High School
Metals Processes
Packet 1
Ritchie

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4TH QUARTER CURRICULUM PACKET

Hayward Community School District
715-634-2619

#HurricaneStrong

Metals Processes- Home Coursework Packet

Mr. Ritchie, 4th Quarter 2019

Hello!

I'm starting off this distance learning packet with some information about how I'd like you to proceed with your Coursework. I'd prefer to be working in the shop, but this is great knowledge to have!

My first questions of everyone are, **Do you have access to a stable and reliable internet connection?**

Your first assignment is to call me at (715) 651-7188. My office hours are 9 a.m. to 1 p.m. Daily. The purpose of this call is to discuss the options for you to turn in your completed work. I am providing assignments for 6 weeks of lessons even though we are scheduled to be back in school on Monday, April 27th. (At the time this was written.)

This packet coursework is REQUIRED and will be graded on a pass/fail grade scale. You have will have assignments worth 75 points weekly and extra credit activities will be available throughout the course.

Expectations:

- I would like you to work on this course for at least 20-30 minutes every weekday. I often give extra credit to those that choose to go above and beyond.
- I would like you to keep a journal of what you have completed during the week, any questions, comments, etc. The details are listed at the top of the next page.
- I would like you to call, Facetime, Video Chat or otherwise contact me **once a week** after you have completed your assignment. We will schedule a day of the week so that we can be consistent. **My office hours are 9 a.m. to 1 p.m. Daily. Please leave a message if I happen to be on the other line.**

Enrichment Activities

- Enrichment activities and other fun stuff will be posted on Google Classroom. These may be links to videos, tutorials, etc.
- You may spend extra time and effort in developing your skills with an experienced family member. Please follow local and national health recommendations and be safe!

ALWAYS REMEMBER! If you are stuck, have questions, want to learn more, or **need help in any way, I am here for you. Save my number (715) 651-7188 or send an email** **jritchie@hayward.k12.wi.us**

Accountability Journal:
The purpose of this document is for you to write, in at least three well-written sentences, your own daily notes to narrate your progress in this course.

Photo Journal Daily Requirements:
1. At least 3 well-written sentences.
2. Save these reports weekly and turn in with your assignments.

Example:

(Have your photos available to turn in separately)

Day & Date	Journal Entry
Monday 4/13/2020	Today I took time to read pages 5-15 in the text and underlining words I thought were the main ideas. I was able to complete the chapter worksheet for chapter three. I thought the video about steel making was interesting.

Metals Processes
Week 1

PART 1

Introduction

As a three-time winner of the "Teacher of the Year" award, Gerald Mason has a firm hold on the interest, affection, and respect of his students and supervisors. At various times during his 27 years as an Industrial Technology Instructor, Gerald's city, school district, and state have each awarded him that high honor.

It all started for Gerald when he was a boy and used an old dining room table to mount some woodworking machines, a single electric motor, a line shaft, and a set of pulleys. He has been interested in almost anything mechanical ever since. To his basic high school education, he added several vocational courses—welding, machining, and auto mechanics. Then he earned a BS degree in Education and a MA degree in Industrial Education.

Now Gerald, who teaches metalworking in one of the largest school districts in his city, is sharing his interests with his students. In addition to learning the metalworking skills, Gerald and his students study safety precautions, discuss metalworking procedures in industry, do market surveys for metal products, and examine publicity for job openings.

Charles Zilch

Gerald seldom rests, even in the summer. He helps an Industrial Arts Club raise money to buy extra equipment for the classroom. The students have sold 20 can crushers and 40 computer tables that they made on their assembly lines. The money they raised was spent for a computer-controlled typesetter and several other teaching tools.

From Gerald, students learn that metalworking technology is a "good, steady area for future work and an excellent skill for both careers and hobbies."

Gerald Mason
Industrial Technology Instructor

UNIT 1
Careers in Metalworking

Metals are used in thousands of different ways and in thousands of different products and structures. People who work with metals design and make the smallest, largest, fastest, most beneficial, and most unusual things we use. In industries that process metals, and manufacture or service metal products, they work at many different jobs. A knowledge of metalwork can lead to a career in this important, growing industry.

1–1 Learning About Metalwork

Learning to work with metals in an educational setting is the best way to discover how much you like metalwork, Fig. 1–1. Educational courses in metalworking are carefully designed to provide controlled learning experiences. They provide the knowledge and develop the ability needed to work safely with metals, metalworking tools, equipment, and machinery.

The laboratory experiences in your coursework and the information in this textbook will introduce you to a wide range of activities in metalworking.

The metalworking industry is very large and diversified. It offers many exciting careers in the design, manufacture, marketing, and servicing of metal products.

1–2 Factors To Consider in Selecting a Career

It is entirely possible that you will live and work for 30 to 50 years after completing your formal education. Your living, home, pleasures, happiness, and success will depend to a large extent on the satisfaction and amount of income your job provides. Before making a career choice, it is important to know everything you can about the occupation that you plan to make your career. You will want to get answers to the following questions:

1. How much schooling or college education is required?
2. Will the occupation still exist when you finish your education?

Fig. 1-1 Metalworking in the school laboratory may spark your interest in a metalworking career. (Manual High School, Roger Bean)

3. How well does the occupation pay?
4. Is steady employment available?
5. Is the work dangerous?
6. Is there opportunity for advancement?
7. What is the chance of starting your own business?
8. What other opportunities, such as teaching, might be available?

