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FUNDAMENTALS OF MACHINE TOOLS

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Preface

The purpose of this training circular is to provide a better understanding of power-driven machine tools. It also supplements technical manuals in the 9-3400-series covering power-driven machine tools.

One of the main objectives is for this publication is to be clear and understandable. Illustrations throughout this publication show the step-by-step process of many machine shop operations. The tables, charts, formulas, weights, and measurements in this publication can be a ready reference for selecting the proper tooling and math formulas for machining different materials.

The proponent of this publication is HQ TRADOC. Send comments and recommendations on DA Form 2028 directly to the Department of the Army, Training Directorate, ATTN: ATCL-AO, 801 Lee Avenue, Fort Lee, Virginia 23801-1713.

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Chapter 1

INTRODUCTION TO THE MACHINE SHOP

GENERAL INFORMATION

FORMS, RECORDS, AND REPORTS

Accurate records are valuable. Unit officers are responsible for completion of forms, records, and reports. DA Pam 738-750 lists records, reports, and authorized forms that are normally used for inspection and repair. Properly executed forms authorize and record repair or replacement of materiel. The forms, records, and reports document the work required, follow the progress of the work within the shops, and indicate the status of the material upon completion of repairs.

FIELD REPORT OF ACCIDENTS

The reports necessary to comply with the requirements of the Army Safety Program are prescribed in detail in AR 385-40. These reports are required for any accidents involving injury or damage. For a listing of all forms, refer to DA Pam 25-30.

Any deficiencies detected in the equipment covered herein should be immediately reported in accordance with DA Pam 738-750. These reports will be submitted as an Equipment Improvement Recommendation on SF 368.

DEFINITION OF MACHINE TOOLS

Machine tools are power-driven equipment designed to drill, bore, grind, or cut metal or other material.

LISTING OF MACHINE TOOLS

A complete list of machine tools including specialized machine tools currently authorized for issue is in Component List C 3405/70-lL.

SPECIALIZED MACHINE TOOLS

In view of the different design and operating features incorporated in specialized machine tools (cylinder boring machines, brake reliners, valve seat grinders. and so forth) by various manufacturers, no attempt has been made to include information pertinent to them in this manual. For complete information on these tools, see pertinent TM 9-3400-, TM 9-5100-, and TM 9-9000-series technical manuals covering the specific machines.

RISK-MANAGEMENT

To assure a high degree of safety, no machine -tool is to be used unless the risk management process as outlined below is understood and applied by the user and the supervisor:

1. Identify the potential hazard(s) that the machine tool can generate.

2. Assess the probability and severity of the hazard(s) by utilizing the Risk Assessment Matrix in figure 1-1. Risk acceptance decision authority for the risk levels is as follows:

a. Extremely high - CG, TRADOC; DCG, TRADOC; or the Chief of Staff, TRADOC.

b. High - Major subordinate commands, installation commanding generals, and school commandants of general officer rank.

c. Moderate and low - Delegated to the appropriate level in your unit chain of command.

3. Determine the risk control measures that will eliminate the hazard(s) or reduce the risk.

4. Implement the risk control measures before and during operation of the machine tool to eliminate the hazards or reduce their risks.

5. Supervise and evaluate the process. Enforce the established standards and risk control measures. Evaluate the effectiveness of the control measures and adjust/update them as necessary.

SEVERITY			PROBABILITY				
			Frequent	Likely	Occasional	Remote	Unlikely
			A	B	C	D	E
SEVERITY	Catastrophic	I	Extremely High	Extremely High	High	High	Moderate
	Critical	II	Extremely High	High	High	Moderate	Low
	Marginal	III	High	Moderate	Moderate	Low	Low
	Negligible	IV	Moderate	Low	Low	Low	Low

Figure 1-1. Risk assessment matrix.

PROBABILITY

A. **FREQUENT** - Individual soldier/item - Occurs often in the career/equipment service life. All soldiers or item inventory exposed - Continuously experienced during operation/mission.

B. **LIKELY** - Individual soldier/item - Occurs several times in career/equipment service life. - All soldiers or item inventory exposed. - Occurs frequently during operator/mission.

C. **OCCASIONAL** - Individual soldier/item. - Occurs sometimes in career/equipment service life. All soldiers or item inventory exposed. Occurs sporadically, or several times in inventory service or operations/mission.

D. **REMOTE** - Individual soldier/item - Possible to occur in career/equipment service life. All soldiers or item inventory exposed, Remote chance of occurrence - Expected to occur sometime in inventory service life or operation/mission.

E. **UNLIKELY** - Individual soldier/item - Can assume will not occur in career/equipment/service life. All soldiers or item inventory exposed. - Possible, but improbable; occurs only very rarely during operation/mission.

SEVERITY

I. CATASTROPHIC - Death or permanent total disability. System loss. Major property damage.

II CRITICAL - Permanent partial disability. Temporary total disability in excess of 3 months. Major system damage. Significant property damage.

III. MARGINAL - Minor injury. Lost workday accident with compensable injury/illness. Mirror system damage. Minor property damage.

IV. NEGLIGIBLE - First aid or minor supportive medical treatment. Minor system impairment.

RISK LEVELS

EXTREMELY HIGH - Loss of ability to accomplish mission.

HIGH - Significantly degrades mission capabilities in terms of required mission standards.

MODERATE- Degrades mission capabilities in terms of required missions standards.

LOW - Little or no impact on accomplishment of mission.

MACHINE SHOP WORK

SCOPE

Machine shop work is generally understood to include all cold-metal work by which an operator, using either power driven equipment or hand tools, removes a portion of the metal and shapes it to some specified form or size. It does not include sheet metal work and coppersmithing.

LAYING OUT WORK

"Laying out" is a shop term which means to scribe lines, circles, centers, and so forth, upon the surface of any material to serve as a guide in shaping the finished workpiece. This laying out procedure is similar to shop drawing but differs from it in one important respect. The lines on a shop drawing are used for reference purposes only and are not measured or transferred. In layout work, even a slight error in scribing a line or center may result in a corresponding or greater error in the finished workpiece, For that reason, all scribed lines should be exactly located and all scriber, divider, and center points should be exact and sharp.

SCRIBING LINES ON METAL

The shiny surface, found on most metals, makes it difficult to see the layout lines.

Layout dye (Figure 1-2), when applied to the metal surface, makes it easier for the layout lines to be seen. Layout dye is usually blue and offers an excellent contrast between the metal and the layout lines.

Before applying layout dye, ensure that all grease and oil has been cleaned from the work surface. Otherwise the dye will not adhere properly.

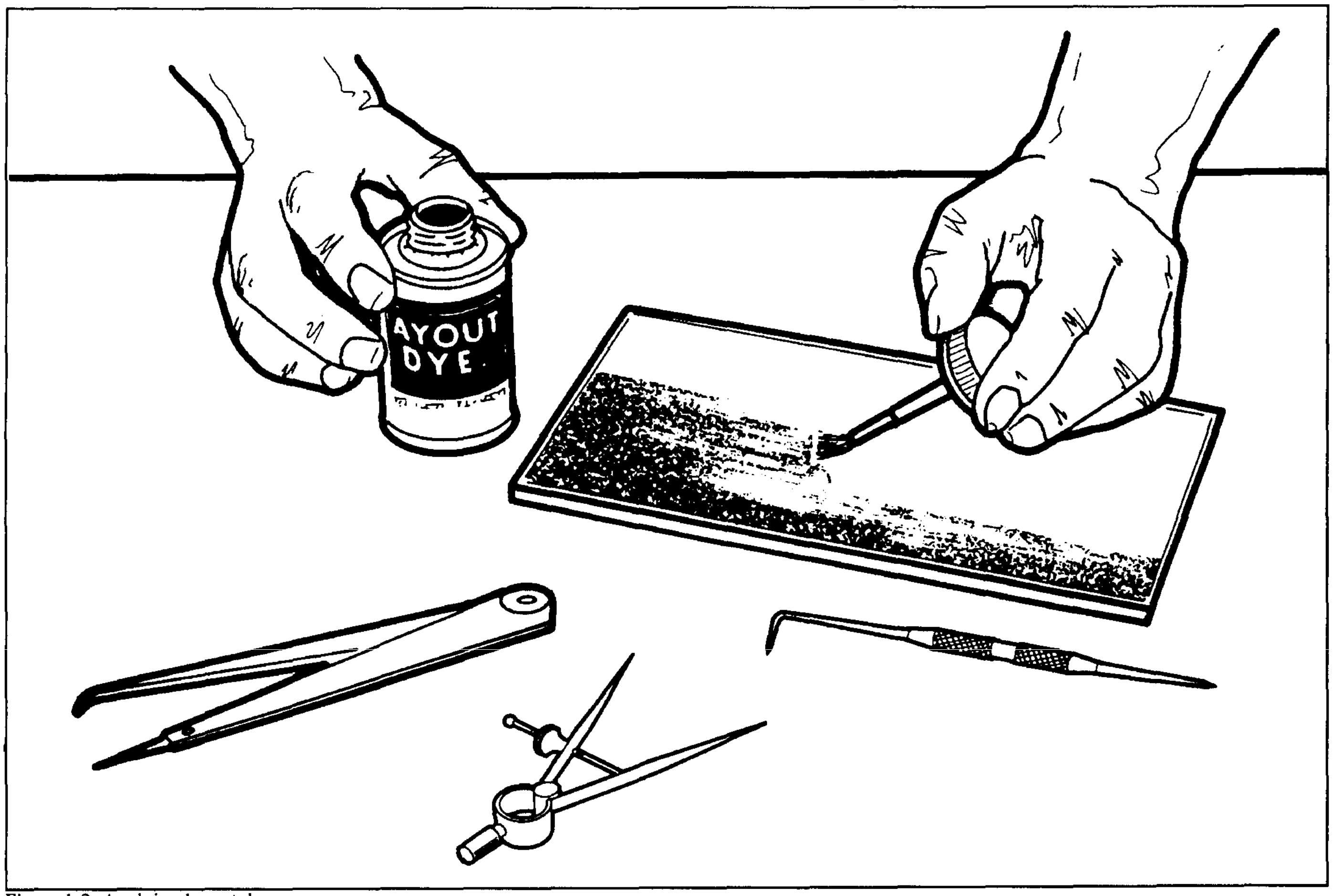


Figure 1-2. Applying layout dye.

COMMON LAYOUT TOOLS

Scriber

To obtain an accurate layout, fine lines must be scribed in the metal. A scriber (Figure 1-3) is the layout tool that is used to produce these lines. The point is made of hardened steel and is kept chain by honing on an oilstone.

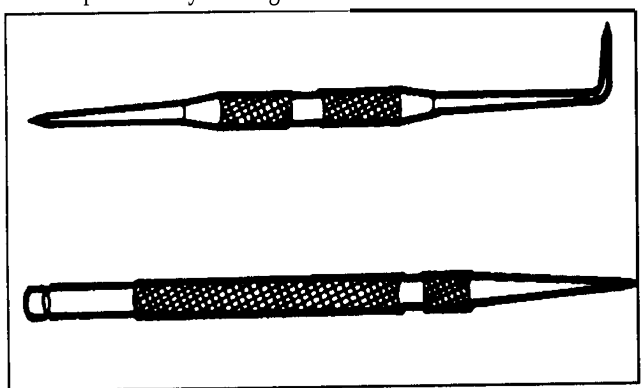


Figure 1-3. Scribers.

Divider

When laying out circles, arcs, and radii, it is best to use the divider (Figure 1-4). The legs of the divider must be of the same length and be kept sharp. The divider cart be used to lay out and measure distances (Figure 1-5). To set the divider to the correct length, place one point on an inch mark of a steel rule and open the divider until the other leg matches the correct measure-merit required (Figure 1-6).

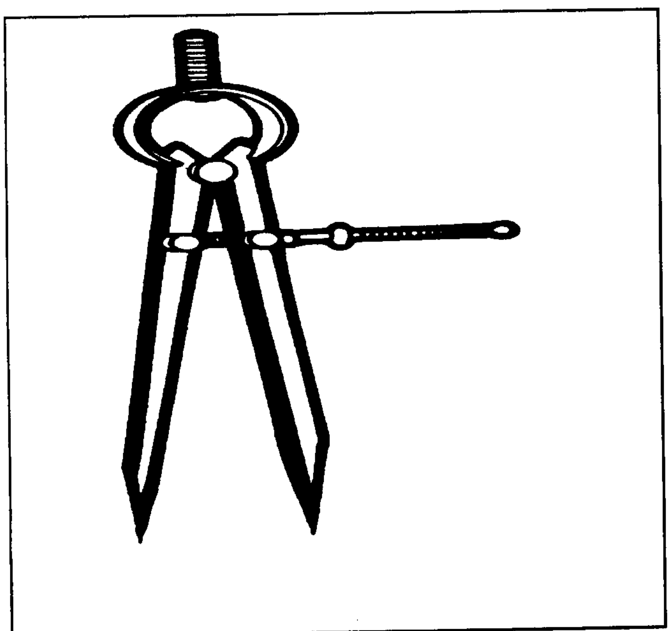


Figure 1-4. Divider.

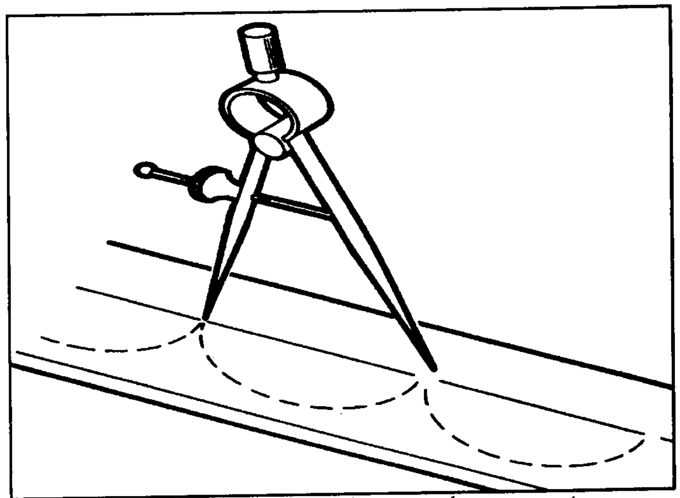


Figure 1-5. Using divider to layout equal measurement.

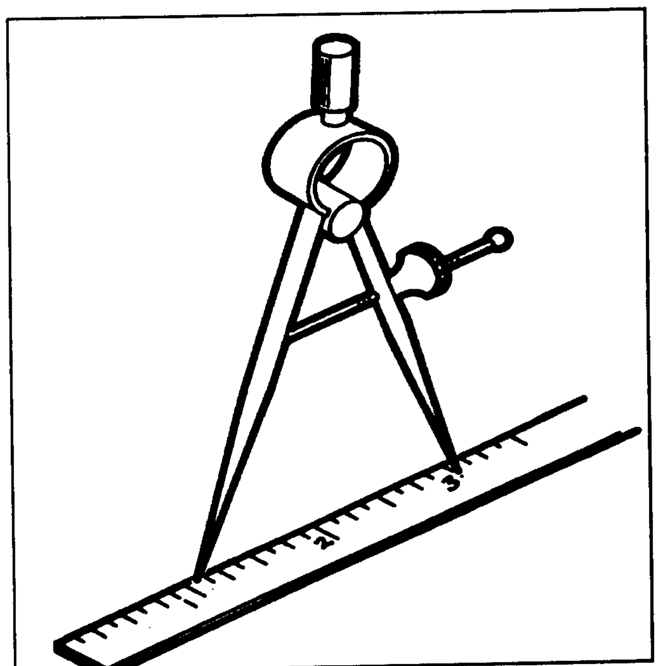


Figure 1-6. Correct method of setting dividers.

Trammel

When scribing circles, arcs, and radii that are too large to be produced with the divider, a trammel should be used (Figure 1-7). The trammel is made of three main parts: the beam, two sliding heads with scriber points, and an adjusting screw that is attached to one of the heads. The trammel can be made to scribe larger distances with the use of extension rods. This layout tool is set in the same manner as the divider.

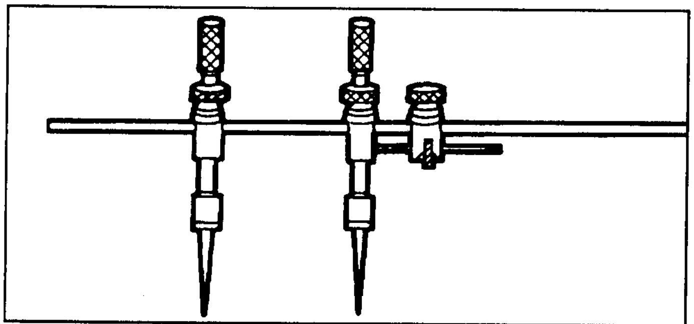


Figure 1-7. Trammel.

Hermaphrodite Caliper

The hermaphrodite caliper (Figure 1-8) is a tool used to lay out lines that are parallel with the edges of the workpiece (Figure 1-9). It can also be used to locate the center of cylindrical shaped workplaces (Figure 1-10).

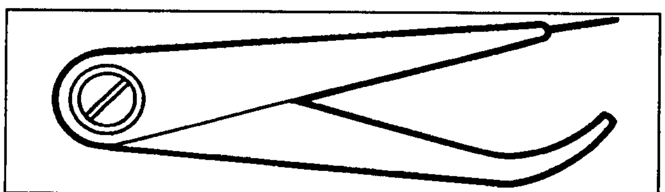


Figure 1-8. Hermaphrodite calipers.

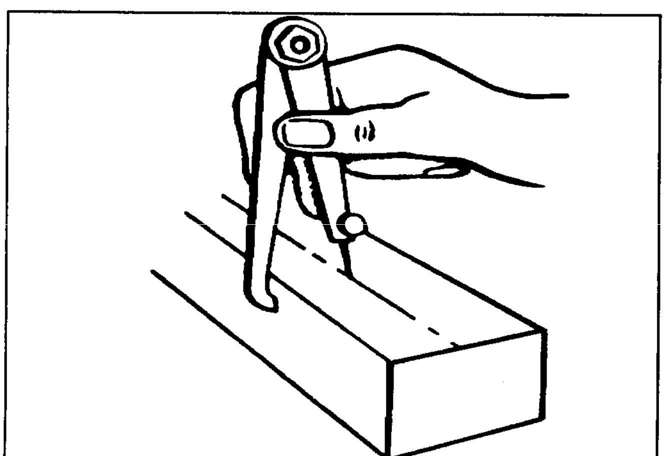


Figure 1-9. Laying out lines parallel to the edge of workpiece.

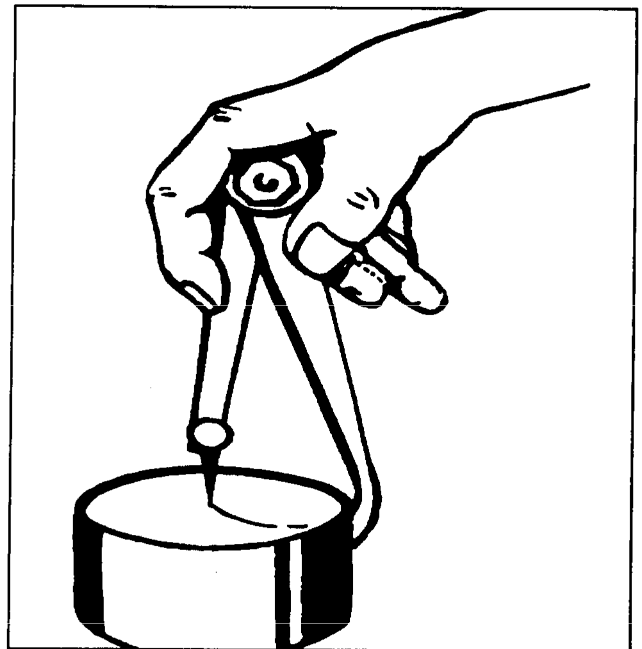


Figure 1-10. Obtaining center of cylindrical work.

Surface Gage

A surface gage (Figure 1-11) is used for many purposes, but is most often used for layout work. The gage can be used to scribe layout lines at any given distance parallel to the work surface (Figure 1-12).

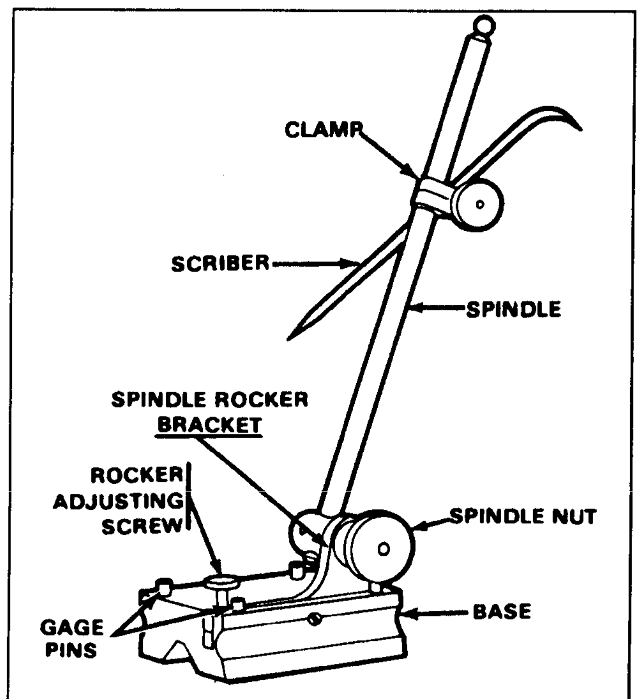


Figure 1-11. Surface gage.

