SECTION A

Introduction

UNIT ONE Shop Safety

UNIT TWO Mechanical Hardware

UNIT THREE Reading Drawings

Of all the manufacturing processes that can be applied to the shaping and forming of raw materials into useful products, machining processes will always remain among the most important. The fundamental cutting processes in machining, those of bringing the work into contact with a cutting tool, are still very much in evidence and will always remain mainstays of the industry. What has changed is the way in which these processes are applied, the cutting tool materials, the material used for products, and the methods of material removal. These new methods are quite different from the classical chip-producing processes. They include the use of lasers, electrical energy, electrochemical processes, ultrasound, high-pressure water jets, and high-temperature plasma arcs as material removal tools.

Computers have enhanced automated manufacturing; machining is no exception. Computer numerical control (CNC) of machine tools has been available for many years. Modern machine tools of all types are equipped with their own computer numerical controls and almost every machining process can now be efficiently automated with an exceptional degree of accuracy, reliability, and repeatability. In fact, machining processes have become so sophisticated and reliable that the human operator of a machine tool may now be replaced with a computer controlled robot (Figure A-1). This application of computer-driven automated equipment will profoundly affect the employment of machinists and machine operators in future years.

The computer has found its way into almost every other phase of manufacturing as well. One important area is computer-aided design (CAD) (Figure A-2). The age of drawing board design is fast drawing to a close. Design is now done on computer terminals, and manufacturing equipment control programs are generated directly in computer-aided manufacturing (CAM), fully computer-aided design and manufacturing (CAD/CAM), or computer-integrated manufacturing (CIM).

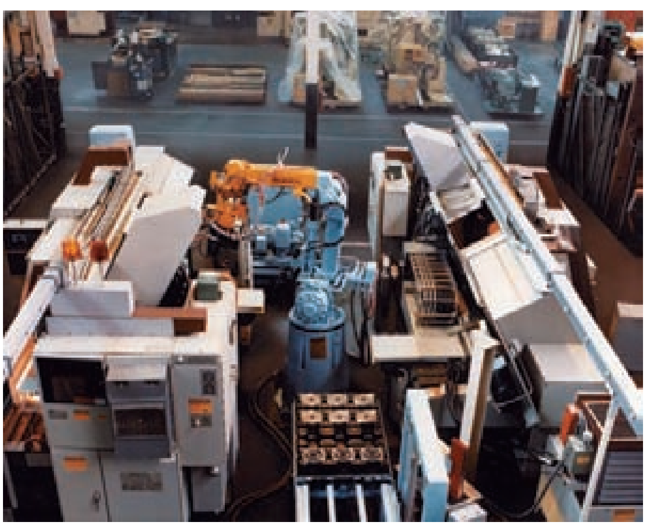


Figure A-1 The machine operator of tomorrow's automated manufacturing industry. A computer-controlled industrial robot loads and unloads parts on a CNC turning center (*Courtesy of MAG Industrial Automation Systems LLC*).

Figure A-2 Computer-aided design (CAD) is fast replacing the drawing board in engineering design applications (*Courtesy of MAG Industrial Automation Systems LLC*).

The ultimate outcome of manufacturing automation will be an entirely automated factory in which material will be automatically transported between manufacturing cells that will perform similar manufacturing or machining operations. Such a system, called a flexible manufacturing system (FMS), will be fully computer controlled and already has become an industry standard (Figures A-3 and A-4).

CAREER OPPORTUNITIES IN MACHINING AND RELATED AREAS

The influence of high technology in machining manufacturing has had, and will continue to have, a significant effect on the types and numbers of jobs available in this field. Many exciting career opportunities are available for those willing to prepare themselves. However, like all technology, machining manufacturing has become a specialized business, and this trend is likely to continue.

Trade-Level Opportunities

Machine Operator The machine operator will be widely employed for some time to come. The machine operator's responsibilities will be to operate computer-driven (CNC)

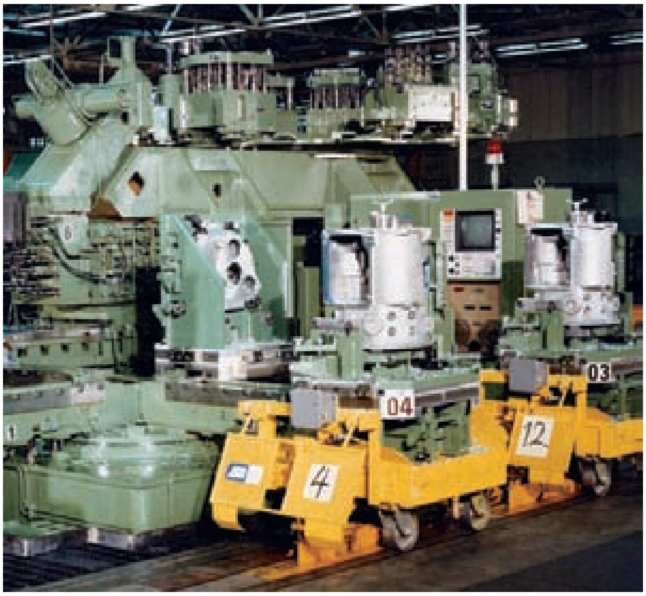


Figure A-3 A specialty CNC machining center forms a work cell in a flexible manufacturing system (FMS). Robot transporters move parts from cell to cell all under computer control (*Courtesy of Giddings & Lewis Machine Tools, LLC*).

machine tools such as turning or machining centers. The operator will observe machine functions and tool performance, change and inspect parts, and perhaps have limited duties in setting up and adjusting machine programming.

Preparation for machine operators will consist of familiarization with conventional machining processes, tooling selection and application, machine control unit operations, reading drawings, related math, limited machine setup, and quality control inspection measurement functions. Machine operators can receive training through trade schools, community college programs, or industrial training programs, or they may learn on the job. The CNC operator will generally work in a fast-paced production environment in companies ranging in size from very small to very large.

Setup The setup person is responsible for setting up the machine tool and assisting the operator in establishing a first article acceptable part at the start of production. Setup people will generally have considerable CNC experience at the operator level and will be familiar with jigs, fixtures, cutting tools, and CNC program operations. The setup person is most likely to learn the work through on-the-job training. Setup people will also work in fast-paced production shops in medium-sized to large companies.

General Machinist The general machinist will have the capability to set up and operate all the common conventional machine shop equipment. This person may receive training through an industrial apprenticeship lasting about four years, through broad-scope community college and trade school education, often tied to a local machining industry, or through on-the-job experience of several years. The general machinist is not exactly disappearing, but much of the production work heretofore done by this individual can now be routinely accomplished on CNC machine tools by machine operators.

The general machinist may work in a job shop environment where many different types of work are performed.

Figure A-4 Parts to be machined are mounted on pallets so that they may be moved from machining center to machining center in different work cells in the flexible manufacturing system (*Courtesy of Giddings & Lewis Machine Tools, LLC*).

In a large company where modeling and prototyping take place, the general machinist will find varied and extremely interesting work.

Automotive Machinist The automotive machinist will work in an engine rebuilding shop where engines are overhauled. This person's responsibilities will be somewhat like those of the general machinist, with specialization in engine work, including boring, milling, and some types of grinding applications. Training for this job may be obtained on the job or through college or trade school programs.

Maintenance Machinist The maintenance machinist has broad responsibilities. The person may be involved in plant equipment maintenance, machine tool rebuilding, or general mechanical repairs, including welding and electrical. The maintenance machinist is often involved with general machine shop work as well as with general industrial mechanical work. The general maintenance machinist is often a vital member of the manufacturing support team in industries of all sizes. This person may receive training through college and trade school programs or on the job.

Tool, Die, and Mold Maker The tool, die, and mold maker, essential in almost every machining manufacturing industry, is often considered to be at the upper end of the machinist trade occupations. The tool and die maker will usually be an experienced general machinist with superior talents developed over years of shop apprenticeship and more years of experience. Tool and die makers may receive training through industrial apprenticeships or college and trade school programs. They may also be selected for industrial training in companies large enough to have an in-house tool and die shop. Although tool and die makers are often chosen only after several years of on-the-job experience, it is possible to start out in tool and die work through an apprenticeship program. Tool and die makers often receive premium pay for their work and are involved with many high-precision machining applications, tool design, material selection, metallurgy, and general manufacturing processes.

Inspector Inspectors handle the dimensional measurement quality control functions. Many people become inspectors after working as machine operators, general machinists, or possibly toolmakers. The machined parts inspector of today will require a knowledge of computerized measurement equipment. Inspectors may be trained on the job or through college and trade school programs.

Production Technician Production technicians will be involved in many different tasks in machining manufacturing industries. Some of these responsibilities relative to maintenance may be similar to those of the maintenance machinist. The production technician will be responsible for installation of production equipment. Both electrical/electronic and mechanical technicians will be needed as manufacturing industries shift toward more computer-integrated manufacturing. The technician, especially in the electrical/electronic areas, will need excellent diagnostic skills so that expensive equipment can be quickly serviced and returned to production. Technicians may obtain training through college and trade school programs or on the job. Areas of knowledge include pneumatics, hydraulics, electrical/electronic systems, computers, and the interrelationships of all these systems in complex manufacturing systems.

Marine Machinist The marine machinist is generally employed in the shipbuilding industry. This trade has many different aspects, including installation, testing, and repairs of all types of shipboard mechanical systems, including hydraulics and pneumatics as well as conventional and nuclear steam systems. The marine machinist may also use portable machine tools brought to the job, including milling, boring, and drilling machines. Marine machinists often use optical instruments to align and locate mechanical components and machine tools.

Apprentice Machinist The apprentice machinist learns the trade by entering a formal training program sponsored by private industrial, trade union, or government entities. The period of training is typically four years long and is a combination of on-the-job experiences and formal classroom education. Apprenticeship curriculum standards are often universal, representing the collective inputs of all levels of the trade from production through management. Serving an apprenticeship represents one of the best and well-established methods of learning a skilled trade.

Helpers and Limited Machinists Many manufacturing industries use limited machinists or machinists' helpers. These individuals assist the journeyperson by providing general help. These trades are often fairly low skill, since the person does not have full responsibility for the work at hand. However, helpers and limited machinists may advance to journeyperson status after a suitable training period.

Professional Career Opportunities

At the professional level, many exciting career opportunities are also available. These careers require college preparation and include industrial technology (IT); industrial engineering (IE); manufacturing engineering; materials engineering; mechanical, electrical, electronic, and computer systems engineering; and CNC programming.

The industrial engineer, industrial technologist, and manufacturing engineer are often involved with the applications of manufacturing technology. These individuals design tooling, set up manufacturing systems, apply computers to manufacturing requirements, and write CNC programs. Design engineers, often using computers, design products and manufacturing equipment and apply new materials in product design.

MACHINING AND YOU

Whether a career in machining or a related area is for you will depend on your personal goals and how much effort you are willing to expend in preparation. No matter which area you might like to pursue, whether it be at the trade or professional level, a working knowledge at the shop level of the machining processes and the related subjects described in this book will provide an excellent basis on which to build an exciting career in industrial manufacturing technology.

PROFESSIONAL PRACTICE

If you are further interested in machine shop career opportunities, discuss the potential with an employment counselor at your school or at your state's human resources department or a private employment agency. Take any opportunities that present themselves to visit local manufacturing companies that employ machinists and discuss the training and preparation required and potential employment opportunities.

Units in This Section

The units in this section deal with the important areas of safety in the machine shop, mechanical hardware, and reading shop drawings. These fundamental technical foundation areas are necessary for anyone involved in any phase of mechanical technology. To start off your study in the proper way, take the time now to familiarize yourself with these important fundamentals.

UNIT ONE

Shop Safety

OBJECTIVES

After completing this unit, you should be able to:

- Identify common shop hazards.
- Identify and use common shop safety equipment.

SAFETY FIRST

Safety is not often thought about as you proceed through your daily tasks. Often you expose yourself to needless risk because you have experienced no harmful effects in the past. Unsafe habits become almost automatic. You may drive your automobile without wearing a seat belt. You know this to be unsafe, but you have done it before and so far no harm has resulted. None of us really likes to think about the possible consequences of an unsafe act. However, safety can and does have an important effect on anyone who makes his or her living in a potentially dangerous environment such as a machine shop. An accident can reduce or end your career as a machinist. You may spend several years learning the trade and more years gaining experience. Experience is a particularly valuable asset. It can be gained only through time spent on the job. Safety becomes economically valuable to you and to your employer. Years spent in training and gaining experience can be wasted in an instant if you should have an accident, not to mention a possible permanent physical handicap for you and hardship on your family. Safety is an attitude that should extend far beyond the machine shop and into every facet of your life. You must constantly think about safety in everything you do.

PERSONAL SAFETY

Grinding Dust, Hazardous Fumes, and Chemicals

Grinding dust is produced by abrasive wheels and consists of extremely fine metal particles and abrasive wheel particles. These should not be inhaled. In the machine shop, most grinding machines have a vacuum dust collector (Figure A-5). Grinding may be done with coolants that aid in dust control. A machinist may be involved in portable grinding operations. This is common in such industries as shipbuilding. You should wear an approved respirator if you are exposed to grinding dust. Change the respirator filter at regular intervals. Grinding dust can present a great danger to health. Examples include the dust of such metals as beryllium, or the presence of radioactivity in nuclear systems. In these situations, the spread of grinding dust must be controlled carefully.

Some metals, such as zinc, give off toxic fumes when heated above their boiling point. When inhaled, some of these fumes cause only temporary sickness, but other fumes can be severe or even fatal. The fumes of mercury and lead are especially dangerous, as their effect is cumulative in the body and can cause irreversible damage. Cadmium and beryllium compounds are also very poisonous. Therefore, when welding, burning, or heat-treating metals, adequate ventilation is an absolute necessity. This is also true when parts are being carburized with compounds containing potassium cyanide. These **cyanogen** compounds are deadly poisons, and every precaution should be taken when using them. Kasenite, a trade name for a nontoxic carburizing compound, is often found in school shops and in machine shops. Uranium salts are toxic, and all radioactive materials are extremely dangerous.

There is probably a minimum exposure to chemical hazards in the machine shop; however, lubricating oils, cutting oils, various coolants, and possibly some types of degreasing agents or solvents are used. Any of these chemical agents can

Figure A-5 Vacuum dust collector on grinders.

cause both short- and long-term health problems. Cutting oils may smoke when heated and give off noxious fumes. Inhaling any type of smoke can have short- and long-term health risks. Coolants may cause contact dermatitis, a skin irritation problem, and prolonged exposure can cause other long-term health problems. You should seek chemical safety data regarding these products and determine what heath problems both short- and long-term exposures can cause. In the past, exposure to hazardous chemicals was often neglected until serious health problem began to appear, sometimes many years after exposure. Today, in the industrial world, exposure to chemicals has become a keenly studied subject because it is not always known what the results of long-term exposures can mean to lifetime health issues. Chemical hazard awareness programs label chemicals to make employees aware of particular fire, health, and reactivity issues.

