Lesson A5–1

Identifying Metals and Their Physical Properties

Unit A. Mechanical Systems and Technology

Problem Area 5. Metal Fabrication

Lesson 1. Identifying Metals and Their Physical Properties

New Mexico Content Standard:

Pathway Strand: Power, Structural and Technical Systems

Standard: **VIII:** Plan, implement, manage, and/or provide support services to facility design and construction; equipment design, manufacture, repair, and service; and agricultural technology.

Benchmark: **VIII-B:** Follow architectural and mechanical plans to construct building and facilities.

Performance Standard: **3.** Construct with wood and metal.

Student Learning Objectives. Instruction in this lesson should result in students achieving the following objectives:

1. Identify and explain the terms associated with metals.
2. Describe the properties and structures of metals.
3. Explain how steel is manufactured.
4. Describe how metal is classified.
5. Describe the characteristics used to identify metals.

List of Resources.

The following resources may be useful in teaching this lesson:

Recommended Resources. One of the following resources should be selected to accompany the lesson:

Burke, Stanley R., and T.J. Wakeman, *Modern Agricultural Mechanics*, Danville, Illinois: Interstate Publishers, Inc., 1992. (Textbook, Chapter 3)

Phipps, Lloyd J., and Carl L. Reynolds, *Mechanics in Agriculture,* Danville, Illinois: Interstate Publishers, Inc., 1992. (Textbook, Chapter 13)

Other Resources. The following resources will be useful to students and teachers:

Cold Metal Work (VAS 3002a), University of Illinois, Urbana, Illinois: ITCS Instructional Materials. (Section 1)

Shielded Metal-Arc Welding (VAS 3004a), University of Illinois, Urbana, Illinois: ITCS Instructional Materials. (Section 6)

List of Equipment, Tools, Supplies, and Facilities

Writing surface
Overhead projector
Transparencies from attached masters
Copies of student lab sheet
Different types of metals and alloys

Terms.

The following terms are presented in this lesson (shown in bold italics):

Adhesion
Alloy
Annealing
Casting
Compressive strength
Crystal structure
Fatigue strength
Flexure strength
Hardening
Hardness
High temperature creep
Impact strength
Malleable
Shear strength
Space lattice
Steel
Tempering
Tensile strength

Interest Approach. Use an interest approach that will prepare the students for the lesson. Teachers often develop approaches for their unique class and student situations. A possible approach is included here.

Display to the class different types of metals and/or alloys. Explain the uses of each and see if they can identify them. Another idea would be to exhibit broken parts made of different metals. Ask the students how they would complete the task if they were asked to repair the broken parts.

Summary of Content and Teaching Strategies

Objective 1: Identify and explain the terms associated with metals.

Anticipated Problem: What terms are commonly used with metals?

I. Because of the widespread use and necessity for metals in agriculture, it is important for the worker to have a basic understanding of metals and metallurgy when fabricating and making repairs on metals.

A. Metal is an element. There are over 100 known elements, and about 75 percent of them are classified as metals.

B. An ***alloy*** is a mixture of two or more metals, or of metals and one or more non-metals.

1. The elements added to a metal to form an alloy may be either metal or non-metal.
2. In most cases alloys have more desirable properties and are less expensive than pure metals.

C. ***High temperature creep*** is the slow stretching of steel under stress at high temperatures.

D. ***Adhesion*** is the sticking together of two unlike metals involving a mechanical bond. The mechanical bond involves the flowing of a metal in a liquid form into the pores of a metal in a solid form.

E. ***Annealing*** is the softening of metal and removing of the brittleness. The annealing process is done by heating the metal to a cherry red and then allowing it to cool slowly in vermiculite, dry hot sand, or a furnace.

F. ***Tempering*** is obtaining the desired hardness and toughness in metal.

G. The process of making steel harder is known as ***hardening***. This is done by heating the steel to a cherry red color, then cooling it quickly in water.