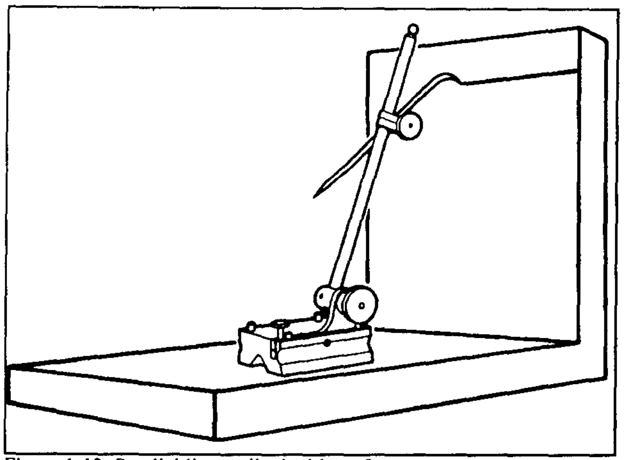


Figure 1-12. Parallel line scribed with surface gage.

The spindle may be adjusted to any position with respect to the base and tightened in place with the spindle nut (Figure 1-11). The rocker adjusting screw provides for finer adjustment of the spindle by pivoting the spindle rocker bracket. The scriber can be positioned at any height and in any desired direction on the spindle by adjusting the scriber. A surface plate and combination square (Figure l-13) are needed to set the surface gage to the correct dimension.

Surface Plate

A surface plate (Figure l-14) provides a true, smooth, plane surface. It is used in conjunction with surface and height gages as a level base on which the gages and the workpiece are placed to obtain accurate measurements. These plates are made of semi-steel or granite and should never be used for any job that would scratch or nick the surface.

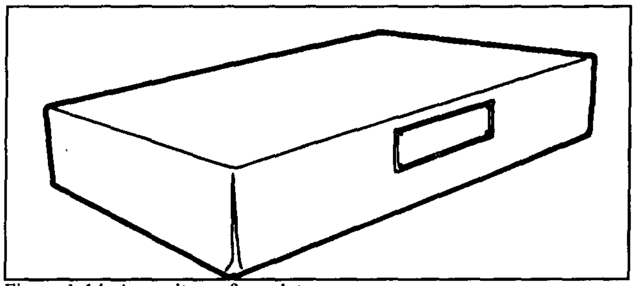


Figure 1-14. A granite surface plate.

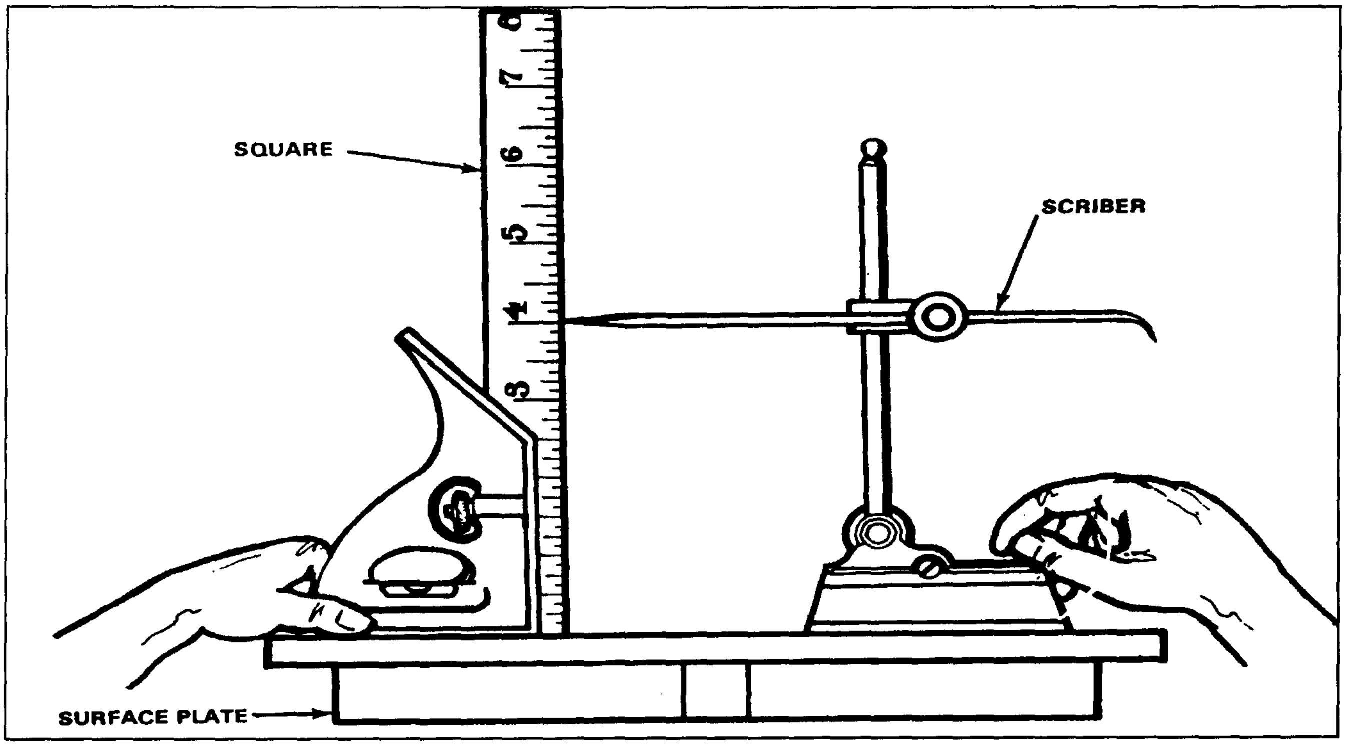


Figure 1-13. Setting surface gage scriber on surface plate 2.

Vernier Height Gage

The vernier height gage (Figure 1-15) is a caliper with a special foot block to adapt it for use on a surface plate. Height gages are available in several sizes: the most common are the 10, 18, and 24 inch gages in English measure and the 25 and 46 cm gages in metric measure. Like the vernier caliper, these height gages are graduated in divisions of 0.025 inch and a vernier scale of 25 units for reading measurements to thousandths of an inch. Always be sure the bottom of the foot block (Figure 1-15) is clean and free from burrs.

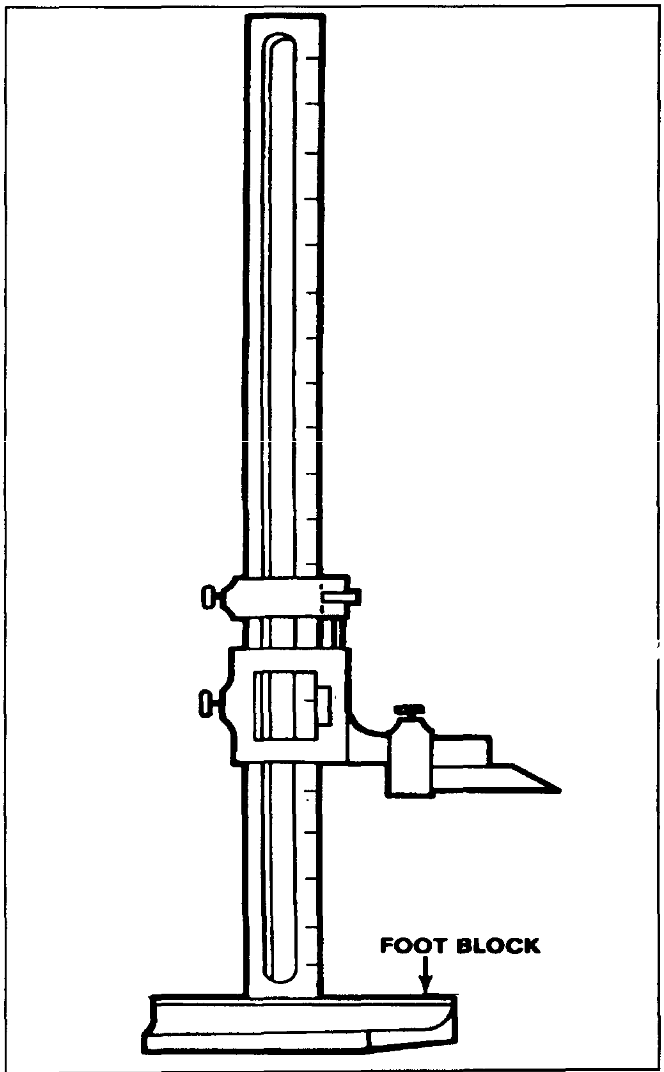


Figure 1-15. Vernier height gage.

Figure 1-16 shows the height gage with a tungsten carbide marker. This marker is used to lay out lines on glass, hardened steel. or other hard materials.

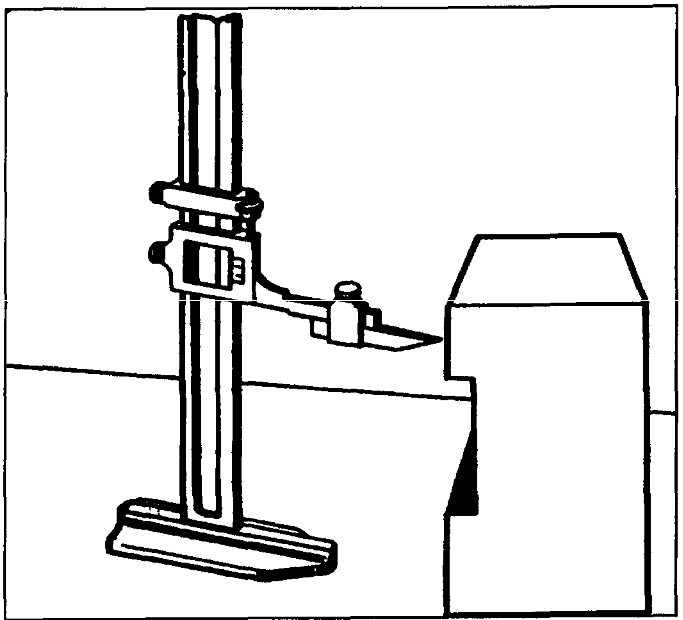


Figure 1-16. Using height gage with carbide marker.

Figure 1-17 illustrates the use of an offset scriber with the height gage. This scriber reaches below the gage base. Do not attempt to adjust the sliding jaw while it is clamped to the upright beam.

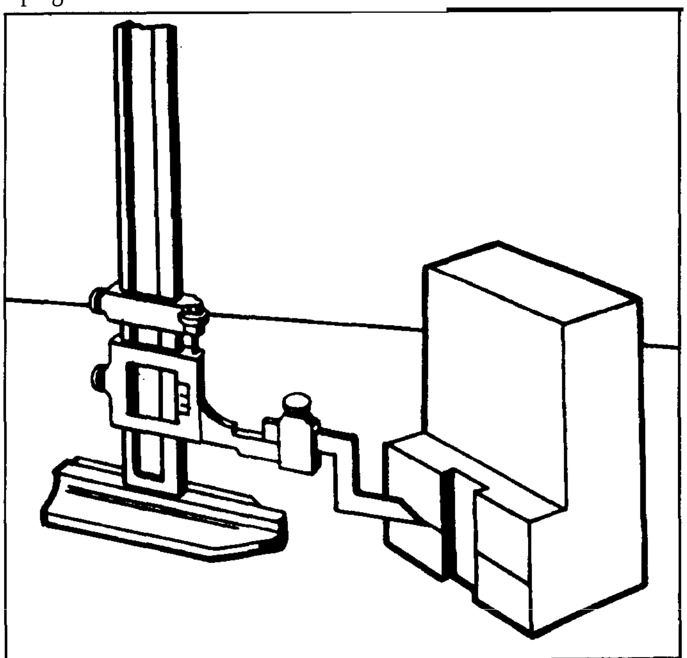


Figure 1-17. Using height gage with offset scriber.

Combination Square Set

The combination square set (Figure 1-18) is used for a number of layout operations. The set consists of a blade (graduated rule), square head, protractor, and center head.

Blade

The blade is designed to allow the different heads to slide along the blade and be clamped at any desired location. The groove in the blade is concave to eliminate dirt buildup and permit a free and easy slide for the heads. By removing all the heads, the blade may be used alone as a rule.

Square Head

The square head is designed with a 45° and 90° edge, which makes it possible to be used as a try square and miter square. By extending the blade below the square, it can be used as a depth rule. The square head can also be used as a level.

Protractor Head

The protractor head is equipped with a revolving turret graduated in degrees from 0 to 180 or to 90 in either direction. It is used to measure or lay out angles to an accuracy of 1°.

Center Head

The center head, when inserted on the blade, is used to locate and lay out the center of cylindrical workplaces.

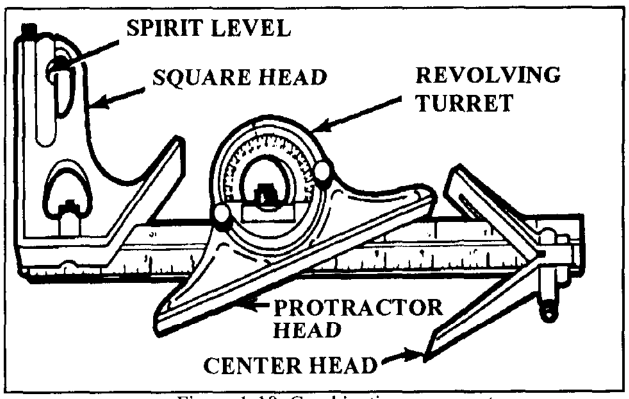


Figure 1-18. Combination square set.

Bevel Protractor

The bevel protractor (Figure 1-19) consists of an adjustable blade with a graduated dial. The blade is usually 12 inches long and 1/16 inch thick. The dial is graduated in degrees through a complete circle of 360°. The most common use for this tool is laying out precision angles. The vernier scale is used for accurate angle adjustments and is accurate to 5 minutes or 1/12°.

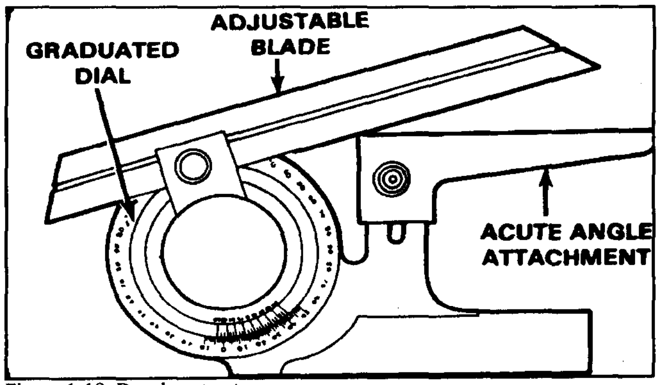


Figure 1-19. Bevel protractor.

STEPS IN MAKING A LAYOUT

Planning before beginning any layout is one of the most important steps. Each job may require different layout tools depending on the accuracy needed; however, there are certain procedures which should be followed in any layout. Figure 1-20 shows a typical layout.

- Study the shop drawing or blueprint carefully before you cut off the stock. Allow enough material to square the ends if required.
- Remove all oil and grease from the work surface and apply layout dye.
- Locate and scribe a reference or base line. All the other measurements should be made from this. If the workpiece already has one true edge, it can be used in place of the reference line.
- Using the base line as a reference line, locate and scribe all center lines for each circle, radius, or arc.
- Mark the points where the center lines intersect using a sharp prick punch.
- Scribe all circles, radii, and arcs using the divider or trammel.
- Using the correct type protractor, locate and scribe all straight and angular lines.
- Scribe all lines for internal openings.
- All layout lines should be clean, sharp, and fine. Reapply layout dye to all messy, wide, or incorrect lines and rescribe.

The layout tools mentioned in this section are only the most commonly used. For more information on the use and care of these tools and other layout and measuring tools, refer to TM 9-243.

JIGS AND FIXTURES

The primary purpose of jigs and fixtures is to align the tool and hold the workpiece properly during machining. A fixture is a device which holds the work while cutting tools are in operation. It differs from a jig in that it has no guides or special arrangements for guiding tools. A jig is also a fixture for locating or holding the work and guiding the cutting tool in operations such as drilling, reaming, counterboring, and countersinking.

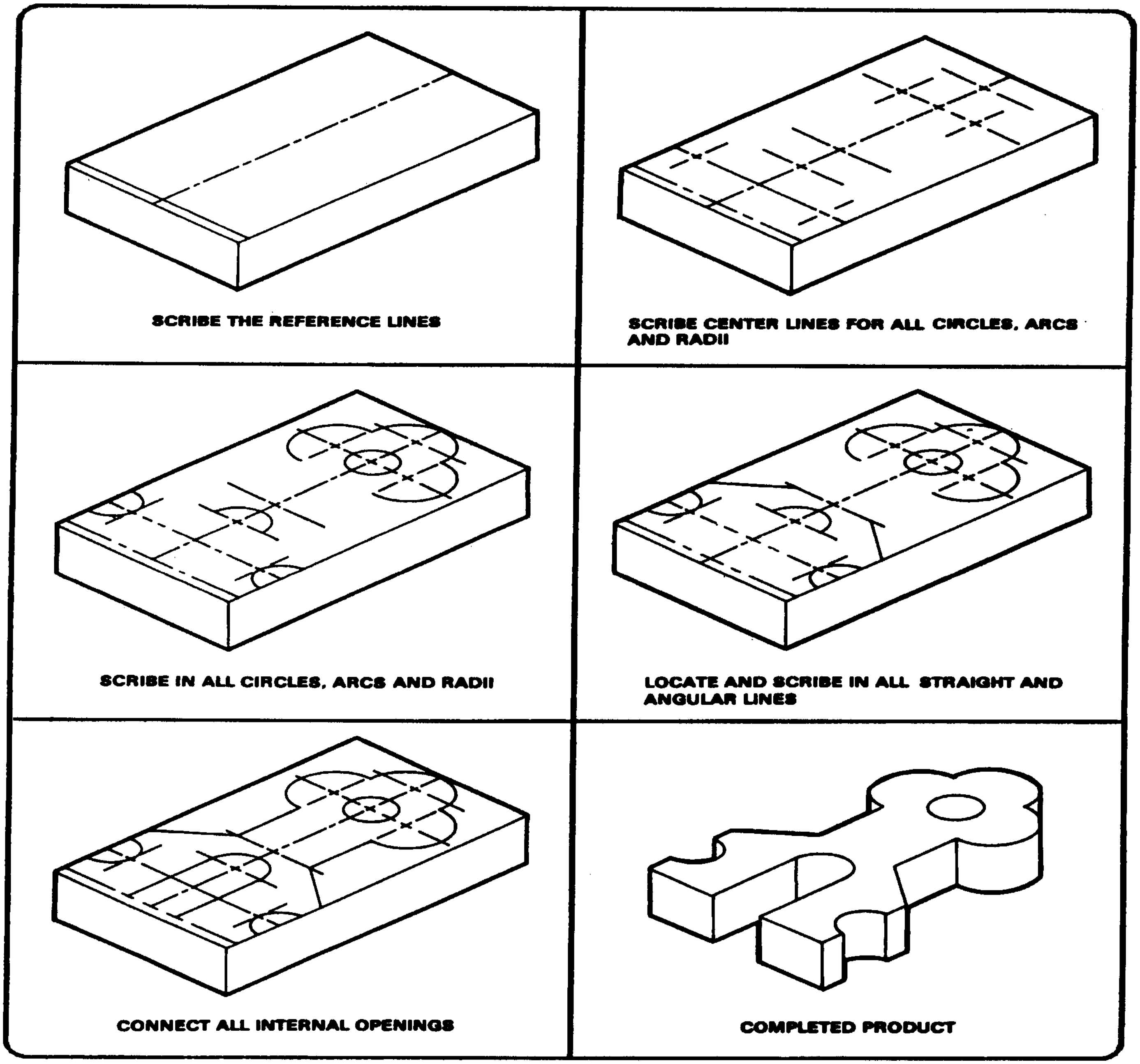


Figure 1-20. Typical Layout.

Jigs and fixtures can greatly reduce the cost of manufacturing large quantities of parts. Their use is also an advantage when the interchangeability and accuracy of the finished products are important. They also can be used in low or limited production jobs if extreme accuracy must be maintained. One of their greatest advantages is that relatively unskilled labor can accomplish the job using these special tools.

MECHANICAL DRAWINGS AND BLUEPRINTS

Mechanical Drawings

A mechanical drawing, made with special instruments and tools, gives a true representation of an object to be made, including its shape, size, description, material to be used, and method of manufacture.

Blueprints

A blueprint is an exact duplicate of a mechanical drawing. These are the most economical and satisfactory working drawings in use. They do not soil easily and are comparatively easy to read. Blueprint paper is a good grade of white paper coated with a chemical solution. making it greenish yellow. A blueprint is made by placing a tracing of a mechanical drawing on a sheet of blueprint paper and exposing it to light. During exposure. the light penetrates where there are no lines or printing on the tracing but does not penetrate where there are lines or printing. The print is then washed in water. which changes the exposed chemical to a dark blue and washes the chemical off where lines and printing prevented exposure. In other words. the process leaves white lines on dark blue background.