Material Safety Data Sheets (MSDS)

A material safety data sheet or MSDS is a page or pages of information describing the properties of particular chemicals, materials, and other substances. Technical data are provided defining the chemical and physical properties of materials, such as melting point, boiling point, flash point, and identifying any toxic elements that are likely to be present during processing or handling. Other items that may be included on an MSDS are proper disposal techniques, first-aid issues from exposure to hazardous materials, and protective equipment required to safely handle the material. Material safety data sheets are available from many different sources including the Occupational Safety and Health Administration (OSHA) and manufacturers' published information. Modern industrial operations often use many hazardous materials. Safety in using and handling and disposing of these materials has become extremely important owing to concerns about environmental pollution and protecting the human workforce from both short- and long-term health concerns.

Eye Protection

Eye protection is a primary safety consideration around the machine shop. Machine tools produce metal chips, and there is always a possibility that these may be ejected from a machine at high velocity. Sometimes they can fly many feet. Furthermore, most cutting tools are made from hard materials. They can occasionally break or shatter from the stress applied to them during a cut. The result can be more flying metal particles.

Eye protection must be worn at all times in the machine shop. Several types of eye protection are available. Plain safety glasses are all that are required in most shops. These have shatterproof lenses that may be replaced if they become scratched. The lenses have a high resistance to impact. Common types include fixed-bow safety glasses (Figure A-6) and flexible-bow safety glasses. The flexible bows may be adjusted to the most comfortable position for the wearer.

Side shield safety glasses must be worn around any grinding operation. The side shield protects the side of the eye from flying particles. Side shield safety glasses may be of the solid or perforated type (Figure A-7). The perforated side shield fits closer to the eye. Bows may wrap around the ear. This prevents the safety glasses from falling off.

Figure A-6 Common fixed-bow safety glasses.

Figure A-7 Perforated side shield safety glasses.

Prescription glasses may be covered with a safety goggle. The full face shield may also be used (Figure A-8). Prescription glasses can be made as safety glasses. In industry, prescription safety glasses are sometimes provided free to employees.

Foot Protection

Generally, the machine shop presents a modest hazard to the feet. However, there is always a possibility that you could drop something on your foot. A safety shoe with a steel toe shield designed to resist impacts is available. Some safety shoes also have an instep guard. Shoes must be worn at all times in the machine shop. A solid leather shoe is recommended. Tennis shoes and sandals should not be worn. You must never even enter a machine shop with bare feet. Remember that the floor is often covered with razor-sharp metal chips.

Figure A-8 Safety goggle and face shield.

Ear Protection

The instructional machine shop usually does not present a noise problem. However, an industrial machine shop may be adjacent to a fabrication or punch press facility. New safety regulations are quite strict regarding exposure to noise. Several types of sound suppressors and noise-reducing earplugs may be worn. Excess noise can cause a permanent hearing loss. Usually, this occurs over a period of time, depending on the intensity of the exposure. Noise is considered an industrial hazard if it is continuously above 85 **decibels (dB),** the units used for measuring the relative intensity of sounds. If the noise level is over 115 dB for short periods of time, ear protection must be worn (Figure A-9). Earmuffs or earplugs should be used wherever high-intensity noise occurs. A considerate worker will not create excessive noise when it is not necessary. Table A-1 shows the decibel level of various sounds; sudden sharp or high-intensity noises are the most harmful to the eardrums.

Clothing, Hair, and Jewelry

Wear a short-sleeved shirt or roll up long sleeves above the elbow. Keep your shirt tucked in and remove your necktie. It is recommended that you wear a shop apron. If you do, keep it tied behind you. If apron strings become entangled in the machine, you may be reeled in as well. A shop coat may be worn as long as you roll up long sleeves. Do not wear fuzzy sweaters around machine tools.

If you have long hair, keep it secured properly. In industry, you may be required to wear a hairnet so that your hair cannot become tangled in a moving machine. The result of this can be disastrous (Figure A-10).

Remove your wristwatch and rings before operating any machine tool. These can cause serious injury if they should be caught in a moving machine part.

Figure A-9 Sound suppressors are designed to protect the ears from damage caused by loud noises.

Table A-1 Decibel Level of Various Sounds

130	—Painful sounds; jet engine on ground
120	—Airplane on ground; reciprocating engine
110	—Boiler factory
	—Pneumatic riveter
100	—
	—Maximum street noise
	—Roaring lion
90	—
	—Loud shout
80	—Diesel truck
	—Piano practice
	—Average city street
70	—
	—Dog barking
	—Average conversation
60	—
	—Average city office
50	—
	—Average city residence
40	—One 10-key calculator
	—Average country residence
30	—Turning page of newspaper
	—Purring cat
20	—
	—Rustle of leaves in breeze
10	—
	—Human heartbeat
0	—Faintest audible sound

Figure A-10 Long hair may be caught and reeled into the machine.

Hand Protection

No device will totally protect your hands from injury. Next to your eyes, your hands are the most important tools you have. It is up to you to keep them out of danger. Use a brush to remove chips from a machine (Figure A-11). Do not use your hands. Chips are not only razor sharp, they are often extremely hot. Resist the temptation to grab chips as they

Figure A-11 Use a brush to clear chips.

come from a cut. Long chips are extremely dangerous. These can often be eliminated by sharpening your cutting tools properly. Chips should *not* be removed with a rag. The metal particles become embedded in the cloth and they may cut you. Furthermore, the rag may be caught in a moving machine. Gloves must not be worn around most machine tools, although they are acceptable when working with a band saw blade. If a glove should be caught in a moving part, it will be pulled in, along with the hand inside it.

Various cutting oils, coolants, and solvents may affect your skin. The result may be a rash or an infection. Avoid direct contact with these products as much as possible, and wash your hands as soon as possible after contact.

Lifting

Improper lifting (Figure A-12) can result in a permanent back injury that can limit or even end your career. Back injury can be avoided if you lift properly at all times. If you must lift a large or heavy object, get some help or use a hoist or forklift. Don't try to be a "superman" and lift something that you know is too heavy. It is not worth the risk. Objects within your lifting capability can be lifted safely by using the following procedure (Figure A-13):

1. Keep your back straight.
2. Squat down, bending your knees.
3. Lift smoothly, using the muscles in your legs to do the work. Keep your back straight. Bending over the load puts an excessive stress on your spine.
4. Position the load so that it is comfortable to carry. Watch where you are walking when carrying a load.
5. If you replace the load back at floor level, lower it in the same manner in which you picked it up.

Scuffling and Horseplay

The machine shop is no place for scuffling and horseplay. This activity can result in a serious injury to you, a fellow student, or worker. Practical joking is also hazardous. What might appear comical to you could result in a disastrous

Figure A-12 The wrong way to lift, placing excessive strain on the back (*Asnuntuck Community College*).

Figure A-13 The right way to lift, with knees bent, using leg muscles to do the work (*Asnuntuck Community College*).

accident to someone else. In industry, horseplay and practical joking are often grounds for dismissing an employee.

Injuries

If you should be injured, report it immediately to your instructor.

IDENTIFYING SHOP HAZARDS

A machine shop is not so much a dangerous place as a potentially dangerous place. One of the best ways to be safe is to be able to identify shop hazards before they can involve you in an accident. By being aware of potential danger, you can better make safety part of your work in the machine shop.

Compressed Air

Most machine shops use compressed air to operate certain machine tools. Often, flexible air hoses hang throughout the shop. Few people realize the large amount of energy stored in a compressed gas such as air. Releasing this energy presents an extreme danger. You may be tempted to blow chips from a machine tool using compressed air. This is not good practice. The air will propel metal particles at high velocity. They can injure you or someone on the other side of the shop. Use a brush to clean chips from the machine. Do not blow compressed air on your clothing or skin. The air may be dirty, and the force can implant dirt and germs into your skin. Air can be a hazard to ears as well. An eardrum can be ruptured.

Should an air hose break or the nozzle on the end come unscrewed, the hose will whip about wildly. This can result in an injury if you happen to be standing nearby. When an air hose is not in use, it is good practice to shut off the supply valve. The air trapped in the hose should be vented. When removing an air hose from its supply valve, be sure that the supply is turned off and the hose has been vented. Removing a charged air hose will result in a sudden venting of air. This can surprise you, and an accident might result.

Housekeeping

Keep the floor and aisles clear of stock and tools. This will ensure that all exits are clear if the building should have to be evacuated. Material on the floor, especially round bars, can cause falls. Clean up oils or coolants that spill on the floor. Several preparations designed to absorb oil are available. These may be used from time to time in the shop. Keep oily rags in an approved safety can (Figure A-14). This will prevent possible fire from spontaneous combustion.

Fire Extinguishers

It is an important safety consideration to know the correct fire extinguisher to use for a particular fire. For example, if you should use a water-based extinguisher on an electrical fire, you could receive a severe or fatal electrical shock. Fires are classed according to types, as given in Table A-2.

There are four basic types of fire extinguishers used in addition to tap water:

1. The dry chemical type is effective on classe B and C fires.
2. The pressurized water and loaded stream types are safe only on class A fires. These types may actually spread an oil or gasoline fire.

Figure A-14 Store oil-soaked rags in an approved safety can.

3. The dry chemical multipurpose extinguisher may be safely used on classe A, B, and C fires.
4. Pressurized carbon dioxide (CO_2) can be used on classes B and C fires.

You should always make yourself aware of the locations of fire extinguishers in your working area. Take time to look at them closely and note their types and capabilities. This way, if there should ever be an oil-based or electrical fire in your area, you will know how to put it out safely.

Electrical

Electricity is another potential danger in a machine shop. Your exposure to electrical hazard will be minimal unless you become involved with machine maintenance. A machinist is mainly concerned with the on and off switch on a machine tool. However, if you are adjusting the machine or performing maintenance, you should unplug it from the electrical service.

Electrical Lock Out and Tag Out Procedures

Owing to the invisible and potentially fatal hazard of electrical energy, manufacturing industries have specific protocols for safely working on electrical equipment. These are called **lock out tag out** procedures. When working on electrical equipment, it is of critical importance to absolutely prevent an accidental energizing of an electrical circuit. In lock out tag out procedures, the source of the power is turned off and the control switches, circuit breakers, or main switches are physically locked out, often using a keyed lock. The circuit is also tagged and signed off by the electrician or other maintenance workers and can be unlocked and reenergized only by the person directly responsible for the lock out tag out procedure.

Carrying Objects

If material is over 6 ft long it should be carried in the horizontal position. If it must be carried in the vertical position, be careful of light fixtures and ceilings. If the material is both long and over 40 lb in weight, it should be carried by two

Table A-2 Types of Extinguishers Used on the Classes of Fire

	Pressurized Water	Loaded Stream	CO_2	Regular Dry Chemical	All-Use Dry Chemical
Class A fires: paper, wood, cloth, etc., where quenching by water or insulating by general-purpose dry chemical is effective	Yes; excellent	Yes; excellent	Small surface fires only	Small surface fires only	Yes; excellent; forms smothering film, prevent reflash
Class B fires: burning liquids (gasoline, oils, cooking fats, etc.), where smothering action is required	No; water will spread fire	Yes; has limited capability	Yes; carbon dioxide has no residual effects on food or equipment	Yes; excellent; chemical smothers fire	Yes; excellent; smothers fire, prevents reflash
Class C fires: fires in live electrical equipment (motors, switches, appliances, etc.), where a nonconductive extinguishing agent is required	No; water is a conductor of electricity	No; water is a conductor of electricity	Yes; excellent; CO_2 is a nonconductor; leaves no residue	Yes; excellent; nonconducting smothering film; screens operator from heat	Excellent; nonconducting smothering film; screens operator from heat

SOURCE: Brodhead Garrett, a member of the School Specialty Family.

people, one at each end. Heavy stock, even if it is short, should be carried by two people.

MACHINE HAZARDS

There are many machine hazards. Each section of this book will discuss the specific dangers applicable to that type of machine tool. Remember that a machine cannot distinguish between cutting metal and cutting fingers. Do not think that you are strong enough to stop a machine should you become tangled in moving parts. You are not. When operating a machine, think about what you are going to do before you do it. Go over a **safety checklist:**

1. Do I know how to operate this machine?
2. What are the potential hazards involved?
3. Are all guards in place?
4. Are my procedures safe?
5. Am I doing something that I probably should not do?
6. Have I made all the proper adjustments and tightened all locking bolts and clamps?
7. Is the workpiece secured properly?
8. Do I have proper safety equipment?
9. Do I know where the stop switch is?
10. Do I think about safety in everything that I do?

INDUSTRIAL SAFETY AND FEDERAL LAW

In 1970, Congress passed the Williams-Steiger Occupational Safety and Health Act. This act took effect on April 28, 1971. The purpose and policy of the act is "to assure so far as possible every working man and woman in the Nation safe and healthful working conditions and to preserve our human resources."

The Occupational Safety and Health Act is commonly known as OSHA. Prior to its passage, industrial safety was the individual responsibility of each state. The establishment of OSHA added a degree of standardization to industrial safety throughout the nation. OSHA encourages states to assume full responsibility in administration and enforcement of federal occupational safety and health regulations.

Duties of Employers and Employees

Each employer under OSHA has the general duty to furnish employment and places of employment free from recognized hazards causing or likely to cause death or serious physical harm. The employer has the specific duty of complying with safety and health standards as defined under OSHA. Each employee has the duty to comply with safety and health standards and all rules and regulations established by OSHA.

Occupational Safety and Health Standards

Job safety and health standards consist of rules for avoiding hazards that have been proven by research and experience to be harmful to personal safety and health. These rules may apply to all employees, as in the case of fire protection standards. Many standards apply only to workers engaged in specific types of work. A typical standard might state that aisles and passageways shall be kept clear and in good repair, with no obstruction across or in aisles that could create a hazard.

Complaints of Violations

Any employee who believes that a violation of job safety or health standards exists may request an inspection by sending a signed written notice to OSHA. This includes anything that threatens physical harm or represents an imminent danger. A copy must also be provided to the employer; however, the name of the person complaining need not be revealed to the employer.

Enforcement of OSHA Standards

OSHA inspectors may enter a plant or school at any reasonable time and conduct an inspection. They are not permitted to give prior notice of this inspection. They may question any employer, owner, operator, agent, or employee in regard to any safety violation. The employer and a representative of the employees have the right to accompany the inspector during the inspection.