To get answers to these questions, ask your parents, teachers, guidance counselor, and relatives about them. Read all you can about the occupation, beginning with information you will find in this unit. Furthermore, a good source of information concerning all types of careers, including metalworking careers, is the **Occupational Outlook Handbook.** This book is brought up-to-date every two years by the U.S. Department of Labor. It is available in many school or public libraries.

1–3 Classification of Occupations

An **occupation** is the kind of job or work at which a person is employed to earn a living. Occupation means the same as **job** or **vocation.** Many kinds of occupations can become rewarding careers.

Because of space limitations, only the descriptions of the more common metalworking occupations are included in this book. A complete listing is provided in the Dictionary of Occupational Titles. It is also published by the Department of Labor and is available in many libraries.

The amount of education and training required for different metalworking occupations varies widely. The training period may range from several days to five years or longer. For example, a drill press operator may be trained to perform simple drilling operations with a small drill press in several days. On the other hand, four years is generally required for training an engineer or a machinist.

General Classifications

Metalworking occupations are broadly classified by the knowledge, kind of skill, and length of training needed to perform the required work. The following occupational classifications are commonly used:

1. unskilled workers
2. semiskilled workers
3. skilled workers
4. technicians
5. technologists
6. engineers.

These general occupational classifications will be explained in the following sections.

1–4 Unskilled Workers

This classification includes workers who require little or no special training for the tasks they perform. This classification includes laborers who handle and move materials manually, floor sweepers, and others who require little training or application of knowledge. The percentage of unskilled workers in the labor force is decreasing and will probably decrease further in the years ahead.

1–5 Semiskilled Workers

This classification includes workers requiring some special training. The training period for semiskilled jobs may range from several days to as much as one year. Examples of semiskilled metalworking jobs include assembly line workers, machine tool operators, inspectors, maintenance mechanics, and punch press operators.

Machine tool operators are generally included in the semiskilled classification. This group includes drill press operators, lathe operators, milling machine operators, and operators of nearly every kind of specialized production machine tool. Machine tool operators are generally employed to operate one kind of machine tool. As the operators become skilled, they can perform all of the operations that can be performed on one machine.

Because the skill and required training varies, semiskilled workers are further classified for job promotion and pay purposes. It is common practice to classify machine tool operators as **Class A, Class B,** or **Class C** operators. The Class A operator possesses more knowledge, skill, and experience than the Class B or Class C operator.

High school or vocational school metalwork or machine shop classes provide valuable experience not only for securing employment but also for advancing more rapidly as a machine tool operator. This kind of experience is also valuable in securing employment in many other kinds of semiskilled jobs in the metalworking industry.

1–6 Skilled Workers

Workers in this classification include those employed in the skilled trades. A trade is a job that generally requires from two to five years to learn. A person generally learns a skilled trade through a combination of shop instruction, classroom instruction, and on-the-job training. The classroom instruction includes **mathematics, blueprint reading, technical theory, science,** and instruction in any other subject required for the trade.

Examples of skilled trades among the metalworking occupations include the following: machinist, layout worker, tool-and-die maker, instrument maker, boilermaker, welder, sheet metalworker, molder, and heat-treater. Descriptions of these trades, the nature of the work involved, and educational training requirements are explained in Section 1–7.

A **tradesman** (a level of skill identified by trade unions), also called a **craftsman,** must be able to perform all of the tasks that are common in the trade. For example, a **machinist** is a skilled worker who must be able to set up and operate the machine tools used in the trade. The machinist must know shop mathematics, blueprint reading, and the use of precision measuring tools.

Methods of Learning a Trade

Apprenticeship is a highly recommended method for learning a skilled trade. An **apprentice** is someone who is employed to learn a trade, usually in an apprentice training program. See Fig. 1–2. The length of the apprenticeship training period may vary for different trades, anywhere from two to five years. The apprenticeship period for becoming a machinist or tool-and-die maker, for example, is usually four years.

To qualify for apprenticeship training in a skilled metalworking trade, you must generally be a high school graduate or have equivalent trade or vocational school education. You must have better-than-average mechanical ability. High school or vocational school graduates are frequently in demand as apprentices for skilled metalworking trades. However, they must have a good background in science, mathematics, English, drafting, and metalworking.

An apprentice is paid while learning a trade. A graduated pay scale is provided so that earnings increase as experience increases. On completion of the apprenticeship, the apprentice becomes a **journeyman.** A journeyman is a worker who has met minimum qualifications for employment as a skilled tradesman.

Fig. 1-2 An apprentice program often provides "one-on-one" instruction from a journeyman machinist. (Cincinnati Milacron)

A certificate is issued upon completion of the apprenticeship training program. This document is recognized by employers and labor unions throughout the country as qualification for entrance into the trade. The new journeyman must continue studying the tools, processes and procedures in the trade to become more highly skilled and to advance further.

The **pickup method** is a second way to acquire the broad knowledge and experience required for employment as a skilled tradesman. This method involves working in one occupational area until sufficient knowledge and experience are obtained to qualify as a skilled worker.

Workers who choose to learn a skilled trade by the pickup method will find that it usually takes longer than serving an apprenticeship. Frequently they must attend vocational or technical schools to learn blueprint reading, shop mathematics, and technical theory of the trade they are learning.

It is becoming increasingly difficult to learn skilled metalworking trades by the pickup method. The apprenticeship method is recognized as a more efficient method for learning a skilled trade.

1-7 Descriptions of Occupations

The following descriptions of skilled and semiskilled metalworking occupations are arranged in alphabetical order.

