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ABSTRACT

These instructional materials provide an orientation to the machine shop for use at the postsecondary level. The first of three sections discusses four important areas of safety: (1) personal safety; (2) safety procedures; (3) safe work practices; and (4) fire prevention. The second section identifies and describes the general purposes of 12 machines. Photographs are provided of each machine. The third section identifies common metals and their machinable characteristics. The four modern industrial metals outlined are: (1) ferrous metals; (2) nonferrous metals; and (3) high temperature and rare metals. A quiz and separate answer sheet are included after each section. (NLA)

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Orientation to Machine Shop

- **Safety**
- **Machine Identification**
- **Metal Identification**

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ORIENTATION TO MACHINE SHOP

I. Safety

- A. Personal Safety
 - 1. Eye protection
 - 2. Clothing, hair, jewelry
 - 3. Ear protection
 - 4. Horse play
- B. Proper Housekeeping
- C. Safe Work Practices
- D. Fire Prevention

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 - 6. Vertical band saw
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 - 8. Horizontal milling machine
 - 9. Vertical milling machine
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 - 12. Cylindrical grinder
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III. Common Metal Identification and Machinable Characteristics

- A. Ferrous Metals
 - 1. Irons
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 - b. malleable cast iron
 - c. ductile cast iron
 - d. machinability of cast iron
 - B. Steels
 - 1. Carbon steels
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 - b. medium carbon steel
 - c. high carbon steel
 - 2. Alloy steels
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 - b. tool steel
 - c. stainless steel
- C. Non-Ferrous Metals
 - 1. Aluminum
 - a. number systems
 - b. machinability characteristics
 - c. aluminum alloys
 - 2. Copper - Based Alloys
 - 3. Magnesium
 - 4. Titanium
- D. High temperature and rare metals

ORIENTATION TO MACHINE SHOP

SAFETY

1. Safety is everyone's business. Safety is not something that should be studied and forgotten. Safe working habits should be developed and practiced throughout ones career. There are four important areas of safety that one needs to consider when operating equipment in a machine shop.

A. Personal Safety contains four important rules to be observed.

1. Eye Protection--Safety glasses should be worn at all times while working in or observing the machine shop to protect the eyes. Safety glasses with side shields and lenses made of shatterproof glass are the most common means of eye protection. They protect the machine operator as well as passers-by. Plastic safety goggles or face shields may be used for those who wear prescription glasses, however, prescription safety glasses with side shields are preferred.
2. Clothing, Hair, Jewelry--Always wear clothing that is appropriate for the job. Loose sweaters or ties should not be worn in the machine shop as they could easily get caught in the machinery. If shop aprons are worn, always tie aprons in the back. While operating machines, gloves should be removed to obtain full control and lessen the chance of accidents. Shoes worn in the machine shop should be steel-toed safety shoes. Long hair must be secured properly with either a tie-back or hair net to prevent injury. All types of jewelry such as watches, rings or bracelets must be removed when operating machines.
3. Ear Protection--Noise in manufacturing plants may reach levels of intensity that can cause hearing loss. Therefore, one should assume responsibility for protecting the ears by wearing proper noise protection devices. Regulations specify that industrial ear muffs or ear plugs should be worn if a continuous noise level of above 85 decibels is measured. They must also be worn during short periods of noise levels above 115 decibels are likely to occur.
4. Horse Play--Practical jokes and distracting co-workers from their work is serious business. Something meant to be funny may end up in serious injury or death to a co-worker. The machine shop is no place for horse play.

8. Bend knees and keep back straight when lifting heavy objects.
 9. Use the proper wrench when working on machines, as this prevents rounded corners on nuts. Replace nuts when worn. Always pull on a wrench rather than push.
 10. When electrical maintenance of a machine is required, always turn off, lock-off, and place an out-of-service tag on the main electrical power supply.
- D. Fire Prevention consists of four steps to be adhered to in the machine shop.
1. Always dispose of oily rags in the proper metal containers.
 2. Be aware of the locations and operations of the fire extinguishers in the shop.
 3. Know the locations of all the fire exits and alarm boxes.
 4. Be sure to direct the flame and sparks away from combustible materials when using a cutting torch.

REVIEW QUESTIONS FOR MACHINE SHOP ORIENTATION

1. Which of the following are the proper types of eyewear to be worn in machine shop?
 - a. Prescription safety glasses
 - b. Safety glasses, goggles, or face shield
 - c. Prescription eye glasses only
 - d. Contact lenses only
 - e. Both a and b
2. When should safety practices be followed?
 - a. Occassionally
 - b. Always
 - c. Never
 - d. On Mondays, Wednesdays, and Fridays.
3. Injury could occur from which of the following circumstances?
 - a. Wearing improper clothing
 - b. Not tying back long hair
 - c. Wearing gloves while operating machines
 - d. Wearing jewelry such as watches, rings, or bracelets
 - e. All of the above
4. What types of hearing protection are acceptable in the machine shop?
 - a. Ear muffs
 - b. Ear plugs
 - c. No protection is required
 - d. Both a and b
5. Ear protection should be worn at which of the following noise levels?
 - a. Below 85 decibels
 - b. Continuous levels above 85 decibels
 - c. Short periods above 115 decibels
 - d. Both b and c
6. Which of the following is acceptable to use when removing metal chips from machines?
 - a. Compressed air
 - b. Shop cloth
 - c. Erush
 - d. Broom