If a violation is discovered, a written citation is issued to the employer. A reasonable time is permitted to correct the condition. The citation must be posted at or near the place of the violation. If after a reasonable time the condition has not been corrected, a fine may be imposed on the employer. If the employer is making an attempt to correct the unsafe condition but has exceeded the time limit, a hearing may be held to determine progress.

Penalties

Wilful or repeated violations may incur monetary penalties. Citations issued for serious violations incur mandatory penalties. A serious violation where extreme danger exists may be penalized for each day of the violation.

OSHA Education and Training Programs

The Occupational Safety and Health Act provides for programs to be conducted by the Department of Labor. These programs provide for education and training of employers and employees in recognizing, avoiding, and preventing unsafe and unhealthful working conditions. The act also provides for training an adequate supply of qualified personnel to carry out OSHA's purpose.

SELF-TEST

1. What is the primary piece of safety equipment in the machine shop?
2. What can you do if you wear prescription eyeglasses?
3. Describe proper dress for the machine shop.
4. What can be done to control grinding dust?
5. What hazards exist from coolants, oils, and solvents?
6. Describe proper lifting procedure.
7. Describe at least two compressed-air hazards.
8. Describe good housekeeping procedures.
9. How should long pieces of material be carried?
10. List at least five points from the safety checklist for a machine tool.

INTERNET REFERENCES

Information on industrial safety and safety equipment:

http://www.osha.gov

http://www.seton.com

UNIT TWO

Mechanical Hardware

Many precision-machined products produced in the machine shop are useless until assembled into a machine, tool, or other mechanism. This assembly requires many types of fasteners and other mechanical hardware. In this unit you will be introduced to many of these important hardware items.

OBJECTIVES

After completing this unit, you should be able to:

- Identify threads and threaded fasteners.
- Identify thread nomenclature on drawings.
- Discuss standard series of threads.
- Identify and describe applications of common mechanical hardware found in the machine shop.

THREADS

The thread is an extremely important mechanical device. It derives its usefulness from the inclined plane, one of the six simple machines. Almost every mechanical device is assembled with threaded fasteners. A *thread* is a helical groove formed on the outside or inside diameter of a cylinder (Figure A-15). These helical grooves take several forms. Furthermore, they have specific and even spacing. One of the fundamental tasks of a machinist is to produce both external and internal threads using several machine tools and hand tools. The majority of threads appear on threaded fasteners. These include many types of bolts, screws, and nuts. However, threads are used for other applications aside from fasteners. These include threads for adjustment purposes, measuring tool applications, and the transmission of power. A close relative to the thread, the helical auger, is used to transport material.

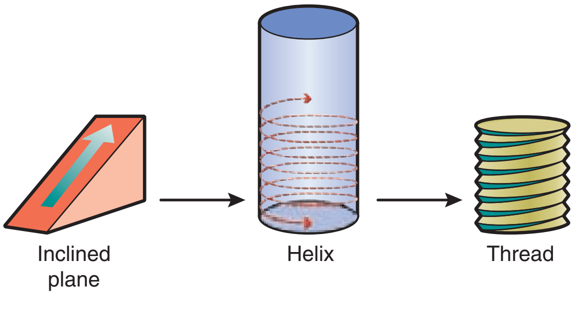


Figure A-15 Thread helix.

THREAD FORMS

There are a number of thread forms. In later units you will examine these in detail, and you will have the opportunity to make several of them on a machine tool. As far as the study of machined hardware is concerned, you will be most concerned with the unified thread form (Figure A-16). The unified thread form is an outgrowth of the American National Standard form. It was developed to help standardize manufacturing in the United States, Canada, and Great Britain. Unified threads, a combination of the American National and the

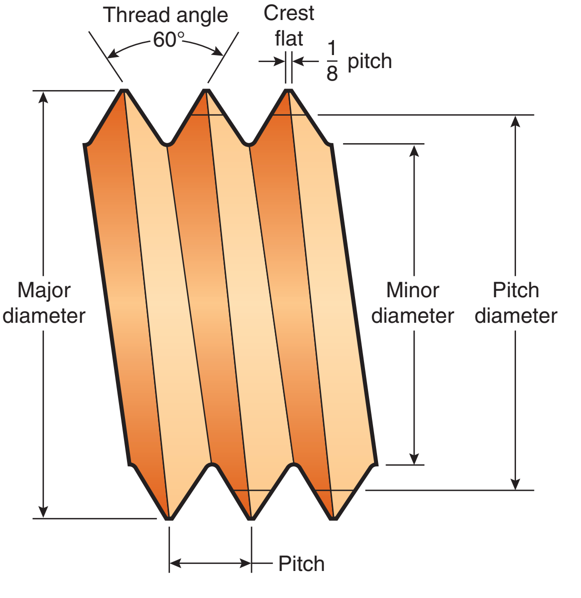


Figure A-16 Unified thread form.

British Standard Whitworth forms, are divided into the following series:

UNC	National Coarse
UNF	National Fine
UNS	National Special

IDENTIFYING THREADED FASTENERS

Unified coarse and *unified fine* refer to the number of threads per inch of length on standard threaded fasteners. A specific diameter of bolt or nut will have a specific number of threads per inch of length. For example, a $\frac{1}{2}$-in.-diameter Unified National Coarse bolt will have 13 threads per inch of length. This bolt will be identified by the following marking:

$$\tfrac{1}{2}\text{ in.}-13\text{ UNC}$$

The $\frac{1}{2}$-in. is the **major diameter**, and 13 is the **number of threads per inch of length.** A $\frac{1}{2}$-in.-diameter Unified National Fine bolt will be identified by the following marking:

$$\tfrac{1}{2}\text{ in.}-20\text{ UNF}$$

The $\frac{1}{2}$-in. is the major diameter and 20 is the number of threads per inch.

The Unified National Special threads are identified in the same manner. A $\frac{1}{2}$-in.-diameter UNS bolt may have 12, 14, or 18 threads per inch. These are less common than the standard UNC and UNF; however, you may see them in machining technology. There are many other series of threads used for different applications. Information and data on these can be found in machinists' handbooks. You might wonder why there need to be a UNC and a UNF series. This has to do with thread applications. For example, an adjusting screw may require a fine thread, while a common bolt may require only a coarse thread.

CLASSES OF THREAD FITS

The preceding information was necessary to understand **thread fit classes**. Some thread applications can tolerate loose threads, while other applications require tight threads. For example, the head of your car's engine is held down by a threaded fastener called a stud bolt, or simply a stud. A stud is threaded on both ends. One end is threaded into the engine block. The other end receives a nut that bears against the cylinder head. When the head is removed, it is desirable to have the stud remain screwed into the engine block. This end requires a tighter thread fit than the end of the stud accepting the nut. If the fit on the nut end is too tight, the stud may unscrew as the nut is removed.

Unified **thread fits** are classified as **1A, 2A, 3A,** or **1B, 2B, 3B.** The **A symbol** indicates an **external** thread. The **B symbol** indicates an **internal** thread. This notation is added to the thread size and number of threads per inch. Let us consider the $\frac{1}{2}$-in.-diameter bolt discussed previously. The complete notation reads

$$\tfrac{1}{2} - 13\text{ UNC 2A}$$

On this particular bolt, the class of fit is 2. The symbol A indicates an external thread. If the notation had read

$$\tfrac{1}{2} - 13\text{ UNC 3B}$$

this would indicate an internal thread with a class 3 fit. This could be a nut or a hole threaded with a tap. Taps are a common tool for producing an internal thread.

Classes 1A and 1B have the greatest manufacturing tolerance. They are used where ease of assembly is desired and a loose thread is acceptable. Class 2 fits are used on the largest percentage of threaded fasteners. Class 3 fits will be tight when assembled. Each class of fit has a specific tolerance on major diameter and pitch diameter. These data may be found in machinists' handbooks and are required for the manufacture of threaded fasteners.

STANDARD SERIES OF THREADED FASTENERS

Threaded fasteners, including all common bolts and nuts, range from quite small machine screws through quite large bolts. Below a diameter of $\frac{1}{4}$-in., threaded fasteners are given a number. Common UNC and UNF series threaded fasteners are listed in Table A-3. Above size 12, the major diameter is expressed in fractional form. Both series continue up to about 4 in.

Table A-3 UNC and UNF Threaded Fasteners

UNC			UNF		
Size	Major Diameter (in.)	Threads/ Inch	Size	Major Diameter (in.)	Threads/ Inch
			0	.059	80
1	.072	64	1	.072	72
2	.085	56	2	.085	64
3	.098	48	3	.098	56
4	.111	40	4	.111	48
5	.124	40	5	.124	44
6	.137	32	6	.137	40
8	.163	32	8	.163	36
10	.189	24	10	.189	32
12	.215	24	12	.215	28
$\frac{1}{4}$ in.	.248	20	$\frac{1}{4}$ in.	.249	28
$\frac{5}{16}$ in.	.311	18	$\frac{5}{16}$ in.	.311	24
$\frac{3}{8}$ in.	.373	16	$\frac{3}{8}$ in.	.373	24
$\frac{7}{16}$ in.	.436	14	$\frac{7}{16}$ in.	.436	20
$\frac{1}{2}$ in.	.498	13	$\frac{1}{2}$ in.	.498	20
$\frac{9}{16}$ in.	.560	12	$\frac{9}{16}$ in.	.561	18
$\frac{5}{8}$ in.	.623	11	$\frac{5}{8}$ in.	.623	18
$\frac{3}{4}$ in.	.748	10	$\frac{3}{4}$ in.	.748	16
$\frac{7}{8}$ in.	.873	9	$\frac{7}{8}$ in.	.873	14
1 in.	.998	8	1 in.	.998	12

All the sizes listed in the table are common fasteners in all types of machines, automobiles, and other mechanisms. Your contact with these common sizes will be so frequent that you will soon begin to recall them from memory.

Metric Threads

With the importation of foreign manufactured hardware in recent years, especially in the automotive and machine tool areas, metric threads have become the prevalent thread type on many kinds of equipment.

The metric thread form is similar to the unified and based on an equilateral triangle. The root may be rounded and the depth somewhat greater. An attempt has been made through international efforts (International Standards Organization, ISO) to standardize metric threads. The ISO metric thread series now has 25 thread sizes with major diameters ranging from 1.6 millimeters (mm) to 100 mm.

Metric thread notations take the following form:

$$\text{M } 10 \times 1.5$$

where M is the major diameter and 1.5 is the thread pitch in millimeters. This thread would have a major diameter of 10 mm and a pitch (or lead) of 1.5 mm. ISO metric thread major diameters and respective pitches are shown in Table A-4.

ISO METRIC THREADS CLASSES OF FIT

Numbers and letters after the pitch number in a thread notation specify the tolerance for both the pitch and the major diameter of external threads and the pitch and the minor diameter of internal threads. The numbers indicate the amount of tolerance allowed; that is, the smaller the number, the smaller the amount of tolerance allowed. The letters indicate the position of the thread tolerance in relation to its basic diameter. Lowercase letters are used for external threads, with the letter e indicating a large allowance, a g a small allowance, and an h no allowance. Conversely, uppercase letters are used for internal threads, with a G used to indicate a small allowance and an H used to indicate no allowance.

The tolerance classes 6H/6g are usually assigned for general-purpose applications. They are comparable to the Unified National 2A/2B classes of fit. The designation 4H5H/4h5h is approximately equal to the Unified National class 3A/3B.

Table A-4 ISO Metric Threads

Diameter (mm)	Pitch (mm)	Diameter (mm)	Pitch (mm)
1.6	.35	20.0	2.5
2.0	.40	24.0	3.0
2.5	.45	30.0	3.5
3.0	.50	36.0	4.0
3.5	.60	42.0	4.5
4.0	.70	48.0	5.0
5.0	.80	56.0	5.5
6.3	1.00	64.0	6.0
8.0	1.25	72.0	6.0
10.0	1.50	80.0	6.0
12.0	1.75	90.0	6.0
14.0	2.00	100.0	6.0
16.0	2.00		

COMMON EXTERNALLY THREADED FASTENERS

Common mechanical hardware includes threaded fasteners such as bolts, screws, nuts, and thread inserts. All these are used in a variety of ways to hold parts and assemblies together. Complex assemblies such as airplanes, ships, or automobiles may have many thousands of fasteners taking many forms.

Bolts and Screws

A general definition of a *bolt* is an externally threaded fastener that is inserted through holes in an assembly. A bolt is tightened with a nut (Figure A-17, right). A *screw* is an externally threaded fastener that is inserted into a threaded hole and tightened or released by turning the head (Figure A-17, left). From these definitions, it is apparent that a bolt can become a screw or vice versa. This depends on the application of the hardware. Bolts and screws are the most common of the threaded fasteners. These fasteners are used to assemble parts quickly, and they make disassembly possible.

The strength of an assembly of parts depends to a large extent on the diameter of the screws or bolts used. In the case of screws, strength depends on the amount of thread engagement. *Thread engagement* is the distance that a screw extends into a threaded hole. The minimum thread engagement should be a distance equal to the diameter of the screw used; preferably, it should be $1\frac{1}{2}$ times the screw diameter. Should an assembly fail, it is better to have the screw break than to have the internal thread stripped from

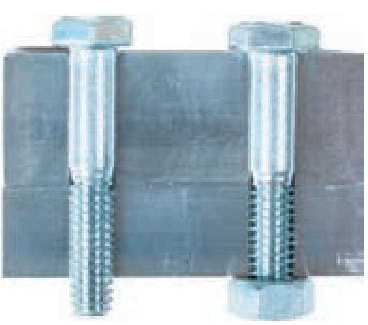


Figure A-17 Screw and bolt with nut.

the hole. It is generally easier to remove a broken screw than to drill and tap for a larger screw size. With a screw engagement of $1\frac{1}{2}$ times its diameter, the screw will usually break rather than strip the thread in the hole.

Machine bolts (Figure A-18) are made with hexagonal or square heads. These bolts are often used in the assembly of parts that do not require a precision bolt. The body diameter of machine bolts is usually slightly larger than the nominal or standard size of the bolt. Body diameter is the diameter of the unthreaded portion of a bolt below the head. A hole that is to accept a common bolt must be slightly larger than the body diameter. When machine bolts are purchased, nuts are frequently included. Common bolts are made with a class 2A unified thread and come in both UNC and UNF series. Hexagonal head machine bolt sizes range from $\frac{1}{4}$ in. diameter to 4 in. A $1\frac{1}{2}$-in. diameter is standard for square head machine bolts.

Stud bolts (Figure A-19) have threads on both ends. Stud bolts are used where one end is semipermanently screwed into a threaded hole. A good example of the use of stud bolts is in an automobile engine. The stud bolts are tightly held in the cylinder block, and easily changed nuts hold the cylinder heads in place. The end of the stud bolt screwed into the tapped hole has a class 3A thread, while the nut end is a class 2A thread.