1. Hardened steel is not only extremely hard but also brittle.
2. Hardening is the first step in tempering.
3. ***Hardness*** is the ability of a material to resist being indented.

H. ***Casting*** is pouring melted metal into a mold so that it will be a certain shape after cooling.

I. The capability of being extended or shaped by being beaten with a hammer or by being pressed by rollers is known as ***malleable***.

Use text material to strengthen student understanding of concepts. Chapter 3 in Modern Agricultural Mechanics and Chapter 13 in Mechanics in Agriculture are recommended.

Objective 2: Describe the properties and structures of metals.

Anticipated Problem: What are the properties and structures of metals?

II. The distinct characteristics used to help identify a given metal are referred to as its properties.

A. These characteristics include: brittleness, color, corrosion resistance, ductility, malleability, and strength.

B. These properties can be categorized into seven broad classifications.

1. Mechanical properties are hardness, brittleness, ductility, percent elongation, toughness, wear, and strength.

a. ***Tensile strength*** is the ability of a metal to resist being pulled apart.

b. ***Compressive strength*** is the ability of a metal to resist deformation by forces pushing it together.

c. ***Shear strength*** is the ability of a metal to resist forces acting in opposite directions.

d. ***Fatigue strength*** is the ability of a metal to take repeated loads without deforming.

e. ***Impact strength*** is the ability of a metal to resist shock.

f. ***Flexure strength*** is the ability of a metal to bend without deforming or breaking.

2. Chemical properties refer to the chemical make-up of the metal and its ability to resist reaction with the environment.

a. Chemical properties are oxide or compound composition; acidity or alkalinity of the metal; corrosion resistance; resistance to acids and salts; and resistance to other chemicals.

b. Corrosion resistant metal will resist deterioration from heat, sunlight, water, and humidity.

3. Physical properties relate to the dimensions, shape, specific gravity, and weight of the metal.

4. Thermal properties are characteristics such as expansion, contraction, thermal conductivity, and specific heat.

5. Optical properties are luster, color, light transmission, and light reflection.

6. Electromagnetic properties are electrical conductivity, magnetic permeability, and galvanic action.

7. Acoustical properties relate to the ability of a metal to transmit and reflect sound.

C. The ***crystal structure*** of a metal is the way molecules of a substance are arranged or how they are packed or fitted together. The pattern these atoms make is called a ***space lattice***. There are 14 lattices involved in the study of metals; only three of the most common structures are of real importance here.

1. The body-centered cubic arrangement has nine atoms.
    a. The main characteristic is their strength and the difficulty with which they are worked when cold.
    b. Examples: iron, molybdenum, chromium, tungsten, and vanadium at room temperature.
2. The face-centered cube arrangement has fourteen atoms.
    a. The main characteristic is that they are plastic and malleable.
    b. Examples: iron, aluminum, nickel, copper, lead, platinum, and silver.
3. The close-packed hexagon arrangement has seventeen atoms.
    a. The main characteristics are that they are non-plastic and must be heated before they can be worked.
    b. Examples: cadmium, cobalt, bismuth, magnesium, titanium, and zinc.

Use TM: A5–1A as visual material for lecture and discussion. An alternative approach is to transfer the information from the transparency masters to a multimedia presentation. Use text material to strengthen student understanding of concepts. Chapter 3 in Modern Agricultural Mechanics and Chapter 13 in Mechanics in Agriculture are recommended.

Objective 3: Explain how steel is manufactured.

Anticipated Problem: How is steel manufactured?

III. ***Steel*** is an alloy of iron and carbon and usually other metals.

A. There are hundreds of different steels, ranging in composition from 99 percent iron and very small amounts of carbon, to steels containing less than 55 percent iron and a large percentage of other metals.

B. There are four major steel making processes: the Bessemer furnace, the open hearth furnace, electric furnace, and the oxygen furnace. All four processes are similar in principle in that pig iron is treated with an oxygen-bearing material to burn out the carbon and impurities. Alloying metals are then added.

