of metals determine what applications suit different metals, and helps identify the various metals. These properties can also determine welding principles and practices.

Mechanical Properties of Metal

Mechanical properties refer to the characteristics of a metal that display when a force is applied to the material.

Examples of mechanical properties:

- *Tensile strength*: the ability of the metal to resist forces that attempt to pull it apart or stretch it. Material that supports a ceiling-mounted shop hoist would need good tensile strength.
- *Compressive strength*: a metal's ability to resist forces that attempt to squeeze or crush (compress) it. A steel support under a bridge would need to have good compressive strength.
- *Hardness*: the ability of a material to resist being indented and punctured. A bulldozer blade would need to be hard to resist damage from rocks and other objects.
- *Ductility*: the ability of metal to become permanently deformed without failure. Sheet metal for a fender needs to be ductile so it can be shaped.
- *Brittleness*: very nearly the opposite of ductility. The tendency of a material to fail suddenly by breaking when stressed, without permanent deformation of the material before failure. A shock absorber mount on a truck would need to lack brittleness. Brittleness is an undesirable mechanical property in most applications of various metals
- *Shear strength*: the ability of a material to withstand opposing forces. Bolts fastening two plates of metal together need to have good shear strength.
- *Torsional strength*: the ability of a material to withstand twisting forces (torque). A truck driveshaft or axle needs to have good torsional strength.

The ability of metals to resist or withstand these mechanical properties directly applies in determining the use of these metals. For example, an axle shaft needs to withstand twisting forces, so high torsional strength steel should be used.

Composition of Ferrous Metals

Steel is iron that has carbon and other alloys added to it to change the properties of the metal. Use of carbon increases the hardness and strength of steel. Table 2 describes the characteristics and properties of several types of iron-based materials.

Table 2. Composition Of Ferrous Metals		
Ferrous Metal	**% Carbon**	**Characteristics/Properties**
Wrought Iron	<0.003%	• Basically pure iron • Superior corrosion and fatigue resistance • Not many common uses, some furniture.
Low Carbon Steel	0.05% – 0.30%	• Also called "mild" steel • Relatively soft, ductile • Easily worked, formed, machined • Easily weldable • 0.05 – 0.15% C used for common types of nails, bolts, pipe and sheets for pressing and stamping • 0.15 – 0.30% C use for bars, plates and structural shapes for building projects.
Medium Carbon Steel	0.30% – 0.55%	• Moderate strength characteristics • Weldable • 0.30% – 0.40%C used for axles, connecting rods, shafting • 0.40 – 0.55%C used for crankshafts, rails, boilers
High Carbon Steel	0.55% – 0.80%	• Strong and hard • Does not bend • Can be heat treated • 0.55 – 0.70% C used for tools which are hammered, pounded • 0.70 – 0.80% C used for punches, drills, chisels, hammers, etc., • Difficult to weld
Very High Carbon Steel (Tool Steel)	0.80% –1.70%	• Very hard and strong (increases as % carbon increases) • Higher quality tools • Often has alloying metals added • Used for drills, files, knives, shear blades, metal cutting saws, etc. • Very difficult to weld
Cast Iron	1.8%– 4.3%	• Not considered a steel • Very hard, brittle; low bending strength, but can be heat treated • Used for machinery, engine, transmission housings • Some types are weldable but require special techniques such as pre – and post-heating

Classifications of Steel

The Society of Automotive Engineers (SAE) and the American Iron and Steel Institute (AISI) have developed a four-digit classification system for steels (see Figure 1):