Carriage bolts (Figure A-20) are used to fasten wood and metal parts together. Carriage bolts have round heads with a square body under the head. The square part of the carriage bolt, when pulled into the wood, keeps the bolt from turning while the nut is being tightened. Carriage bolts are manufactured with class 2A coarse threads.

Figure A-18 Square head bolt and hex head bolt. Square nut and hex nut.

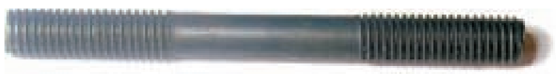


Figure A-19 Stud bolt.

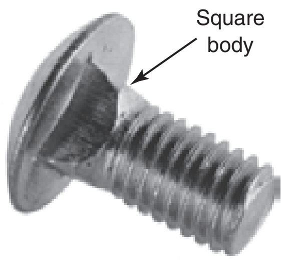


Figure A-20 Carriage bolt.

Machine screws are made with either coarse or fine thread and are used for general assembly work. The heads of most machine screws are slotted to be driven by screwdrivers. Machine screws are available in many sizes and lengths (Figure A-21). Several head styles are also available (Figure A-22). Machine screw sizes fall into two categories. Fraction sizes range from diameters of $\frac{1}{4}$ in. to $\frac{3}{4}$ in. Below $\frac{1}{4}$-in. diameter, screws are identified by numbers from 0 to 12. A No. 0 machine screw has a diameter of .060 in. (60 thousandths of an inch). For each number above zero, add .013 in. to the diameter.

EXAMPLE

Find the diameter of a No. 6 machine screw:

$$\begin{aligned} \text{No. 0 diameter} &= .060 \text{ in.} \\ \text{No. 6 diameter} &= .060 \text{ in.} + (6 \times .013 \text{ in.}) \\ &= .060 \text{ in.} + .078 \text{ in.} \\ &= .138 \text{ in.} \end{aligned}$$

Machine screws 2 in. long or shorter have threads extending all the way to the head. Longer machine screws have a $1\frac{3}{4}$-in. thread length.

Capscrews (Figure A-23) are made with a variety of different head shapes and are used where precision bolts or screws are needed. Capscrews are manufactured with close tolerances and have a finished appearance. Capscrews are made with coarse, fine, or special threads. Capscrews with a 1-in. diameter have a class 3A thread. Those with greater than a 1-in. diameter have a class 2A thread. The strength of screws depends mainly on the kind of material used to make the screw. Different screw materials are aluminium, brass, bronze, low-carbon steel, medium-carbon steel, alloy steel, stainless steel, and titanium. Steel hex head capscrews come in diameters from $\frac{1}{4}$ to 3 in., and their strength is indicated by symbols on the hex head (Figure A-24). Slotted head capscrews can have flat heads, round heads, or fillister heads. Socket head capscrews are also made with socket flat heads and socket button heads.

Figure A-21 Machine screws.

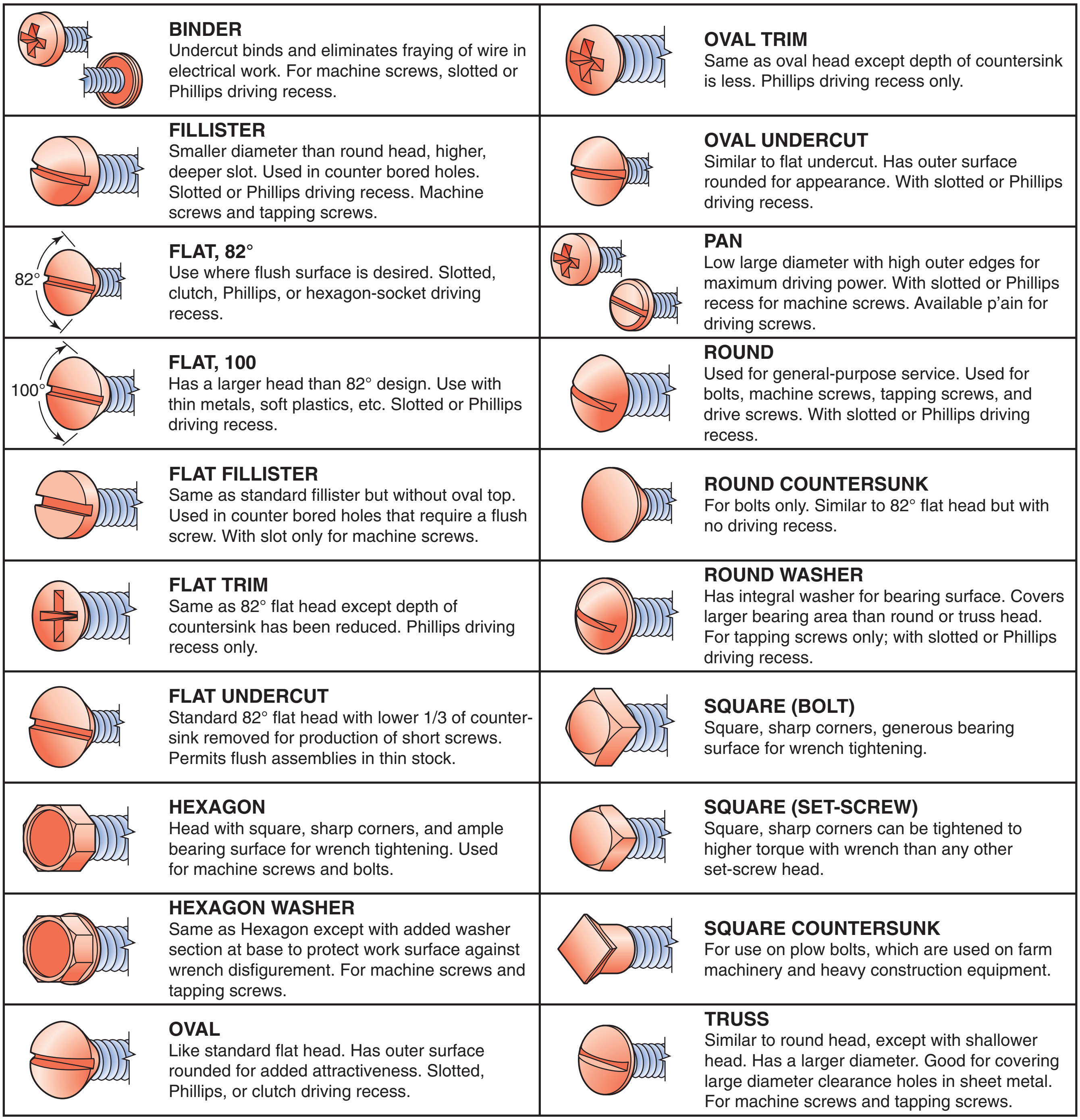


Figure A-22 Machine screw head styles.

Setscrews (Figure A-25) are used to lock pulleys or collars or shafts. Setscrews can have square heads with the head extending above the surface; more often, the setscrews are slotted or have socket heads. Slotted or socket head setscrews usually disappear below the surface of the part to be fastened. A pulley or collar with the setscrews below the surface is much safer for persons working around it. Socket head setscrews may have hex socket heads or spline socket heads. Setscrews are manufactured in number sizes from 0 to 10 and in fractional sizes from $\frac{1}{4}$ to 2 in. Setscrews are usually made from carbon or alloy steel and hardened.

Square head setscrews are often used on toolholders (Figure A-26) or as jackscrews in leveling machine tools (Figure A-27). Setscrews have several different points (Figure A-28). The flat point setscrew will make the least amount of indentation on a shaft and is used where frequent adjustments are made. A flat point setscrew is also used to provide a jam screw action when a second setscrew is tightened on another setscrew to prevent its release through

Figure A-23 Capscrews.

vibration. The oval point setscrew will make a slight indentation as compared with the cone point. With a half dog or full dog point setscrew holding a collar to a shaft, alignment between shaft and collar will be maintained even when the parts are disassembled and reassembled. This is because the shaft is drilled with a hole of the same diameter as the dog point. Cup-pointed setscrews will make a ring-shaped depression in the shaft and will give a slip-resistant connection. Square head setscrews have a class 2A thread and are usually supplied with a coarse thread. Slotted and socket head setscrews have a class 3A UNC or UNF thread.

Bolt head marking	SAE – Society of Automotive Engineers ASTM – American Society for Testing and Materials ASTM Definitions	Material	Minimum tensile strength in pounds per square inch (PSI)
No marks	SAE grade 1 SAE grade 2 Indeterminate quality	Low carbon steel Low carbon steel	65,000 PSI
2 marks	SAE grade 3	Medium carbon steel, cold worked	110,000 PSI
3 marks	SAE grade 5 ASTM – A 325 Common commercial quality	Medium carbon steel, quenched and tempered	120,000 PSI
BB Letters *BB*	ASTM – A 354	Low alloy steel or medium carbon steel, quenched and tempered	105,000 PSI
BC Letters *BC*	ASTM – A 354	Low alloy steel or medium carbon steel, quenched and tempered	125,000 PSI
4 marks	SAE grade 6 Better commercial quality	Medium carbon steel, quenched and tempered	140,000 PSI
5 marks	SAE grade 7	Medium carbon alloy steel, quenched and tempered, roll threaded after heat treatment	133,000 PSI
6 marks	SAE grade 8 ASTM – A 345 Best commercial quality	Medium carbon alloy steel, quenched and tempered	150,000 PSI

Figure A-24 Grade markings for bolts.

Figure A-25 Socket and square head setscrews.

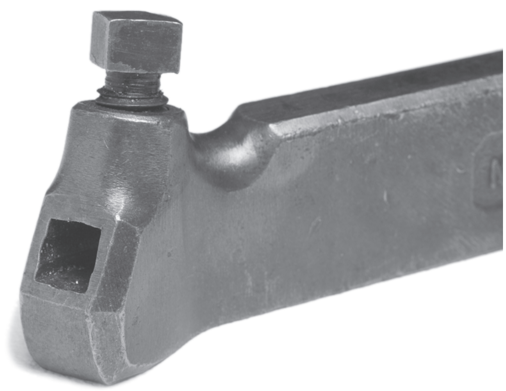


Figure A-26 Square head setscrews are found in toolholders.

Figure A-27 Square head jackscrew.

Figure A-28 Setscrew points.

Thumbscrews and wing screws (Figure A-29) are used where parts are to be fastened or adjusted rapidly without the use of tools.

Figure A-29 Thumbscrew and wing screw.

Thread-forming screws (Figure A-30) form their own threads and eliminate the need for tapping. These screws are used in the assembly of sheet metal parts, plastics, and nonferrous material. Thread-forming screws form threads by displacing material with no cutting action. These screws require an existing hole of the correct size.

Thread-cutting screws (Figure A-31) make threads by cutting and producing chips. Because of the cutting action these screws need less driving torque than thread-forming screws. Applications are similar to those for thread-forming screws. These include fastening sheet metal, aluminium, brass, die castings, and plastics.

Drive screws (Figure A-32) are forced into the correct size hole by hammering or with a press. Drive screws make permanent connections and are often used to fasten name plates or identification plates on machine tools.

COMMON INTERNALLY THREADED FASTENERS

Nuts

Common nuts (Figure A-33) are manufactured in as many sizes as there are bolts. Most nuts are either hex (hexagonal) or square in shape. Nuts are identified by the size of the bolt they fit, not by their outside size. Common hex nuts are made in different thicknesses. A thin hex nut is called a *jam nut*. It is used where space is limited or where the strength of a regular nut is not required. Jam nuts are often used to lock other nuts (Figure A-34). Regular hex nuts are slightly thinner than their size designation. A $\frac{1}{2}$-in. regular hex nut is $\frac{7}{16}$ in. thick. A $\frac{1}{2}$-in. heavy hex nut is $\frac{31}{64}$ in. thick. A $\frac{1}{2}$-in.-high hex nut measures $\frac{11}{16}$ in. thick. Other common nuts include various stop nuts or locknuts. Two common types are the elastic stop nut and the compression stop nut. They are used in applications where the nut might vibrate off the bolt. Wing nuts and thumb nuts are used where quick assembly or disassembly by hand is desired. Other hex nuts are slotted or castle nuts. These nuts have slots cut into them. When the slots are aligned with holes in a bolt, a cotter pin may be used to prevent the nut from turning. Axles and spindles on vehicles have slotted nuts to prevent wheel bearing adjustments from slipping.

Cap or acorn nuts are often used where decorative nuts are needed. These nuts also protect projecting threads from accidental damage. Nuts are made from many different

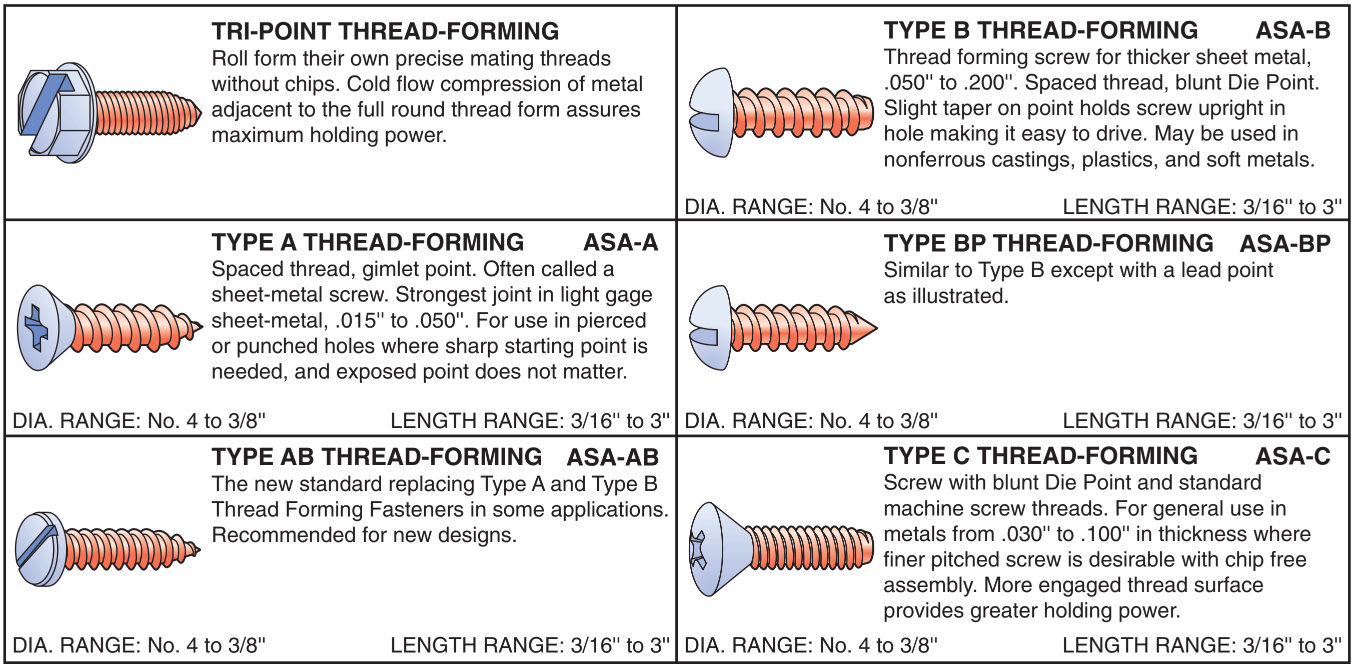


Figure A-30 Self-tapping screws.