C. There are two general types of steel: carbon and alloy. Approximately 80 to 90 percent of steel produced is carbon steel. Carbon steels contain 0.05 to 1 percent carbon and less than 1.5 percent of the other elements. The strength of steel increases as the carbon content increases, but the hardness, brittleness, and difficulty of fabrication also increase. There are hundreds of alloy steels. The effects of additives varies. Some of these effects are as follows:

1. Chromium makes the alloy hard and increases the wear and corrosion resistance of steel. Steels containing more than 4 percent chromium are called stainless steels.

2. Sulfur is added to aid in machinability of the steel.
3. Silicon is added to improve the electrical, mechanical, and thermal characteristics.
4. Nickel is added to increase the toughness and strength.
5. Vanadium is added to increase the strength.
6. Tungsten is used to produce tool steels that will maintain a cutting edge at high heat.
7. Aluminum helps to provide a hardened surface.
8. Molybdenum tends to increase the hardness and the endurance limits of steel.
9. Oxygen forms iron oxide which is not desirable.
10. Phosphorus is found in all steels. When present in high percentages it is considered an impurity. At low percentages it improves machinability.
11. Carbon added to iron changes the physical properties. The amount of change is directly proportional to the amount of carbon added to the iron.

Use text material to strengthen student understanding of concepts. Chapter 3 in Modern Agricultural Mechanics and Chapter 13 in Mechanics in Agriculture are recommended.

Objective 4: Describe how metal is classified.

Anticipated Problem: How is metal classified?

IV. Of the known elements, about 80 to 90 are technically considered metals. Of these, 10 to 15 are considered important in agricultural mechanics. These metals can be broken down into four groups and classified as follows:

A. Ferrous metals—Metals whose chief ingredient is iron. Pig iron, cast iron, wrought iron, and steel are examples.
   1. Pig iron or cured iron, is iron ore changed to pig iron by a blast furnace.
   2. Cast iron is a product of pig iron and contains a considerable amount of carbon and some impurities. It is brittle and granular in structure. It is formed by pouring into special castings.
      a. Gray cast iron has been cooled slowly, allowing carbon to separate from the iron into pockets of carbon in the form of graphite. Gray cast iron is used in sprockets, stoves, and manifolds.
      b. White cast iron has been cooled quickly to prevent separation of carbon. White cast iron is used for agitators in grain drills.
      c. Malleable cast iron has been made soft, strong, and malleable through a long reheating and cooling process called annealing. Malleable cast iron will bend slightly, such as for a conventional mower guard.
   3. Wrought iron, a product of pig iron that has had most of the carbon removed, is a two-component metal consisting of high purity iron and iron silicate. Wrought iron is the only ferrous metal that contains siliceous slag. The slag is responsible for the desirable properties of wrought iron, particularly its resistance to corrosion and fatigue. It is used for rivets, porch furniture, and decorative roof supports.

4. Steel is iron characterized chiefly by its carbon content.

B. Non-ferrous metals are those which have no iron and are made up of a single element. These are aluminum, copper, lead, magnesium, nickel, tin, tungsten, zinc, silver, and gold.

1. Aluminum is a silver-white, malleable, ductile metal. It is known for its electrical conductivity, heat conductivity, rust resistance, and light weight.
2. Copper, reddish-brown in color, is used for tubes, wire, sheets, and plates. It has excellent workability, either hot or cold, and the highest electrical and heat conductivity of all commercial metals.
3. Lead has a bluish-white color and a bright luster. It is soft, highly malleable, and ductile; has slight tenacity; and is a poor conductor of electricity. It is used for making pipe and containers for corrosive liquids.
4. Magnesium is a very lightweight, silver-white metal, which is malleable and ductile and burns in air. It is usually found in the alloy known as dowmetal. It is useful for airplane bodies, truck and auto wheels, ladders, lawn mower frames, and any place where weight reduction is important.
5. Nickel is a hard, malleable, ductile, tenacious white metal that is somewhat magnetic. It is valuable for the alloys it forms with other metals.
6. Tin does not corrode in humid conditions, adheres tenaciously to iron, has a low melting point, and is used extensively in solder, brass, bronze, and pewter.
7. Tungsten, one of the heaviest metals, is used for making filaments for incandescent lamps. Tungsten carbide is almost as hard as diamond and is used extensively for cutting tools.
8. Zinc, a bluish-white metal at ordinary temperatures, is brittle but malleable at high temperatures and is used as a galvanizing metal coating to prevent corrosion.
9. Silver is a shiny, white metal used mostly for ornamental work, jewelry, and tableware. Silver is the best conductor of electricity.
10. Gold is most often used for ornamental jewelry.