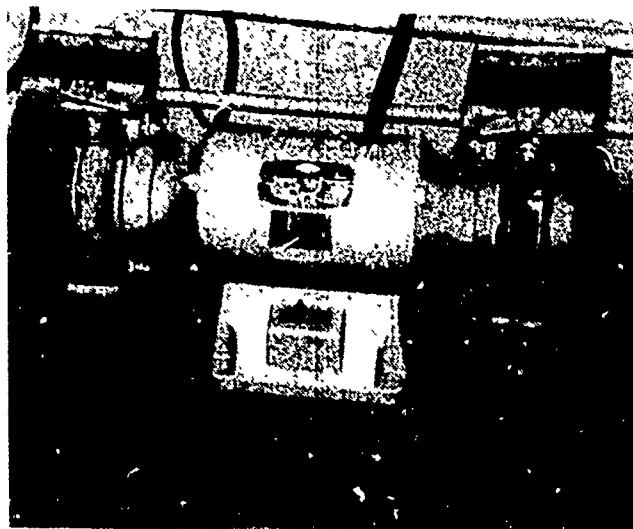
Answers to Orientation to Machine Shop

1. e
2. b
3. e
4. d
5. d
6. c
7. b
8. d

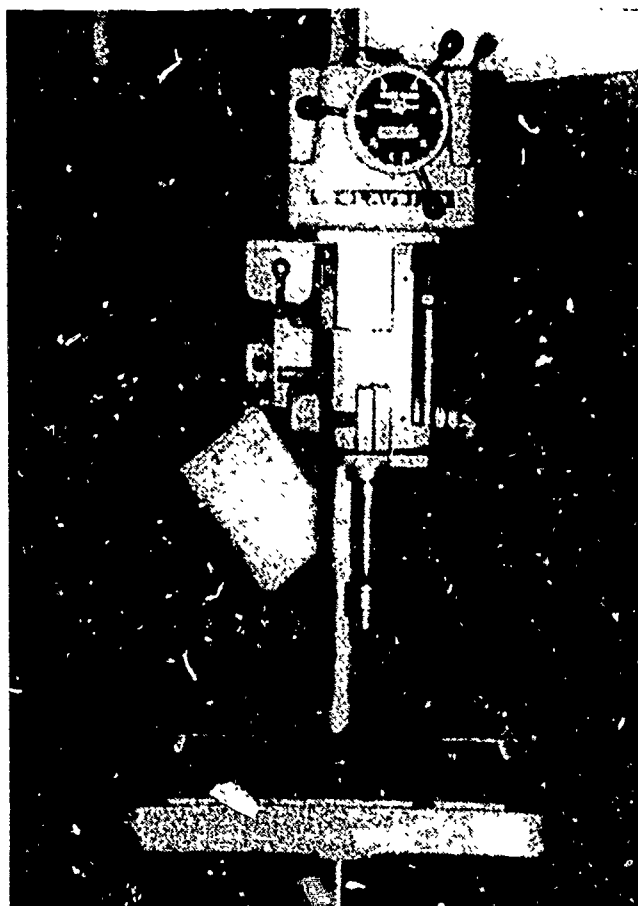
MACHINE IDENTIFICATION

Machines General Purposes and Identification

1. Bench Grinder--Its general purpose is to shape and sharpen tool bits, drill bits, hand tools and other work pieces that need rough grinding.