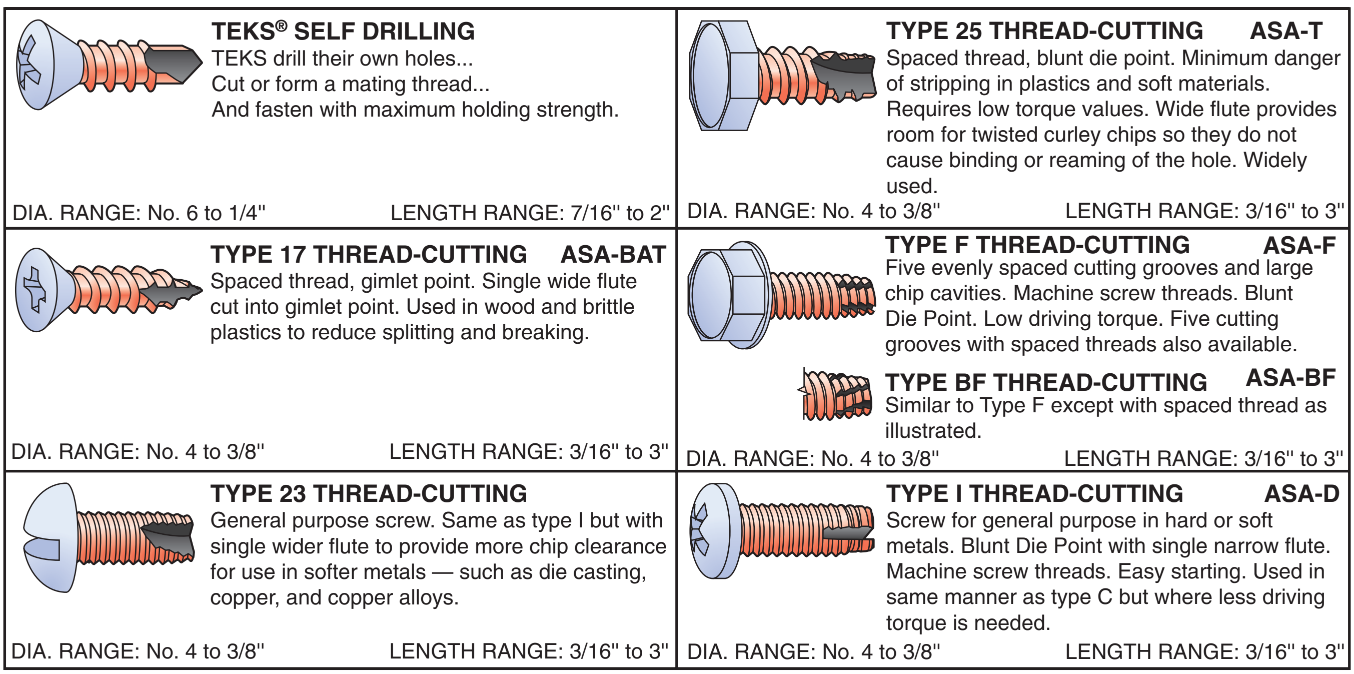


Figure A-31 Thread-cutting screws.

materials, depending on their application and strength requirements.

INTERNAL THREAD INSERTS

Internal thread inserts may be used when an internal thread is damaged or stripped and it is not possible to drill and tap for a larger size. A thread insert retains the original thread size; however, it is necessary to drill and tap a somewhat larger hole to accept the thread insert.

One common type of internal thread insert is the wedge type. The thread insert has both external and internal threads. This type of thread insert is screwed into a hole tapped to the same size as the thread on the outside of the insert. The four wedges are driven in using a special driver (Figure A-35). This holds the insert in place. The internal thread in the insert is the same as the original hole.

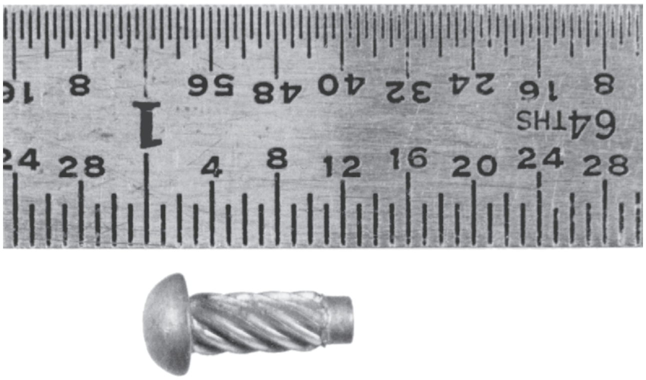


Figure A-32 Drive screw.

Figure A-33 Common nuts.

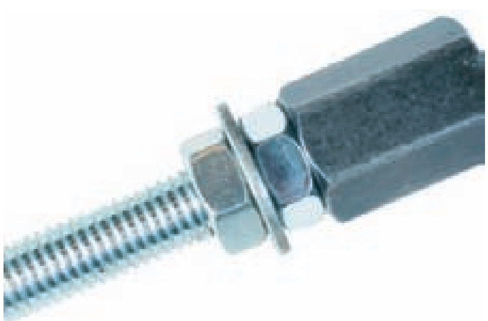


Figure A-34 Jam nuts.

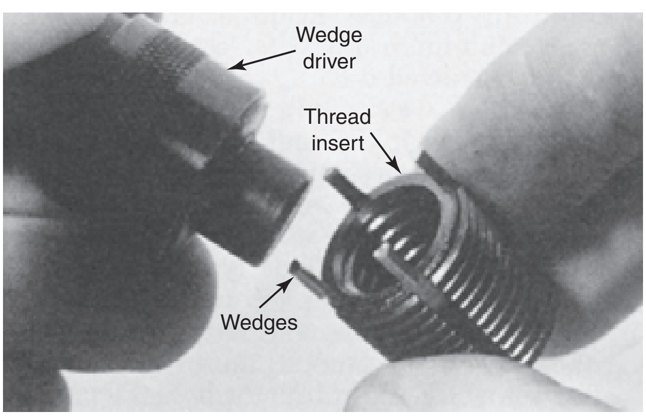


Figure A-35 Wedge-type internal thread insert.

A second type of internal thread insert is also used in repair applications as well as in new installations. Threaded holes are often required in products made from soft metals such as aluminium. If bolts, screws, or studs were to be screwed directly into the softer material, excessive wear could result, especially if the bolt was taken in and out a number of times. To overcome this problem, a thread insert made from a more durable material may be used. Stainless steel inserts are frequently used in aluminium (Figure A-36). This type of thread insert requires an insert tap, an insert driver, and a thread insert (Figure A-37). After the hole for the thread insert is tapped, the insert driver is used to screw the insert into the hole (Figure A-38). The end of the insert coil must be broken off and removed after the insert is screwed into place. The insert in the illustration is used to repair spark plug threads in engine blocks.

Figure A-36 Stainless steel thread insert used in an aluminium valve housing.

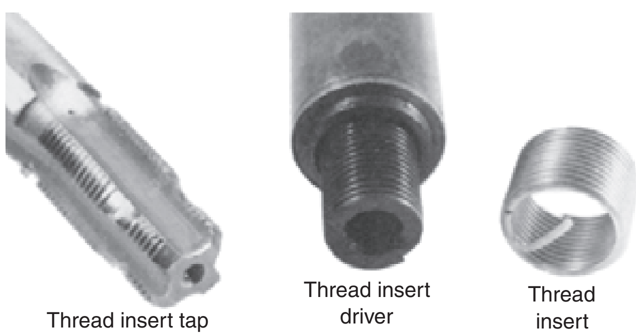


Figure A-37 Thread insert tap, driver, and repair insert for spark plug holes.

Figure A-38 Thread insert driver.

WASHERS, PINS, RETAINING RINGS, AND KEYS

Washers

Flat washers (Figure A-39) are used under nuts and bolt heads to distribute the pressure over a larger area. Washers also prevent the marring of a finished surface when nuts or screws are tightened. Washers can be manufactured from many different materials. The nominal size of a washer is intended to be used with the same nominal-size bolt or screw. Standard series of washers are narrow, regular, and wide. For example, the outside diameter of a $\frac{1}{4}$-in. narrow washer is $\frac{1}{2}$ in., the outside diameter of a $\frac{1}{4}$-in. regular washer is almost $\frac{3}{4}$ in., and the diameter of a wide $\frac{1}{4}$-in. washer measures 1 in.

Lock washers (Figure A-40) are manufactured in many styles. The helical spring lock washer provides hardened bearing surfaces between a nut or bolt head and the components of an assembly. The spring-type construction of this lock washer will hold the tension between a nut and bolt assembly even if a small amount of looseness should develop. Helical spring lock washers are manufactured in series: light, regular, heavy, extra duty, and hi-collar. The hi-collar lock washer has an outside diameter equal to the same nominal-size socket head cap screw. This makes the use of these lock washers in a counterbored bolt hole possible. Counterbored holes have the end enlarged to accept the bolt head. A variety of standard tooth lock washers are produced, the external type providing the greatest amount of friction

Figure A-39 Wide, regular, and thin (or instrument) flat washers.

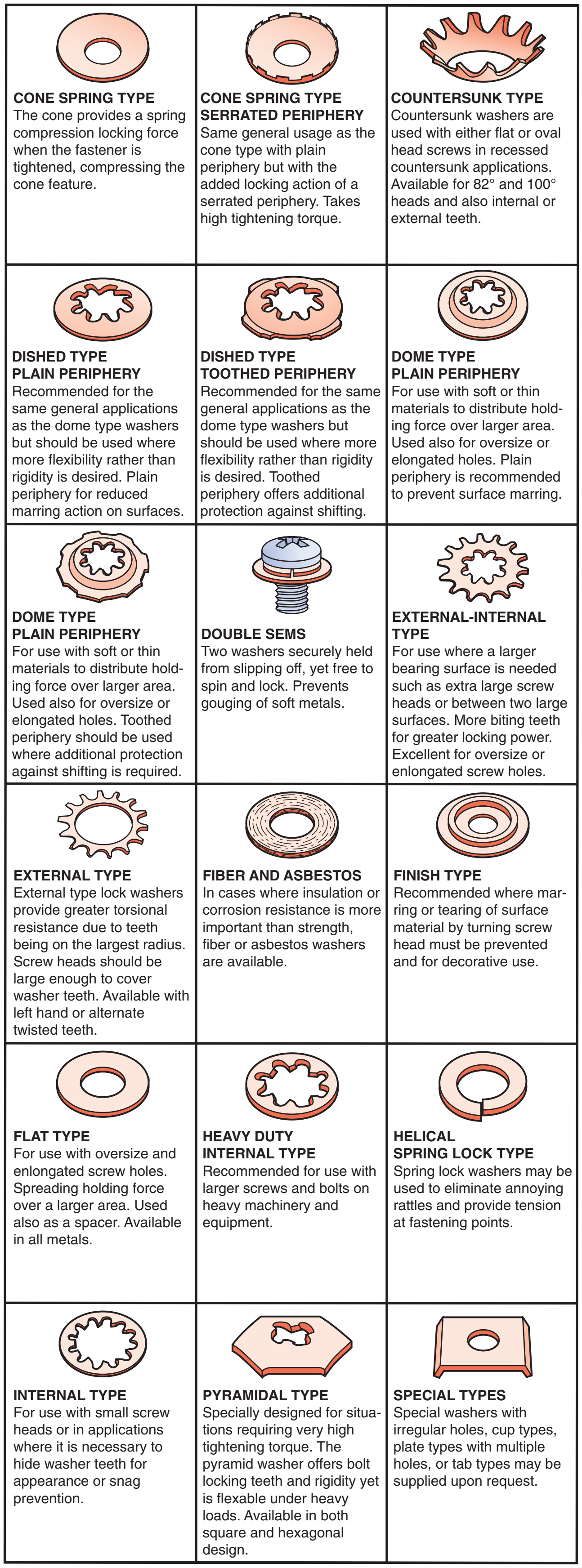


Figure A-40 Lock washers.

or locking effect between fastener and assembly. For use with small head screws and where a smooth appearance is desired, an internal tooth lock washer is used. When large bearing area is desired or where the assembly holes are oversized, an internal–external tooth lock washer is available. A countersunk tooth lock washer is used for a locking action with flat head screws.

Pins

Pins (Figure A-41) find many applications in the assembly of parts. Dowel pins are heat-treated and precision ground. Their diameter varies from the nominal dimension by only plus or minus .0001 in. ($\frac{1}{10000}$ of an inch). **Dowel pins** are used where accurate alignments must be maintained between two or more parts. Holes for dowel pins are reamed to provide a slight press fit. Reaming is a machining process during which a drilled hole is slightly enlarged to provide a smooth finish and accurate diameter. Dowel pins only locate. Clamping pressure is supplied by the screws. Dowel pins may be driven into a blind hole. A blind hole is closed at one end. When this kind of hole is used, provision must be made to let the air that is displaced by the pin escape. This can be done by drilling a small through hole or by grinding a narrow flat the full length of the pin. Always use the correct lubricant when making screw and pin assemblies.

One disadvantage of dowel pins is that they tend to enlarge the hole in an unhardened workpiece if they are driven in and out several times. When parts are intended to be disassembled frequently, **taper pins** will give accurate alignment. Taper pins have a taper (diminishing diameter) of $\frac{1}{4}$ in. per foot of length and are fitted into reamed taper holes. If a taper pin hole wears larger because of frequent disassembly, the hole can be reamed larger to receive the next larger size of taper pin. Diameters of taper pins range in size from $\frac{1}{16}$ in. in. to $\frac{11}{16}$ in. measured at the large end. Taper pins are identified by a number from $\frac{7}{0}$ (small diameter) to number 10 (large diameter) as well as by their length. The large end diameter is constant for a given size pin, but the small diameter changes with the length of the pin. Some taper pins have a threaded portion on the large end. A nut can be threaded on the pin and used to pull the pin from the hole much like a screw jack. This facilitates removal of the pin.

Figure A-41 Pins.