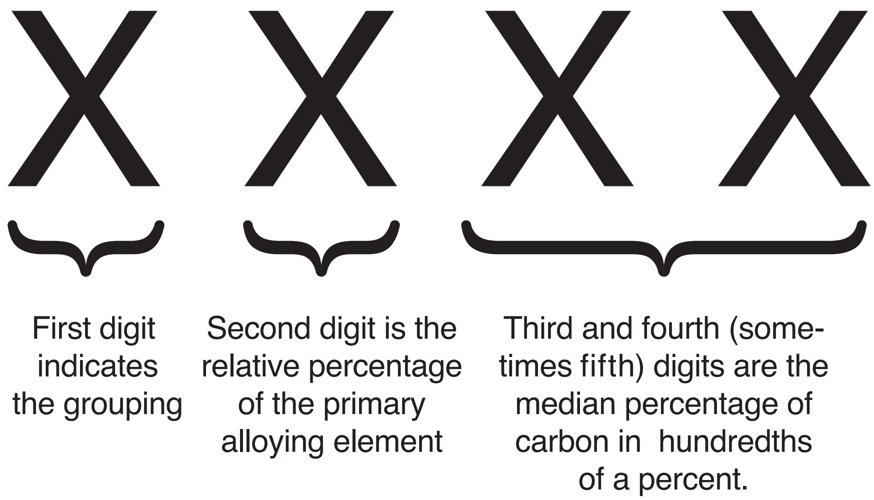

Figure 1. Classification Of Steel

The SAE groups of steels are:

- Carbon Steels 10XX and 11XX
- Manganese Steels 13XX and 15XX
- Nickel Steels 23XX and 25XX
- Nickel-Chromium Steels 31XX, 33XX
- Molybdenum Steels 40XX, 41XX, etc.
- Chromium Steels 51XX, 52XX
- Chromium-Vanadium Steel 61XX
- Multiple Alloy Steels 8XXX, 9XXX

Therefore, an AISI/SAE 1018 steel is a relatively pure carbon steel that has a 0.18% carbon content, making it a low carbon (mild) steel often used in shafts, pins, parts or agricultural equipment. An AISI/SAE 4130 steel is considered a “Chrome-Moly” steel with a 0.30% carbon content often used for bicycle frames, aircraft parts and welded tubing used in transportation of pressurized gas.

ASTM International

ASTM International is an international standards organization that sets standards for a variety of products, systems, materials and services. One of these materials is carbon steel. See Table 3 for carbon steel grade classifications.

Table 3. Carbon Steel Grade Classifications	
Designation	**Title**
A36	Carbon structural steel
A131	Structural steel for ships
A242	High-strength low-alloy structural steel
A283	Low and intermediate tensile strength carbon steel plates
A328	Steel sheet piling
A514	High-yield-strength, quenched, and tempered alloy steel plate, suitable for welding
A529	High-strength carbon-manganese steel of structural quality
A690	High-strength low-alloy nickel, copper, phosphorus steel H-piles and sheet piling with atmospheric corrosion resistance for use in marine environments

Distortion

Metals expand when heated and contract (shrink) upon cooling. *Distortion* occurs when a metal does not return to its original shape and/or position. Generally, you cannot stop distortion from occurring, but you can work with the metal to control it. Distortion is often a big challenge when fabricating a metal project.

During the heating and cooling cycle inherent in the welding process, *thermal expansion* of the weld metal and adjacent base material is not uniform. This produces stresses in the metals that cause distortion. The degree of distortion depends on the stresses generated. Several physical and mechanical properties of the welding metals affect how they expand and contract as they are heated and cooled. As the heat in a weld area increases, the *yield strength*, *modulus of elasticity* and thermal conductivity of steel all decrease, while its *coefficient of thermal expansion* and *specific heat* increase.

Heat Affected Zone

Figure 2 shows the areas affected by heat input during the welding process. As the illustration depicts, the *heat affected zone (HAZ)*, is an area in the base metal that, while not melted, still has had its properties altered by the heat of welding. The high temperatures from the welding process followed by re-cooling causes this change, which extends outward from the weld interface. These areas can vary in size and levels of intensity and tend to cause a reduction in the strength of the material through the zone.