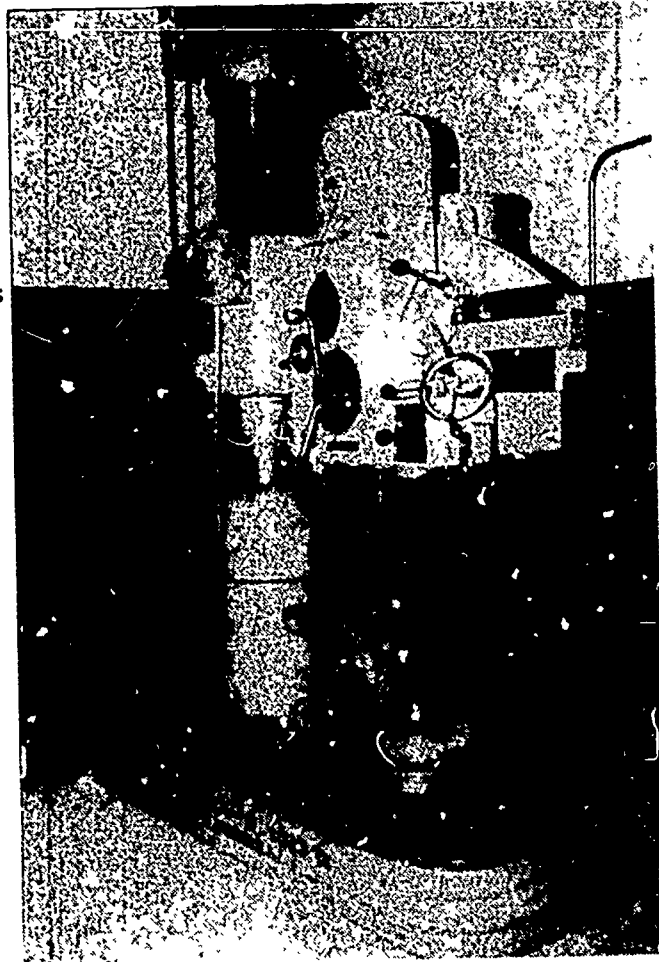


2. Drill Press--Used to hold or support a piece of material and rotate a cutting tool to drill a hole in the material.

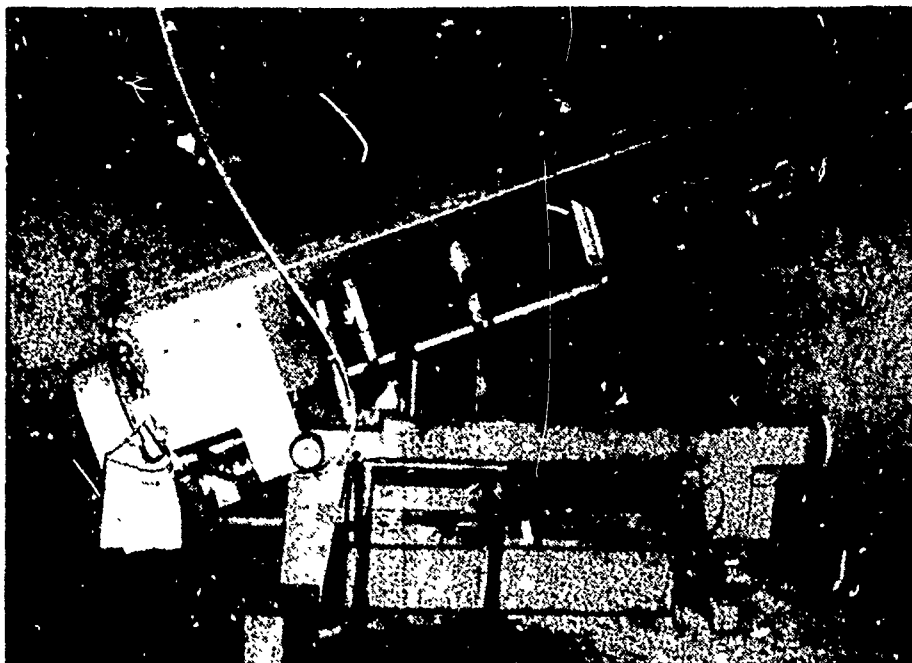


3. Radial Drill Press--

Used for large operations that are too heavy to be repositioned. The work is clamped to the table and the drill head is moved to the correct position. The power feed allows the press to do other operations as well, such as boring and reaming.



4. Horizontal Band Saw--Used for cutting a long length of material into shorter lengths that are needed to perform operations on other machines.



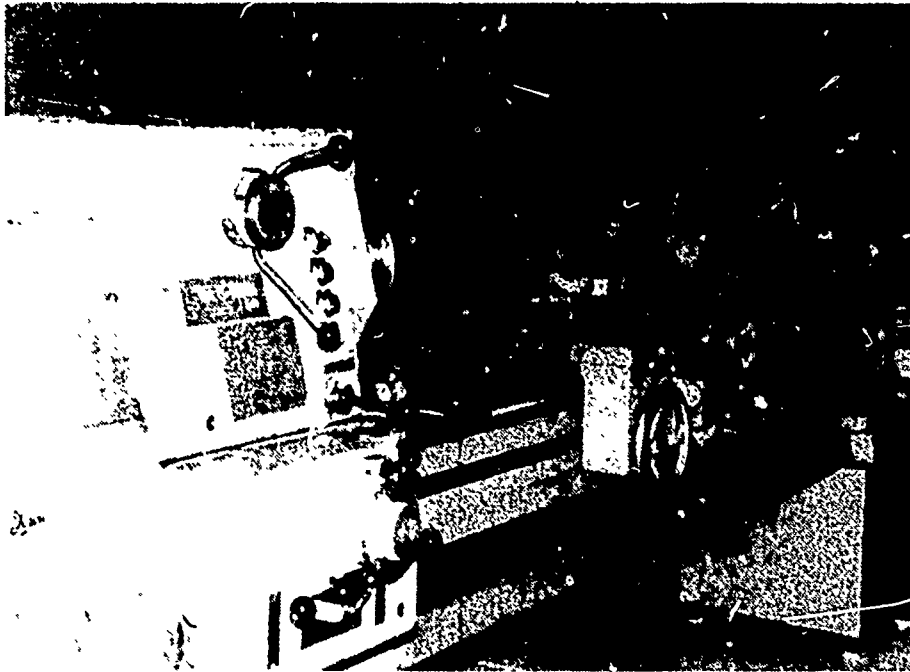
5. Abrasive Cutoff Saw--It is a cutoff saw, but its primary function is to cut non-metallic materials, such as slate, stone, brick, or glass.