A **grooved pin** is either a cylindrical or a tapered pin with longitudinal grooves pressed into the pin body. This causes the pin to deform. A grooved pin will hold securely in a drilled hole even after repeated removal.

Roll pins can also be used in drilled holes with no reaming required. These pins are manufactured from flat steel bands and rolled into cylindrical shape. Roll pins, because of their spring action, will stay tight in a hole even after repeated disassemblies.

Cotter pins are used to retain parts on a shaft or to lock a nut or bolt as a safety precaution. Cotter pins make a quick assembly and disassembly possible.

Retaining Rings

Retaining rings are fasteners used in many assemblies. Retaining rings can be easily installed in machined grooves, internally in housings, or externally on shafts or pins (Figure A-42). Some types of retaining rings do not require grooves but have a self-locking spring-type action. The most common application of a retaining ring is to provide a shoulder to hold and retain a bearing or other part on an otherwise smooth shaft. They may also be used in a bearing housing (Figure A-43). Special pliers are used to install and remove retaining rings.

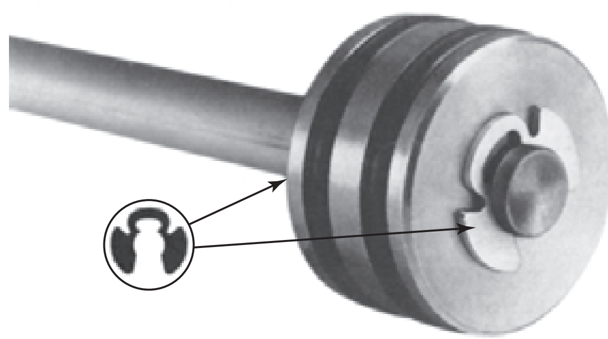


Figure A-42 External retaining ring used on a shaft (*TRUARC Company LLC*).

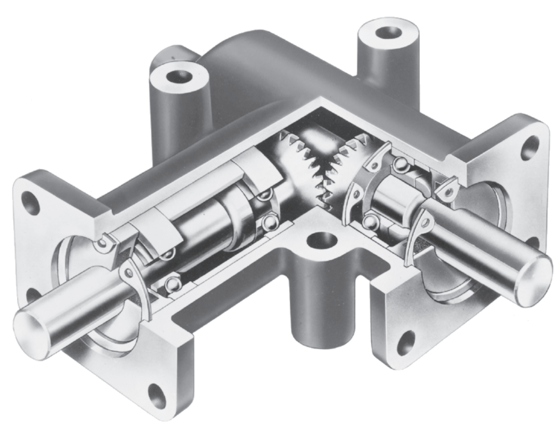


Figure A-43 Internal retaining rings used to retain bearings (*TRUARC Company LLC*).

Keys

Keys (Figure A-44) are used to prevent the rotation of gears or pulleys on a shaft. Keys are fitted into key seats in both the shaft and the external part. Keys should fit the key seats rather snugly. **Square keys,** where the width and the height are equal, are preferred on shaft sizes up to a $6\frac{1}{2}$-in. diameter. Above a $6\frac{1}{2}$-in. diameter, rectangular keys are recommended. **Woodruff keys,** which almost form a half circle, are used where relatively light loads are transmitted. One advantage of Woodruff keys is that they cannot change their axial location on a shaft because they are retained in a pocket. A key fitted into an end-milled pocket will also retain its axial position on the shaft. Most of these keys are held under tension with one or more setscrews threaded through the hub of the pulley or gear. Where extremely heavy shock loads or high torques are encountered, a **taper key** is used. Taper keys have a taper (diminishing diameter) of $\frac{1}{8}$ in. per foot. Wherever a tapered key is used, the key seat in the shaft is parallel to the shaft axis, and a taper to match the key is in the hub. Where only one side of an assembly is accessible, a **gib head taper key** is used instead of a plain taper key. When a gib head taper key is driven into the key seat as far as possible, a gap remains between the gib and the hub of the pulley or gear. The key is removed for disassembly by driving a wedge into the gap to push the key out. A **feathered key** is secured in a key seat with screws. A feathered key is often a part of a sliding gear or sliding pulley.

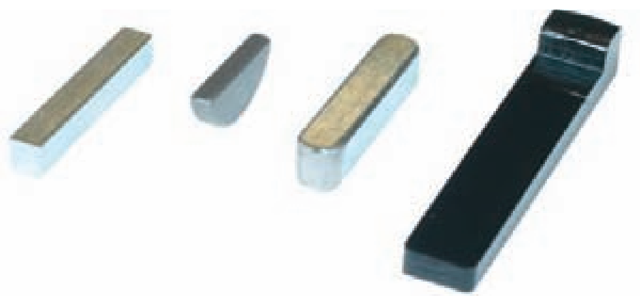


Figure A-44 Keys.

SELF-TEST

1. What is the difference between a bolt and a screw?
2. How much thread engagement is recommended when a screw is used in an assembly?
3. When are class 3 threads used?
4. What is the difference between a machine bolt and a cap screw?
5. What is the outside diameter of a No. 8 machine screw?
6. Where are setscrews used?
7. When are stud bolts used?
8. Explain the difference between thread-forming and thread-cutting screws.
9. Where are castle nuts used?
10. Where are cap nuts used?
11. Explain two reasons why flat washers are used.
12. What is the purpose of a helical spring lock washer?
13. When is an internal–external tooth lock washer used?
14. When are dowel pins used?
15. When are taper pins used?
16. When are roll pins used?
17. What are retaining rings?
18. What is the purpose of a key?
19. When is a Woodruff key used?
20. When is a gib head key used?

INTERNET REFERENCES

Information on mechanical hardware:

http://www.reidsupply.com

http://www.remcobolt.com

UNIT THREE

Reading Drawings

From earliest times, people have communicated their thoughts through drawings. The pictorial representation of an idea is a vital line of communication between the designer and the people who produce the final product. Technological design would be impossible if not for the several different ways an idea may be represented by a drawing. The drawing also provides an important testing phase for an idea. Many times an idea may be rejected at the drawing board or computer-aided design (CAD) terminal stage before a large investment is made to equip a manufacturing facility and risk production of an item that fails to meet design requirements.

OBJECTIVE

After completing this unit, you should be able to:

- Read and interpret common detail drawings found in the machine shop.

This does not mean that all design problems can be solved on the drafting board or CAD terminal. Almost anything can be represented by a drawing, even those designs that would be quite impossible to manufacture. It is important that the designer be aware of the problems that confront the machinist. On the other hand, you must fully understand all the symbols and terminology on the designer's drawing. You must then interpret these terms and symbols to transform the ideas of the designer into useful products.

ISOMETRIC DRAWING

An isometric drawing (Figure A-45) is one method used to represent an object in three dimensions. In the isometric format, the lines of the object remain parallel and the object is drawn about three isometric axes that are 120 degrees apart.

OBLIQUE DRAWING

Object lines in the oblique drawing (Figure A-46) also remain parallel. The oblique differs from the isometric in that one axis of the object is parallel to the plane of the drawing. Isometric and oblique are not generally used as working drawings for the machinist. However, you may occasionally see them in the machine shop.

EXPLODED DRAWINGS

The exploded drawing (Figure A-47) is a type of pictorial drawing designed to show several parts in their proper location prior to assembly. Although the exploded view is not used as the working drawing for the machinist, it has an important place in mechanical technology. Exploded views appear extensively in manuals and handbooks used for repair and assembly of machines and other mechanisms.

ORTHOGRAPHIC DRAWINGS

Orthographic Projection Drawings

In almost every case, the working drawing for the machinist will be in the form of the **three-view** or **orthographic drawing.** The typical orthographic format always shows an object in the three-view combination of side, end, and top (Figure A-48). In some cases, an object can be completely shown by a combination of only two orthographic views. However, any orthographic drawing must have a minimum of two views to show an object completely. The top view may be referred to as the plan view. The front or side views may be referred to as the elevation views. The terms *plan* and *elevation* may appear on some drawings, especially those of large complex parts, assemblies, or architectural plans. The top, front, and right-side views are the most common on typical drawings. Left-side, rear, and bottom views are also seen occasionally, depending on the complexity of the part being illustrated.

Hidden Lines for Part Features Not Visible

Features that are not visible are indicated by dashed lines. These are called hidden lines, as they indicate the locations

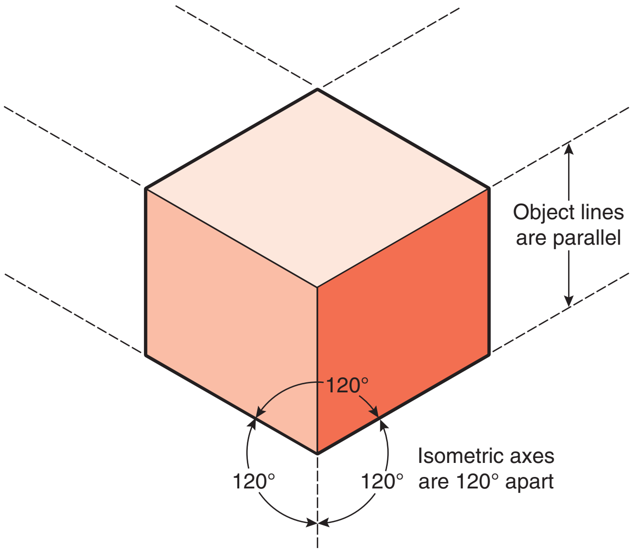


Figure A-45 Isometric drawing.

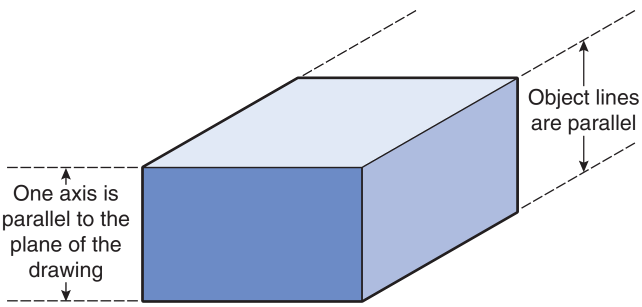


Figure A-46 Oblique drawing.

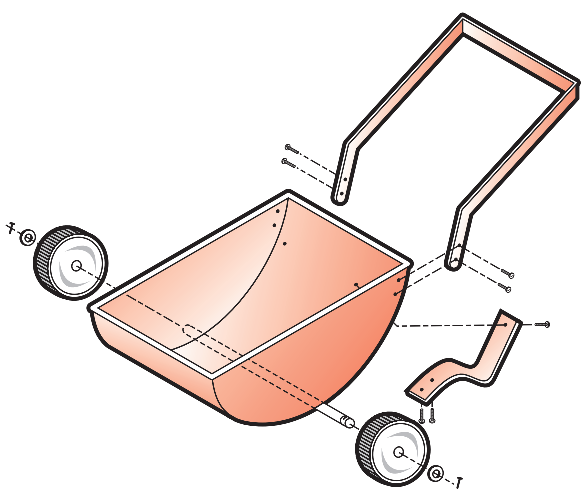


Figure A-47 Exploded drawing.

of part features hidden from view. The plain bearing (Figure A-49) is shown in a typical orthographic drawing. The front view is the only one in which the hole through the bearing, or bore, can be observed. In the side and top views, the bore is not visible. Therefore, it is indicated by dashed or hidden lines. The

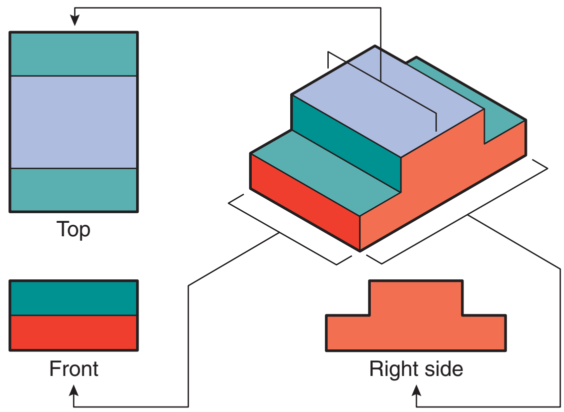


Figure A-48 Standard orthographic drawings.

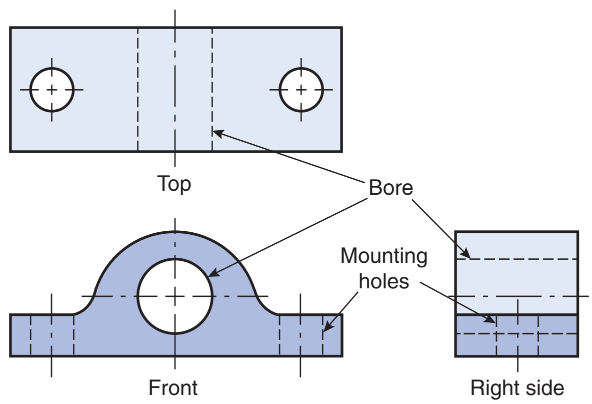


Figure A-49 Hidden lines for part features not visible.

mounting holes through the base are visible only in the top view. They appear as hidden lines in the front and side views.

Sectioned Views

When internal features are complex to the extent that indicating them as hidden lines would be confusing, a sectioned drawing may be employed. Two common styles of sections are used. In the full section (Figure A-50*a*), the object has been cut completely through. In the half section (Figure A-50*b*), one quarter of the object is removed. The section indicator line shows the plane at which the section is taken. For example (Figure A-50*a*), the end view of the object shows the section line marked AA. Section line BB (Figure A-50*b*) indicates the portion removed in the half section. An object may be sectioned at any plane as long as the section plane is indicated on the drawing.

Auxiliary Views

One of the reasons for adopting the orthographic drawing is to represent an object in its true size and shape. This is not possible with the pictorial drawings discussed earlier. Generally, the orthographic drawing meets this requirement. However, the shape of certain objects is such that

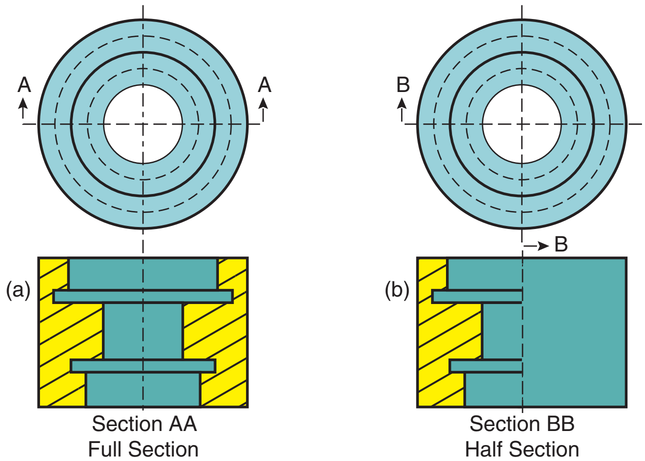


Figure A-50 Sectioned drawings.