Aircraft-and-Engine Mechanic

An aircraft-and-engine mechanic inspects, repairs, and overhauls airplanes. The person must be able to use hand tools, run basic machine tools, and use precision measuring instruments. Some of the work is greasy and dirty, and some work has to be done outdoors.

Aircraft-and-engine mechanics should have a high school education and must attend a technical institute. They will learn engine theory, electricity-electronics, sheet metalwork, welding, and other subjects needed in the trade. It takes two to four years to learn the trade.

To qualify for employment in jobs that require an **FAA** license, an aircraft-and-engine mechanic must pass tests given by the **Federal Aviation Agency.**

The airplane mechanic must guard against gasoline fumes, explosions, and the danger of inhaling poisonous carbon monoxide gas.

Auto Body Repair Mechanic

Auto body repair requires such metalworking skills as spot welding, arc welding, flame cutting, soldering, and riveting. Skillful use of straightening and smoothing tools is also required to be able to restore damaged bodies to like-new condition. Formal training in auto body repair can usually be obtained at vocational schools.

Boilermaker

The boilermaker assembles prefabricated parts made of **iron** and **steel plates** to make boilers, tanks, and machines. A boilermaker can also repair these assemblies. The boilermaker must drill and punch holes, use machines for cutting and bending the plates, drive hot **rivets,** and read **blueprints.**

Boilermakers work at the site where the boiler, tank, or machine is to be assembled. They must be skilled in using tools and equipment for installation and repair. There is the danger of being burned by hot boilers and rivets. It takes about four years as a helper to become a boilermaker.

Coremaker

A coremaker makes **cores** used to form holes or hollow parts in **castings.** Coremaking is described in Unit 32. The coremaker should learn mathematics and also learn how to read blueprints. A person may learn the trade in a foundry during an apprenticeship of about four years. The coremaker's job is closely related to the **molder's** trade.

Diemaker

The diemaker makes metal forms or patterns, called **dies,** that are used in **punch**

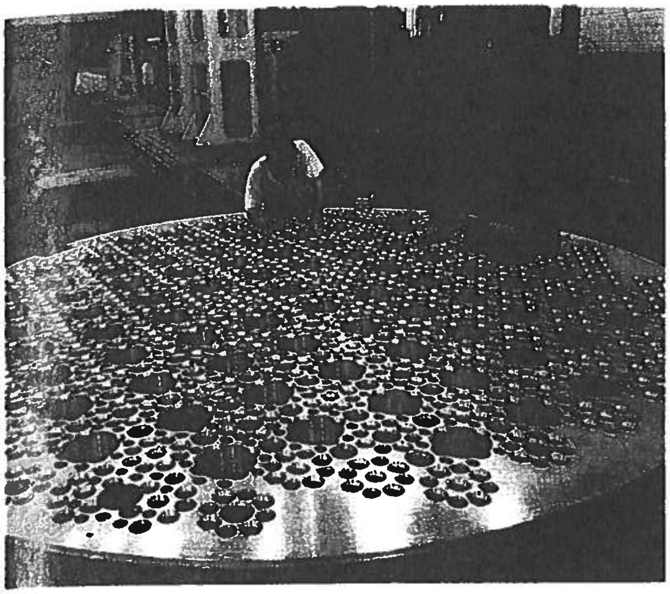


Fig. 1-3 An expert machinist used a precision boring machine to make several hundred holes in this nuclear reactor core. Each hole was located precisely within a few ten-thousandths of an inch. (Litton Industries, Inc.)

presses to stamp out forms in metal. Automobile fenders and other sheet metal parts are made with such dies. Diemakers can set up and run all standard machine tools. They must read blueprints, make **sketches,** use **layout tools,** and measure with **micrometers** (Fig. 1-3).

Diemakers use most of the information in this book. They must have good eyesight to make fine measurements. Diemakers should have at least a high school education. They will learn the trade and progress faster, however, if they are technical school or trade school graduates and are good at mathematics and drafting. It takes four to five years to learn the trade as an apprentice.

A diemaker is seldom without work and is one of the last persons to be laid off. The diemaker's, **diesinker's** and **toolmaker's** trades are closely related.

Diesinker

The diesinker makes **drop forging dies** that are used in **drop hammers** to hammer hot steel into the desired shape.

The diesinker must have good eyesight, read blueprints, make sketches, use layout tools, and measure with micrometers. A diesinker should have the same educational preparation as the diemaker.

Forge Operator

A forge operator runs a **forging press,** on which automobile axles, wrenches, etc. are forged. The forge operator must have a knowledge of iron and steel and must be able to read blueprints. He or she should have at least a high school education and must be strong and healthy. The work is hot, heavy, dirty, and noisy. The danger of being burned by hot metal is always present.

Gagemaker or Instrument Maker

The gagemaker, sometimes called an **instrument maker,** makes and repairs all kinds of gages and is a type of **toolmaker.** To do this a person must be able to set up and run any machine in the shop. Good eyesight is required to make accurate measurements. The gagemaker must read blueprints, make **sketches, lay out** the work, and use most of the information in this book.

The worker will learn the trade much quicker and progress faster as a technical school or trade school graduate. It takes at least four years to learn the trade.

Heat-treater

A heat-treater is one who performs heat-treatment operations on steel and other metals. A knowledge of how to **harden, temper, case-harden, anneal,** and **normalize** metal is required. This work is usually learned by working in the heat-treating department of a factory. A heat-treater should have at least a high school education. The work is hot and there is danger of being burned by hot metal and hot liquids. The heat-treater must sometimes guard against poisonous fumes.