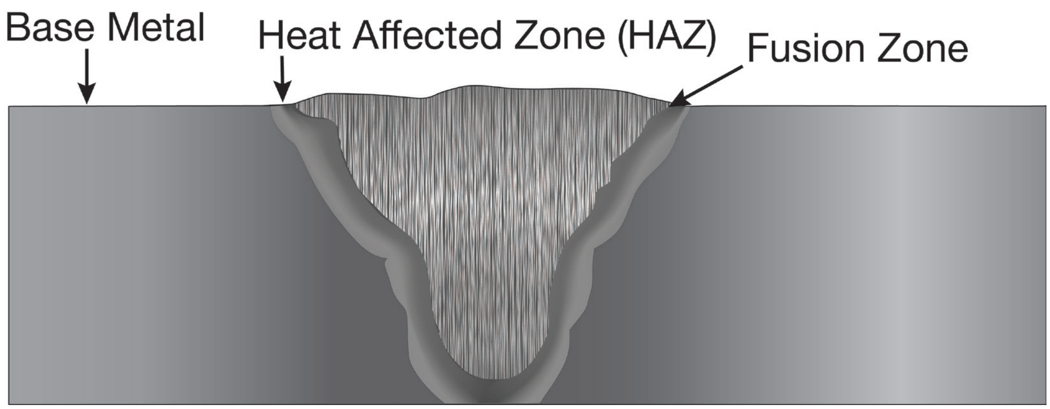

Figure 2. Heat Affected Zone

Conclusion

The wide range of properties of metals makes them quite versatile. For instance:

- A less-malleable metal would be necessary for a construction tool.
- Metals with more luster are ideal for jewelry.
- Cookware requires a metal that is a good conductor of heat.

Knowing at least the most basic properties of metals, as well as how different metals react to the welding process allows welders to make quality welds.

Material Science in Welding

Course: Principles of Welding

Objective(s):

1. Define metallurgy terms.
2. Compare and contrast ferrous and nonferrous metals.
3. Describe three physical properties of metals.
4. Describe five mechanical properties of metals.
5. Compare and contrast different types of ferrous metals based on carbon content and uses.

Resources:

Handouts

- ☐ AQ: Material Science in Welding Student Assessment

Reference Materials

- ☐ LP: Material Science in Welding
- ☐ SR: Material Science in Welding Student Reference
- ☐ PPT: Material Science in Welding

Terms:

alloy: A material having metallic characteristics and made up of two or more elements, one of which is a metal.

brittleness: The tendency of a material to fail suddenly by breaking when stressed, without permanent deformation of the material before failure.

coefficient of thermal expansion/contraction: The ratio showing how much any dimension of a given material (including metal) changes as temperature changes (measurement of expansion and contraction per heat transfer). For example, when a material is heated, it either expands or contracts. The amount this occurs within a given temperature range is called the coefficient of expansion.

compressive strength: A metal's ability to resist forces that attempt to squeeze or crush it.

distortion: The undesired alteration of a part usually caused by mechanical or thermal means; may also be applied to wave forms.

ductility: The tendency of a material to physically deform under an applied mechanical stress.

electrical conductivity: The rate at which electric current will flow through the metal.

ferrite (Fe): Pure iron crystal structure.

ferrous metals: Metals that contain iron as the primary element. Ferrous metals are the most common type of welded metal.

hardness: The ability of a material to resist indentation, penetration, abrasion and/or scratching.

heat affected zone (HAZ): The portion of the base metal that has not been melted but whose mechanical properties have been altered by the heat of welding.

magnetic: A material that can be attracted to magnets; magnetic forces can be used to weld workpieces together.

melting point: The temperature at which a solid becomes a liquid. Welding requires metals to reach their melting points.

modulus of elasticity: The ratio of tensile stress to the strain it causes, within that range or elasticity where there is a straight-line relationship between stress and strain. The higher the modulus, the lower the degree of elasticity.

nonferrous metal: A metal that does not contain iron. Nonferrous metals are more difficult to weld than ferrous metals.

shear strength: The ability of a material to withstand opposing forces.

specific heat: The quantity of heat necessary to raise a unit mass of a substance by one degree Celsius (1.8°F). If twice as much energy is added to a substance, its temperature should increase by twice as much. Specific heat is usually expressed in joules.

tensile strength: The ability of the metal to resist forces that attempt to pull it apart or stretch it. thermal conductivity: The rate at which heat flows through metal.

thermal conductivity: The rate at which heat flows through metal.

thermal expansion: The increase in the dimensions of a metal due to an increase in its temperature.

torsional strength: The ability of a material to withstand twisting forces (torque).

yield strength: The ability of a metal to tolerate gradual progressive force without permanent deformation.

Situation:

Prior to this lesson, students should have completed the Welding Technology lesson.

Interest Approach (Motivation):

1. Divide students into small groups.
2. Briefly review the terms listed on the first page of the student reference.
3. Direct students to sort the vocabulary words into categories of their choosing. Advise them that they will need to justify their groupings.
4. Once all groups have finished, ask a volunteer from each group to share their work. Discuss the appropriateness of the categories.