C. Ferrous alloys are metals made up largely of ferrous materials but having other elements in sufficient quantities to change the ferrous characteristics.

1. Manganese steel can stand strain, hammering, shock, and hard wear. It is used for the jaws of ore crushers, power shovels, chains, gears, and safes.
2. Chromium steel resists rust, shock, scratches, and stains. It is used for bearings, safes, ore crushers, and is the basis for high-quality stainless steel.
3. Nickel steel is strong, hard, elastic, tough, and durable. It does not rust easily and is used for springs, cables, axles, shafts, and armor plate.
4. Stainless steel seldom rusts and is used for cutlery, precision measuring instruments, dentistry supplies, auto parts, and engine valves.
5. Tungsten steel adds hardness to steel and allows it to withstand heat. Tungsten carbide is the hardest metal known and is used for various cutting surfaces.

6. Molybdenum steels are known for their strength and hardness and are used for hacksaw blades, high-grade machinery parts, bearings, and auto parts.
7. Vanadium steel is tough and can withstand great shocks as well as resist corrosion. It is used for springs, gears, and vibrating parts of machinery.
8. High-speed steel contains one or more alloying elements.

D. Non-ferrous alloys are made up of two or more nonferrous elements.
1. Brass is an alloy of copper and zinc. It is ductile, malleable, and acid resistant.
2. Bronze is an alloy of copper and tin that behaves very much like brass when welded.
3. Solder types are lead and tin solder, copper and zinc alloy solder, and silver and copper alloy solder.
4. Pewter is an alloy of 92 percent tin, 5 percent antimony and 3 percent copper.
5. Monel is an alloy of 60 percent nickel and 40 percent copper.

E. Grading and classifying steel.
1. Because steel varies in carbon content and alloying elements, a system to group it using standards established by the Society of Automotive Engineers (SAE) was developed.
2. In the SAE numbering system, the first digit indicates the general type of steel. The second digit indicates the percentage of the main alloy in the steel. The third and fourth digits show the percent of carbon in the steel in hundredths of one percent.

Use TM: A5–1B as visual material for lecture and discussion to reinforce the SAE numbering system. An alternative approach is to transfer the information from the transparency masters to a multimedia presentation. Use text material to strengthen student understanding of concepts. Chapter 3 in Modern Agricultural Mechanics, Chapter 13 in Mechanics in Agriculture, Section 6 in Shielded Metal-Arc Welding (VAS 3004a), and Section 1 in Cold Metal Work (VAS 3002a) are recommended.

Objective 5: Describe the characteristics used to identify metals.

Anticipated Problem: What characteristics are used to identify metals?

V. Physical and chemical tests are used to determine the type of metal. Because so many kinds of metals are used in agriculture it is very important that you learn to identify them.

A. The Appearance Test involves identification of a metal by its appearance and use. Color and appearance make certain metals such as copper, brass, and bronze easy to identify.
B. The Magnetic Test involves identification of metal by the use of a magnet.
C. The Chisel Test involves identification of metal by the use of a hammer and cold chisel.
D. The Fracture Test involves identification of metal by fracturing the metal and observing the grain.
E. The Flame Test involves identification of metals by applying a flame to them and watching what occurs.

F. The Spark Test involves identification of metals by applying them to a grinding wheel and observing the spark that is generated. The color, shape, average length, and activity of the sparks are characteristics of the material being tested.