Inspector

An inspector examines materials, parts, or assemblies while they are being made or immediately after they are finished (Fig. 1-4). Inspectors must be expert at reading blueprints and using all kinds of measuring tools and gages. An inspector should have at least a high school education.

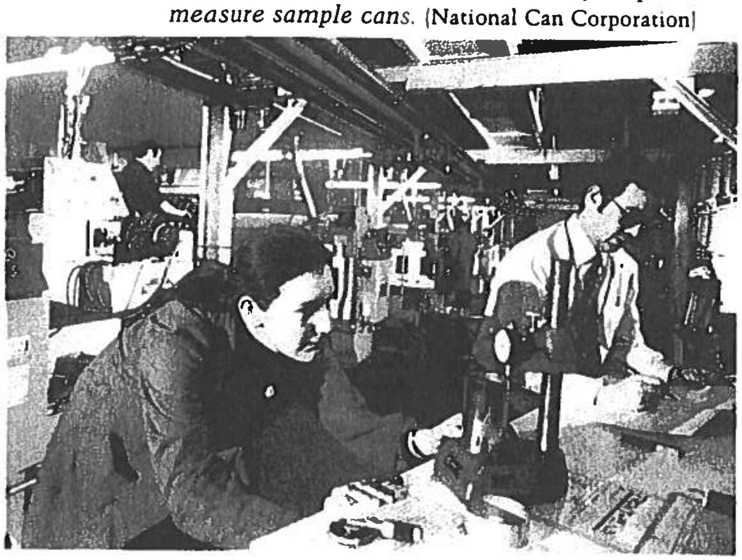
Jeweler

The jeweler makes high-grade jewelry of platinum, gold, and silver. This work requires good eyesight, even though much of it is done while looking through a magnifying glass. The jeweler must know how to run a **jeweler's lathe** and other small hand and machine tools. The jeweler should have a high school or trade school education and learn the trade as an **apprentice.**

Layout Worker

A layout worker reads the dimensions given on blueprints. Then, with fine measuring and marking tools, the layout worker draws lines and marks on the metal surface to show where to cut or form the metal. Knowledge of mathematics, how things are made in the shop, and the properties of various metals is essential.

Fig. 1-4 *At this plant in Spain, cans are manufactured to tolerances as low as 50 millionths of an inch. To control production quality, these technicians continually inspect and measure sample cans.* (National Can Corporation)



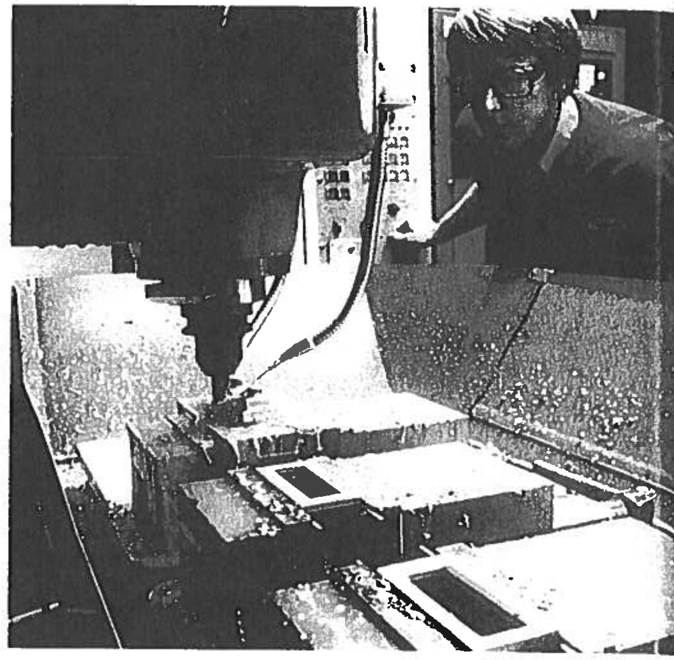


Fig. 1-5 *Computer software is used to give precision control to many machining operations. Some machinists operating these machines may need special knowledge of such programs.* (Hewlett Packard Company)

The layout worker is a diemaker, diesinker, machinist, toolmaker, or sheet metalworker who is chosen to do layout work for the other workers.

Machine Operator

A machine operator earns a living by adjusting and running only one machine, therefore becoming **specialized** in the operation of that machine. If machine operators run **drill presses,** they are **drill press operators;** if they run **lathes,** they are **lathe operators.** There are also **planer operators, milling machine operators** (Figs. 1-5 and 6), and **grinding machine operators.**

A person can learn to run some of these machines in three to six months. However, it may take a year or more to become expert on some of them. A machine operator should have a high school education and should be able to read blueprints and micrometers.