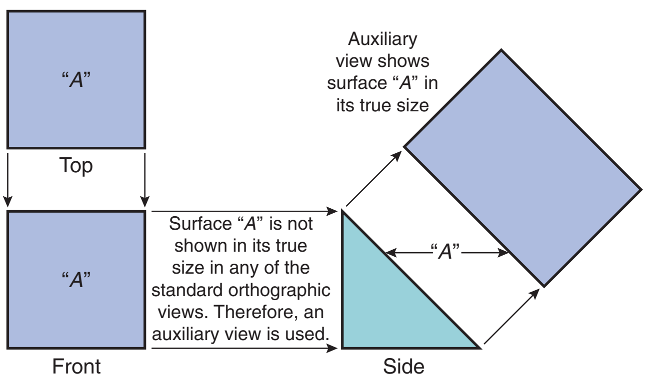


Figure A-51 Auxiliary view.

their actual size and shape are not truly represented. An **auxiliary view** may be required (Figure A-51). On the object shown in the figure, surface A does not appear in its true size in any of the standard orthographic views. Therefore, surface A is projected to the auxiliary view, thus revealing its true size.

READING AND INTERPRETING DRAWINGS

Scale

In some cases, an object may be represented by a drawing the same size as the object. In other cases, an object may be too large to draw full size, or a small part may be better represented by a larger drawing. Therefore, all drawings are drawn to a specific **scale.** For example, when the drawing is the same size as the object, the scale is said to be full, or $1 = 1$. If the drawing is one-half size, the scale is one-half, or $\frac{1}{2} = 1$. A drawing twice actual size would be double scale, or $2 = 1$. The scale used is generally indicated on the drawing.

Dimensioning of Detail and Assembly Drawings

You will primarily come in contact with the **detail drawing.** This is a drawing of an individual part and, in almost all cases, will appear in orthographic form. Depending on the type of work you are doing, you may also see an **assembly drawing.** The assembly drawing is a drawing of subassemblies or several individual parts assembled into a complete unit. For example, a drawing of a complete automobile engine would be an assembly drawing. In addition, a detail drawing of each engine component would also exist.

A detail drawing contains all the essential information you need to make the part. Most important are the **dimensions.** Dimensioning refers generally to the sizes specified for the part and the locations of its features. Furthermore, dimensions reflect many design considerations, such as the fit of mating parts, that will affect the operation characteristics of all machines. Much of the effort you expend performing the various machining operations will be directed toward controlling the dimensions specified on the drawing.

Several styles of dimensioning appear on drawings. The most common of these is the standard **fractional inch** notation (Figure A-52). The outline of the part as well as several holes are dimensioned according to size and location. Generally, the units of the dimensions are not shown. Note that certain dimensions are specified to be within certain ranges. This range is known as **tolerance.**

Tolerance refers to an acceptable range of part size or feature location and is generally expressed in the form of a minimum and maximum limit. The bore (Figure A-52) is shown to be $1.250\ \text{in.} \pm .005\ \text{in.}$ This notation is called a **bilateral tolerance** because the acceptable size range is both above and below the nominal (normal) size of 1.250 in. The bored hole can be any size from 1.245 to 1.255 in. diameter. The thickness of the part is specified as $1.000 + .000$ and $-.002$. This tolerance is **unilateral**, as all the range is on one side of nominal. Thus the thickness could range from .998 to 1.000 in.

No tolerance is specified for the outside dimensions of the part or the locations of the various features. Since these dimensions are indicated in standard fractional form, the tolerance is taken to be plus or minus $\frac{1}{64}$ in. unless otherwise specified on the drawing. This range is known as **standard tolerance** and applies only to dimensions expressed in standard fractional form.

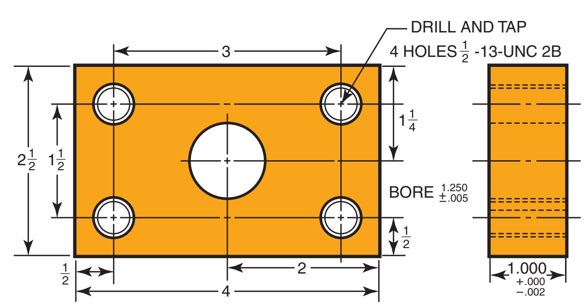


Figure A-52 Fractional inch dimensioning.

Another system of dimensioning used in certain industries is **decimal inch** notation (Figure A-53). In this case, tolerance is determined by the number of places indicated in the following decimal notation:

2 places	.00 tolerance is ± .01
3 places	.000 tolerance is ± .005
4 places	.0000 tolerance is ± .0005

Always remember that standard tolerances apply only when no other tolerance is specified on the drawing.

The **coordinate** or **absolute** system of dimensioning (Figure A-54) may be found in special applications such as numerically controlled machining. In this system, all dimensions are specified from the same zero point. The figure shows the dimensions expressed in decimal form. Standard fraction notation may also be used. Standard tolerances apply unless otherwise specified.

With the increase in metrification in recent years, some industries have adopted a system of dual dimensioning of drawings with both metric and inch notation (Figure A-55). Dual dimensioning has, in some cases, created a degree of confusion for the machinist. Hence, industry is constantly devising improved methods by which to differentiate metric and inch drawing dimensions. You must use caution when reading a dual-dimensioned drawing to ensure that you are conforming your work to the proper system of measurement for your tools. In the figure, metric dimensions appear above the line and inch dimensions appear below the line.

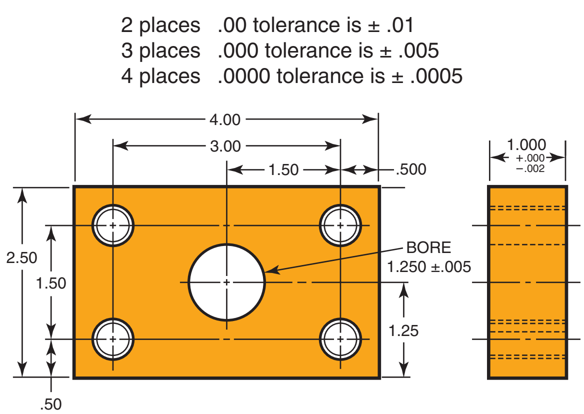


Figure A-53 Decimal inch dimensioning.

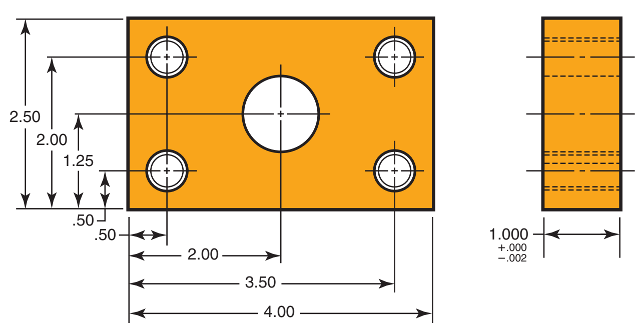


Figure A-54 Coordinate or absolute dimensioning.

Abbreviations for Machine Operations

Working drawings contain several symbols and abbreviations that convey important information to the machinist (Figure A-56). For example, certain machining operations may be abbreviated. **Countersinking** is a machining operation in which the end of a hole is shaped to accept a flat head screw. On a drawing, countersinking may be abbreviated as CS or CSK. The desired angle will also be specified. In **counterboring,** the end of a hole is enlarged in diameter so that a bolt head may be recessed. Counterboring may be abbreviated C'BORE. **Spotfacing** is usually spelled out. This operation is similar to counterboring except that the spotfacing depth is sufficient only to provide a smooth and flat surface around a hole.

Finish Marks

Often, you will perform work on a part already partially shaped. An example of this might be a casting or forging. The **finish mark** (Figure A-57) is used to indicate which surfaces are to be machined. Furthermore, the finish mark may also indicate a required degree of surface finish. For example, a finish mark notation of 4, 32, or 64 refers to a specific surface finish. The numerical data with the surface finish symbol indicates the average height of the surface deviations measured in **microinches** (millionths of inches). A microinch equals one millionth of an inch (.000001 in.).

Other Common Symbols and Abbreviations

External and internal radii are generally indicated by the symbol *R* and the specified size. **Chamfers** may be indicated by size and angle, as shown in Figure A-58.

Threads on drawings are generally represented by symbols (Figure A-58). However, they may occasionally be drawn in detail. Thread notations on drawings include form, size, number of threads per inch or per millimeter, and class of fit. Consider the following example of a thread notation:

$$\tfrac{1}{2} - 13 \text{ UNC 2A}$$

This drawing notation indicates the following information about the thread:

$\frac{1}{2}$	Major thread diameter in inches
13	Number of threads per inch of thread length. This is the number of complete revolutions of the thread helix per inch of thread length. The *pitch* of a thread is defined as the reciprocal of the number of threads per inch, or $1/N$, where N is the number of threads per inch. In this example, the pitch is $\frac{1}{13}$ in. (.0769 in.). This also defines the *lead* of the thread.

UNC Form and series: Unified National form (UN) Coarse series (C)
Fine series is denoted UNF (e.g., $\frac{1}{2}$ − 20 UNF 2A)
2 Class of fit (the dimensional relationship of mating threads; class of fit is 1, 2, or 3)
A External thread (internal thread is denoted by B)

There is a great deal to know about threads. Often, much of the machinist's work will involve cutting various threads using several machine and hand tools. This subject is covered in greater detail in later units. For the present you should just be able to recognize thread notations as they appear on typical machine shop drawings.

A specific bolt circle or pitch circle is often indicated by the abbreviation **D.B.C.** or **B.C.** meaning **diameter of bolt circle.** The size of the diameter is indicated by normal dimensioning or with an abbreviation such as $1\frac{1}{2}$ D.B.C. or $1\frac{1}{2}$ B.C.

DRAWING FORMATS

A designer's idea may at first appear as a freehand sketch in one of the pictorial forms discussed previously. After further discussion and examination, the decision may be made to have a part or an assembly manufactured. This necessitates suitable orthographic drawings that can be supplied to the machine shop. The original drawings produced by the drafting department are not used directly by the machine shop. These original drawings must be carefully preserved, as a great deal of time and money has been invested in them. If sent directly to the machine shop, they would soon be destroyed by constant handling. Therefore, a copy of the original drawing is made.

Several methods are employed to obtain copies of original drawings. One of the most common is **blueprinting.** Any number of drawings may be made and distributed to the various departments of a manufacturing facility. For example, assembly drawings are needed in the assembly area,

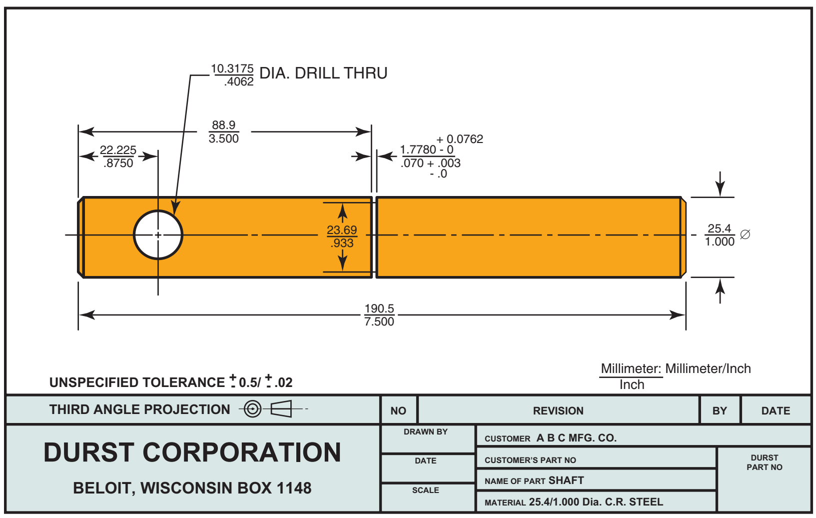


Figure A-55 Dual dimensioning: metric and inch.

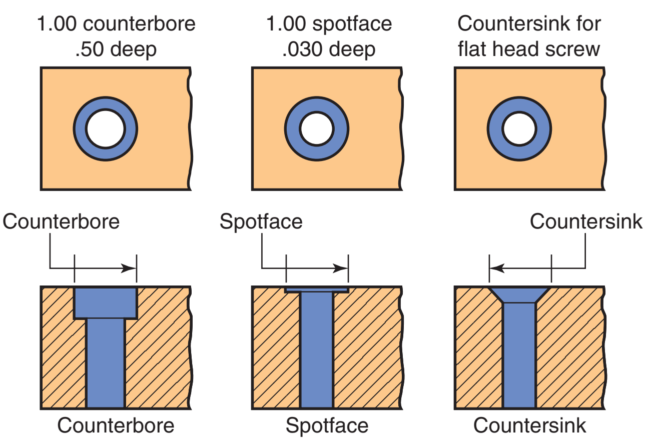


Figure A-56 Countersinking, counterboring, and spotfacing symbols.

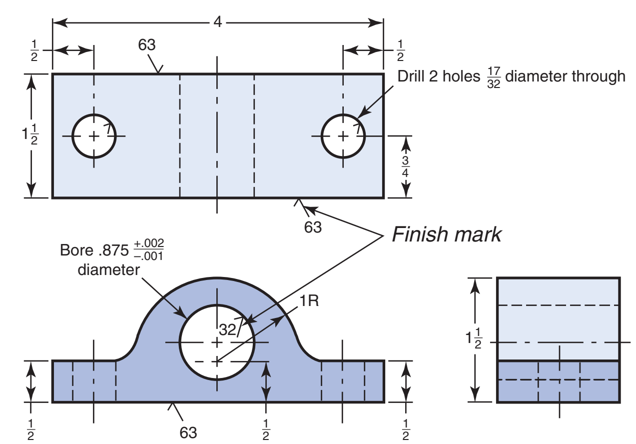


Figure A-57 Finish marks.

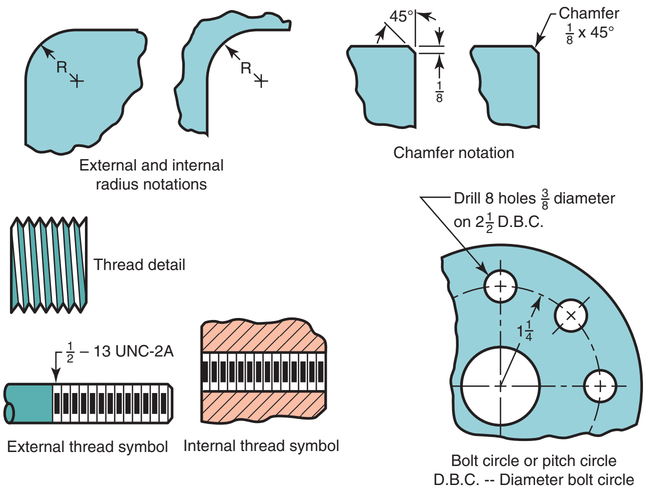


Figure A-58 Other symbols and abbreviations.

whereas drawings of individual parts are required at the machine tool stations and in the inspection department.