Teacher Tip: Explain that it is important to be familiar the specific language of welding in order to make sense of documents used and to communicate with others in the field.

Instructional Directions/Materials	Content Outline, Instructional Procedures and/or Key Questions
Recommend student-inquiry method of instruction, including guided discussion, readings, and demonstration-performance. Use examples, real examples of welds, projects, tools, supplies. Keep it simple. The best instructors are able to clearly describe processes using basic terms, simple explanations and lots of applied examples. Distribute a copy of **SR: Material Science in Welding** Student Reference and provide 15-18 minutes for reading and review. Supervised reading with questioning— Following reading, probe student thinking to determine the extent of student knowledge on the topic. Encourage students to analyze concepts and increase comprehension.	
Begin every lesson with a short review of previous learning—daily reviews strengthen previous learning and lead to fluent recall. Show **PPT: Material Science in Welding** Show slide #2.	**Use the lines below to list previous material for review.** • ______________________________ • ______________________________ • ______________________________ • ______________________________ • ______________________________

Instructional Directions/Materials	Content Outline, Instructional Procedures and/or Key Questions

Show **PPT: Material Science in Welding**

Show slide #3.

Objectives

1. Define metallurgy terms.
2. Compare and contrast ferrous and nonferrous metals.
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Show **PPT: Material Science in Welding**

Show slide #4-5.

Types of Metals

Metals can be classified as being either ferrous or nonferrous.

- Ferrous metals
  - » Primary metal – iron
  - » Chemical symbol: Fe
  - » Ferrite: the form of pure iron found at room temperature
- Nonferrous: the primary elements in the metals are not iron
  - » Aluminum
  - » Copper
  - » Magnesium
  - » Nickel
  - » Tin
  - » Zinc
  - » Titanium
- Generally, ferrous metals are magnetic and most nonferrous metals are not.
- Alloys: Metals made of a combination of metal elements and other materials that substantially change their physical and mechanical properties
  - » Example: stainless steel, made of iron, nickel and chromium

Instructional Directions/Materials | Content Outline, Instructional Procedures and/or Key Questions

Show **PPT: Material Science in Welding**

Show slide #6.

Physical Properties of Metals

- Characteristics observed when some form of energy changes the metal.
- Determine what different metals can be used for and can also be used to help identify metals.
- Can also determine welding properties and practices.
- Examples:
  - » Magnetic
  - » Melting point
  - » Thermal conductivity
  - » Electrical conductivity

Show **PPT: Material Science in Welding**

Show slide #7.

The ability of metals to resist and withstand these mechanical properties is directly applied when determining what metals are used for. For example, steel would need to be used for an axle driveshaft to withstand twisting forces.

Mechanical Properties of Metals

- The characteristics of a material that are displayed when a force is applied to the material
- Examples:
  - » Tensile strength
  - » Compressive strength
  - » Hardness
  - » Ductility
  - » Brittleness
  - » Shear strength
  - » Torsional strength

Instructional Directions/Materials

Show **PPT: Material Science in Welding**

Content Outline, Instructional Procedures and/or Key Questions

Application Examples

Tensile strength:

- A support that hangs a shop ceiling hoist would need good tensile strength or it wouldn't hold the weight of the ceiling hoist.

Compressive strength:

- A steel support under a bridge would need to have good compression strength to avoid collapse.

Hardness:

- A bulldozer blade would need to hard to cut through the soil.

Ductility:

- Sheet metal for a fender or shield needs to ductile so it can be shaped.

Brittleness:

- A shock absorber mount on a truck would need to lack brittleness or it would shatter.

Shear strength:

- Bolts fastening two plates of metal together need to have good shear strength or the bolts will break.

Torsional strength:

- A truck driveshaft or axle needs to have good torsional strength or the amount of torque will break the shaft.