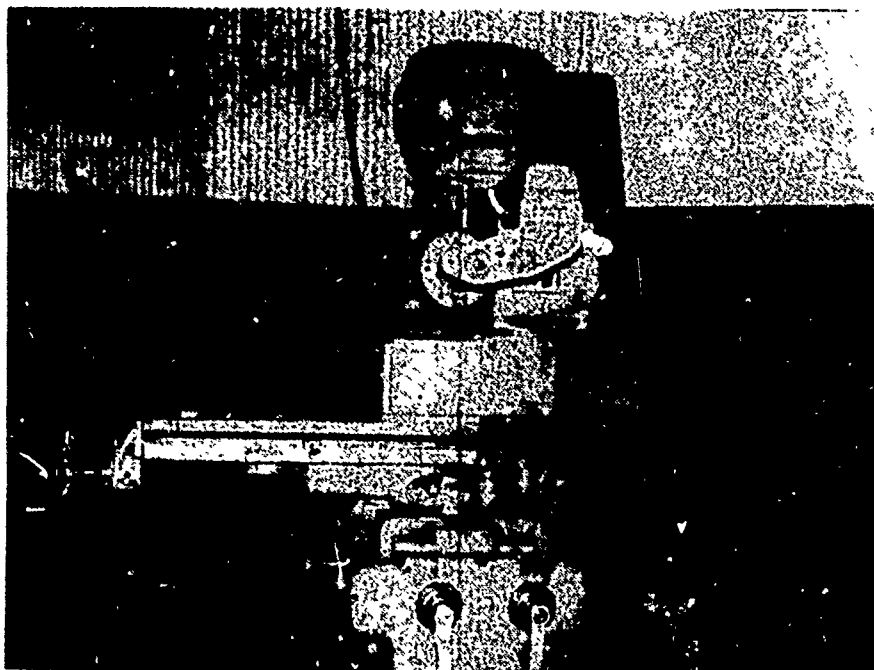
6. Vertical Band Saw--Used for straight cutting, but can also perform other types of cuts, such as contour cutting and internal cutting.



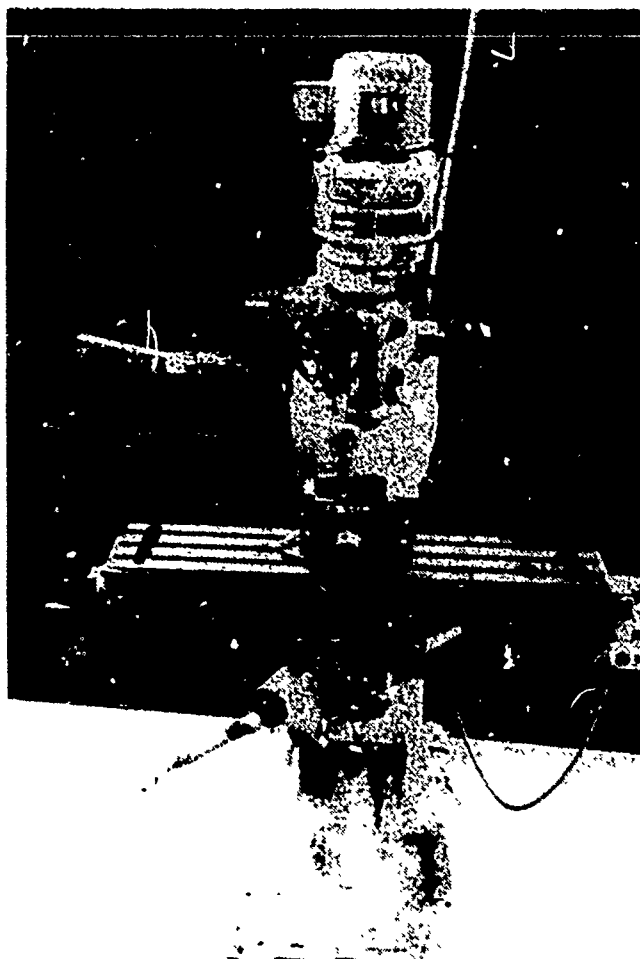
7. Engine Lathe--It rotates its work against a fixed cutting tool that moves cross-wise and length-wise to the axis of the workpiece. The work is shaped to specific dimensions.