Working From Drawings

Detail prints usually show only the individual part or piece that must be produced. They show two or more orthographic (straight-on) views of the object. and in special cases. they may show an isometric projection. without dimension lines, near the upper right corner. An isometric projection shows how the part will look when made. Each drawing or blueprint carries a number. located in the upper left-hand corner and in the title box in the lower right-hand corner of the print. The title box also shows the part name, the scale used, the pattern number. the material required. the assembly or subassembly print number to which the part belongs. the job order number, the quantity and date of the order. and the names or initials of the persons who drew. checked. and approved the drawings (Figure 1-20). Accurate and satisfactory fabrication of a part described on a drawing depends upon the following:

- Correctly reading the drawing and closely observing all data on the drawing.
- Selecting the correct tools and instruments for laying out the job.
- Use the baseline or reference line method of locating the dimensional points during layout. thereby avoiding cumulative errors.
- Strictly observing tolerances and allowances.
- Accurate gaging and measuring of work throughout the fabricating process.
- Giving due consideration when measuring for expansion of the workpiece by heat generated by the cutting operations. This is especially important when checking dimensions during operations, if work is being machined to close tolerances.

Limits of Accuracy

Work must be performed within the limits of accuracy specified on the drawing. A clear understanding of tolerance and allowance will help you avoid making small, but potentially large errors. These terms may seem closely related but each has a very precise meaning and application. The paragraphs below point out the meanings of these terms and the importance of observing the distinctions between them.

Tolerance

Working to the absolute or exact basic dimension is impractical and unnecessary in most instances: therefore, the designer calculates. in addition to the basic dimensions, an allowable variation. The amount of variation. or limit of error permissible is indicated on the drawing as plus or minus (+) a given amount. such as + 0.005 or + 1/64. The difference between the allowable minimum and the allowable maximum dimension is tolerance. When tolerances are not actually specified on a drawing, fairly concrete assumptions can be made concerning the accuracy expected. by using the following principles, For dimensions which end in a fraction of an inch. such as 1/8, 1/16, 1/32, 1/64. consider the expected accuracy to be to the nearest 1/64 inch. When the dimension is given in decimal form the following applies: If a dimension is given as 2.000 inches, the accuracy expected is +0.005 inch: or if the dimension is given as 2.00 inches, the accuracy expected is +0,010 inch. The +0.005 is called in shop terms, "plus or minus five thousandths of an inch.” The + 0.010 is called “plus or minus ten thousandths of an inch.”

Allowance

Allowance is an intentional difference in dimensions of mating parts to provide the desired fit. A clearance allowance permits movement between mating parts when assembled. For example, when a hole with a 0.250-inch diameter is fitted with a shaft that has a 0.245-inch diameter, the clearance allowance is 0.005 inch. An interference allowance is the opposite of a clearance allowance. The difference in dimensions in this case provides a tight fit. Force is required when assembling parts which have an interference allowance. If a shaft with a 0.251-inch diameter is fitted in the hole identified in the preceding example, the difference between the dimensions will give an interference allowance of 0.001 inch. As the shaft is larger than the hole, force is necessary to assemble the parts.

Precautions

Be sure you have the correct print for the part to be made or repaired. You want the print which has not only the correct title, but also the correct assembly number. Never take a measurement with a rule directly from the print because the tracing from which the print was made may not have been copied from the original drawing perfectly and may contain scaling errors. Also, paper stretches and shrinks with changes in atmospheric conditions. Dimensions must be taken only from the figures shown on the dimension lines. Be very careful in handling all blueprints and working drawings. When they are not in use, place them on a shelf, in a cabinet, or in a drawer. Return them to the blueprint file as soon as the job is done. Blueprints and working drawings are always valuable and often irreplaceable. Make it a point never to mutilate, destroy, or lose a blueprint.

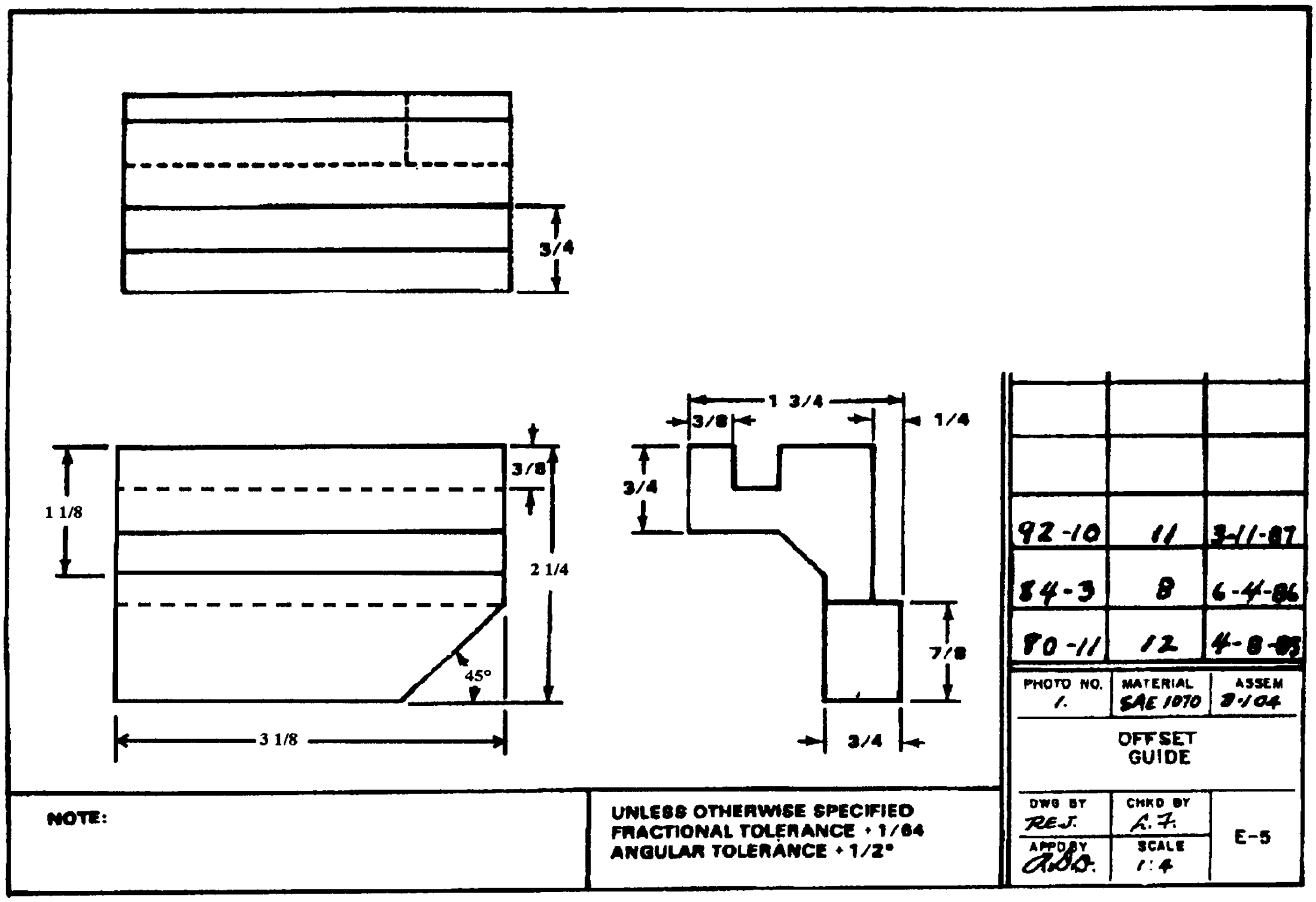


Figure 1-21. Typical blueprint.

GENERAL SHOP SAFETY

All tools are dangerous if used improperly or carelessly. Working safely is the first thing the user or operator should learn because the safe way is the correct way. A person learning to operate machine tools must first learn the safety regulations and precautions for each tool or machine. Most accidents are caused by not following prescribed procedures. Develop safe work habits rather than suffer the consequences of an accident.

Most of the safety practices mentioned in this section are general in nature. Safety precautions for specific tools and machines are described in detail in the chapters along with the description of the equipment. Study these carefully and be on the alert to apply them.

EYE PROTECTION

Using eye protection in the machine shop is the most important safety rule of all. Metal chips and shavings can fly at great speeds and distances and cause serious eye injury. Safety glasses must be worn when working with handcutting tools, since most handcutting tools are made of hardened steel and can break or shatter when used improperly.

There are many different types of safety glasses available in the supply system; however, the ones that offer the best protection are the safety glasses with side shields. Safety goggles should be worn over prescription glasses. For specific information about eye protection, contact the Occupational Health Clinic or refer to TB MED 586.

HAZARDOUS NOISE PROTECTION

Noise hazards are very common in the machine shop. High intensity noise can cause permanent loss of hearing. Although noise hazards cannot always be eliminated, hearing loss is avoidable with ear muffs, ear plugs, or both. These are available through the local supply system or from the Occupational Health Clinic. Ear plugs must be properly fitted by qualified personnel. For specific information on hearing protection, refer to TB MED 501.

FOOT PROTECTION

The floor in a machine shop is often covered with razor-sharp metal chips, and heavy stock may be dropped on the feet. Therefore, safety shoes or a solid leather shoe must be worn at all times. Safety shoes are available in the supply system. These have a steel plate located over the toe and are designed to resist impact. Some safety shoes also have an instep guard.

GRINDING DUST AND HAZARDOUS FUMES

Grinding dust from abrasive wheels is made up of extremely fine particles of the metal and the wheel. Some grinding machines are equipped with a vacuum dust collector. When operating a grinder without a vacuum, wear an approved respirator to avoid inhaling the dust. Whenever possible, use coolant when grinding. This will aid in dust control. Grinding dust can be very dangerous to your health, especially beryllium or parts used in nuclear systems. These materials require careful control of grinding dust.

Metals such as zinc give off toxic fumes when heated above their boiling point. Inhaling these fumes may cause temporary sickness, or death. The fumes produced from lead and mercury are very harmful, as their effect is cumulative in the body and can cause irreversible damage. When unsure of the materials being machined, it is advisable to wear a respirator. For more specific information on respirator safety, refer to TB MED 502.

PROPER LIFTING PROCEDURES

Using improper lifting procedures may result in a permanent back injury. Back injury can be avoided if the correct lifting procedures are followed. When lifting heavy or large objects, get some assistance or use a hoist or forklift.

Objects within your ability can be lifted safely as long as the following procedures are followed:

- Keep your back straight.
- Squat down, bending at the knees.
- Use the leg muscles to do the work and lift slowly. Do not bend over the load as this will put excessive strain on your spine.
- Carry the object where it is comfortable, and pay close attention to where you are walking and objects around you.
- When placing the object back on the floor, use the same procedures as when it was lifted.

ELECTRICAL SAFETY

Exposure to electrical hazard will be minimal unless the operator becomes involved with machine repair. The machine operator is mostly concerned with the on and off switch on the machine tool. However, if adjustments or repairs must be made, the power source should be disconnected. If the machine tool is wired permanently, the circuit breaker should be switched off and tagged with an appropriate warning statement. Most often the power source will not be disconnected for routine adjustment such as changing machine speeds. However, if a speed change involves a belt change, make sure that no other person is likely to turn on the machine while the operator's hands are in contact with belts and pulleys.

SAFETY RULES FOR MACHINE TOOLS

Since different cutting tools and machining procedures are used on various machine tools, the safety precautions for each may vary. The following are general safety rules for any machine tool:

- Gears, pulleys, belts, couplings, ends of shafts having keyways, and other revolving or reciprocating parts should be guarded to a height of 6 feet above the floor. The guards should be removed only for repairing or adjusting the machine and must be replaced before operating it.
- Safety setscrews should be used in collars and on all revolving or reciprocating members of the machine tool or its equipment.
- Do not operate any machine tool without proper lighting.
- Never attempt to operate any machine tool until you fully understand how it works and know how to stop it quickly.
- Never wear loose or torn clothing and secure long hair, since these items can become caught in revolving machine parts. Ties should be removed and shirt sleeves should be rolled up above the elbow.
- Gloves should never be worn when operating machinery except when absolutely necessary.
- Always stop the machine before cleaning it or taking measurements of the workpiece.
- Do not lubricate a machine while it is in motion. Injury to the operator and damage to the machine may result from this practice.
- Never remove metal chips, turnings, or shavings with your hands; they may cause a serious cut. If the shavings are long, stop the machine and break them with pliers or a bent rod, and then brush chips off the machine. Remove cast-iron chips, which break into small pieces, with a brush. Never wipe away chips when the machine is operating.
- Always wear safety glasses or goggles while operating machine tools. Also, wear respiratory protection if operation creates hazardous dust. All persons in the area where power tools are being operated should also wear safety eye protection and respirators as needed.
- Know where tire extinguishers are located in the shop area and how to use them.
- Never wear jewelry while working around machine tools. Rings, watches, or bracelets maybe caught in a revolving part which could result in the hand being pulled into the machine.
- Avoid horseplay. Tools are very sharp and machines are made of hard steel. An accidental slip or fall may cause a serious injury.
- Never use compressed air without a safety nozzle to clean machines or clothing. It will blow sharp, dangerous metal chips a long distance.
- Keep the floor around machines free of tools, stock, oil, grease, and metal chips. Tripping over metal on the floor, especially round bars, can cause dangerous falls. Wipe up all oil, grease, and cutting fluid spills on the floor as soon as possible to prevent a fall. Metal chips are very sharp and can easily become embedded in the soles of shoes, making them very slippery, especially when walking on a concrete floor.
- Never place tools or other materials on the machine table. Cluttering up a machine with tools or materials creates unsafe working conditions. Use a bench or table near the machine for this purpose.
- Always use a rag when handling sharp cutters such as milling cutters and end mills.

- Do not expose power tools to rain or use in damp or wet locations.
- Always secure the workpiece. Use clamps or a vise. It is safer than using your hands, and it frees both hands to operate the tool
- Do not abuse electrical cords. Never carry a tool by its cord or yank it to disconnect it from a receptacle. Keep electrical cords away from heat, oil, and sharp edges. Have damaged or worn power cords and strain relievers repaired or replaced immediately.
- Remove adjusting keys and wrenches. Form a habit of checking to see that keys and wrenches are removed from tools before turning them on.
- Do not operate any machine tool while under the influence of drugs, alcohol, or any medication that could cause drowsiness.

SAFETY COLOR CODE MARKINGS AND SIGNS

USE OF PAINT

All maintenance shops and work areas should be marked with the correct colors to identify hazards, exits, safe walkways, and first-aid stations. It is acceptable to use material other than paint, such as decals and tapes, in the appropriate, similar colors. Listed below are the main colors authorized for use in maintenance shops.

Red color markings should be used to identify the following equipment or locations:

- Fire alarm boxes (pull boxes).
- Fire blanket boxes.
- Fire extinguishing containers.
- Fire extinguishers, unless painting is unnecessary. For large areas and when the extinguisher is not readily visible to the area occupants, use red on the housing wall or support above the extinguisher to show its location.
- Fire hose locations.
- Fire pumps.
- Fire sirens.
- Sprinkler piping.
- Fire buckets.
- Fire reporting telephone stations.
- Store all idle tools in a safe, dry place.
- Provide visitors to the work area required personnel protection equipment.
- An exception may be made to comply with local laws or when current facilities provide green exit signs.
- Emergency stop buttons for electrical machinery.
- Emergency stop bars on hazardous machines.
- Yellow color markings should be used to identify the following equipment or locations:
- Industrial areas where particular caution is needed, such as handrails, guardrails, bottom edge of overhead doors, or top and bottom treads of stairways.
- Fire hydrant barrels.
- Caution signs.
- Piping systems containing flammable material.
- Waste containers for highly combustible material.
- A hazardous area or a safe aisle within a hazardous area.

- Lower pulley blocks and cranes.
- Coverings and guards for guy wires.
- Pillars, posts, or columns that are physical or shop hazards.
- Fixtures suspended from ceilings or walls that extend into normal operating areas.
- Corner markings for storage piles.
- Exposed and unguarded edges of platforms, pits, and wells.

Green color markings normally on a white color background should be used for the following equipment or locations:

- First-aid equipment.
- First-aid dispensaries.
- Stretchers.
- Safety starting buttons on machinery.
- Safety instruction signs.

Black and white are the basic colors for designating housekeeping and interior traffic markings. The following are examples of where solid white, solid black, single-color striping, alternate stripes of black and white, or black and white squares will be used.

- Locations and width of aisles in nonhazardous areas.
- Dead ends of aisles or passageways.
- Directional signs.
- Locations of refuse cans.
- White corners of rooms or passageways.
- Clear floor area around first-aid, fire-fighting, and their emergency equipment.

Blue color markings are used on the outside of switch boxes electrical controls that are the starting point or power source for hazardous electrical machinery or equipment.

Orange markings are used to designate dangerous parts of machines or energized equipment, including electrical conduits, which may cut, crush, shock, or injure.

CATEGORIES OF SIGNS

Signs are placed in categories according to their purpose. Use the examples in the following paragraphs as guides when choosing the correct sign design to display a message. In overseas commands, the use of International Standard Safety Signs is encouraged and authorized.

WORDING OF SIGNS

Ensure that the wording of any sign-

- Is concise and easy to read.
- Contains enough information to be easily understood.
- Is designed for the message to be carried in a picture when appropriate.
- Is a positive rather than a negative statement when appropriate.
- Is bilingual with the second language common to the local personnel when appropriate.

SIGN INSPECTION AND MAINTENANCE

Signs should be inspected regularly and maintained in good condition. They should be kept clean, well illuminated, and legible. Replace or repair damaged or broken signs. All signs will be designed with rounded or blunt corners and with no sharp projections. Put the ends or heads of bolts or other fastening devices where they will not cause a hazard.

SELECTION OF SIGN SIZE

When choosing a sign, consider dimensions that will permit economical use of standard size material. Base the size of the sign on the following:

- Location at which the sign will be placed.
- Character of the hazard involved.
- Purpose of the sign.
- Distance from which the sign should be legible.

REQUIRED SIGN COLORS

All signs require a predominant color based on the sign's purpose. Below are the five types of signs and their predominant color.

- Danger signs: RED.
- Caution signs: YELLOW.
- Safety instruction signs: GREEN.
- Directional signs: BLACK.
- Informational signs: A variety of colors may be used, except for red, yellow, or magenta (purple).

DANGER SIGNS

Danger signs should only be used when immediate hazard exists. There will be no variations in the type or design of signs posted to warn of specific danger. All personnel will be instructed that danger signs indicate immediate danger and that special precautions are necessary.

CAUTION SIGNS

Caution signs should be used only to warn against potential hazards or to caution against unsafe practices. All personnel will be instructed that a caution sign indicates a possible hazard against which proper precautions will be taken.

DIRECTIONAL SIGNS

Directional signs should be used in sufficient numbers to indicate the way to stairways, fire escapes, exits, and other locations.

Many other safety media are available for use in military maintenance shops.

Chapter 2

PROPERTIES, IDENTIFICATION, AND HEAT TREATMENT OF METALS

GENERAL

PURPOSE

This chapter contains basic information pertaining to properties and identification of metal and heat-treating procedures used for metals. For more specific information on metal and heat-treating techniques, refer to TM 43-0106.

METAL CLASSIFICATION

All metals may be classified as ferrous or nonferrous. A ferrous metal has iron as its main element. A metal is still considered ferrous even if it contains less than 50 percent iron, as long as it contains more iron than any other one metal. A metal is nonferrous if it contains less iron than any other metal.

Ferrous

Ferrous metals include cast iron, steel, and the various steel alloys, The only difference between iron and steel is the carbon content. Cast iron contains more than 2-percent carbon, while steel contains less than 2 percent. An alloy is a substance composed of two or more elements. Therefore, all steels are an alloy of iron and carbon, but the term "alloy steel" normally refers to a steel that also contains one or more other elements. For example, if the main alloying element is tungsten, the steel is a "tungsten steel" or "tungsten alloy." If there is no alloying material, it is a "carbon steel."

Nonferrous

Nonferrous metals include a great many metals that are used mainly for metal plating or as alloying elements, such as tin, zinc, silver, and gold. However, this chapter will focus only on the metals used in the manufacture of parts, such as aluminum, magnesium, titanium, nickel, copper, and tin alloys.

PROPERTIES OF METALS

GENERAL

The internal reactions of a metal to external forces are known as mechanical properties. The mechanical properties are directly related to each other. A change in one property usually causes a change in one or more additional properties. For example, if the hardness of a metal is increased, the brittleness usually increases and the toughness usually decreases. Following is a brief explanation of the mechanical properties and how they relate to each other.

TENSILE STRENGTH

Tensile strength is the ability of a metal to resist being pulled apart by opposing forces acting in a straight line (Figure 2-1). It is expressed as the number of pounds of force required to pull apart a bar of the material 1 inch wide and 1 inch thick.

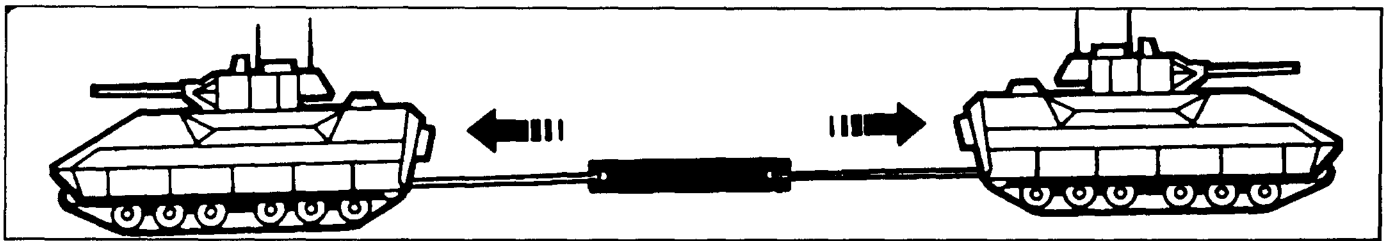


Figure 2-1. Tensile strength

SHEAR STRENGTH

Shear strength is the ability of a metal to resist being fractured by opposing forces not acting in a straight line (Figure 2-2). Shear strength can be controlled by varying the hardness of the metal.