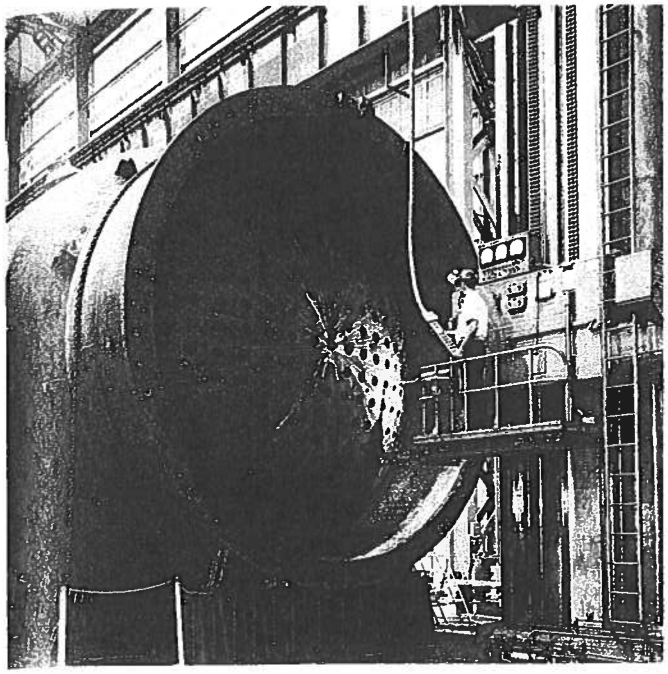


Fig. 1-6 This machine operator is responsible for the precision drilling of holes. (CBI Industries, Inc.)

There is the danger of being cut by sharp tools and sharp metals. Some of the work is greasy and dirty. This job is related to the machinist's, described below.

Machine Setup Workers

The machine setup worker specializes in getting machine tools ready for operation, and instructs machine operators in their use. He or she keeps an eye on the machines run by the machine operators, and keeps them adjusted. The machine setup worker may be a fully qualified machinist or may have learned how to set up these machines while employed as a machine operator. An ability to read blueprints and to use all kinds of measuring tools and gages is required.

Machinist

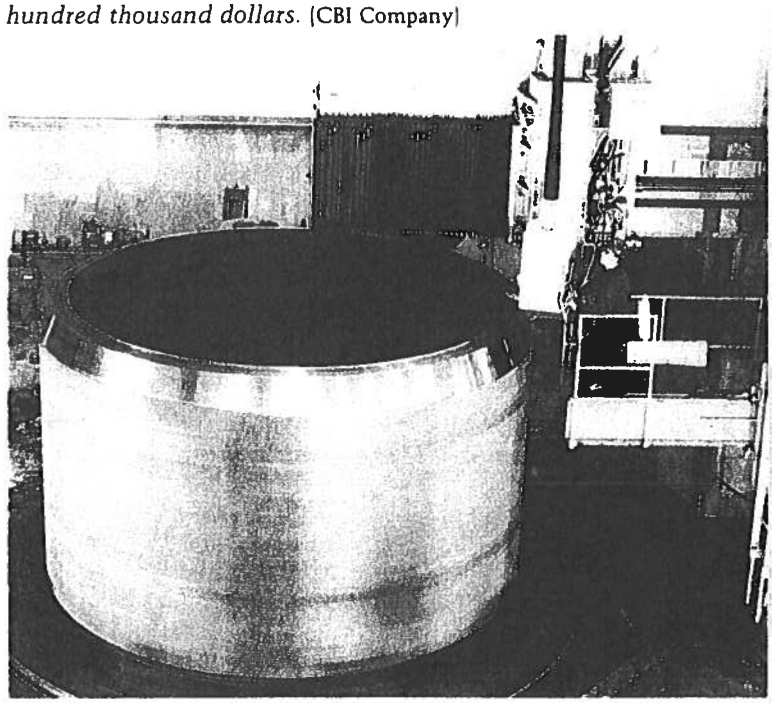
Machinists make precision metal parts, and repair and construct machine tools. They can set up and run standard machine tools (Fig. 1-7), read blueprints, make sketches, use layout tools, and measure with micrometers. A machinist uses most of the information given in this book.

Good eyesight is essential, because the machinist must make fine measurements. A machinist must also have superior judgment of **depth** and **distance,** and also have good **coordination.** A high school education is preferred. The trade will be learned quicker and progress made faster if the machinist is a technical school or trade school graduate. It takes four years to learn the trade as an apprentice. There is the danger of being cut by sharp tools and metal, and some of the work is greasy and dirty.

Maintenance Mechanic

A maintenance mechanic is skilled in working with machines and in shaping and joining materials by using tools and instruments. **Preventive maintenance** is a major part of the job. Maintenance mechanics inspect equipment, oil and grease machines, and clean and repair parts, thus **preventing** breakdowns or work delays.

Fig 1-7 This machinist is turning a part for a liquid storage tank. The numerically controlled machine required an investment of several hundred thousand dollars. (CBI Company)



Metal Patternmaker

The metal patternmaker is a machinist who makes the **metal patterns** that are used to make molds in the **foundry.** These patterns are prepared from metal stock or from rough **castings.**

It takes about four years to learn the trade as an apprentice. The work is interesting and usually steady.

Metal Spinner

A metal spinner forms bowls, cups, trays, saucers, vases, pitchers, and other circular shapes by pressing flat pieces of sheet metal over forms that turn on the **lathe. Metal spinning** is explained in Unit 31. The metal spinner must have manipulative skill, be able to read drawings, and should have a high school education. There is danger of being cut by sharp tools and metals.

Millwright

A millwright moves and installs heavy machines and equipment in shops, and constructs any special foundation for them. The millwright must read blueprints and **lubricate, dismantle,** or **repair** the machinery installed. A person should have at least a high school education, and may learn the trade as an apprentice.

Molder

The molder makes **molds** of various materials for making metal castings. The molder should have a high school education and know how to read blueprints. It takes about four years to learn the trade as an apprentice.

The work may be hot, dusty, and dirty. There is the danger of being burned by hot metal and sparks. The molder's and **coremaker's** trades are closely related.