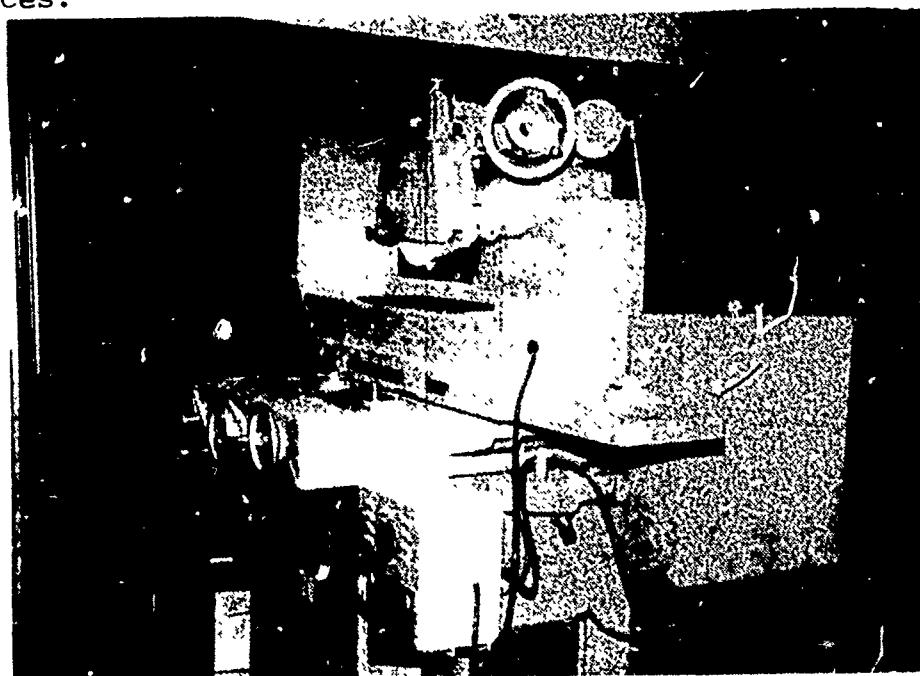
8. Horizontal Milling Machine--Used to cut square pieces of material to specific dimensions. The material is clamped to the table and is moved into the cutter, which is supported on a horizontal shaft.



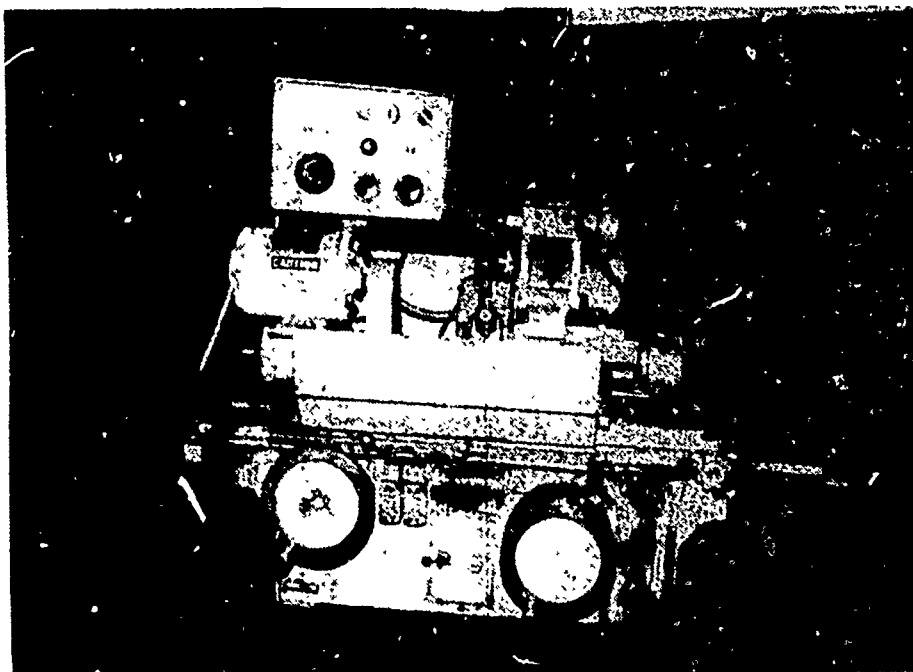
9. Vertical Milling Machine--This machine is also used to cut square pieces of material to specific dimensions. The table moves the material into the cutter, but the cutter is in a vertical position.