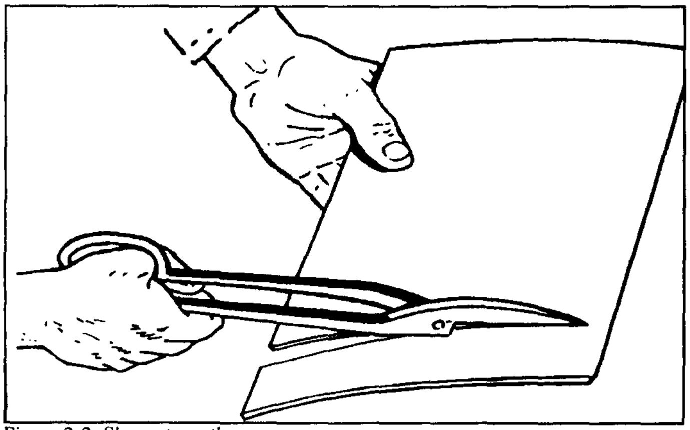


Figure 2-2. Shear strength.

COMPRESSIVE STRENGTH

Compressive strength is the ability of a metal to withstand pressures acting on a given plane (Figure 2-3).

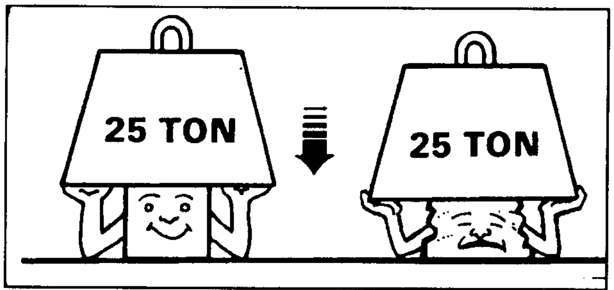


Figure 2-3. Compressive strength.

ELASTICITY

Elasticity is the ability of metal to return to its original size and shape after being stretched or pulled out of shape (Figure 2-4).

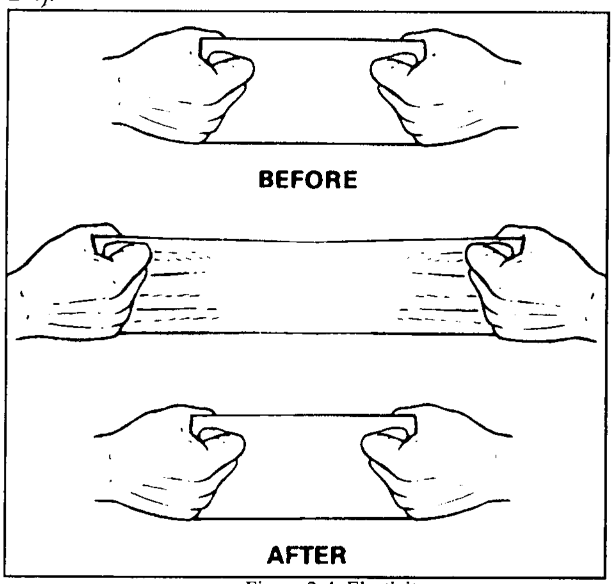


Figure 2-4. Elasticity.

DUCTILITY

Ductility is the ability of a metal to be drawn or stretched permanently without rupture or fracture (Figure 2-5). Metals that lack ductility will crack or break before bending.

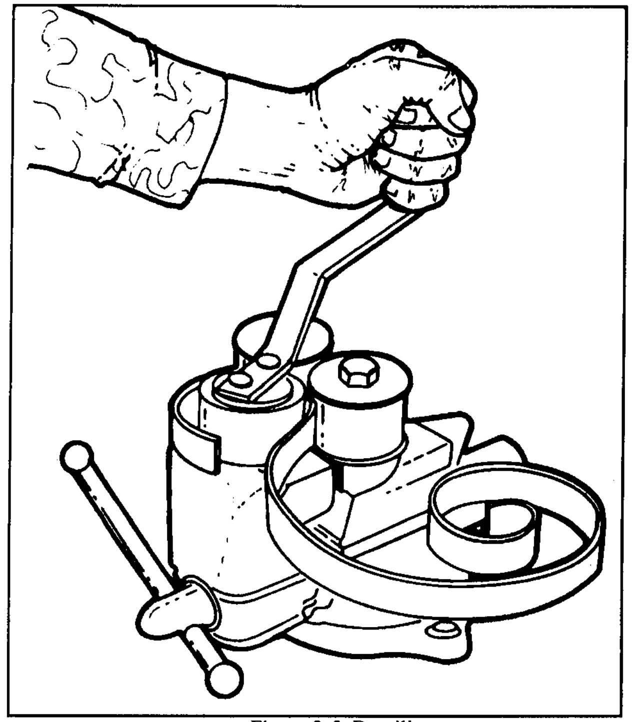


Figure 2-5. Ductility.

MALLEABILITY

Malleability is the ability of a metal to be hammered, rolled, or pressed into various shapes without rupture or fracture (Figure 2-6).

Figure 2-6. Malleability.

TOUGHNESS

Toughness is the ability of a metal to resist fracture plus the ability to resist failure after the damage has begun. A tough metal can withstand considerable stress, slowly or suddenly applied, and will deform before failure.

HARDNESS

Hardness is the ability of a metal to resist penetration and wear by another metal or material. It takes a combination of hardness and toughness to withstand heavy pounding. The hardness of a metal limits the ease with which it can be machined, since toughness decreases as hardness increases. The hardness of a metal can usually be controlled by heat treatment.

MACHINABILITY AND WELDABILITY

Machinability and weldability are the ease or difficulty with which a material can be machined or welded.

CORROSION RESISTANCE

Corrosion resistance is the resistance to eating or wearing away by air, moisture, or other agents.

HEAT AND ELECTRICAL CONDUCTIVITY

Heat and electrical conductivity is the ease with which a metal conducts or transfers heat or electricity.

BRITTLENESS

Brittleness is the tendency of a material to fracture or break with little or no deformation, bending, or twisting. Brittleness is usually not a desirable mechanical property. Normally, the harder the metal, the more brittle it is.

IDENTIFICATION OF METALS

GENERAL

Part of the metalworker's skill lies in the ability to identify various metal products brought to the shop. The metalworker must be able to identify the metal so the proper work methods can be applied. For Army equipment, drawings should be available. They must be examined in order to determine the metal to be used and its heat treatment (if required). If no drawing is available, knowledge of what the parts are going to do will serve as a guide to the type of metal to use.

TESTING OF METALS

Simple tests can be made in the shop to identify metals. Since the ability to judge metals can be developed only through personal experience, practice these tests with known metals until familiar with the reactions of each metal to each type of test.

Appearance Test

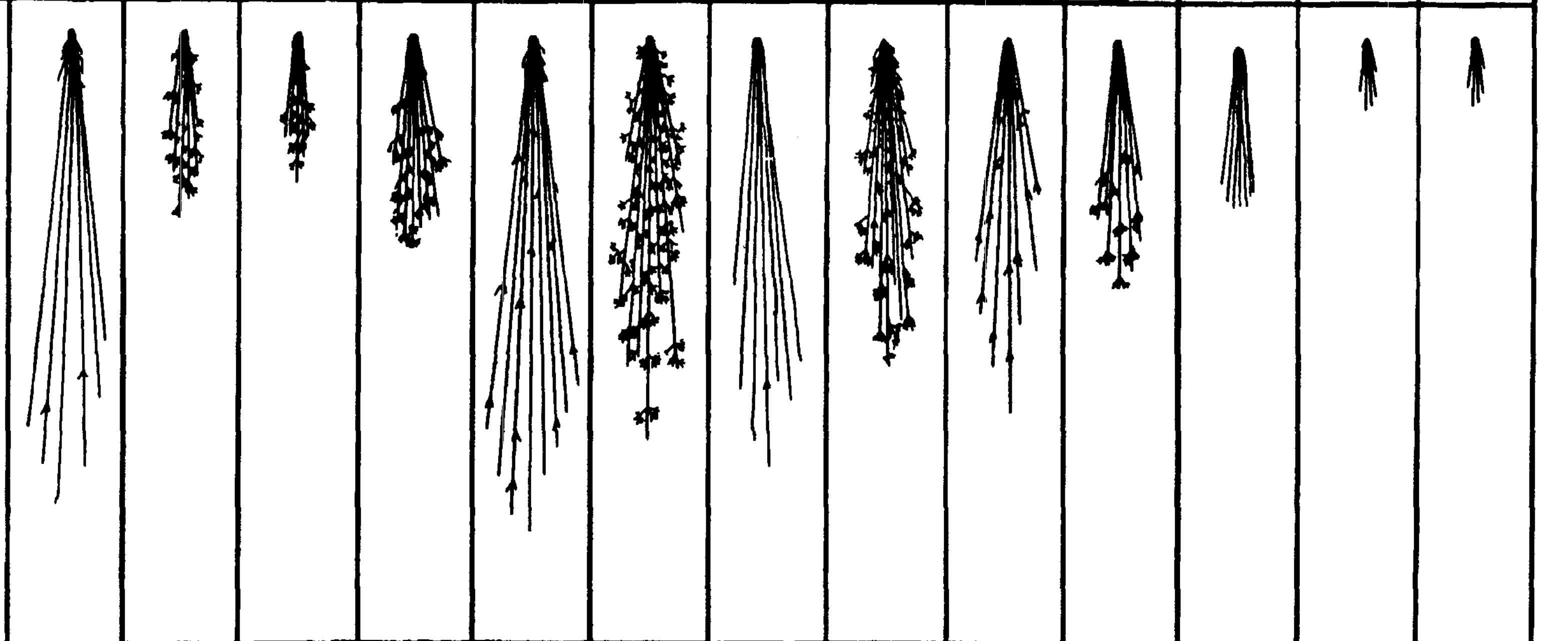
This test includes such things as the color and appearance of machined as well as unmachined surfaces.

Fracture Test

Some metals can be quickly identified by looking at the surface of the broken part or by studying the chips produced with a hammer and chisel.

Spark Test

This is a simple identification test used to observe the color, spacing, and quantity of sparks produced by grinding. It is a fast and convenient method of sorting mixed steels with known spark characteristics. This test is best conducted by holding the steel stationary and touching a high-speed portable grinder to the steel with sufficient pressure to throw a spark stream about 12 inches long. The characteristics of sparks generated by a spark grinding test are shown in Figure 2-7. These spark patterns provide general information about the type of steel, cast iron, or alloy steel. In all cases, it is best to use standard samples of metal when comparing their sparks with that of the test sample.



	WROUGHT IRON	GRAY CAST IRON	WHITE CAST IRON	ANNEALED MALLEABLE IRON	MACHINE STEEL (AISI 1020)	CARBON TOOL STEEL	HIGH SPEED STEEL (18-4-1)	AUSTENITIC MANGANESES STEEL	STAINLESS STEEL (TYPE410)	TUNGSTEN CHROMIUM DIE STEEL	STELLITE	CEMENTED TUNGSTEN CARBIDE	NICKEL
STREAM													
VOLUME	LARGE	SMALL	VERY SMALL	MODERATE	LARGE	MODERATLY LARGE	SMALL	MODERATELY LARGE	MODERATE	SMALL	VERY SMALL	EXTREMELY SMALL	VERY SMALL
LENGTH	LONG	SHORT	SHORT	SHORT	LONG	LONG	LONG	LONG	LONG	AVERAGE	SHORT	VERY SHORT	SHORT
COLOR CLOSE TO WHEEL	STRAW	RED	RED	RED	WHITE	WHITE	RED	WHITE	STRAW	RED	ORANGE	LIGHT ORANGE	ORANGE
STREAKS NEAR END OF STREAM	WHITE	STRAW	STRAW	STRAW	WHITE	WHITE	STRAW	WHITE	WHITE	STRAW BLUE WHITE	ORANGE	LIGHT ORANGE	ORANGE
QUANTITY OF SPURTS	VERY FEW	MANY	FEW	MANY	FEW	VERY MANY	EXTREMELY FEW	MANY	MODERATE	MANY	NONE	NONE	NONE
NATURE OF SPURTS	FORKED	FINE REPEATING			FORKED	FINE REPEATING	FORKED	FINE REPEATING	FORKED	FINE REPEATING			

Figure 2-7, Spark test.

THE ROCKWELL HARDNESS NUMBER IS DETERMINED BY THE DEPTH OF THE IMPRESSION WHILE THE BRINELL HARDNESS NUMBER IS DETERMINED BY THE AREA OF THE IMPRESSION

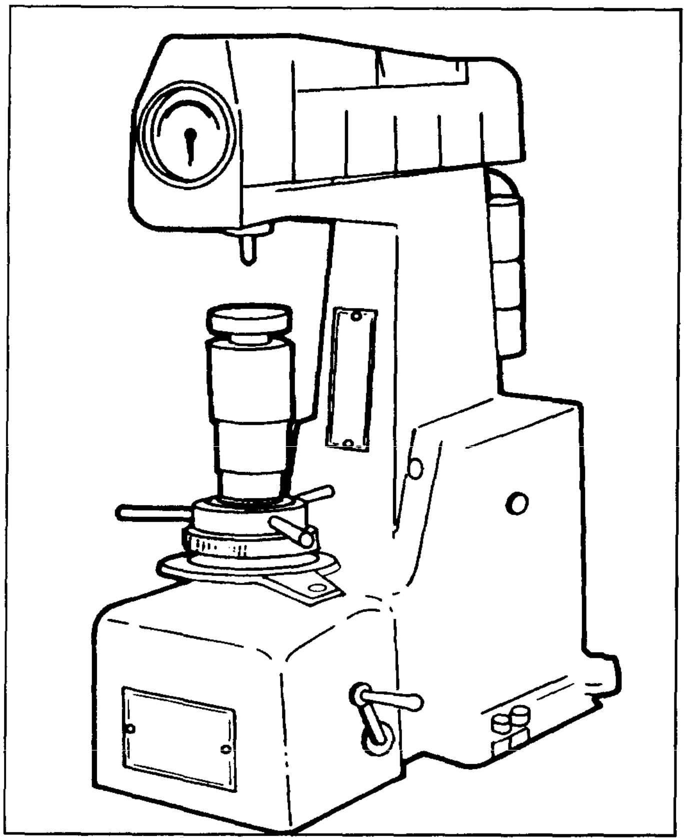


Figure 2-8. Rockwell hardness tester.

File Test

One simple way to check for hardness in a piece of metal is to file a small portion of it. If it is soft enough to be machined with regular tooling, the file will cut it. If it is too hard to machine, the file will not cut it. This method will indicate whether the material being tested is softer or harder than the file, but it will not tell exactly how soft or hard it is. The file can also be used to determine the harder of two pieces of metal; the file will cut the softer metal faster and easier. The file method should only be used in situations when the exact hardness is not required. This test has the added advantage of needing very little in the way of time, equipment, and experience.

Rockwell Hardness Test

This test determines the hardness of metals by measuring the depth of impression which can be made by a hard test point under a known load. The softer the metal, the deeper the impression. Soft metals will be indicated by low hardness numbers. Harder metals permit less of an impression to be made, resulting in higher hardness numbers. Rockwell hardness testing is accomplished by using the Rockwell hardness testing machine (Figure 2-8).

Brinell Hardness Fest

Brinell hardness testing operates on almost the same principle as the Rockwell test. The difference between the two is that the Rockwell hardness number is determined by the depth of the impression while the Brinell hardness number is determined by the area of the impression. This test forces a hardened ball, 10 mm (0.3937 *in)* in diameter, into the surface of the metal being tested, under a load of 3,000 kilograms (approximately 6,600 lb). The area of this impression determines the Brinell hardness number of the metal being tested. Softer metals result in larger impressions but have lower hardness numbers.

NUMERICAL CODES

Perhaps the best known numerical code is the Society of Automotive Engineers (SAE) code. For the metals industry, this organization pioneered in developing a uniform code based on chemical analysis. SAE specification numbers are now used less widely than in the past; however, the SAE numerical code is the basic code for ferrous metals Figure 2-9).

The SAE system is based on the use of four-or five digit numbers.

- The first number indicates the type of alloy used; for example, 1 indicates a carbon steel.
- Two indicates nickel steel.
- The second, and sometimes the third, number gives the amount of the main alloy in whole percentage numbers.
- The last two, and sometimes three, numbers give the carbon content in hundredths of 1 percent (0.01 percent).

The following examples will help you understand this system:

SAE 1045

1- Type of steel (carbon).

0- Percent of alloy (none).

45- Carbon content (0.45-percent carbon).

TYPES OF STEEL	SAE NUMBERS
CARBON STEELS	1XXX
Plain Carbon	10XX
Free Cutting, Manganese	X13XX
Free Cutting, Screw Stock	11XX
HIGH MANGANESE	T13XX
NICKEL STEELS	2XXX
.50% Nickel	20XX
1.50% Nickel	21XX
3.50% Nickel	23XX
5.00% Nickel	25XX
NICKEL-CHROMIUM STEELS	3XXX
1.25% Nickel : .60% Chromium	31XX
1.75% Nickel : 1.00% Chromium	32XX
3.50% Nickel : 1.50% Chromium	33XX
3.00% Nickel : .80% Chromium	34XX
Corrosion and Heat Resisting	30XXX
MOLYBDENUM STEELS	4XXX
Chromium-Molybdenum	41XX
Chromium-Nickel-Molybdenum	43XX
Nickel-Molybdenum	46XX & 48XX
CHROMIUM STEELS	5XXX
.60% to 1.10% Chromium	51XX
1.2% to 1.5% Chromium	52XXX
Corrision and Heat Resistant	51XXX
Chromium-Vanadium Steels	6XXX
Tungsten Steels	7XXXX & 7XXX
Silcon-Manganese Steels	9XXX

Figure 2-9. SAE numerical code.

SAE 2330

2- Type of steel (nickel).

3- Percent of alloy (3-percent nickel).

30- Carbon content (0.30-percent carbon).

SAE 71650

7- Type of steel (tungsten).

16- Percent of alloy (16-percent tungsten).

50- Carbon content (0,50-percent carbon).

SAE 50100

5- Type of steel (chromium).

0- Percent of alloy (less than l-percent chromium).

100- Carbon content (1-percent carbon).

AA Code

A system similar to the SAE classifications for steel and alloys has been developed by the Aluminum Association (AA) for wrought aluminum and aluminum alloys.

This identification system of aluminum, as shown in Figure 2-10, consists of a four-digit number which indicates the type of alloy. control over impurities, and the specific alloy. The first number indicates the type of alloy. For example, 2 is copper, 3 is manganese, 4 is silicone, and so forth. The second number indicates the control that has been used. The last two numbers usually indicate an assigned composition. Thus, AA-2024 means:

2 - Type of alloy (copper).

O - Control of impurities.

24 - Exact composition (AA number 24).

Aluminum alloys vary greatly in their hardness and physical condition. These differences are called "temper," Letter symbols represent the different tempers, In addition to a letter, one or more numbers are sometimes used to indicate further differences. The temper designation is separated from the basic four-digit identification number by a dash; for example, 2024-T6. In this case there is an aluminum alloy, 2024, with a T6 temper (solution heat treated and then artificially aged). Figure 2-11 shows the numerals 2 through 10 that have been assigned in the AA system to indicate specific sequences of annealing, heat treating, cold working, or aging.

MAJOR ALLOYING ELEMENTS

ALUMINUM AT LEAST 99% PURE	1XXX
COPPER	2XXX
MANGANESE	3XXX
SILICON	4XXX
MAGNESIUM	5XXX
MAGNESIUM AND SILICON	6XXX
ZINC	7XXX
OTHER ELEMENTS	8XXX
UNUSED SERIES	9XXX

Figure 2-10. Aluminum alloy groups.

METHODS OF MARKING

Stenciling

A stencil and white or black paint, whichever shows up better on the metal being marked, should be used when the size of the metal piece permits. The federal or military specification numbers should be stenciled on the metal in vertically or hoizontally aligned rows. The distance between the vertical rows should not exceed 36 inches, and the distance between the horizontal rows should not exceed 10 inches.

GENERAL

Stamping

Stamping the specification number into the metal should be used when it is impossible to use the stencil method. It is usually necessary to cut or eliminate the marked portion of the metal prior to using the material for work stock. Therefore, the marking should be located where waste will be held to a minimum. Gothic style numerals and letters should be used; the height may be 1/16 inch, 1/8 inch, or 1/4 inch, depending upon the size of the material being marked.

TEMPER DESIGNATION	
Symbol	**Designation**
—F	As fabricated.
—O	Annealed, recrystallized (wrought products only).
—H	Strain hardened.
—H1	Plus one or more digits. Strain hardened only.
—H2	Plus one or more digits. Strain hardened and then partially annealed.
—H3	Plus one or more digits. Strain hardened and stabilized.
—W	Solution heat treated—unstable temper. This designation is specified only when the period of natural aging is indicated.
—T	Treated to produce stable tempers other than —F, —O, or —H.
—T2	Annealed (cast products only).
—T3	Solution heat-treated and then cold worked.
—T4	Solution heat-treated.
—T5	Artificially aged only.
—T6	Solution heat-treated and then artifically aged.
—T7	Solution heat-treated and then stabilized.
—T8	Solution heat-treated cold-worked and then artifically aged.
—T9	Solution heat-treated, artificially aged and then cold-worked.
—T10	Artifically-aged and then cold worked.