Use TM: A5–1C and A5–1D as visual material for reinforcing how to identify metals. An alternative approach is to transfer the information from the transparency masters to a multimedia presentation. Use text material to strengthen student understanding of concepts. Chapter 3 in Modern Agricultural Mechanics, Chapter 13 in Mechanics in Agriculture, Section 6 in Shielded Metal-Arc Welding (VAS 3004a), and Section 1in Cold Metal Work (VAS 3002a) are recommended. Have students complete LS: A5–1A to apply the concepts of this objective.

Review/Summary. Focus the review and summary of the lesson around the student learning objectives. Call on the students to explain the content associated with each objective. Use their responses as the basis for determining any areas that need re-teaching. Questions at the end of each chapter in the recommended textbooks may also be used in the review/summary. Use the lab activities in reviewing and reinforcing student learning.

Application. Application can involve one or more of the following student activities using the attached lab sheet. It is understood that before attempting the lab activities, proper safety precautions in the agriculture mechanics shop must be covered thoroughly.

Identifying Metals—LS: A5–1A

Evaluation. Evaluation should focus on student achievement of the objectives for the lesson. Various techniques can be used, such as student performance, on the application activities. A sample written test is attached.

Answers to Sample Test:

Part One: Matching

1 = e, 2 = k, 3 = c, 4 = h, 5 = i, 6 = l, 7 = a, 8 = f, 9 = g, 10 = d, 11 = b, 12 = j

Part Two: Completion

1. Steel
2. ferrous
3. Brass
4. general type, percentage, carbon
5. non-ferrous

Part Three: Short Answer

1. Mechanical, Chemical, Physical, Thermal, Optical, Electromagnetic, and Acoustical.
2. Appearance, Magnetic, Chisel, Fracture, Flame, and Spark.

Sample Test Name _____

Test

Lesson A5–1: Identifying Metals and Their Physical Properties

Part One: Matching

Instructions. Match the term with the correct response. Write the letter of the term by the definition.

a. alloy	e. fatigue strength	i. malleable
b. annealing	f. flexure strength	j. shear strength
c. casting	g. hardness	k. tempering
d. compressive strength	h. impact strength	l. tensile strength

_____ 1. The ability of a metal to take repeated loads over and over again without deforming.

_____ 2. Obtaining the desired hardness and toughness in metal.

_____ 3. Pouring melted metal into a mold so that after cooling it will be a certain shape.

_____ 4. The ability of a metal to resist shock.

_____ 5. The capability of being extended or shaped by being beaten with a hammer or by being pressed by rollers.

_____ 6. The ability of a metal to resist being pulled apart.

_____ 7. A mixture of two or more metals or of metals and one or more non-metals.

_____ 8. The ability of a metal to bend without deforming or breaking.

_____ 9. The ability of a material to resist being indented.

_____ 10. The ability of a metal to resist deformation by forces pushing it together.

_____ 11. Softening of metal and removing the brittleness.

_____ 12. The ability of a metal to resist forces acting in opposite directions.

Part Two: Completion

Instructions. Provide the word or words to complete the following statements.

1. _____ is an alloy of iron and carbon and usually other metals.
2. Metals whose chief ingredient is iron are called _____ metals.
3. _____ is an alloy of copper and zinc.

4. In the SAE numbering system, the first digit indicates the _____ _____of steel, the second digit indicates the _____ of the main alloy in the steel, and the third and fourth digits show the percent of _____in the steel in hundredths of 1 percent.
5. Metals which have no iron and are made up of a single element are_____ metals.

Part Three: Short Answer. Use complete sentences.