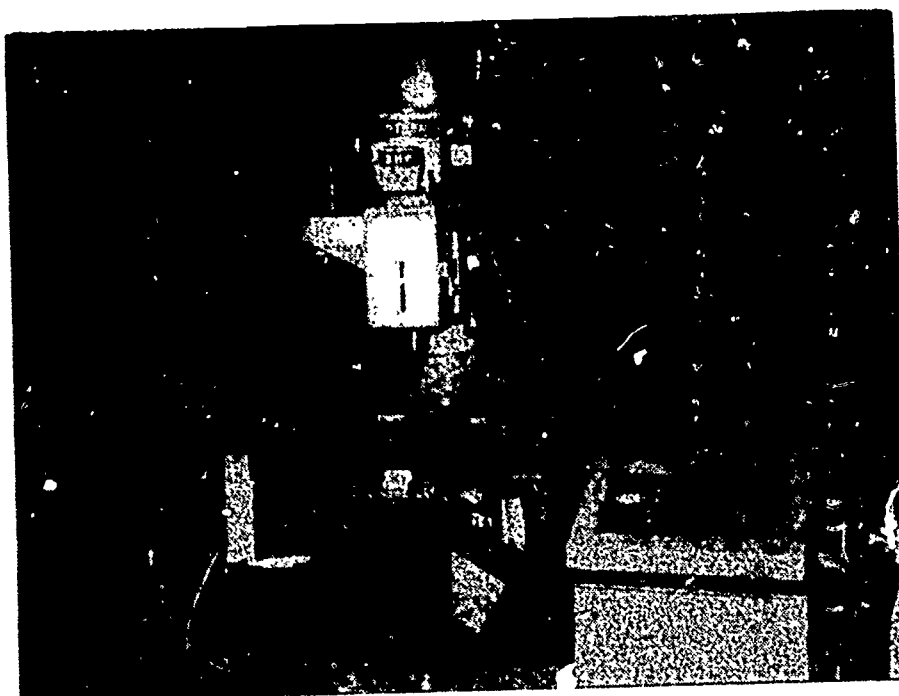
10. Surface Grinder--Used to finish pieces or parts that have already been machined to produce better finishes and closer tolerances.



11. Cylindrical Grinder--Its purpose is to grind a diameter of a workpiece accurately to size with a high surface finish.



12. CNC Machines--Computer Numerical Control can be placed on every type of machine. The CNC controls the functions or movements of the machine by the means of a computer program.



MACHINE IDENTIFICATION QUIZ

DIRECTIONS: Fill in the blank with the correct type of machine.

- a. abrasive cutoff saw
 - b. bench or pedestal grinder
 - c. cnc machine
 - d. cylindrical grinder
 - e. drill press
 - f. engine lathe
 - g. horizontal band saw
 - h. horizontal milling machine
 - i. radial drill press
 - j. surface grinder
 - k. vertical band saw
 - l. vertical milling machine
1. A _____ is used to cut out a 3-D shape by simply following the layout lines.
 2. For drilling and boring a large hole in a large die cast piece, a _____ would be used.
 3. A _____ is used to turn a round piece of material into a thread shaft.
 4. For conditioning a badly worn screw driven tip, one would use a _____.
 5. To cut bricks for a proper fit, one would use a _____.

6. A _____ is used when multiple cutters are used on a simple arbor for cutting multiple slots when stepping in a square block of material.
7. For obtaining a better surface finish on a square piece of metal, a _____ would be used.
8. A _____ is used for cutting a key way on a shaft.
9. To cut long pieces of material shorter for easier handling, a _____ would be used.
10. A _____ is used to drill straight and accurate size holes in a variety of materials.
11. A _____ is used for sharpening cutters that have become dull, which leave poor finishes and rough edges.
12. _____ can be used in production and non-production set-ups and run fully automatic by reading a computer program.

**COMMON METAL IDENTIFICATION
AND
MACHINABLE CHARACTERISTICS**

A working knowledge of various metals and their common terms is essential when working in the machine shop.

Modern industrial metals are classified into three groups:

- Ferrous Metals
- Non-Ferrous Metals
- High Temperature and Rare Metals

I. **Ferrous Metals**--These metals consist of cast irons and steels and their alloys. The most commonly used of the cast irons are gray cast iron, malleable cast iron, and ductile cast iron.

A. **Irons**

1. **Gray Cast Iron**--This iron can be identified by the appearance of a fracture in a casting having a dark color. It is widely used in the machining field because of its ability to be cast into intricate shapes, its low cost and its wide range of useful properties. Its outstanding properties include machinability, excellent wear resistance, range of tensile strength and elastic limits. It has tensile strengths ranging from 20,000-70,000 PSI and elastic limit loaded up to 80 percent of its maximum strength. Examples of parts made from gray cast iron are ways of lathes, cylinder liners, cams, gears, and sprockets.

2. **Malleable Cast Iron**--This type of iron is softer than gray cast iron and has easier machining characteristics. It has a greater toughness and resistance to shock which makes it applicable in farm implements, such as plows, harrows, rakes, and tractors. It is also used in hardware for small tools and pipe fittings.

3. **Ductile Cast Iron**--This iron is similar to malleable iron, but has a higher content of magnesium which gives it a higher strength and can be bent easily without breaking. It can also be melted and cast into complex shapes. Examples of parts made from this iron are hollow automobile shafts and connecting rods for diesel engines.