Figure 2-11. Temper designation of aluminum.

FERROUS METALS

Ferrous metals are those that contain iron as the base metal. The properties of ferrous metals may be changed by adding various alloying elements. The chemical and mechanical properties need to be combined to produce a metal to serve a specific purpose. The basic ferrous metal form is pig iron. Pig iron is produced in a blast furnace that is charged with an iron ore, coke, and limestone. The four principal iron ores are hematite, limonite, magnetite and faconite.

CAST IRON

Cast iron is a metal that is widely used. It is a hard, brittle metal that has good wear resistance. Cast iron contains 2 to 4 percent carbon. White cast iron is very hard and is used mostly where abrasion and wear resistance is required. White cast iron may be made into malleable iron by heating it; then cooling it very slowly over a long period of time. Malleable iron is stronger and tougher than white cast iron; however, it is much more expensive to produce. Gray iron is another form of cast iron. It is used mostly for castings because of its ability to flow easily into complex shapes.

WROUGHT IRON

Wrought iron is an iron that has had most of its carbon removed. It is tough; however, it can be bent or twisted very easily. Wrought iron is used mostly in ornamental ironwork, such as fences and handrails, because it is welded or painted easily and it rusts very slowly.

STEEL

Steel is an alloy of iron and carbon or other alloying elements. When the alloying element is carbon, the steel is referred to as carbon steel. Carbon steels are classified by the percentage of carbon in “points” or hundredths of 1 percent they contain.

Low Carbon Steel

(Carbon content up to 0.30 percent or 30 points).

This steel is soft and ductile and can be rolled, punched, sheared, and worked when either hot or cold. It is easily machined and can be readily welded by all methods. It does not harden to any great amount; however, it can be easily case- or surface-hardened.

Medium Carbon Steel

(Carbon content from 0.30 to 0.50 percent or 30 to 50 points).

This steel may be heat-treated after fabrication. It is used for general machining and forging of parts that require surface hardness and strength. It is made in bar form in the cold-rolled or the normalized and annealed condition. During welding, the weld zone will become hardened if cooled rapidly and must be stress-relieved after welding.

High Carbon Steel

(Carbon content from 0.50 to 1.05% or 50 to 105 points)

This steel is used in the manufacture of drills, taps, dies, springs, and other machine tools and hand tools that are heat-treated after fabrication to develop the hard structure necessary to withstand high shear stress and wear. It is manufactured in bar, sheet, and wire forms, and in the annealed or normalized condition in order to be suitable for machining before heat treatment. This steel is difficult to weld because of the hardening effect of heat at the welding joint.

Tool Steel

(carbon content from 0.90 to 1.70 percent or 90 to 170 points)

This steel is used in the manufacture of chisels, shear blades, cutters, large taps, woodturning tools, blacksmith’s tools, razors, and other similar parts where high hardness is required to maintain a sharp cutting edge. It is difficult to weld due to the high carbon content.

High-Speed Steel

High-speed steel is a self-hardening steel alloy that can withstand high temperatures without becoming soft. High-speed steel is ideal for cutting tools because of its ability to take deeper cuts at higher speeds than tools made from carbon steel.

Tungsten Carbide

Tungsten carbide is the hardest man-made metal. It is almost as hard as a diamond. The metal is molded from tungsten and carbon powders under heat and pressure. Tools made from this metal can cut other metals many times faster than high-speed steel tools.

Alloy Steels

Steel is manufactured to meet a wide variety of specifications for hardness, toughness, machinability, and so forth. Manufacturers use various alloying elements to obtain these characteristics. When elements other than carbon, such as chromium, manganese, molybdenum, nickel, tungsten, and vanadium are used. The resulting metals are called alloy steels. Figure 2-12 shows some of the general characteristics obtained by the use of various alloying elements.

NONFERROUS METALS

There are many metals that do not have iron as their base metal. These metals, known as nonferrous metals, offer specific properties or combinations of properties that make them ideal for tasks where ferrous metals are not suitable. Nonferrous metals are often used with iron base metals in the finished product.

ALUMINUM

Aluminum and its alloys are produced and used in many shapes and forms. The common forms are castings, sheet, plate, bar, rod, channels, and forgings. Aluminum alloys have many desirable qualities. They are lighter than most other metals and do not rust or corrode under most conditions. Aluminum can be cast-forged, machined, and welded easily.

MAGNESIUM

Magnesium alloys are produced and used in many shapes and forms, for example, castings, bars, rods, tubing, sheets and plates, and forgings. Their inherent strength, light weight, and shock and vibration resistance are factors which make their use advantageous. The weight for an equal volume of magnesium is approximately two-thirds of that for aluminum and one-fifth of that for steel. Magnesium has excellent machining qualities; however, care must be taken when machining because the chips are highly flammable. Magnesium fires bum so hot that they cannot be extinguished by conventional fire extinguishers.

COPPER

Copper is a reddish metal, very ductile and malleable, and has high electrical and heat conductivity. Copper can be forged, cast, and cold worked. It also can be welded, but its machinability is only fair. The principal use of commercially pure copper is in the electrical industry where it is made into wire or other such conductors. It is also used in the manufacture of nonferrous alloys such as brass, bronze, and monel metal. Typical copper products are sheet roofing, cartridge cases, bushings, wire, bearings, and statues.

BRASS AND BRONZE

Brass, an alloy of copper and zinc (60 to 68 percent copper and 32 to 40 percent zinc), has a low melting point and high heat conductivity. There are several types of brass such as naval, red, admiralty, yellow, and commercial. All differ in copper and zinc content. All may be alloyed with other elements such as lead, tin, manganese, or iron, and all have good machinability and can be welded. Bronze is an alloy of copper and tin and may contain lead, zinc, nickel, manganese, or phosphorous. It has high strength, is rust or corrosion resistant, has good machinability, and can be welded.

TYPES OF STEEL	SAE NUMBERS (GENERAL SERIES)	CHARACTERISTICS RESULTING FROM THE ALLOYING ELEMENTS ADDED
CARBON STEELS	1000	Surface Hardness and Strength
NICKEL STEELS	2000	Toughness
CHROME-NICKEL STEELS	3000	Toughness and Depth Hardness
MOLYBDENUM STEELS	4000	Eliminates Brittleness and increases Depth Hardness
CHROME-MOLYBDENUM STEELS	4100	High Strength and Toughness
CHROMIUM STEELS	5000	Corrosion Resistance and Hardness
CHROME-VANADIUM	6000	Depth Hardness and toughness at Sub-zero Temperature
TUNGSTEN STEELS	7000	Hardness at High Temperatures
CHROME-NICKEL-MOLYBDENUM STEELS	8000	Toughness and Strength (General Purpose Steel)
SILICONE-MANGANESE STEELS	9000	Depth Hardness and Toughness Under Impact

Figure 2-12. General characteristics of common alloys.

LEAD

Lead is used mainly in the manufacture of electrical equipment such as lead-coated power and telephone cables and storage batteries. Zinc alloys are used in the manufacture of lead weights, bearings, gaskets, seals, bullets, and shot. Many types of chemical compounds are produced from lead. Among these are lead carbonate (paint pigment) and tetraethyl lead (antiknock gasoline). Lead is also used for X-ray protection (radiation shields). Lead has more fields of application than any other metal. It can be cast, cold worked, welded, and machined. Lead has low strength with heavy weight.

TIN

The major use of tin is in coating steel. It is the best container for preserving perishable food. Tin, in the form of foil, is often used in wrapping food products. A second major use of tin is as an alloying element. Tin is alloyed with copper to produce bronze, with lead to produce solder, and with antimony and lead to form babbitt. Tin can be die cast, cold worked, machined, and soldered; however, it cannot be welded.

NICKEL

Nickel is used in making alloys of both ferrous and nonferrous metals. Chemical and food processing equipment, electrical resistance heating elements, ornamental trim, and parts that must withstand elevated temperatures are all produced from nickel containing metal. Alloyed with chromium, it is used to make stainless steel. Nickel alloys are readily welded by either gas or arc methods and can be machined, forged, cast, and easily formed.

COBALT-CHROMIUM-TUNGSTEN MOLYBDENUM WEAR-RESISTANT ALLOYS

These alloys feature a wear resistance which makes them ideal for metal-cutting operations. Their ability to retain hardness even at red-heat temperatures also makes them especially useful for cutting tools. Common cutting tools will lose their edge at high heat, whereas this alloy group is actually tougher at red heat than it is when cold; as a result, higher speeds and feeds may be used when machining with tools made with these alloys.

PRECIOUS METALS

These include silver, gold, platinum, palladium, iridium, osmium, rhodium, and ruthenium, and their alloys. These alloys are produced under technical and legal requirements. Gold alloys used for jewelry are described in karats. The karat is the content of gold expressed in twenty-fourths. An 18-karat gold alloy would contain 18/24 gold (75 percent by weight). Other than jewelry, there are many industrial uses for precious metals.

HEAT TREATMENT OF METALS

Heat treatment is any one of a number of controlled heating and cooling operations used to bring about a desired change in the physical properties of a metal. Its purpose is to improve the structural and physical properties for some particular use or for future work of the metal. There are five basic heat treating processes: hardening, case hardening, annealing, normalizing, and tempering. Although each of these processes bring about different results in metal, all of them involve three basic steps: heating, soaking, and cooling.

HEATING

Heating is the first step in a heat-treating process. Many alloys change structure when they are heated to specific temperatures. The structure of an alloy at room temperature can be either a mechanical mixture, a solid solution, or a combination solid solution and mechanical mixture.

A mechanical mixture can be compared to concrete. Just as the.sand and gravel are visible and held in place by the cement. The elements and compounds in a mechanical mixture are clearly visible and are held together by a matrix of base metal. A solid solution is when two or more metals are absorbed, one into the other, and form a solution. When an alloy is in the form of a solid solution, the elements and compounds forming the metal are absorbed into each other in much the same way that salt is dissolved in a glass of water. The separate elements forming the metal cannot be identified even under a microscope. A metal in the form of a mechanical mixture at room temperature often goes into a solid solution or a partial solution when it is heated. Changing the chemical composition in this way brings about certain predictable changes in grain size and structure. This leads to the second step in the heat treating process: soaking.

SOAKING

Once a metal part has been heated to the temperature at which desired changes in its structure will take place, it must remain at that temperature until the entire part has been evenly heated throughout. This is known as soaking. The more mass the part has, the longer it must be soaked.

COOLING

After the part has been properly soaked, the third step is to cool it. Here again, the structure may change from one chemical composition to another, it may stay the same, or it may revert to its original form. For example, a metal that is a solid solution after heating may stay the same during cooling, change to a mechanical mixture, or change to a combination of the two, depending on the type of metal and the rate of cooling. All of these changes are predictable. For that reason, many metals can be made to conform to specific structures in order to increase their hardness, toughness, ductility, tensile strength, and so forth.

HEAT TREATMENT OF FERROUS METALS

All heat-treating operations involve the heating and cooling of metals, The common forms of heat treatment for ferrous metals are hardening, tempering, annealing, normalizing, and case hardening.

HARDENING

A ferrous metal is normally hardened by heating the metal to the required temperature and then cooling it rapidly by plunging the hot metal into a quenching medium, such as oil, water, or brine. Most steels must be cooled rapidly to harden them. The hardening process increases the hardness and strength of metal, but also increases its brittleness.

TEMPERING

Steel is usually harder than necessary and too brittle for practical use after being hardened. Severe internal stresses are set up during the rapid cooling of the metal. Steel is tempered after being hardened to relieve the internal stresses and reduce its brittleness. Tempering consists of heating the metal to a specified temperature and then permitting the metal to cool. The rate of cooling usually has no effect on the metal structure during tempering. Therefore, the metal is usually permitted to cool in still air. Temperatures used for tempering are normally much lower than the hardening temperatures. The higher the tempering temperature used, the softer the metal becomes. High-speed steel is one of the few metals that becomes harder instead of softer after it is tempered.

ANNEALING

Metals are annealed to relieve internal stresses, soften them, make them more ductile, and refine their grain structures. Metal is annealed by heating it to a prescribed temperature, holding it at that temperature for the required time, and then cooling it back to room temperature. The rate at which metal is cooled from the annealing temperature varies greatly. Steel must be cooled very slowly to produce maximum softness, This can be done by burying the hot part in sand, ashes, or some other substance that does not conduct heat readily (packing), or by shutting off the furnace and allowing the furnace and part to cool together (furnace cooling).

NORMALIZING

Ferrous metals are normalized to relieve the internal stresses produced by machining, forging, or welding. Normalized steels are harder and stronger than annealed steels. Steel is much tougher in the normalized condition than in any other condition. Parts that will be subjected to impact and parts that require maximum toughness and resistance to external stresses are usually normalized. Normalizing prior to hardening is beneficial in obtaining the desired hardness, provided the hardening operation is performed correctly. Low carbon steels do not usually require normalizing, but no harmful effects result if these steels are normalized. Normalizing is achieved by heating the metal to a specified temperature (which is higher than either the hardening or annealing temperatures), soaking the metal until it is uniformly heated, and cooling it in still air.

CASE HARDENING

Case hardening is an ideal heat treatment for parts which require a wear-resistant surface and a tough core, such as gears, cams, cylinder sleeves, and so forth. The most common case-hardening processes are carburizing and nitriding. During the case-hardening process, a low-carbon steel (either straight carbon steel or low-carbon alloy steel) is heated to a specific temperature in the presence of a material (solid, liquid, or gas) which decomposes and deposits more carbon into the surface of a steel. Then, when the part is cooled rapidly, the outer surface or case becomes hard, leaving the, inside of the piece soft but very tough.

HEAT TREATMENT OF NONFERROUS METALS

Two types of heat-treating operations can be performed on nonferrous metals. They are annealing and solution heat treating.

ANNEALING

Most nonferrous metals can be annealed. The annealing process consists of heating the metal to a specific temperature, soaking, and cooling to room temperature. The temperature and method of cooling depend on the type of metal. Annealing is often accomplished after various cold working operations because many nonferrous metals become hard and brittle after cold working. Also, annealing is used to remove the effects of solution heat treatment so that machining or working qualities can be improved.

SOLUTION HEAT TREATMENT

The tensile strength of many nonferrous alloys can be increased by causing the materials within the alloy to go into a solid solution and then controlling the rate and extent of return to an altered mechanical mixture. This operation is called solution heat treatment. After an alloy has been heated to a specified temperature, it is "quenched" or cooled rapidly, which traps the materials in the solid solution attained during the heating process. From this point, the process varies greatly depending on the metal. To be sure the materials in the alloy do not revert to their original configuration after a period of time, a process of aging or precipitation hardening must follow. In this process the materials in the alloy are allowed to change or to precipitate out of the solid solution.

This process occurs under controlled conditions so that the resultant grain structure will produce a greater tensile strength in the metal than in its original condition. Depending on the alloy, this precipitation process can also consist of simply aging the alloy at room temperature for a specified time and then air-cooling it; this is called artificial aging.

Aluminum alloys can be obtained in various conditions of heat treatment called temper designations. Figure 2-11, on page 2-9, shows the various temper designations and the process to which they apply. The term "strain-hardened" refers to aging or hardening that has been brought about by coldworking the alloy. "Stabilizing" refers to a particular aging process that freezes or stops the internal changes that normally would take place in the alloy at room temperature. Magnesium alloys can be subjected to all of the nonferrous heat treatments, but the different alloys within the series require different temperatures and times for the various processes. Copper alloys are generally hardened by annealing. The nickel alloys can also be annealed and certain types can be hardened by heat treatment. Likewise, titanium may be annealed (mostly relieve machining or cold-working stresses) but is not noticeably affected by heat treatment.

Chapter 3

PORTABLE MACHINE TOOLS

The portable machine tools identified and described in this chapter are intended for use by maintenance personnel in a shop or field environment. These lightweight, transportable machine tools, can quickly and easily be moved to the workplace to accomplish machining operations. The accuracy of work performed by portable machine tools is dependent upon the user's skill and experience.

Portable machine tools are powered by self-contained electric motors or compressed air (pneumatic) from an outside source. They are classified as either cutting took (straight and angle hand drills, metal sawing machines, and metal cutting shears) or finishing tools (sanders, grinders, and polishers).

SAFETY PRECAUTIONS

GENERAL

Portable machine tools require special safety precautions while being used. These are in addition to those safety precautions described in Chapter 1.

PNEUMATIC AND ELECTRIC TOOL SAFETY

Here are some safety precautions to follow:

- Never use electric equipment (such as drills, sanders, and saws) in wet or damp conditions.
- Properly ground all electric tools prior to use.
- Do not use electric tools near flammable liquids or gases.
- Inspect all pneumatic hose lines and connections prior to use.
- Keep constant watch on air pressure to stay within specified limits.
- Keep all equipment in proper working order, and use the equipment according to the manufacturer's instructions.
- Remove chuck keys from drills prior to use.
- Hold tools firmly and maintain good balance.
- Secure the work in a holding device, not in your hands.
- Wear eye protection while operating these machines.
- Ensure that all lock buttons or switches are off before plugging the machine tool into the power source.
- Never leave a portable pneumatic hammer with a chisel, star drill, rivet set, or other tool in its nozzle.

ELECTRIC EXTENSION CORDS

Use the right wire gage for the length of the cord. As the length of the extension cord increases, heavier gage wire must be used. Lengthening extension cords by connecting several small gage cords together causes a serious drop in voltage. This results in the cord overheating. Extension cords that overheat will bum away the insulation, creating a potential electric shock hazard and fire hazard. See Table 3-1, Appendix A, for proper gage and length of extension cords.

PORTABLE DRILLS

PURPOSE AND TYPES

The portable drill is a hand-supported, power-driven machine tool that rotates twist drills, reamers, counterbores, and similar cutting tools. The portable drill may be electrically powered by means of an internal electric motor (Figure 3-1) or may be pneumatically powered (Figure 3-2). Portable drills are rated by the maximum size hole that can be drilled in steel without overtaxing the motor or drill.

Therefore, a 1/4-inch-capacity drill is capable of drilling a 1/4-inch diameter hole or smaller in steel. Portable electric and pneumatic drills rated at 1/4 to 1/2-inch maximum capacities are usually equipped with geared drill chucks for mounting straight, round shank twist drills or other similar tools by using a chuck key (Figure 3-3). Heavier portable drills (Figure 3-4) having a 3/4- to 1 1/4-inch capacity use taper shank chucks to mount drills and other similar tools.

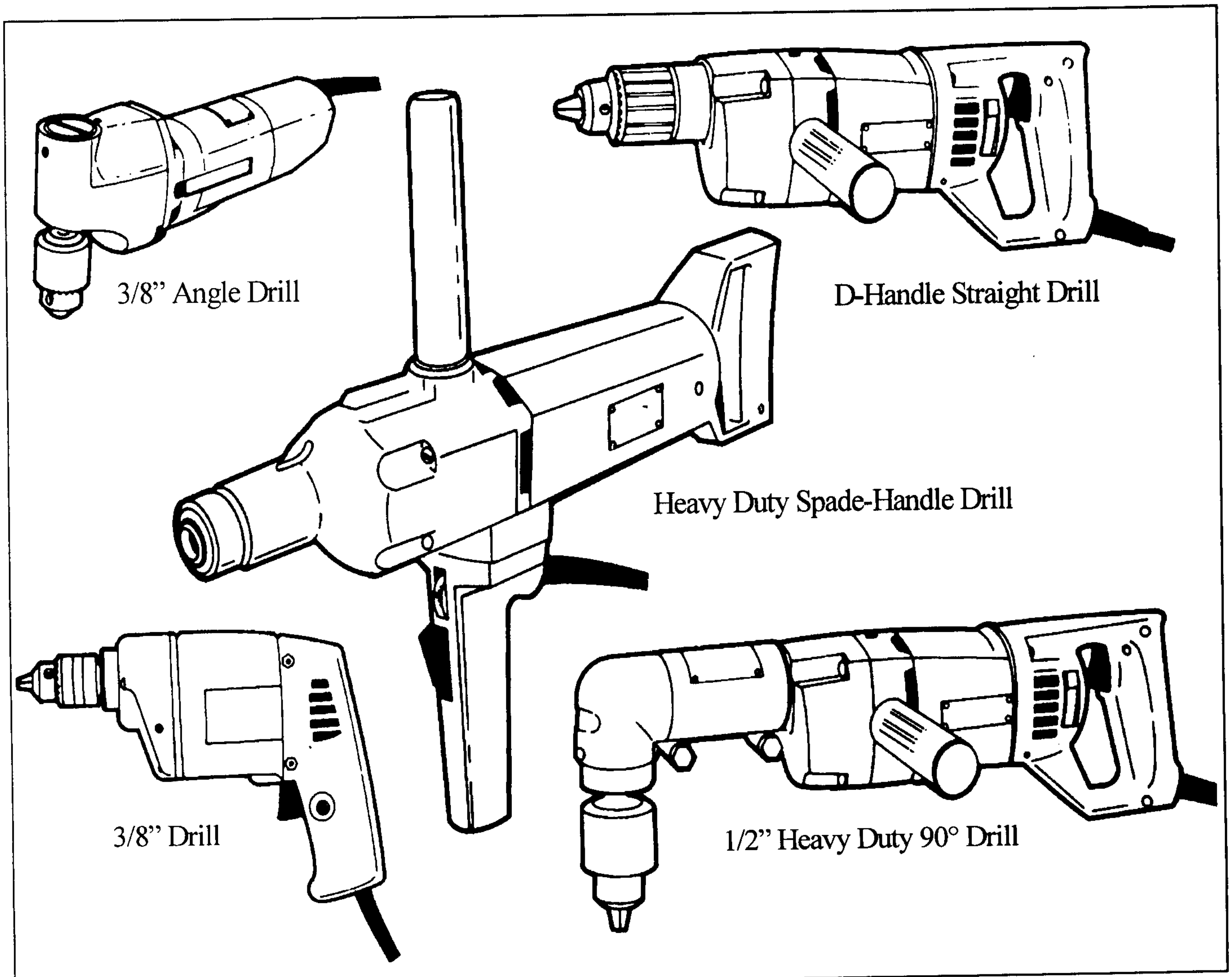


Figure 3-1. Portable electric hand drills.