Instructional Directions/Materials

Content Outline, Instructional Procedures and/or Key Questions

Formative Assessment: Physical and Mechanical Properties of Metal

1. Group students into teams of four, assigning each student a number 1-4.
2. Direct students to create two lists: physical properties of metal and mechanical properties of metal.
3. On the board, create a list titled “Physical.”
4. When the allotted time is up,call out a number from 1-4. That student then shares one of the group’s answers for the physical properties of metal. As each group shares, list the answer on the board.
5. Continue to call out numbers until all students have had a chance to respond or all properties have been listed.
6. Repeat the process for the mechanical properties.

Show **PPT: Material Science in Welding**

Show slide #8-10.

Composition of Ferrous Metals

Steel is iron (ferrite) that has carbon added to it to change the properties of the metal. The carbon is used to increase the hardness of steel. The types of carbon steel metals:

- Wrought Iron:
  - » <0.003% carbon
  - » Basically pure iron
  - » Not many common uses, some older furniture.
- Low Carbon Steel:
  - » <0.30% carbon
  - » Also called “mild” steel
  - » Relatively soft, malleable, workable
  - » Easily weldable
  - » Used for common types of nails, bolts, building projects

Instructional Directions/Materials	Content Outline, Instructional Procedures and/or Key Questions

- Medium Carbon Steel:
    - 0.30% - 0.55% carbon
    - Moderate strength characteristics
    - Weldable
    - Used for structural pieces, angle iron, I- beams, etc.,
    - Sometimes referred to as “structural” steel -- used for equipment frames
- High Carbon Steel:
    - 0.55% - 0.80% carbon,
    - Hard
    - Does not bend
    - Can be heat treated
    - Used for tools which are hammered, pounded
    - Used for drills, chisels, hammers, etc.
    - Difficult to weld
- Tool Steel (Very High Carbon Steel):
    - 0.80% –1.70% carbon
    - Very hard
    - Higher quality tools
    - Often has alloying metals added
    - Used for drills, files, saws, many other tools
    - Very difficult to weld
- Cast Iron
    - 1.8%– 4.3 % carbon,
    - Not considered a steel
    - Very hard
    - Brittle
    - Low bending strengths, but can be heat treated
    - Used for machinery, engine, transmission housings
    - Some types are weldable but require special techniques such as pre- and post-heating

Instructional Directions/Materials

Show **PPT: Material Science in Welding**

Show slides #11-13.

Content Outline, Instructional Procedures and/or Key Questions

Classifications of Steel

The Society of Automotive Engineers (SAE) developed a four digit classification system for steel metals:

- First digit: indicates the grouping
- Second digit: the relative percentage of the primary alloying element
- Third and fourth (sometimes fifth) digits: the median percentage of carbon in hundredths of a percent

The SAE groups of steels:

- Carbon Steels 10XX
- Manganese Steels 13XX and 15XX
- Nickel Steel 23XX and 25XX
- Nickel-Chromium Steels 31XX, 33XX
- Molybdenum Steels 40XX, 41XX, etc.
- Chromium Steels 51XX, 52XX
- Chromium-Vanadium Steel 61XX
- Multiple Alloy Steels 8XXX, 9XXX

Steel Classification Examples:

- SAE 1018 steel
  - » Relatively pure carbon steel
  - » Has a 0.18% carbon content
  - » Low carbon (mild) steel
  - » Often used in shafts, pins, part or agricultural equipment
- SAW 4130 steel
  - » Considered a “Chrome-Moly” steel
  - » Has a 0.30% carbon content
  - » Often used in aircraft and welded tubing applications

Instructional Directions/Materials	Content Outline, Instructional Procedures and/or Key Questions

Show **PPT: Material Science in Welding**
 	
Show slide #14.
	ASTM International
	• International standards organization
	• Sets standards on a variety of products, systems, materials and services – including carbon steel
	• Carbon steel grade classifications
	  » A36 – carbon structural steel
	  » A131 – structural steel for ships
	  » A242 – high-strength low-alloy structural steel
	  » A283 – low and intermediate tensile strength carbon steel plates
	  » A328 – steel sheet piling
	  » A514 – high-yield-strength, quenched, and tempered alloy steel plate, suitable for welding
	  » A529 – high-strength carbon-manganese steel of structural quality
	  » A690 – high-strength low-alloy nickel, copper, phosphorus steel h-piles, and sheet piling with resistance for use in marine environments

	Formative Assessment: Ferrous vs. Nonferrous 1. Divide students into small groups. 2. Instruct students to create a graphic organizer (like a Venn diagram or a T-chart) to compare ferrous and nonferrous metals. 3. Collect these to assess student understanding.