4. **Machinability of Cast Iron**--All cast irons can be readily machined once the hard outer surface has been penetrated. Because of this outer surface, which is quite abrasive, carbide tools are recommended when machining cast iron.

3. Steels

Steel is an iron alloy and may be classified into two groups: carbon steels and alloy steels.

1. Carbon steels are divided into three categories according to the amount of carbon content: low carbon steel, medium carbon steel, and high carbon steel.

a. **Low Carbon Steel**--The two most common low carbon steels used in machine shops are mild or machine steel and cold rolled steel. Parts made from this type of steel are common parts that do not need to be hardened, such as bolts, nuts, washers, and simple shafts. Mild steel and cold rolled steel can be identified by marking with a file, as the file should bite easily into the metal. It machines well, but leaves build-up on the tool.

b. **Medium Carbon Steel**--Medium carbon steel is used when a greater tensile strength is required. It can also be identified by marking with a file, which will require pressure to cut into the metal. It machines well with high speed tools. Medium carbon steels are used for many machine parts, automotive gears, camshafts, crank shafts, and precision shafts.

c. **High Carbon Steels**--High carbon steels are used for parts that must be heat-treated, such as hammers, wrenches, pliers, heavy machine parts, control rods, types of springs, and agricultural equipment. When identifying with a file, the file cuts in with difficulty. The steel is readily machinable, but carbide tools are recommended.

All carbon steels can be found with a hot or cold rolled finish and are differentiated by visual observation. Hot-rolled steel always has a heat scale or black mill scale surface, whereas the cold-rolled steel has a bright shiny metallic luster on its surface.

2. **Alloy Steels**--These steels contain other alloy materials in addition to carbon. Some examples of other materials in alloy steel are nickel, chromium, molybdenums, vanadium, manganese, tungsten, and cobalt. With the addition of such elements, steels like high speed steel, tool steel, and stainless steel are made.

a. **High Speed Steel**--This steel is very hard and can only be cut with carbide tools. When file testing, it can be cut only with difficulty. Most lathe tools, mill cutters, drills, and reamers are made from high speed steel.

b. **Tool Steel**--This steel is extremely hard and is usually used in making punches, dies, and shears. It can only be filed with extreme pressure and is difficult to machine even with carbide tools.

c. **Stainless Steel**--These steels have one common characteristic, they all contain enough chromium so they become corrosive resistant. All stainless steels can be machined like normal steel, but additional precautions must be observed. Tools must be as large as possible to dispense heat, feeds must be high enough to prevent work hardening, and machines should have minimum play to prevent tools from riding the work. All stainless steels fall into three basic groups: Austenitic, Martensitic, and Ferritic.

1. The **Austenitic** group can be identified by its white appearance and its non-magnetic characteristic. The 300 series of stainless steel is in this category.

2. The **Martensitic** group is hardenable, thus making the cutlery grades of stainless steel to be found in this group. It is also magnetic.

3. The **Ferritic** group is the softest and the least expensive of the three. It is used for such things as building trim, and pots and pans. It can be identified by its bluish-white color and its magnetic quality.

II. Non-ferrous Metals

These metals are metals that contain little or no iron. Non-ferrous metals include metals such as aluminum, copper-based alloys, magnesium, and titanium.

A. Aluminum

The term aluminum identifies more than just one type of metal. Aluminum has an entire family ranging from pure aluminum, which is extremely soft, to aluminum alloys, which are stronger than structural steel.

1. **Number System**--The aluminum family has its own number system starting with 1100, which is the pure aluminum, the 2000 series, which is the copper alloys, 3000 series containing manganese alloy, 4000 series containing silicon alloy, 5000 series having magnesium as the alloy, 6000 series containing silicon and magnesium alloy, and 7000 series which contains zinc alloy.

2. Machinability Characteristics--The following are the machinability characteristics of the more commonly used aluminum alloys:

1100-3003--These two have good machinability, but turnings are long and stringy. Cutting tools must have large top and side rake angles and have sharp and smooth cutting edges.

5052--Also has long stringy chips. The machinability is good, but surface finish is not as good as 3003.

5056--It has a good machinability and has a good chip disposal.

2017-T4 and **2016-T6**--Both of these alloys leave excellent surface finish, but the 2016-T6 causes a greater tool wear than 2017-T4 when machining.

2024-T3--It has good machinability and leaves excellent surface finishes with properly sharpened tools.

6061-T6--This alloy contains silicon, which make it abrasive and hard to machine causing tool wear. With proper lubrication and a heavy cut, a good surface finish can be obtained.

7075-T6--This is the highest strength aluminum that is available commercially. It has good machinability qualities and leaves attractive surface finishes.

3. Aluminum Alloys--In identifying aluminum, the make up of all aluminum alloys determines the machinability, color, and luster. Alloys that contain a non-abrasive such as copper, magnesium and zinc have improved machinability, a bright gray or silver color and a bright luster or shine. Alloys with more abrasive mixtures such as silicon have a surface color of slightly gray with little luster. These also reduce tool life when machining.