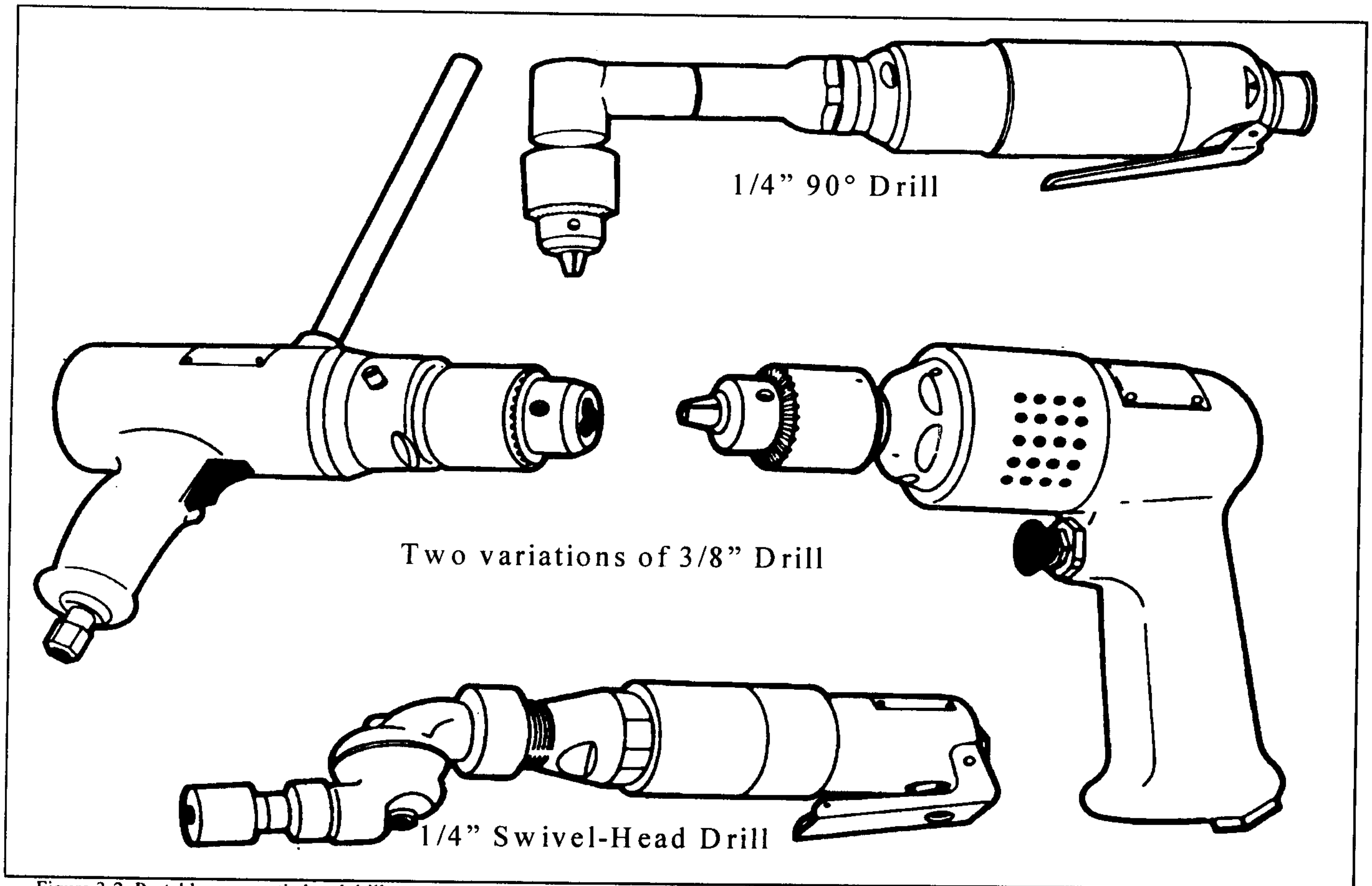


Figure 3-2. Portable pneumatic hand drills.

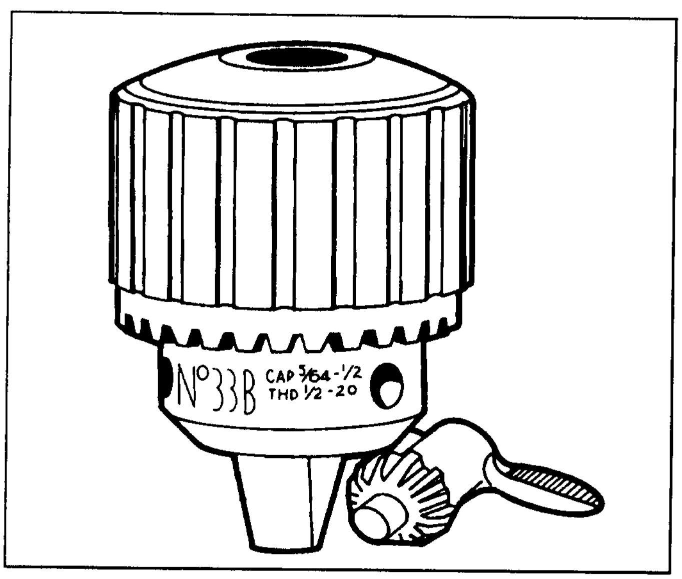


Figure 3-3. Geared drill chuck and chuck key.

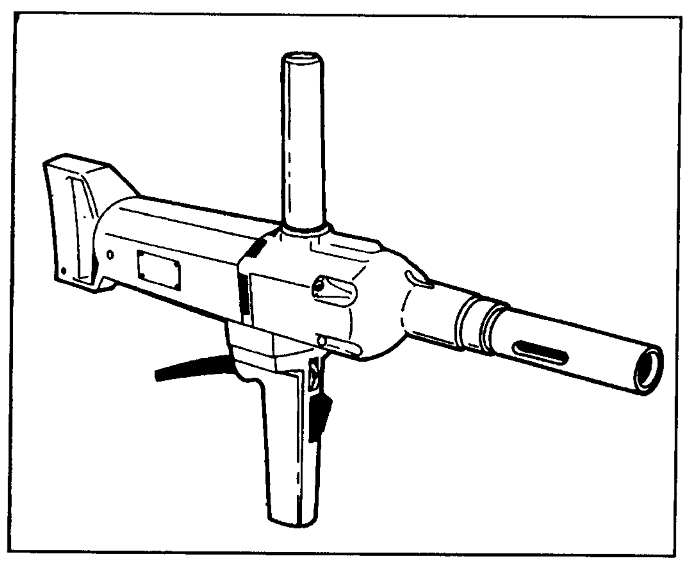


Figure 3-4. 1-inch capacity portable electric drill.

Portable drills have many different characteristics (Figure 3-5) depending on how the job is to be done. They may be set for one speed or they maybe variable speed drills. A variable speed drill is an excellent tool for use as a power screwdriver. Portable drills may be equipped with a reversing switch to allow a screwdriver attachment to reverse bolts and screws out of holes. Special 90° angle portable drills (Figure 3-8) are available for drilling in confined spaces where a standard size drill will not have sufficient clearance. For corners and tight spots, a 360° angle portable pneumatic drill (Figure 3-2) is available which can be swiveled to any desired angle and locked into position. Most portable drills have a lock button near the on-off switch which allows for continuous operation without holding the trigger. Side handles and rear spade handles (Figure 3-5) can be attached to most drills to stabilize drilling and to allow for better control. Special devices. such as a vertical stand (Figure 3-6) or feed screw (Figure 3-7), can be used on some of the portable drills to make a job easier or more proficient.

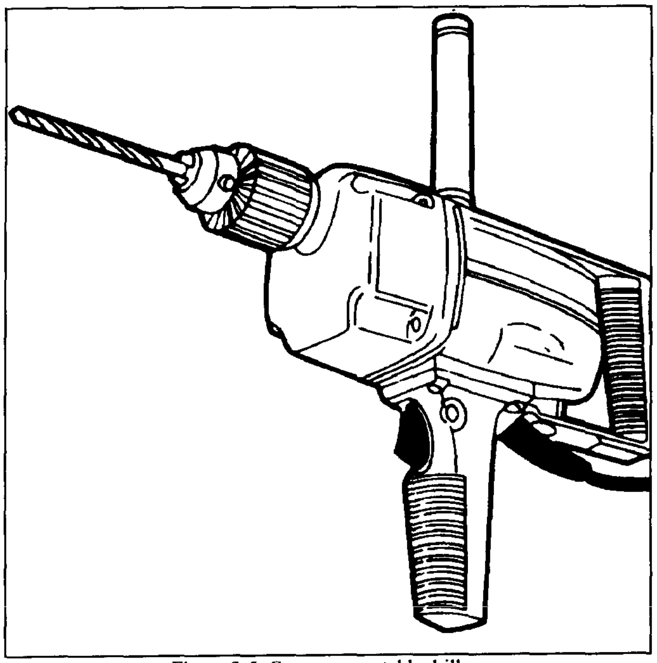


Figure 3-5. Common portable drill.

The size, type. and power capacity of portable drills selected depends on the job to be performed. Before attempting a drilling job, check the capabilities of the portable drill with the manufacturer's instruction manual.

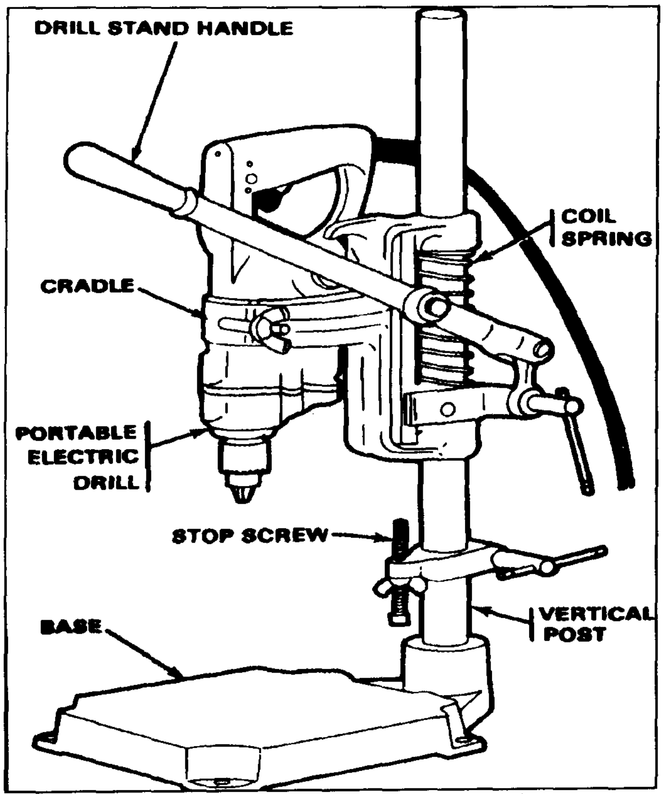


Figure 3-6. Portable electric drill with vertical stand.

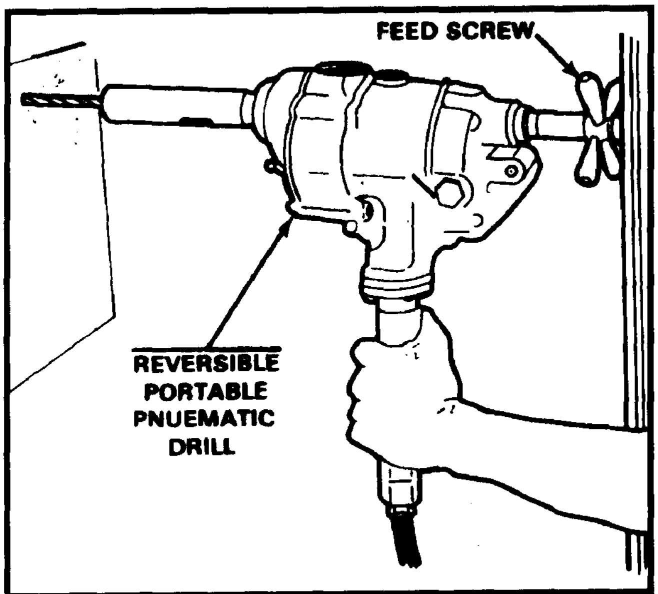


Figure 3-7. Operation of the portable drill showing the use of the feed screw.

DRILLING OPERATIONS

Operation of the portable electric and pneumatic drills differs from recommended operating procedures for the upright drilling machine. The portable drill is hand supported for most operations, and the cutting speed of the drill is fixed or dependent upon the operator to control. When hand supported, the drill must be carefully aligned with the workpiece (Figure 3-9) and this alignment must be maintained throughout the drilling operation. Care must be taken not to lose control of the portable drill and allow it to be wrenched from the operator's hands. The larger portable drills (Figure 3-10) can be very dangerous if not held firmly by the operator. If the cutting speed is fixed, the operator must learn to control the feed of the portable drill by applying sufficient pressure for the drill to cut, but not too much pressure as to cause overheating of the twist drill or stalling of the portable drill motor.

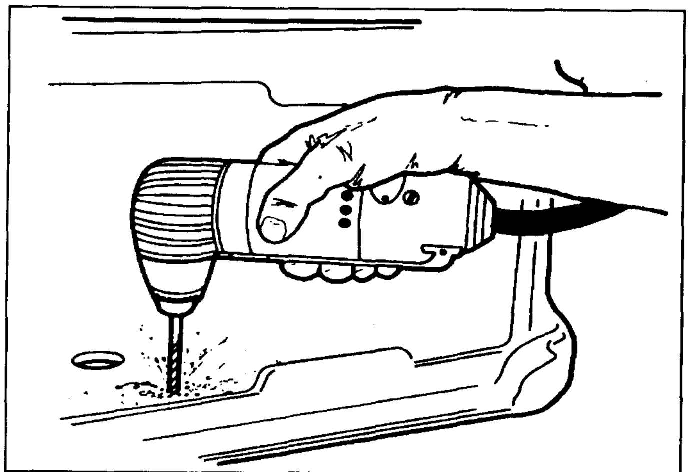


Figure 3-8. Hand drilling operation in confined space using the 90° angle drill.

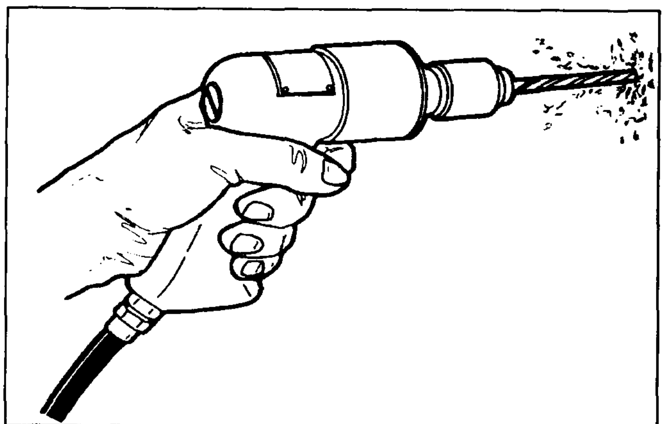


Figure 3-9. Drilling with a portable drill.

When metal is to be drilled with the portable drill, the workpiece must be prepared by locating the center position of the potential hole and marking the location with a center punch. When a large drill is to be used, it will be necessary first to drill a pilot hole slightly larger in diameter than the thickness of the larger drill's web, which will allow for the drag caused by the larger drill's chisel edge (Figure 3- 11).

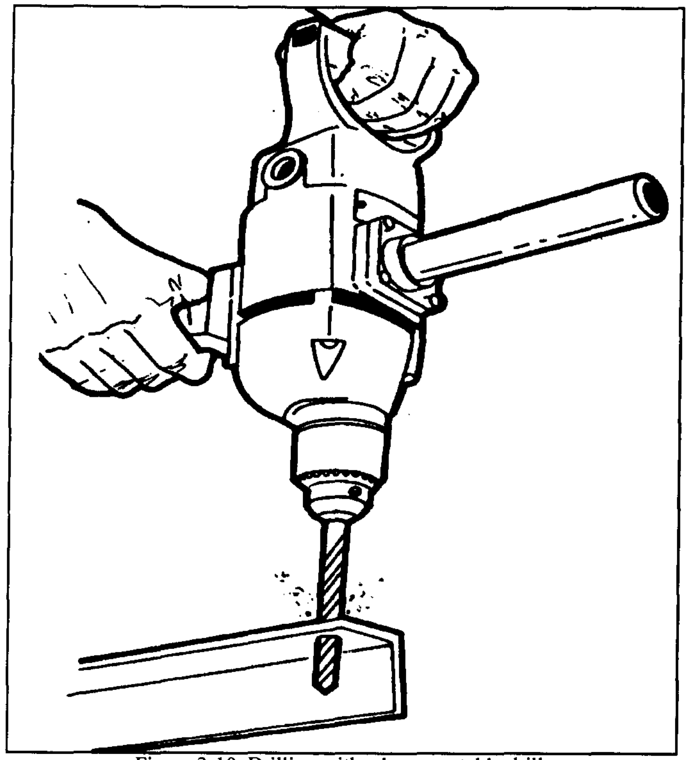


Figure 3-10. Drilling with a large portable drill.

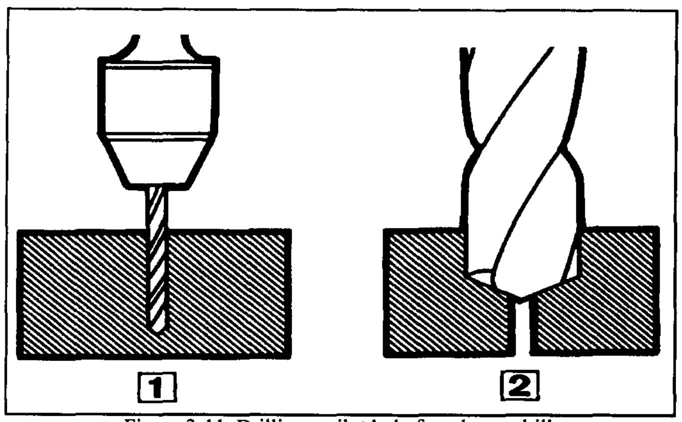


Figure 3-11. Drilling a pilot hole for a larger drill.

Portable pneumatic drills require special attention to lubricate their internal moving parts. Each drill may be made slightly different, so refer to the pertinent lubrication order or manufacturer's instruction manual before drilling.

For drilling by hand, the workpiece must be mounted securely. Thin workplaces should be backed up with a thicker piece of wood or metal to prevent the drill from snagging in the workpiece. Do not attempt to hold any workpiece by hand or serious injury could result.

Select a twist drill of the proper size for the hole to be drilled. Ensure that the twist drill selected has the right type of shank for the type of chuck mounted on the portable drill. Taper shank drills cannot be mounted in a drill with a geared chuck. Check each twist drill for sharp cutting edges prior to use.

After securing the twist drill in the proper chuck, connect the portable drill to its power source. Position the portable drill perpendicular to the workpiece and center the chisel point of the drill in the center-punched hole of the workpiece. Apply firm but not too heavy pressure upon the portable drill, pull the trigger or throttle button to start the drill.

Apply a few drops of cutting oil to the twist drill and hole (Figure 3-12) to improve the cutting action and prevent overheating of the twist drill. For long drilling operations, stop the drill and allow it to cool; then apply additional cutting oil to the drilling area. The lock button can be engaged for lengthy cutting operations.

Continue drilling the hole while applying enough pressure to produce a clean chip, but not so much pressure as to cause the motor to strain or the drill to bind. The drill must be held firmly at all times to prevent the drill from being wrenched from the hands of the operator if the flutes of the drill should snag on a metal burr in the hole.

As the twist drill nears the back wall of the workpiece, release the lock button so that the drill can be stopped immediately if required. Decrease the feed pressure as the drill breaks through, and cautiously feed the drill through the wall of the workpiece. If the drill should snag on a burr, stop drilling immediately and withdraw from the hole. Carefully feed the drill back into the hole while the drill is turning to cut through the burr.

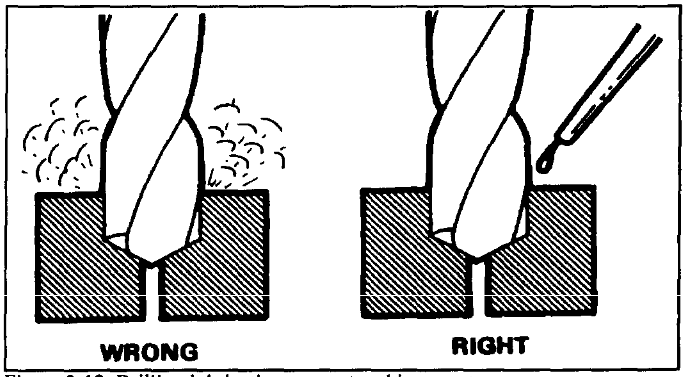


Figure 3-12. Drilling lubrication, correct and incorrect.