The typical detail drawing format (Figure A-59) contains a suitable title block. In many cases, the name of the firm appears in the title block (Figure A-55). The block also contains the name of the part, specified tolerance, scale, and the initials of the draftsperson. A finish mark notation may also appear. The drawing may also contain a change block. Often, designs may be modified after an original drawing is made. Subsequent drawings will reflect any changes. A drawing may also contain one or more general notes. The notes contain important information for the machinist. Therefore, you should always find and read any general notes appearing on a blueprint.

A typical assembly drawing format contains essentially the same information as found on the detail plan (Figure A-60). However, assembly drawings generally show only those dimensions that pertain to the assembly. Dimensions of the individual parts are found on the detail plans. In addition to the normal information, a **bill of materials** appears on the assembly plan. This bill contains the part number, description, size, material, and required quantity of each piece in the assembly. Often, the source of a specific item not manufactured by the assembler will be specified in the bill of materials. An assembly drawing may also include a list of references to detail drawings of the parts in the assembly. Any general notes containing information regarding the assembly will also be included.

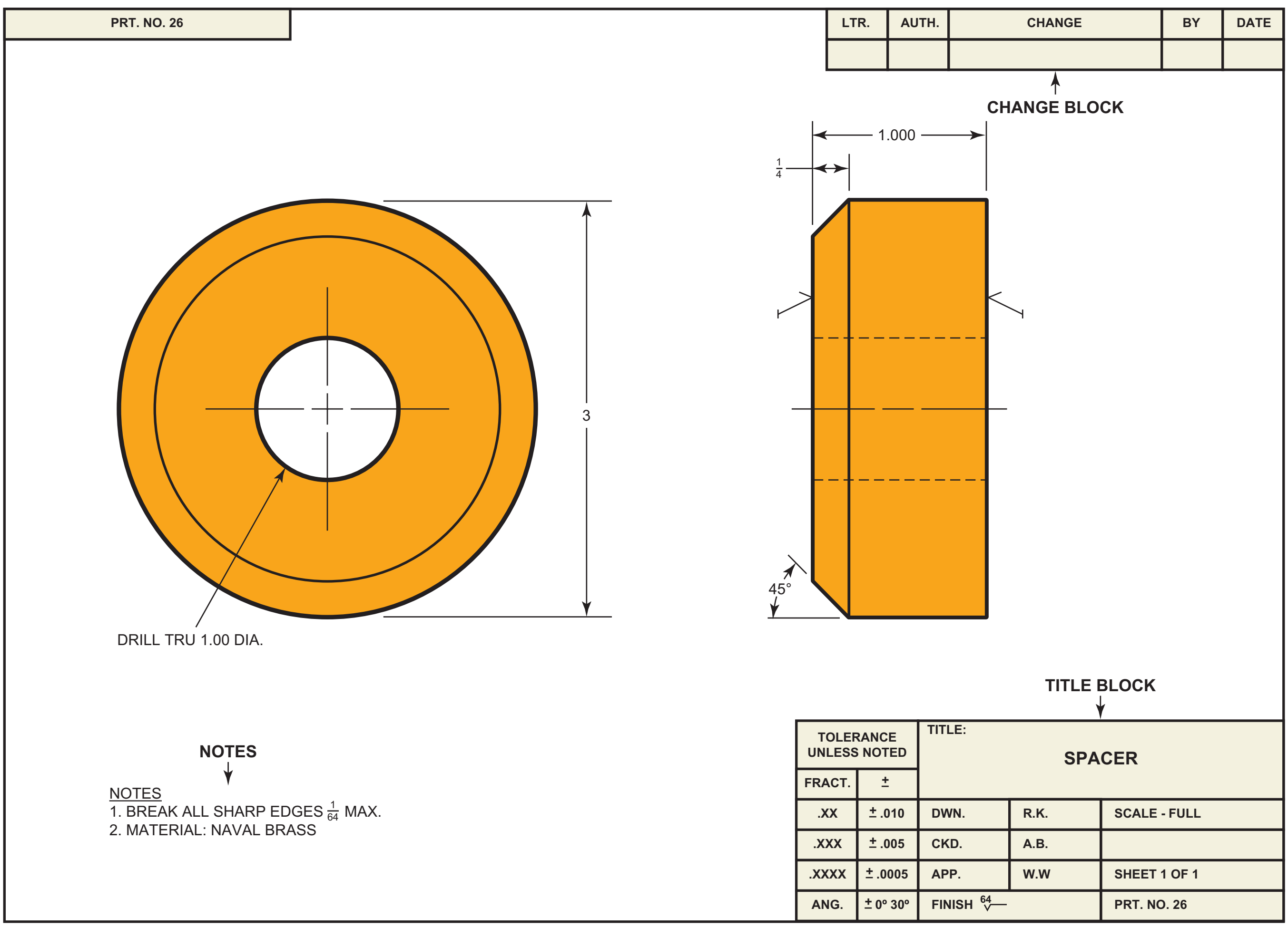
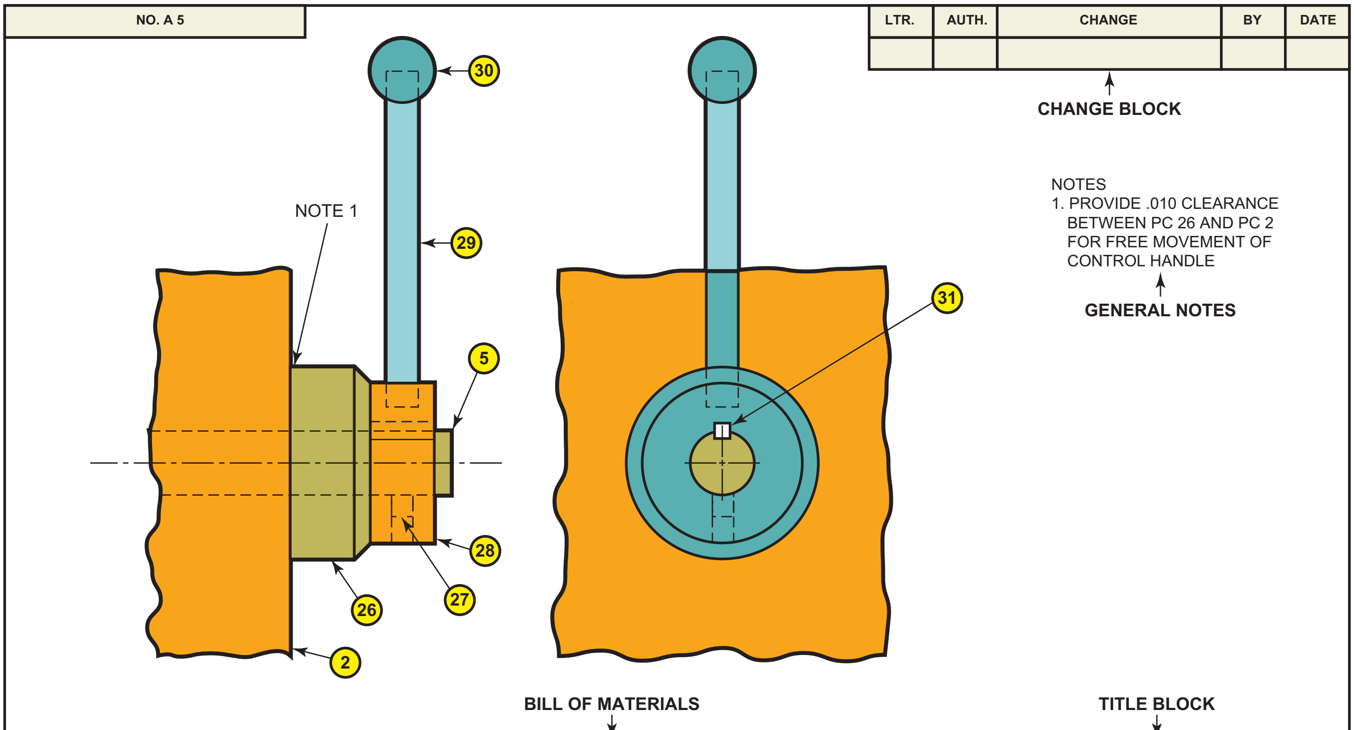


Figure A-59 Detail drawing.



26	SPACER	DET. 26	NAVAL BRASS	1
27	SCREW, SET	$\frac{3}{8}$ 16	STEEL	1
28	HANDLE, HUB	DET. 28	STEEL 1020	1
29	HANDLE	$\frac{1}{2}$ DIA	STEEL 1020	1
30	KNOB	1 DIA	PLASTIC	1
31	KEY	$\frac{1}{4} \times \frac{1}{4} \times 1$	STEEL	1
PC.NO.	DESCRIPTION	SIZE	SIZE	REQ.

TOLERANCE UNLESS NOTED		TITLE: CONTROL HANDLE ASSEMBLY		
FRACT.	$\pm \frac{1}{64}$	DRN.	R.K.	SCALE $\frac{1}{2}" = \frac{3}{4}"$
.XX	±.010	CKD.	A.B.	
.XXX	±.005	APPD.	W.W	
.XXXX	±.0005			SHEET 1 OF 1
ANG.	±0° 30'	FINISH		

Figure A-60 Assembly drawing.

SHOP TIP

When reading any drawings in the machine shop, be sure to:

1. Read any and all notes on the drawing.
2. Be sure that you are using the latest revision of a drawing. Errors can occur by machining parts to older drawing revisions. If you are unsure about the revision, check with your supervisor or instructor.

SELF-TEST

1. Sketch the object in Figure A-61 as it would appear in correct orthographic form.

For problems 2 to 10, refer to Figure A-62.

2. What is the minimum size of the hole through the clevis head?
3. What length of thread is indicated on the drawing?
4. What is the tolerance of the slot in the clevis head?
5. What radius is specified where the shank and clevis head meet?
6. What is the total length of the part?
7. What is the width of the slot in the clevis head?
8. Name two machining operations specified on the drawing.
9. What are the size and angle of the chamfer on the thread end?
10. What does note 1 mean?

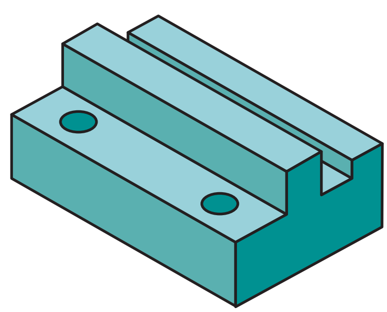


Figure A-61

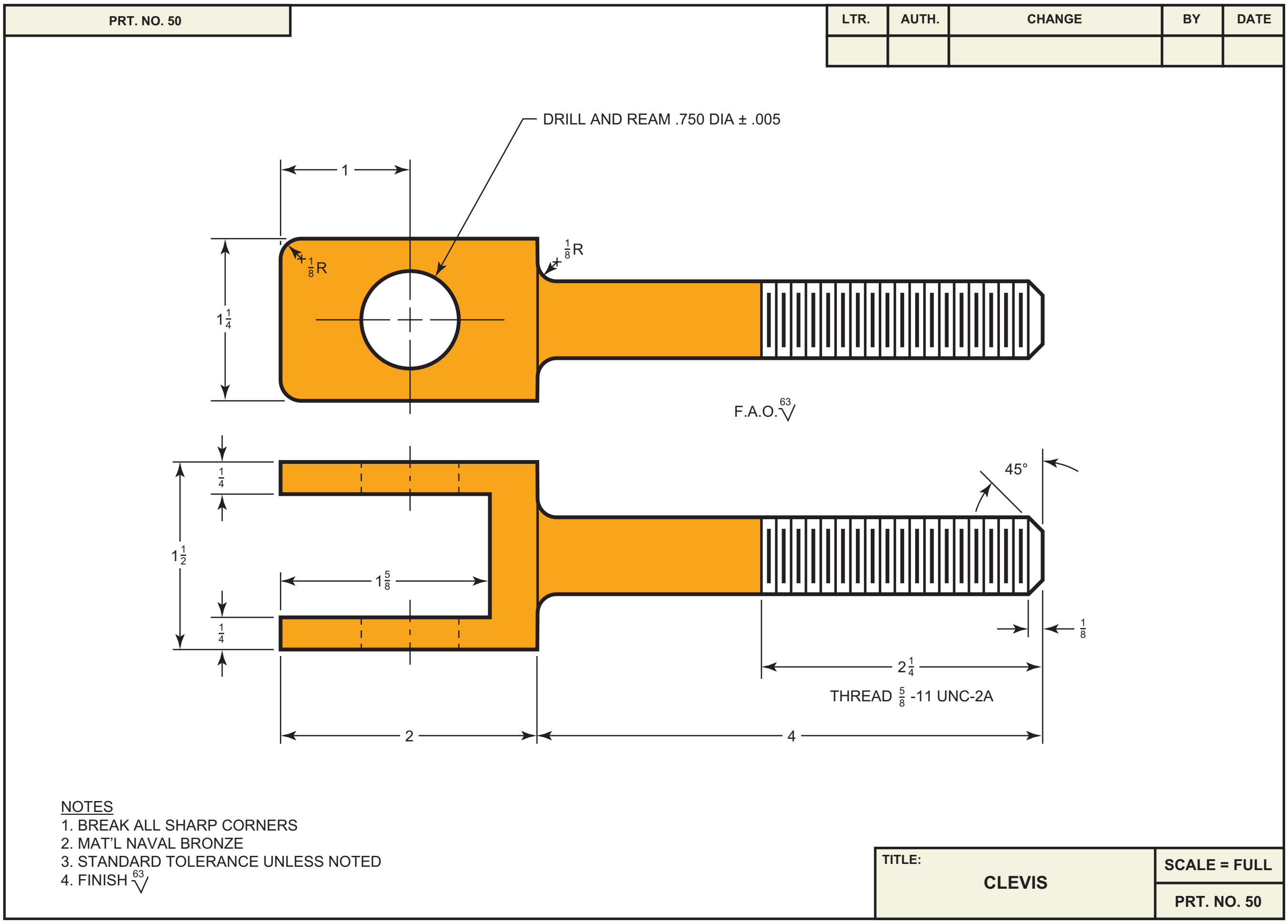


Figure A-62

INTERNET REFERENCES

http://en.wikipedia.org/Wiki/Engineering_drawings

http://design-technology.info