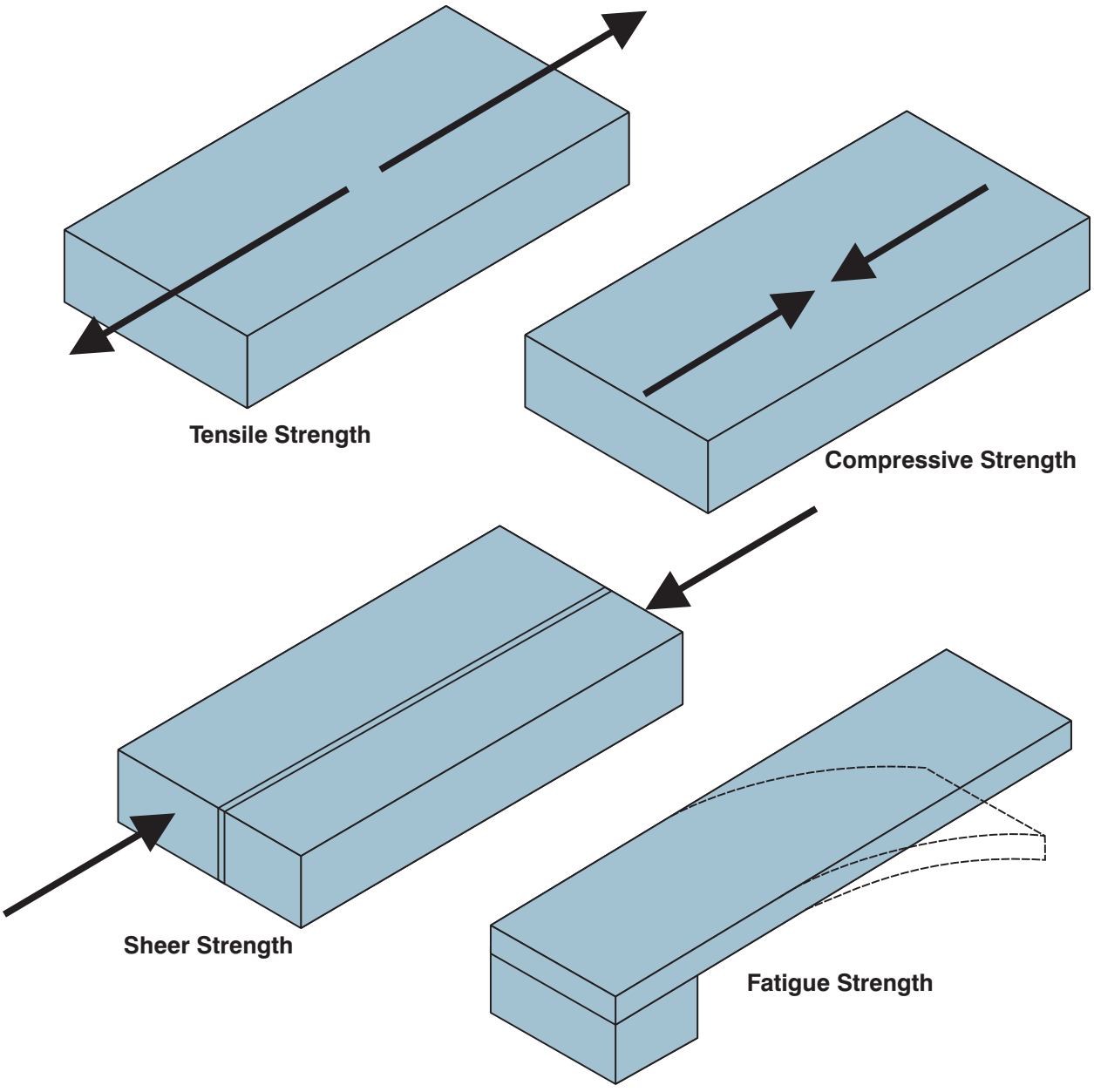
Instructions. Provide information to answer the following questions.

1. The distinct characteristics used to help identify a given metal are referred to as its properties. These properties can be categorized into seven broad classifications. Identify those seven properties.