When a portable drill is mounted to a vertical stand, the operating procedure is identical to that used for the upright drilling machine. Use the lock button while drilling and use the hand lever to drill to the required depth.

Portable drilling operations can be difficult to an inexperienced operator. It is difficult to keep the twist drill perpendicular to the workpiece during drilling, and it is hard to drill to a desired depth accurately. If help is available, use the buddy system to keep the drill aligned while drilling. To drill to depth, mark the twist drill with a light colored marking pen or a strip of tape and keep a close watch on the drill as it cuts. Another way to drill to depth accurately using the portable drill is to use a jig, such as a piece of metal pipe or tubing cut to length, to indicate when the drill has reached the desired depth.

PORTABLE GRINDERS

PURPOSE AND TYPES

The portable grinder is a lightweight, hand-operated machine tool. It can be powered electrically or pneumatically, depending on the model selected. The portable grinder is used in the field or maintenance shop to grind excess metal from welds, remove rust, and for special finishing operations around the work area. Since this tool is hand operated, the quality of the work depends upon the ability and experience of the operator.

A small portable chuck type grinder may be known as a die grinder and is available with a number of accessories.

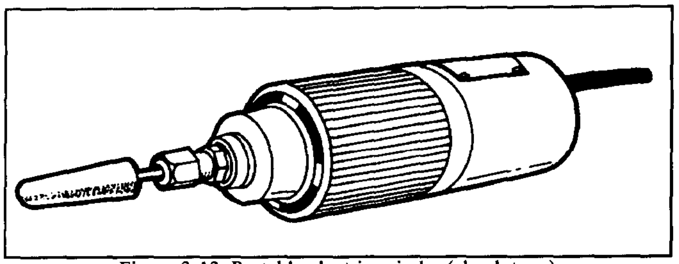


Figure 3-13. Portable electric grinder (chuck type).

These accessories include rotary files, small circular saws, wire brushes, assorted grinding wheels, and small sanding and polishing disks. These accessories are mounted to straight shank arbors which fit into the collet chuck of the grinder. Special reduction collets are provided so that smaller diameter arbors or shanks can be mounted in the chuck. Operations performed with this portable grinder include shaping and smoothing intricate dies and castings, removing burrs from edges and surfaces, cleaning and repairing threaded parts, repairing keyways and splines, grinding bevels, countersinking holes. and repairing scored and mutilated surfaces.

The portable grinder (wheel type) (Figure 3-14) can be electric or pneumatic and is designed for heavy-duty portable grinding operations. It is capable of mounting and rotating 6-inch-diameter grinding abrasive wheels and 6-inch-diameter wire brushes and polishing wheels. This grinder is used as a hand grinder for removing rust, corrosion, and sharp burrs from large workpieces (Figure 3-15).

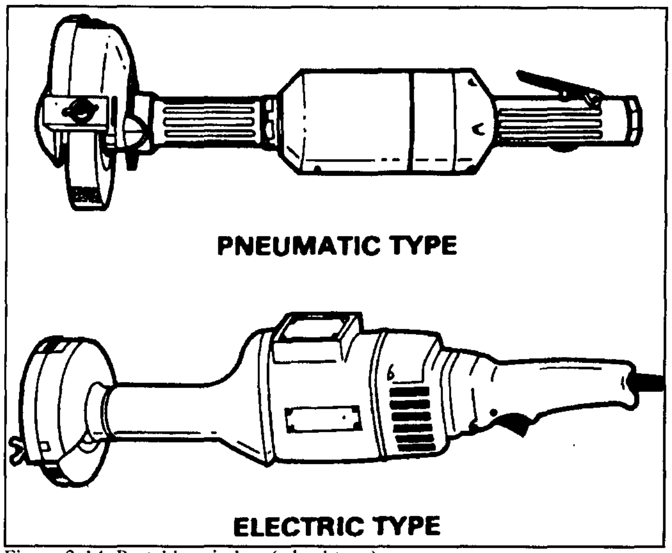


Figure 3-14 Portable grinders (wheel type).

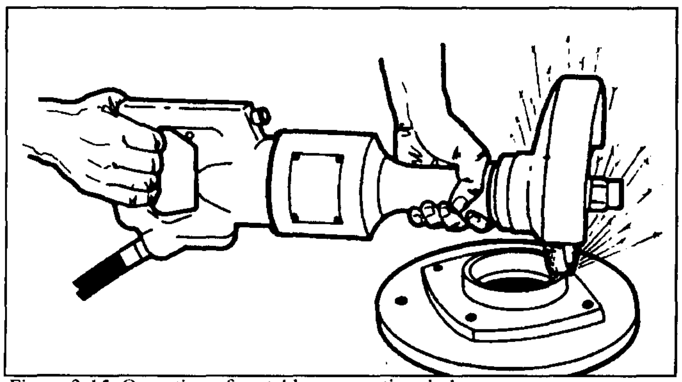


Figure 3-15. Operation of portable pneumatic grinder.

Most portable grinders come with a grinder stand (Figure 3-16). Mounted on this stand, the grinder can be used to sharpen twist drills and cutter bits in the machine shop. Most grinders also come equipped with a wheel guard that should remain in place at all times to protect the operator from flying sparks and waste material. The portable grinder is designed so that the face of the grinding wheel is used; never use the side of the wheel or serious injury or damage could occur (Figure 3-17).

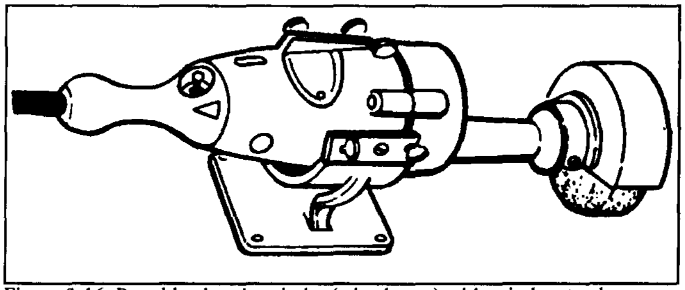


Figure 3-16. Portable electric grinder (wheel type) with grinder stand.

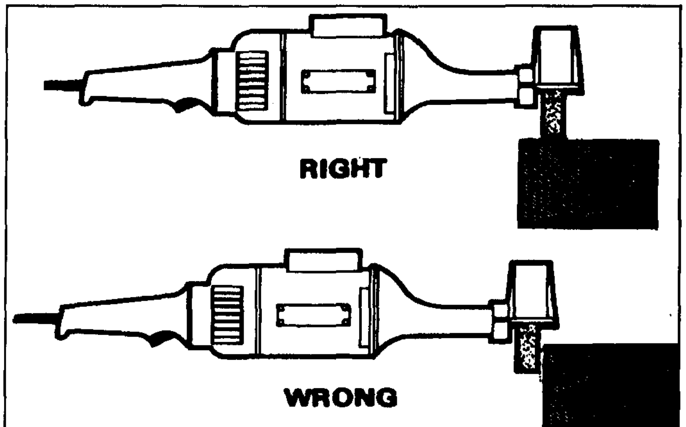


Figure 3-17 Correct and incorrect methods of using the portable grinder (wheel type).

The angle grinder (disk type) (Figure 3-18) can be electric or pneumatic, and is designed for heavy duty grinding operations. The angle grinder consists of a depressed center abrasive grinding disk with wheel guard attached to the basic portable motor assembly (Figure 3-19). Care must be taken to check the wheel for cracks and to ensure that the wheel guard stays in place while operating.

OPERATIONS WITH PORTABLE GRINDERS

Before operating any portable grinder, check the grinding wheel for cracks and check that the arbor hole is the proper size for the grinder to be used. When operating these grinders, keep a light pressure on the work to avoid damaging the wheel or overheating the workpiece.

Both the small and the larger portable grinders operate at a high speed, so avoid letting the wheel rest on one spot for too long. This could cause the work to burn or the wheel to crack and explode. Always check the manufacturer's instruction. manual before operation to ensure the grinding wheel's maximum rated speed is rated higher than the maximum speed of the grinder.

When grinding, buffing, or polishing with any portable grinder, always keep a firm grip on the tool to avoid injury or damage to equipment

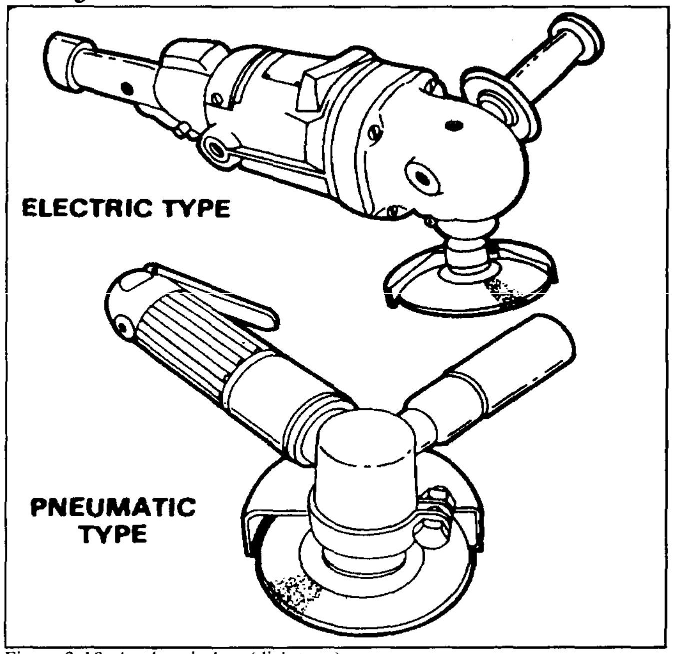


Figure 3-18. Angle grinders (disk type).

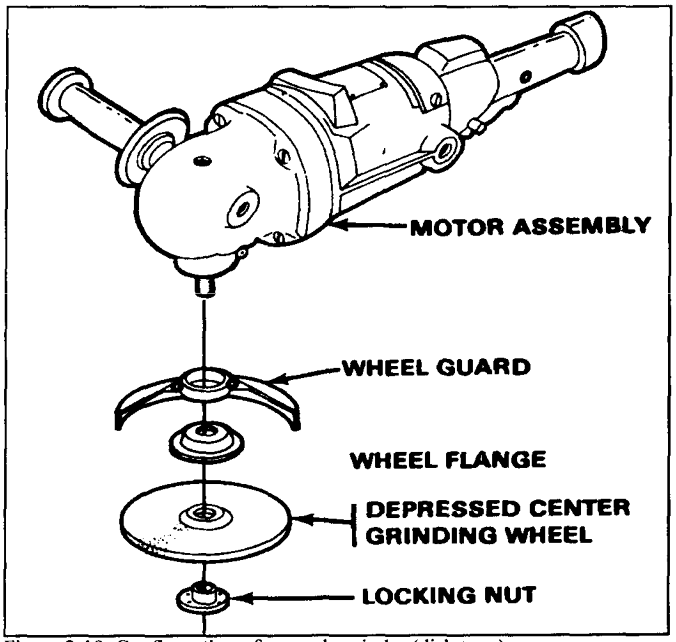


Figure 3-19. Configuration of an angle grinder (disk type).

PORTABLE SANDERS AND POLISHERS

PURPOSE AND TYPES

Portable sanders and polishers are used for surface finishing of materials such as metal, wood, ceramics, and plastics. Both tools are Lightweight and fairly easy cooperate. They can be powered electrically or pneumatically and can be light-duty or heavy duty.

Portable sanders are used to remove paint, rust, corrosion, and imperfections from the surface of workplaces to produce a smooth surface for finishing. Field and machine shop maintenance personnel use the disk-type portable sander (Figure 3-20). The disk-type portable sander has a high-speed motor that rotates an abrasive disk, wire wheel, or a grinding wheel to prepare a surface for finishing. For sanding, a disk of abrasive paper is mounted with a flexible backing pad on the motor spindle (Figure 3-21). The basic motor unit is similar to the motor unit used for angle grinding, but with sanding there is no need for a wheel guard. On some models the motor spindle can be locked by depressing a lock button to install or remove the sanding disks. A side handle on the motor housing is used to support the sander during operation. This handle can be removed and screwed into the opposite side of the motor housing for left-handed operation. Pneumatic sanders have an advantage over electric sanders because they are lighter in weight and easier to handle which usually produces a better finished product.

NOTE: Portable sanders are not intended for use as portable abrasive cutoff saws. The torque for cut off sawing will ruin the soft gearing in the sander motor unit.

Various abrasive disks are used in the operation of the portable electric sander. These disks consist of different abrasive grains that have been bonded or glued onto a cloth or paper disk (see Table 3-2) in Appendix A..

The backing material that supports the abrasive disk is made of a tough vulcanized rubber or fiber that can withstand hard use and constant flexing. Normally, the abrasive grain used on the disk is aluminum oxide, and the bonding agent is glue or special resin. Abrasive disks come in open-coat or closed-coat types, depending on the work to be performed. The closed-coat disk has the abrasive grains bonded close together, while the open-coat disk has the abrasive grains spaced further apart. Open-coat abrasive disks are used for sanding soft materials that could possibly load up a closed-coat disk, for example, wood sanding, removing paint and rust, and plastic. Closed-coat abrasive disks are used for sanding metal, finishing ceramics, and for smoothing rougher sanded areas.

Most portable sanders come with an instruction manual and those accessories that the manufacturer recommends for its use. These accessories can include a sanding setup which includes a flexible rubber backing plate, several types of sanding disks, and the hardware to secure the disk to the motor assembly. Other accessories may include flexible grinding disks with wheel guards, wire wheels, and odd-shaped grinding cups with the appropriate wheel guard. Only use accessories approved by the manufacturer to avoid injury or damage to equipment.

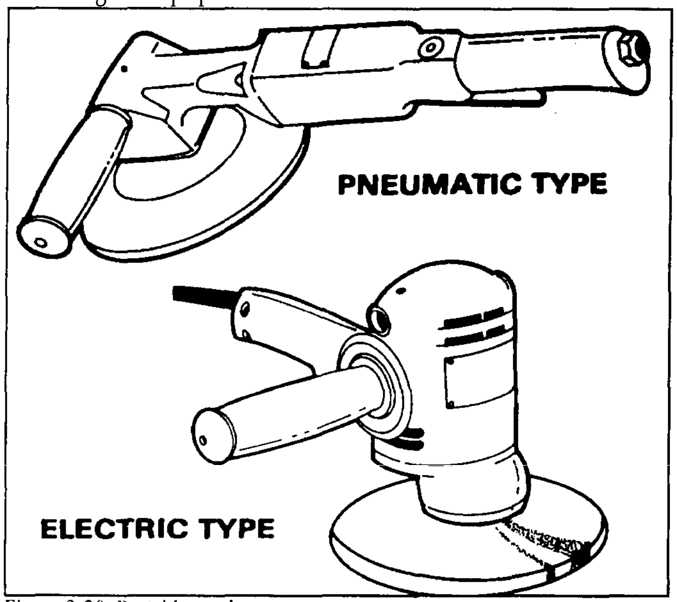


Figure 3-20. Portable sanders.

The portable polisher (Figure 3-22) is used to produce a super finish or shine to the workpiece surface. Polishing or buffing a surface is desirable at times to increase smoothness and make the surface easier to clean. By polishing a surface, a workpiece can also be made more wear resistant. Portable polishers are generally more powerful than portable sanders

Since they encounter a greater frictional resistance when in operation, portable polishers operate at slower speeds than portable sanders so as not to mar the finished surface. Pneumatic portable polishers are lighter in weight than electric models and may make fewer buffing marks on the finish. In order to improve the surface quality of a workpiece through polishing, it is necessary to use a soft bonnet or cover over the sander backing pad.

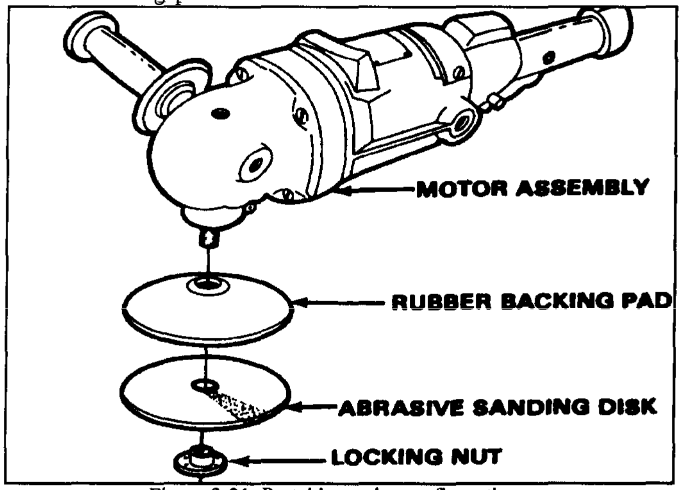


Figure 3-21. Portable sander configurations.

Lamb's wool polishing bonnets are recommended with a soft rubber cushion pad separating the bonnet and the backing pad. Polishing compound, which is a mild abrasive, is used to help polish the surface. A left- or right-handed side handle is attached to the motor housing to help control the polisher during operations.

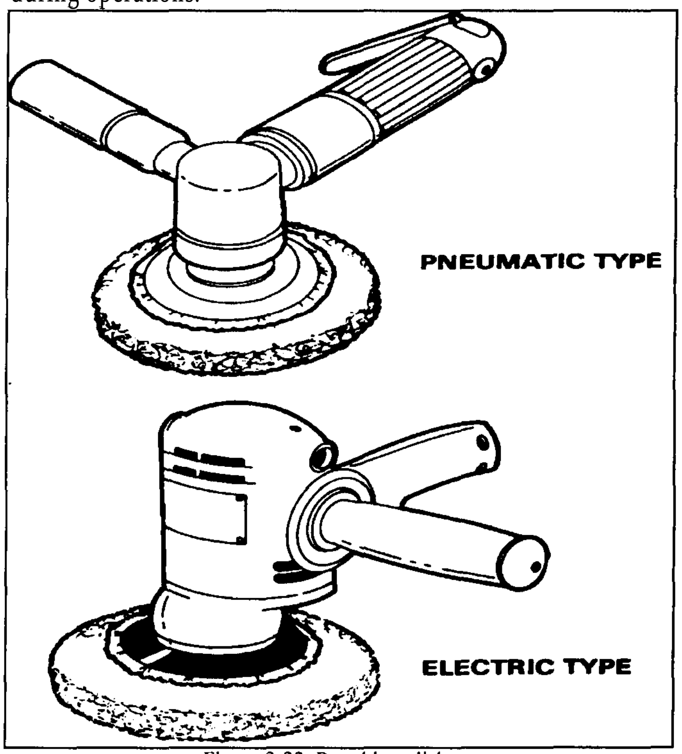


Figure 3-22. Portable polishers.

OPERATIONS WITH THE PORTABLE SANDER AND POLISHER

Operating the portable sander is difficult due to the rotating force of the disk, so the quality of the work depends mostly on the experience of the machine operator. Hold the portable sander so that the abrasive disk forms an angle of approximately 15° to the workpiece surface (Figure 3-23). Apply just enough pressure against the sander to bend the sanding pad and abrasive disk so that about 2 inches of the disk contact the surface. Move the sander from side to side, overlapping each path with the next. If the sander cuts irregularly or is hard to control, the sander is most likely at an angle less than the required 15° to the workpiece. If the sander gouges or leaves rough edges, the angle formed by the sander is most likely too great. When the sander is operating, keep it moving back and forth across the workpiece or lift it free to avoid damaging the surface.

The portable polisher looks like the portable sander but it is built with a slower speed and high torque needed for polishing. Polishing is performed by placing the spinning lamb's wool polishing bonnet lightly against the workpiece and moving the polisher lightly back and forth while maintaining a light pressure on the workpiece. Avoid pressing down too hard, or the surface could get damaged. Use separate polishing bonnets for different polishing abrasives, glazes, or waxes. Reapply polishing compound as needed to keep a smooth finish.