Plumber

The plumber installs and repairs sewer and drain pipes, water pipes, gas pipes, meters, sinks, bathtubs, showers, faucets, tanks, and similar equipment.

Plumbers should have a high school or trade school education, must learn mathematics, read blueprints, and know something about building construction in general. The work is often dirty and disagreeable. It takes five years to learn the trade as an apprentice. To obtain a license, an apprentice must pass a state examination. The plumber's, **pipefitter's,** and **steamfitter's** trades are closely related.

Polisher and Buffer

A polisher and buffer uses abrasive belts, discs, or wheels to smooth metal, and buffing wheels to polish metal. The work is usually learned on the job. It is dusty and dirty work.

Sales Representative for Machines, Tools, or Materials

A person selling machines must often know how to demonstrate their use, and must be able to answer any questions about them. It is also necessary to know how they are made.

A sales representative for machines or tools has often worked at a trade such as **diemaker, diesinker, machinist,** or **toolmaker** and often is a college graduate. Sales personnel must also know something about advertising, how to show or display goods, and how to write contracts for the things they sell. They must have a knowledge of the goods made by their company's competitors to compare these goods with those they are trying to sell. There are courses in **salesmanship** that can be studied. The salesperson must be neat and pleasant, must speak good English, and must know when to talk and when to be silent. Some sales personnel travel over a large territory, and are away from home for long periods.

Sheet Metalworker

A sheet metalworker makes and repairs such things as furnace ducts, furnaces, ventilators, signs, eave troughs, metal roofs, metal furniture and lockers, and automobile and airplane bodies, which are made out of **sheet metal.** Work may be done in a factory, on buildings, or on ships.

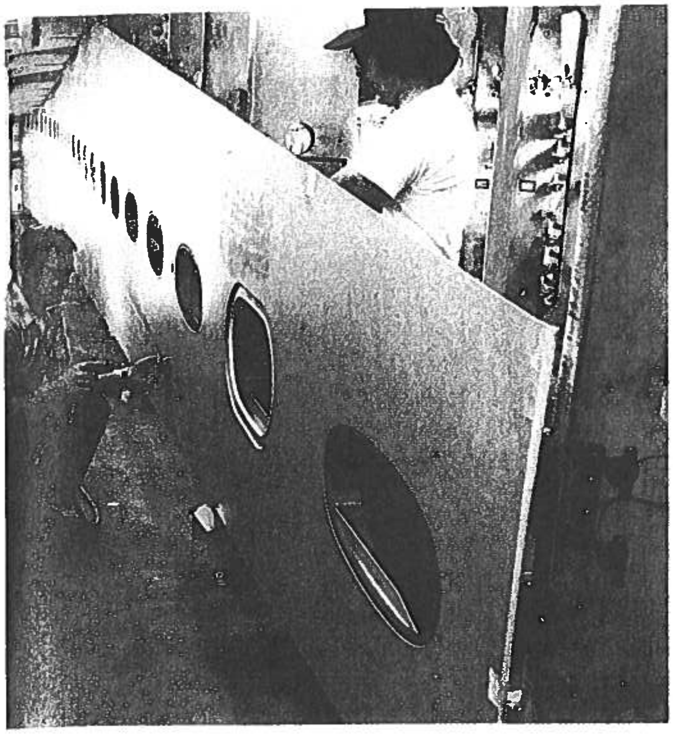


Fig. 1-8 Many sheet metal workers are needed to build aircraft bodies. While the techniques are specialized, aircraft sheet metalworkers use the basic principles of assembling and fastening sheet metal. (Boeing)

Sheet metalworkers must know how to **rivet, solder,** and read blueprints. They should have a high school or trade school education, know **geometry, drafting,** and how to make **patterns.** This trade takes three to four years to learn.

Spring and fall are the busy seasons for outdoor work. Factory work is more steady. The work is noisy at times, and there is the danger of falling from high places and of being cut by sharp edges of metal. The sheet metalworker must also guard against **lead poisoning,** caused by solder made of **lead** and **tin.** The sheet metalworker's and **tinsmith's** trades are closely related (Fig. 1-8).

Structural Steelworker

You have seen the great steel frames that form the skeletons of large buildings or skyscrapers. Fastening the many steel beams and frames together is called **structural steelwork** (Fig. 1-9). You may have seen a structural steelworker stand on a steel beam and swing high in the air. The structural steelworker also builds bridges and ships on which the big parts are **welded** or **riveted** together. Blueprints must be read, and it is necessary to be a careful and strong outdoor worker and a good climber. There is the danger of falling from high places.

Toolmaker

The toolmaker makes and repairs all kinds of special tools, cutting tools, **jigs,** and **gages.** Because these are measured with fine instruments, the toolmaker's eyesight must be good. The toolmaker can set up and run all standard machine tools. He or she must read blueprints, make sketches, use layout tools, and measure with micrometers. The toolmaker uses most of the information in this book.

Toolmakers should have at least a high school education, but they will progress faster if they are technical school or trade school graduates. Knowledge of mathematics and drafting is necessary. It takes four to five years to learn the trade as an apprentice.

There is the danger of being cut by sharp tools and metals. The toolmaker's, **diemaker's, diesinker's,** and **gagemaker's** trades are closely related.

Fig. 1-9 Structural steel workers assemble girders and beams used in commercial and industrial buildings. They join the structural shapes with welds, rivets, or bolts.