B. Copper-based Alloys

Copper is a base metal for producing other types of alloys. For example: When copper and zinc are put together, brass is produced. When copper is put together with tin, bronze is made. A new addition to the copper family is Beryllium Copper which is the joining of the two elements.

1. Copper is probably the oldest metal known to man. Although it becomes hard when working with it, it can be shaped easily. When working with copper, cutting tools must be kept sharp, but heavy cuts can be made because of its toughness and softness. Copper can be identified by its reddish-brown color.

2. **Brass** can be identified by its color, ranging from a reddish yellow color to a silvery yellow color. Most brasses can be easily machined with little tool wear and easy chip removal.

3. **Bronze** is usually identified by having a darker color and being harder than brass. It usually has more elements added to it, such as phosphorus, aluminum and nickel. Most bronzes are fairly easy to machine with sharp cutting tools.

4. **Beryllium Copper** has the same machining quality of copper, but some precaution should be observed because of Beryllium could pose a health hazard, due to the quantity of dust created when machining. It can be identified by its color which is darker than that of copper. One unique quality is that Beryllium Copper can be heat-treated.

C. Magnesium

This non-ferrous metal has a light, dull gray color and can easily be identified by its light weight in relation to its volume. The magnesium alloys are the lightest of the structural metals. Magnesium has excellent machining properties, but care must be taken because of the possibility that the chips may ignite from heat generated during cutting. Water-based coolant must be avoided in the case of fire because the water reacts with the chips and intensifies the fire. Sand or graphite should be used to put out the fire.

D. Titanium

This metal bridges the gap between aluminum and steel because it is as strong as steel, but only half as heavy as steel. Titanium has a bright silvery, gray color and can stand continuous serviceable temperatures of up to 800 degrees Fahrenheit. When machining titanium, tools must be sharp and cutting speeds must be slower than those used for steel.

III. High Temperature and Rare Metals

These two metal classifications can be combined into the same explanation. There are many types of metals that are used for special purposes and will not be described here. Such metals are used for high temperature conditions, wear, and corrosion resistance. Such metals are nickel, base- alloys, molybdenum, tantalum, tungsten, and many more which are generally used for aerospace and highly technical applications.

**QUESTIONS - Common Metal Identification &
Machine Characteristics**

Select the best answer for the following:

1. Care must be taken when machining this type of metal because the chip could ignite if too much heat is generated.
 - a. Magnesium
 - b. Beryllium Copper
 - c. Brass
 - d. Aluminum

2. Care must be taken when machining this type of metal because the dust made by a cutter could cause a health hazard.
 - a. Magnesium
 - b. Beryllium Copper
 - c. Aluminum
 - d. Titanium

3. This metal is as strong as steel, but weighs half as much as steel.
 - a. Aluminum
 - b. Copper
 - c. Brass
 - d. Titanium

4. This metal has a dull gray color and is the lightest in weight of all the structural metals.
 - a. Aluminum
 - b. Magnesium
 - c. Titanium
 - d. Brass

5. Which type of cutting tool is used when machining cast iron?
 - a. High Speed Steel
 - b. Carbide
 - c. Tool Steel
 - d. Drill Rod

6. A type of iron that has a dark gray color at a fracture and has the ability to be formed to intricate shapes.
 - a. Gray Cast Iron
 - b. Malleable Cast Iron
 - c. Ductile Cast Iron
 - d. Wrought Iron

7. This type of steel is commonly found in the machine shop, can be filed and machined easily, but leaves build up on the top of the tools.
- a. High Speed Steel
 - b. Stainless Steel
 - c. Low Carbon Mild Steel
 - d. High Carbon Steel
8. Carbon Steels that have a black mill scaly finish indicate what?
- a. Cold Rolled Steel
 - b. Hot Rolled Steel
 - c. Hot Rolled Cold Finished Steel
 - d. Hot Drawn Steel
9. This category of Stainless Steels are non-magnetic and have a whitish color.
- a. Austenitic
 - b. Martensitic
 - c. Ferritic
 - d. Cerium
10. Which type of aluminum would you select for having the highest strength, good machining qualities, and which leaves good surface finish?
- a. 1100
 - b. 5056
 - c. 6061-T6
 - d. 7075-T6

TRUE OR FALSE

11. All Stainless Steels are non-magnetic because they contain chromium.
- T F
12. Alloy Steels are steels that have a mixture of elements added to normal iron.
- T F
13. Carbon Steel can come in both hot and cold rolled finishes.
- T F
14. Cold rolled steel can be identified by its smooth and shiny surface.
- T F

ANSWERS - METAL IDENTIFICATION

1. a
2. b
3. d
4. b
5. b
6. a
7. c
8. b
9. a
10. d
11. false
12. true
13. true
14. true

END

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