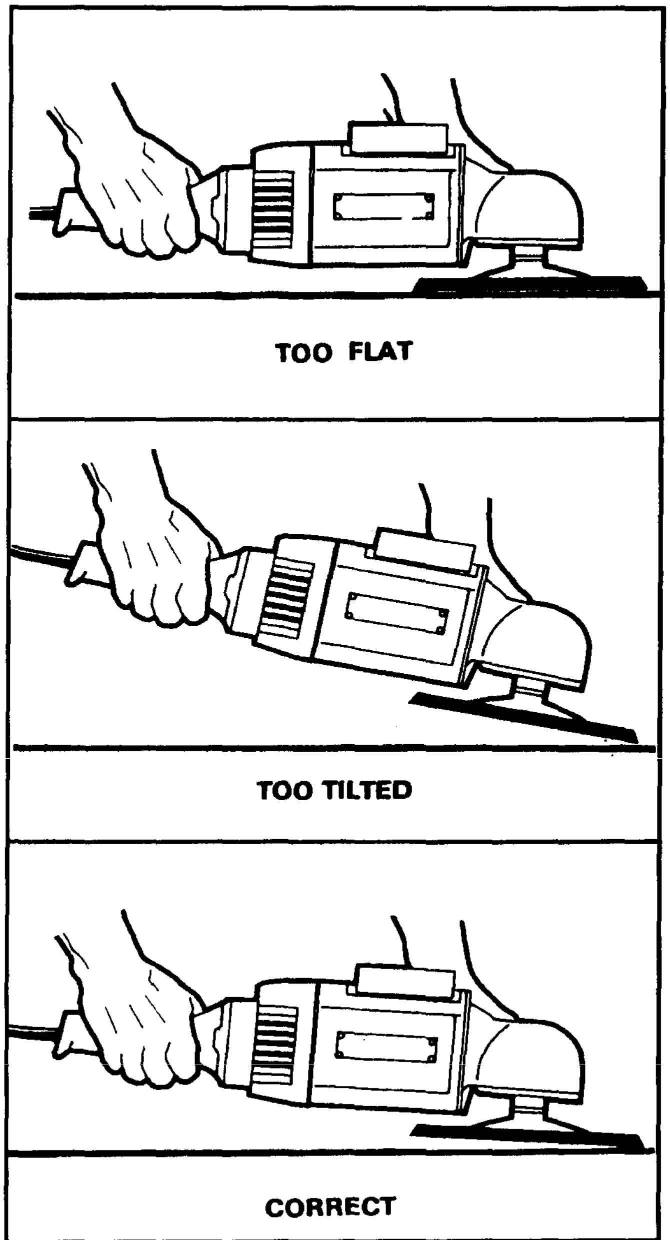


Figure 3-23. Correct and incorrect methods of using the electric sander.

PORTABLE METAL SAWING MACHINES

PURPOSE AND TYPES

The portable metal sawing machines described in this section are those lightweight and easily transportable saws that are used in a field or normal machine shop by maintenance personnel. These saws can be used to cut stock that is too big or too long to move to a maintenance shop to be cut. The following portable sawing machines are described in this section: the portable hacksawing machine, the portable band sawing machine, and the portable reciprocating saw. Two of these saws are operated by hand, so the quality of work depends upon the experience and skill of the operator. Portable metal sawing machines can be used in the maintenance shop to cut wood, steel, plastics, electrical conduit, tubing, pipes, and shop stock, and for auto body work.

THE PORTABLE HACKSAWING MACHINE

The portable hacksawing machine (Figure 3-24) is not designed to be hand-held, but to lock onto the workpiece with a self-contained vise. This saw has a built-in electric motor that causes a power hacksaw blade to reciprocate at a fixed speed of 115 strokes per minute. The machine is capable of cutting solid steel 3 inches square and at an angle to 45°. This saw can be used in a horizontal, angular, or vertical position, having an adjustable counterbalance to compensate for operating the sawing machine in a vertical position. A 10-inch power hacksaw blade is used with this machine, producing a 4-inch stroke. A tension screw permits increasing or decreasing the blade pressure with each cut. The portable hacksawing machine will support itself when fastened very securely to a stationary workpiece, using the self-contained vise.

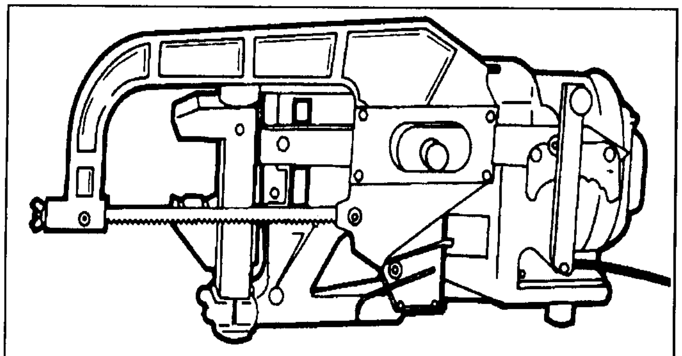


Figure 3-24. Portable hacksawing machine.

To operate the portable hacksawing machine, insert a power hacksaw blade of 18, 24, or 32 teeth per inch, depending on the material to be cut. Then, check the adjustment of the tension screw and the adjustment of the counterbalance lever. Turning the tension screw clockwise will increase the amount of lift the hacksaw blade makes on each return stroke and will increase the downward pressure of the blade on each cutting stroke. Counterclockwise rotation of the screw will decrease the lift and pressure. This control should be adjusted to cause the hacksaw blade to lift 1/8 inch on each return stroke to provide maximum cutting speed and efficiency. The counter balance lever controls the downward pressure exerted upon the hacksaw blade by the weight of the saw frame. By moving the counterbalance lever to the left, the pressure is decreased. Moving the lever to the right increases the pressure. Mount the workpiece squarely or angularly in the vise, depending on the type of cut desired. Start the sawing machine and observe the cutting action. If the machine strains, the blade pressure may be too heavy.

If the machine cuts very slowly, increase the pressure. Continuously check the power hacksaw blade for sharpness. If the blade is dull, it should be replaced. When the machine cuts completely through the material, the saw frame will fall and trip the motor switch, stopping the saw.

When the sawing machine is used in the vertical position, the counterbalance lever must be positioned in the farthest right notch of the guide bar ratchet to compensate for the lack of gravitational pressure normally applied to the blade by the saw frame. This practice should be attempted only if the workpiece can be clamped very securely in the vise and cannot be wrenched loose during vertical sawing, or damage to personnel or equipment could occur .

THE PORTABLE BAND SAWING MACHINE

The portable band sawing machine (Figure 3-25) or portable band saw is a lightweight, hand-held unit powered by an electric motor. The saw motor and gears rotate a solid steel band saw blade around two large wheel pulleys and through several saw blade guides at such an angle to give clearance to the workpiece being cut. The portable band saw can cut steel round stock to 3 3/8 inch diameter or steel rectangular stock 3 3/8-inch thick by 4 1/8 inch wide. The portable metal band sawing blades are 44 7/8 inches long and can have from 6 to 24 teeth per inch, providing a wide range of cutting capabilities (see Table 3-3 in Appendix A). Single-speed band saw models are designed for softer metals, such as brass, aluminum, and mild steel. Two-speed and variable speed models can be switched to a low speed to cut harder metals, such as stainless steel or tungsten. The band saw blade is completely enclosed, using the motor housing as a blade guard, except for the exposed part of the blade that does the sawing. A hand grip and trigger switch are provided on one end of the saw and a knob grip is on the other end to provide for maximum control while sawing.

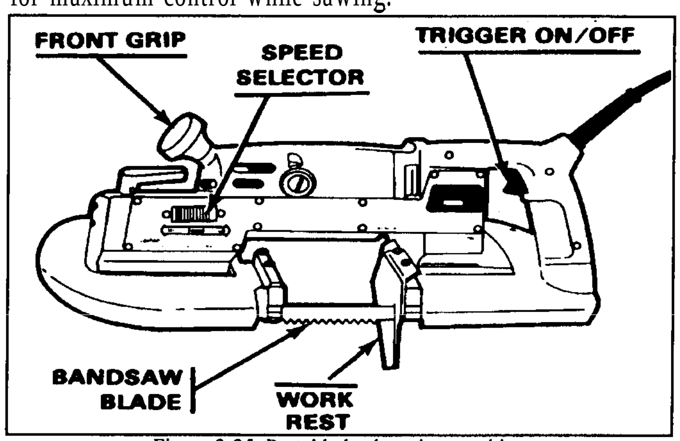


Figure 3-25. Portable hacksawing machine.

To start sawing, make sure that the material to be cut is held very securely in the vise to avoid excessive vibration. Select the appropriate blade for the material to be cut and mount the blade securely into the portable band saw in accordance with the manufacturer's instructions. Take hold of the front knob grip handle and rear hand grip handle and squeeze the trigger switch to start the saw blade in motion. Set the speed appropriately if operating a two-speed or variable-speed model. Gently lower the portable band saw onto the workpiece, being careful to use the weight of the machine as pressure to cut. If the operator uses additional pressure on the workpiece, the saw blade will slow down and reduce the cutting efficiency. Hold the machine steady and the saw blade straight to avoid twisting or breaking the blade. At the completion of the cut, do not allow the saw to fall onto the workpiece. Maintain hand control of the machine, release the trigger switch, and allow the blade to stop before setting down the saw. Never use a liquid coolant with the portable band sawing machine as this could damage the saw guide bearings or rubber pulleys. Lubricate and service each saw as specified in the manufacturer's instructions.

THE PORTABLE RECIPROCATING SAW

The portable reciprocating saw (Figure 3-26) is a hand-held lightweight machine tool that can be electrically or pneumatically powered, depending on the model selected. The saw motor and gearing cause a single knife-like blade to move rapidly in and out, sawing across a workpiece as hand pressure is applied. The saw may be a one-speed model or two speed model. The one-speed model operates at high speed only and is used for cutting soft materials like wood or sheet rock. The two-speed models have a switch that can move the speed from high speed to low speed, so that harder materials, such as metal pipes and steel sheets, can be cut.

The portable reciprocating saw, with the proper blade installed, can cut through steel stock up to 1 inch square or steel pipe up to 4 inches in diameter. An enclosed hand grip handle with trigger switch is provided at one end of the saw and another hand grip is toward the front of the saw, near the blade, to provide for maximum control while sawing. The blade freely protrudes from an angled work rest that is attached to the motor housing. There is no blade guard, so care must be exercised at all times.

To start sawing, ensure the material to be cut is held securely to avoid vibration that could break the saw blade. Select the right blade for the material to be cut and mount the blade into the blade clamp according to the manufacturer's instructions. Check the speed setting, get a firm grip on both handles, and squeeze the trigger switch. Guide the saw so that the work rest is against the workpiece and lower the saw until the blade starts cutting into the workpiece. Keep a firm grip through the saw cut and control the saw to avoid twisting or breaking the blade. After the cut is completed, maintain control of the saw and release the trigger switch. Allow the blade to come to a complete stop before laying the tool down. Periodically lubricate and service the portable reciprocating saw according to the manufacturer's instructions.

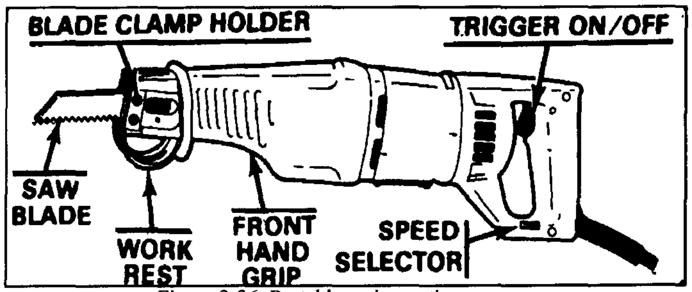


Figure 3-26. Portable reciprocating saw.

PORTABLE METAL CUTTING SHEARS PURPOSE AND TYPES

PURPOSE AND TYPES

The portable metal cutting shears are lightweight, hand-held power tools used to cut through sheet metal. These shears are capable of continuous cutting along a straight or irregular line on a workpiece. Field and machine shop maintenance personnel use the portable metal cutting shears for sheet metal trimming, auto body work, duct work, aircraft structural repair, and cutting template patterns. These tools can be powered by an electric motor or air depending on the model selected.

There are two basic types of portable metal cutting shears: the heavy-duty type with the upper movable blade (single-cut) (Figure 3-27), and the light-duty type with the scissor action blade (doublecut) (Figure 3-28). Both types of shears work well, but there are slight differences in the operation and capabilities of each. Since these are hand controlled tools, the quality of work performed depends upon the experience and skill of the operator.

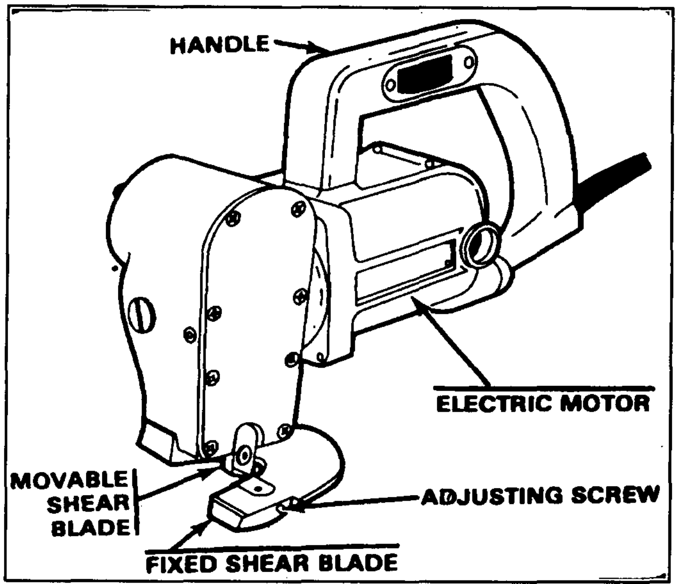


Figure 3-27. Portable electric heavy-duty cutting shears (single cut).

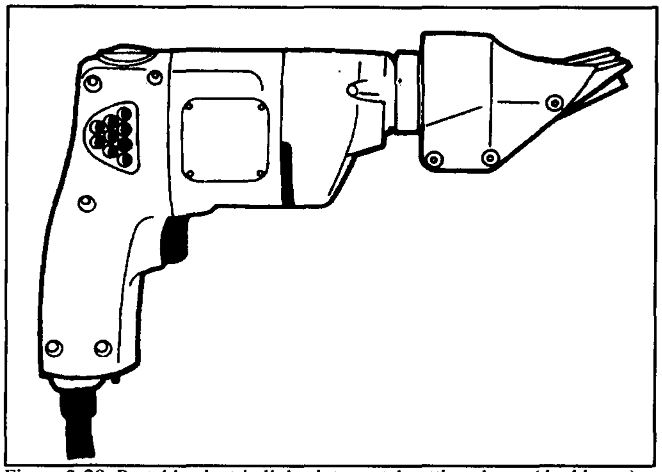


Figure 3-28. Portable electric light-duty metal cutting shears (double cut).

The heavy-duty portable metal cutting shears have an upper, movable shear blade that moves up and down very rapidly over a fixed lower blade so that a continuous single-cut action occurs. The single-cutting action of these shears can cause the sheet metal being cut to warp or bend, so these shears are not recommended for making precision templates or very flat sheet metal pieces. Some models of the very heavy-duty portable metal cutting shears can cut mild sheet steel up to #6 gage or about 3/16-inch, but most maintenance shops use the normal heavy-duty shears capable of cutting up to #12 gage (about 7/64-inch) or thinner. Softer metals can be slightly thicker than the rating for sheet metal and still be cut successfully. The heavy-duty type shear has a blade clearance adjustment so that the best cutting action can be obtained for each type and thickness of metal.

The light-duty portable metal cutting shears operate with a scissor-like motion that makes a double cut by removing a strip of metal about 1/4 inch wide which produces a distortion-free piece (Figure 3-29). These shears are used for thin sheet metal, such as #18 gage (about 3/64-inch) or thinner. A hole about 3/8 inch in diameter is needed to gain access for inside cutting. The rapidly reciprocating blade enables these shears to cut intricate patterns, make models, trim gaskets, and cut out templates from different sheet metal materials. These light-duty type of shears are lighter in weight and much easier to handle than the larger heavy-duty type. The cutting blade clearance is set at the factory, so the only adjustment is to sharpen the blades if the cutting action becomes difficult.

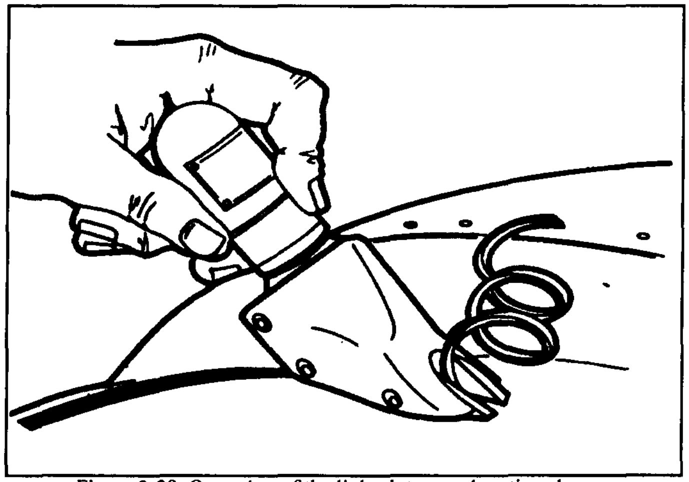


Figure 3-29. Operation of the light-duty metal cutting shears.

OPERATION OF THE PORTABLE METAL CUTTING SHEARS

Successful operation of the portable metal cutting shears depends upon two important factors: sharp shear blades and proper shear blade clearance. The shear blades are easily taken out and sharpened or replaced as needed. Each model is slightly different, so follow the manufacturer's instructions on sharpening or changing the shear blades. When sharpening the shear blades, grind only the top and bottom edges. Never grind the sides of the blades.

If the metal being cut twists or jams beneath the blades, the most likely cause is excessive blade clearance. If the shears bind or stall when cutting through the metal, or if the blades tend to double shear and produce a burred edge, then the blade clearance is probably too small. Sharpen or replace the shear blades if the cutting action becomes slowed or stops, or if the workpiece edges become burred.

Before starting to cut, scribe a line on the workpiece. Holding the portable metal cutting shears in one hand, start cutting from the edge of the sheet metal while keeping the scribed line alongside the reciprocating blade. Only a light forward pressure is required to guide the shears through the metal. Any irregular contours can be followed quickly and easily because one blade is always visible to the operator. If the shear blades are sharp and the clearance for the blades is correct, a clean, smooth cutting action should occur.

PORTABLE COOLANT ATTACHMENT

PURPOSE

The portable coolant attachment is a device for supplying coolants and cutting oils for cutting operations with machine tools when continuous application of a coolant or cutting oil is required. The portable coolant attachment consists of a container to hold the coolant or cutting oil, a pump to force the coolant through a flexible hose directed at the cutting tool and workpiece, and a pan arrangement beneath the machine tool to catch the coolant or cutting oil, filter it, and return it to the container.

The portable coolant attachment (Figure 3-30) is self-contained and powered by an electric motor. The coolant container and catch pans are attached to the bed or frame of the machine tool beneath the work area, and a flexible metal hose is positioned where the stream of coolant or cutting oil from the pump will flood the workpiece and cutting tool at their point of contact. The pans beneath the workpiece catch the coolant as it splashes from the workpiece and strain the coolant as it flows back to the container for recirculation. Coolant can be controlled by a valve at the base of the flexible hose. A pipe plug is provided at the base of the container to drain the coolant from the container after use. The portable coolant attachment moves easily from one machine to another to provide various machines with cooling capabilities.

COOLANT ATTACHMENT OPERATION

The portable coolant attachment serves the needs of a machine shop in a field or regular maintenance facility. It provides coolant for lathes, mills, drilling machines, grinders, sawing machines, and other machine tools. The attachment should be set up under the area of the machine tool that does the cutting action and needs to be cooled. The drip or catch pans should be arranged horizontally to catch the coolant as it drips from the workpiece. Position the flexible hose so that it directs a stream of coolant to the point of contact between the cutting tool and the workpiece.

The portable coolant attachment is a device for supplying coolants and cutting oils for cutting operations with machine tools when continuous application of a coolant or cutting oil is required. The portable coolant attachment consists of a container to hold the coolant or cutting oil, a pump to force the coolant through a flexible hose directed at the cutting tool and workpiece, and a pan arrangement beneath the machine tool to catch the coolant or cutting oil, filter it, and return it to the container.

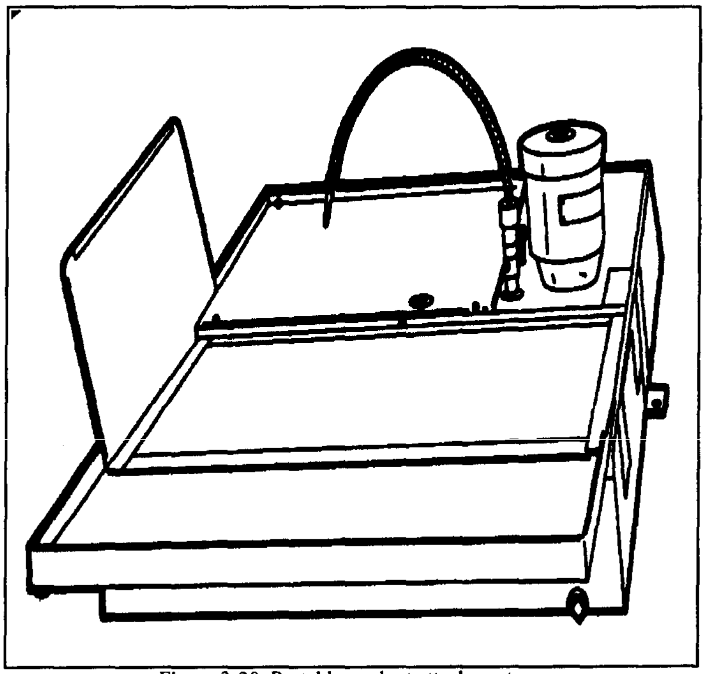


Figure 3-30. Portable coolant attachment.

If the cutting tool moves along the workpiece, clip the hose end to the cutting tool carriage so that the hose will move with the tool.

The material to be machined will determine whether to use a coolant or a cutting oil. Fill the container of the portable coolant attachment with the selected coolant or cutting oil. Start the pump motor of the attachment before starting the machine tool to check the flow of coolant over the workpiece being machined, and adjust the stream flow as necessary. Start the machine tool and perform the cutting operation. At the conclusion of the operation, stop the pump motor. Drain the coolant or cutting oil from the container by removing the plug at the bottom of the container. Clean out the container, pump, and hose before using a different type of coolant.