Tool Programmer, Numerical Control

A tool programmer analyzes and schedules the operations involved in machining metal parts on **numerically controlled** machine tools. Numerically controlled machine tools process parts automatically, with little effort or control on the part of the machine tool operator (Fig. 1-10).

The tool programmer reads and interprets the blueprint of a part to be machined. Then, the programmer analyzes and lists on a **program sheet** in proper sequence, the machine operations involved in machining the part.

The programmer must indicate (1) the kinds of operations to be performed, (2) the tools to be selected and used, (3) the correct cutting speeds and feeds, and (4) when cutting fluids are to be used. Hence, a tool programmer must have a good knowledge of mathematics, blueprint reading, and machine shop operations. With large, complex, multipurpose machine tools, a knowledge of a **computer-assisted programming language** is necessary.

Welder

The welder joins metal parts by melting the parts together with the use of the **oxyacetylene welding process,** the **electric-arc welding process,** or with other welding processes (Fig. 1-11). A highly skilled welder knows how to use a number of different welding processes, and is able to weld many different metals.

The welder should know about different metals and how to read blueprints. A beginner can learn to do simple welding jobs in a few hours. However, becoming skilled in welding with several different processes may take from six months to several years. There is danger of being burned by the torch or hot metal. Welders must be **licensed** in many states.

The welder is very important in industry today and will continue so in the future.

1-8 Technicians

Technician occupations are among the fastest growing in the United States. Technicians are workers whose jobs often require the application of scientific and mathematical principles. They usually work directly under scientists, engineers, or industrial managers. Industry needs several technicians for every professional engineer (Fig. 1-12).

In general, the educational requirements for technicians include high school graduation and two years of post-high school training. This kind of technical training is available in many types of schools, including technical institutes, junior colleges, community colleges, area technical schools, armed forces schools, and extension divisions of colleges and universities.

Technician occupations generally require technical education and training that ranks between the requirements of the skilled tradesman and those of the technologist. Technicians usually possess more knowledge of drafting, mathematics, science, and technical writing than a skilled craftsman. However, they are not expected to know as much about these subjects as technologists or engineers.

Fig. 1-10 *This numerically controlled laser measuring machine is being checked by an experienced technician.* (Hewlett Packard Company)

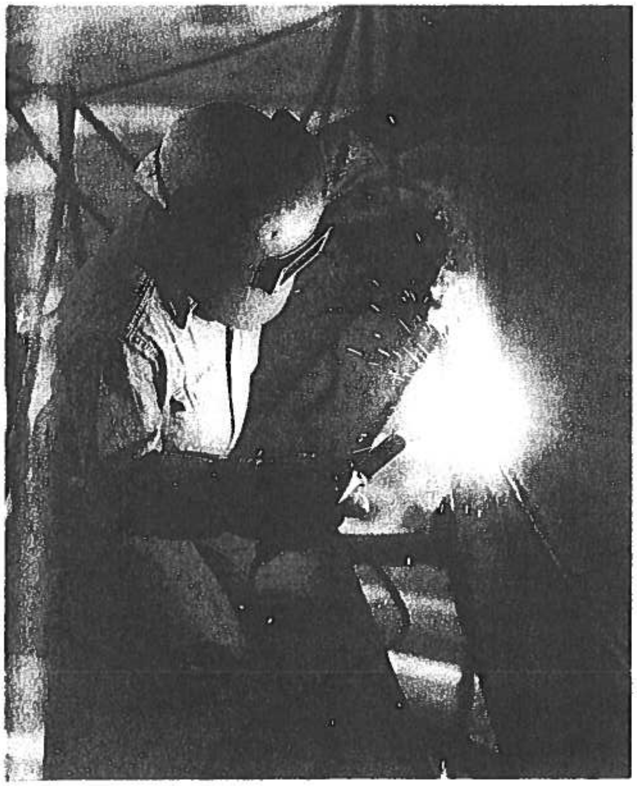


Fig. 1-11 This welder is arc welding a tank to be used for liquid storage. (CBI Company)

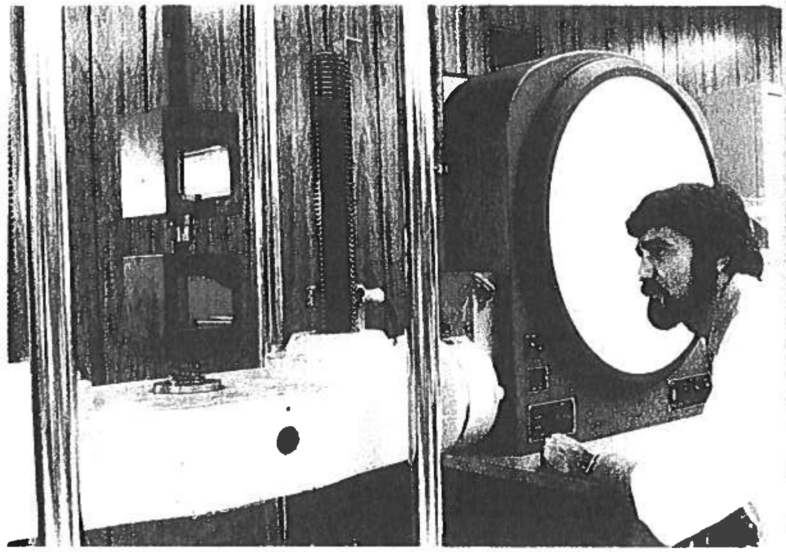


***Fig. 1-12** Using a standard tensile test machine, this technician subjects an aircraft engine bolt to a force of 600,000 pounds.* (Fairchild Industries)

Technicians usually train in only one area of technology, such as the following: mechanical technology, tool technology, industrial or manufacturing technology, aeronautical technology, automotive technology, civil engineering technology, metallurgical technology, instrumentation technology, and safety technology. Technicians usually are not required to perform as skilled craft workers; however, a knowledge of skilled trade practices and procedures is often required. The following descriptions are for technicians in metalworking industries.