2. There are six "tests" that can be used to identify metals. What are those six tests?

TM: A5–1A

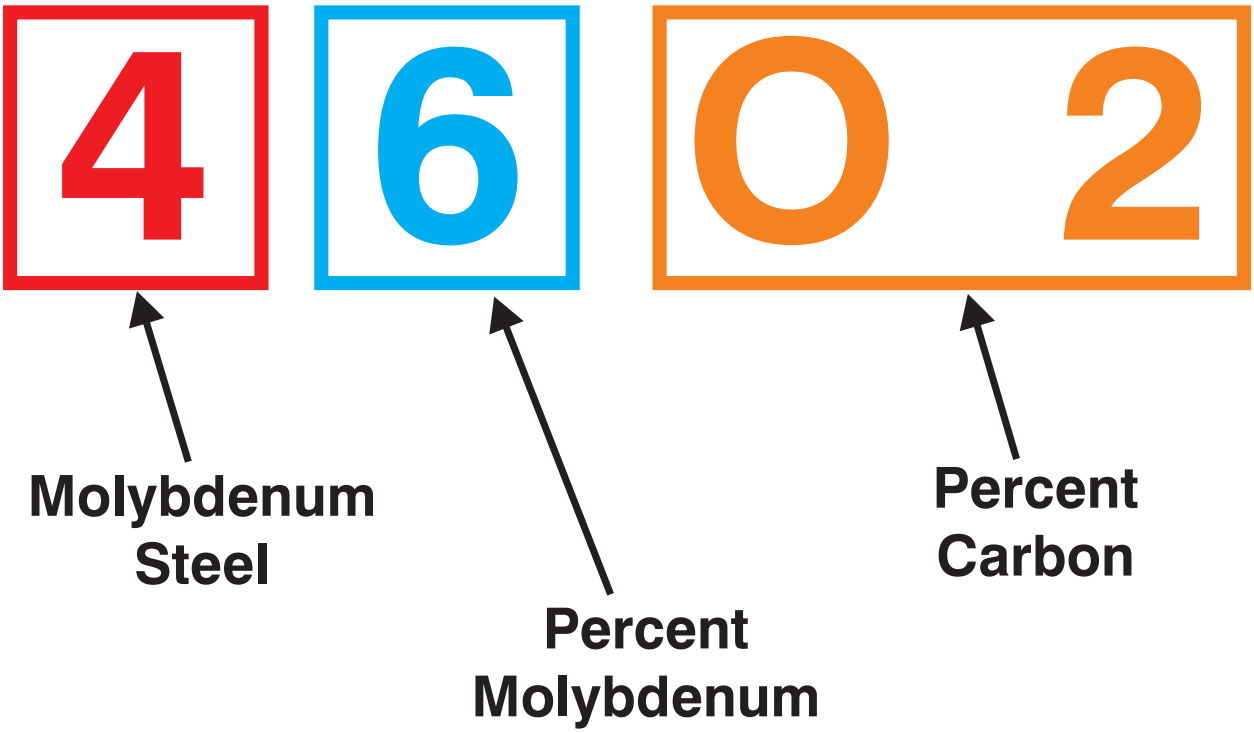
PROPERTIES OF METALS



(Courtesy, Interstate Publishers, Inc.)

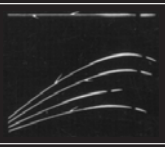
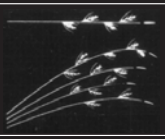
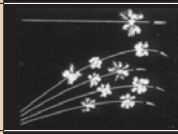
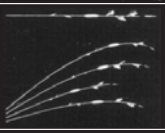
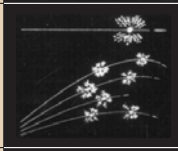
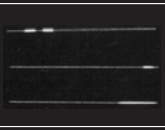
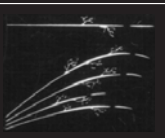
TM: A5–1B