Instructional Directions/Materials

Content Outline, Instructional Procedures and/or Key Questions

Show **PPT: Material Science in Welding**

Show slides #15.

Metals expand when heated and upon cooling, the metals contract (shrink).

Generally, you cannot stop distortion; you can only work with the metal to control it. Distortion oftentimes is a big challenge when fabricating a metal project.

Distortion

- When a metal does not return to its original shape and/or position.
- Degree of distortion in a weldment related to stresses generated from the non-uniform expansion and contraction of weld metal and adjacent base material during heating and cooling cycle of welding process.
- As the heat in a weld area increases:
  - » Yield strength, modulus of elasticity and thermal conductivity decreases
  - » Coefficient of thermal expansion and specific heat increases

Show **PPT: Material Science in Welding**

Show slides #16.

A very important principle to help control distortion is to keep the HAZ as small as possible. This is a major reason why we often use multi-pass welds, as a single, large weld will create more distortion as the weld cools and contract.

Heat Affected Zone (HAZ)

- An area in the base metal which, while not melted, still has had its microstructure and properties altered by welding.
  - » High temperatures from welding process followed by re-cooling causes change outwardly from weld interface extending to the end of the sensitizing temperature in the base metal
  - » Can vary in size and levels of intensity
  - » Tend to cause a reduction in the strength of the material through its zone

STEM Connection

Engineering:

Identify and compare ASTM steel shapes and strengths of materials for angle, channel, beam, tube, pipe and bar. Using Steel Sizes and Weights Handbook, determine the weight per foot, depth, width and web dimensions for common steel shapes. How do designers use this information when selecting materials?

Instructional Directions/Materials

Content Outline, Instructional Procedures and/or Key Questions

Closure / Summary:

Use an instructor-led discussion that reviews the key points of this lesson.

Summary:

Involve all students in a question/answer discussion of the key concepts and facts of the lesson.

Refer back to the high carbon steel nails used with the interest approach. Ask the students about the processes used and why the quench nails snapped off and the annealed nails were able to bend.

Review the eight areas presented in the lesson, emphasize the applications in welding, special emphasis on the heat treating processes, the HAZ and the effects of distortion. All of the principles are related and based upon the properties and characteristics of the metals.

Assessment:

Hand out AQ and read over the directions with the students.

Assessment Key

1. A-True
2. B-False
3. B-False
4. A-True
5. A-True
6. C-It has 0.18%
7. B-Iron
8. A-Physical
9. A-Aluminum
10. A-Expand, contract

Material Science in Welding Assessment

Name: ______________________________ **Date:** ______________

True or False

Directions: *Choose True if the statement is correct. Choose False if the statement is incorrect.*

1. Tensile strength is the ability of the metal to resist being pulling apart.
   A. True B. False

2. During the welding process the weld metal and adjacent base material expand and contract uniformly.
   A. True B. False

3. Properties of the base metal in the heat-affected zone are unchanged by the welding process.
   A. True B. False

4. The primary element that differentiates ferrous from nonferrous metal is iron.
   A. True B. False

5. The carbon content of a given type of steel determines its strength properties.
   A. True B. False

Multiple Choice

Directions: *Choose the letter of the best answer.*

6. SAE 1018 steel has which of these characteristics?
   A. It is considered a high carbon steel
   B. It is 1.8% iron
   C. It has 0.18% carbon
   D. It is considered difficult to weld

7. Magnetism is a physical property in steel that is related to the percentage of this element?
   A. Aluminum
   B. Iron
   C. Magnesium
   D. Chrome

8. The ________ properties of a metal are characteristics that are observed when some form of energy changes the metal.
   A. Physical
   B. Mechanical
   C. Chemical
   D. Both A and B

Material Science in Welding Assessment

9. _________ is a nonferrous lightweight metal that is a good conductor of heat and electricity.
   A. Aluminum
   B. Nickel
   C. Steel
   D. Cast iron

10. _________ during the heating cycle and _________ during the cooling cycle.
   A. Expand, contract
   B. Contract, expand
   C. Shrink, grow
   D. Both A and B