SAE GRADING AND CLASSIFYING SYSTEM



TM: A5–1C

METHODS OF IDENTIFYING METALS

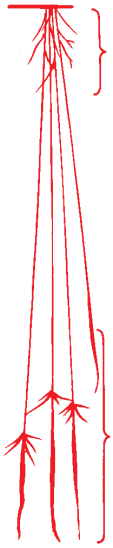
Metal	Test					
	Appearance	Magnetic	Chisel	Fracture	Flame	Spark*
Low carbon steel	Dark grey	Strongly magnetic	Continuous chip, smooth edges, chips easily	Bright grey	Melts fast, becomes bright red before melting	 Long yellow carrier lines (approx. .20% carbon or below)
Medium carbon steel	Dark grey	Strongly magnetic	Continuous chip, smooth edges, chips easily	Very light grey	Melts fast, becomes bright red before melting	 Yellow lines sprigs very plain now (approx. .20% to .45% carbon)
High carbon steel	Dark grey	Strongly magnetic	Hard to chip, can be continuous	Very light grey	Melts fast, becomes bright red before melting	 Yellow lines bright burst very clear numerous star burst (approx. .45% carbon and above)
High sulphur steel	Dark grey	Strongly magnetic	Continuous chip, smooth edges, chips easily	Bright grey, fine grain	Melts fast, becomes bright red before melting	 Swelling carrier lines cigar shape
Manganese steel	Dull cast surface	Non magnetic	Extremely hard to chisel	Coarse grained	Melts fast, becomes bright red before melting	 Bright white fan-shaped burst
Stainless steel	Bright, silvery smooth	Depends on exact analysis	Continuous chip, smooth bright color	Depends on type, bright	Melts fast, becomes bright red before melting	 1. Nickel-black shape close to wheel. 2. Moly-short arrow shape tongue (only). 3. vanadium-long spearpoint tongue (only).
Cast iron	Dull grey evidence of sand mold	Strongly magnetic	Small chips, about 1/8 in., not easy to chip, brittle	Brittle	Melts slowly, becomes dull red before melting	 Red carrier lines (very little carbon exists)
Wrought iron	Light grey smooth	Strongly magnetic	Continuous chip, smooth edges, soft and easily cut and chipped	Bright grey, fibrous appearance	Melts fast, becomes bright red before melting	 Long straw color lines (practically free of bursts or sprigs)

*For best results, use at least 5,000 surface feet per minute on grinding equipment. ($\frac{\text{Cir.} \times \text{R.P.M.}}{12}$ S.F. per Min.)

(Courtesy, Interstate Publishers, Inc.)

TM: A5–1D

SPARK TEST FOR IDENTIFYING METALS

Wrought Iron	Low-Carbon Steel	High-Carbon Steel	Alloy Steel
 Color–straw yellow Average stream length with power grinder–65 in. Volume large Long shafts ending in forks and arrowlike appendages Color–white	 Color–white Average stream length with power grinder–70.in. Volume–moderately large Shafts shorter than wrought iron and in forks and appendages Forks become more numerous and sprigs appear as carbon content increases	 Color–white Average stream length with power grinder–55 in. Volume–large Numerous small and repeating sprigs	 Color–straw yellow Stream length varies with type and amount of alloy content Shafts may end in forks, buds or arrows, frequently with break between shaft and arrow. Few if any, sprigs Color–white
White Cast Iron	**Gray Cast Iron**	**Malleable Iron**	**Nickel**
 Color–red Color–straw yellow Average stream length with power grinder–20 in. Volume–very small Sprigs–finer than gray iron, small and repeating	 Color–red Color–straw yellow Average stream length with power grinder–25 in. Volume–small Many sprigs, small and repeating	 Color–straw yellow Average stream length with power grinder–30 in. Volume–moderate Longer shafts than gray iron ending in numerous small repeating sprigs	 Color–orange Average stream length with power grinder–10 in. Short shafts with no forks or sprigs

(Courtesy, Interstate Publishers, Inc.)

LS: A5–1A Name_____

Lab Sheet

Identifying Metals

On the sheet provided, identify the given metal samples using the appearance, magnetic, chisel fracture, flame and/or spark test(s).

Sample #	Type of Test	Observation	Name
1			
2			
3			
4			
5			
6			
7			
8			