Aeronautical Technicians

Technicians in this area assist engineers and scientists with problems involving the design, production, and testing of aircraft, rockets, helicopters, missiles, and spacecraft. They aid engineers by preparing layouts of structures, collecting information and making calculations, checking drawings, and performing many other duties.

Industrial Technicians

Industrial technicians are also called **manufacturing technicians** or **production technicians.** Industrial technicians assist industrial engineers, manufacturing engineers, and tool engineers in a wide variety of problems. They are particularly important in **metals manufacturing industries.**

They assist engineers with problems concerning the efficient use of employees, materials, and machines in the production of goods and services. These problems may involve plant layout, development and installation of special production machinery, planning the flow of raw materials or parts, developing materials-handling procedures, and controlling inventories. Industrial technicians are also concerned with time-and-motion studies, analysis of production procedures and costs, quality control of finished products, and packaging methods.

Instrumentation Technician

The instrumentation technician assists engineers in designing, developing, and making many different kinds of special measuring instruments and gages. Such instruments and

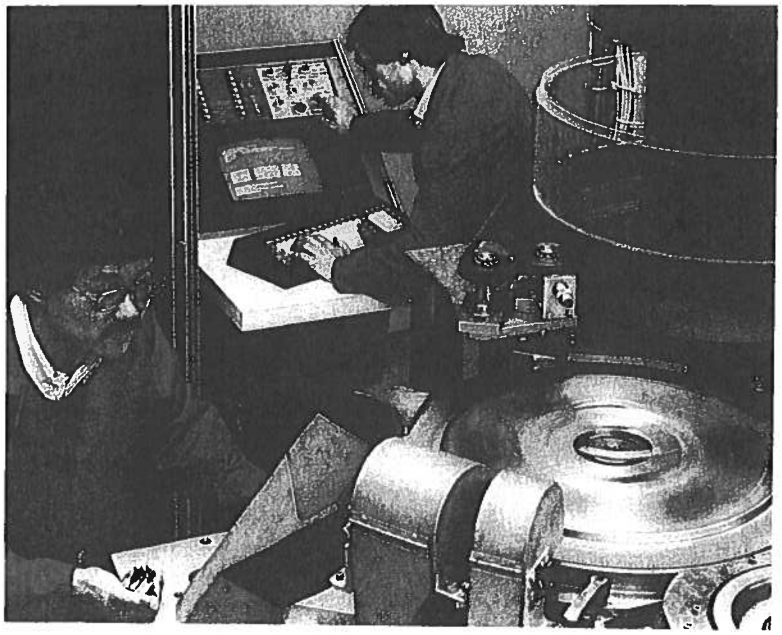


Fig. 1-13 Some small parts must be precisely manufactured. Here, parts specifications are carefully checked by the technicians in the background. This technician in the foreground performs a visual spot check. (Battelle Pacific Northwest Laboratories)

measuring devices are used for automatic regulation and control of machinery; measurement of weight, time, temperature, and speed of moving parts; measurement of volume, mixtures, and flow; and recording of data.

Mechanical Technician

Mechanical technicians assist engineers with problems involved in the design and development of machine tools, production machinery, automotive engines, diesel engines, and other kinds of machinery. They also assist engineers in making sketches and drawings of machine parts; estimating material and production costs; solving design problems involving surface finish, stress, strain, and vibration; and developing and performing test procedures on machines or equipment.

When making performance tests, technicians use many kinds of measuring instruments and gages (Fig. 1-13). They also prepare written reports of test results, including graphs, charts, and other data concerning the performance and efficiency of the equipment.

The **tool designer** is a well-known specialist who works in mechanical technology. The **tool design technician** designs tools, jigs, fixtures, and holding devices for many kinds of production machines. This specialist may also supervise others in making the tools.

Metallurgical Technician

Metallurgical technicians test samples of metals for their **chemical content, hardness, tensile strength, toughness, corrosion resistance, durability,** and **machinability.** They also assist **metallurgists** in developing improved methods of extracting metals from their **ores** and in the development of new metals and **alloys.**

1-9 Technologists

The occupational classification of **technologist** is a category of professional worker ranking between the engineer and the technician. Technologists are graduates of four-year colleges, where they receive academic preparation in **mathematics, physics, chemistry, engineering, graphics, computer programming, business organization,** and **management.** Many of the technologist degree programs require one or more periods of on-the-job work experiences called **internships.** The internships provide valuable professional experiences impossible to obtain in the classroom.

Engineering technologists are prepared to serve in positions of **engineering support.** With the work of the engineer becoming more and more theoretical, technologists are taking over much of the practical, or **applied,** work. The technologist may be called upon to do the on-site surveys, mathematical computations, design studies, laboratory experiments, and other tasks once performed by engineers. With technical and managerial abilities beyond those of the two-year technician, the engineering technologist may also supervise a staff of technicians.

Industrial technologists are employed either in technical positions or in positions of **middle management.** Some types of positions open to industrial technologists include department head; personnel manager; training

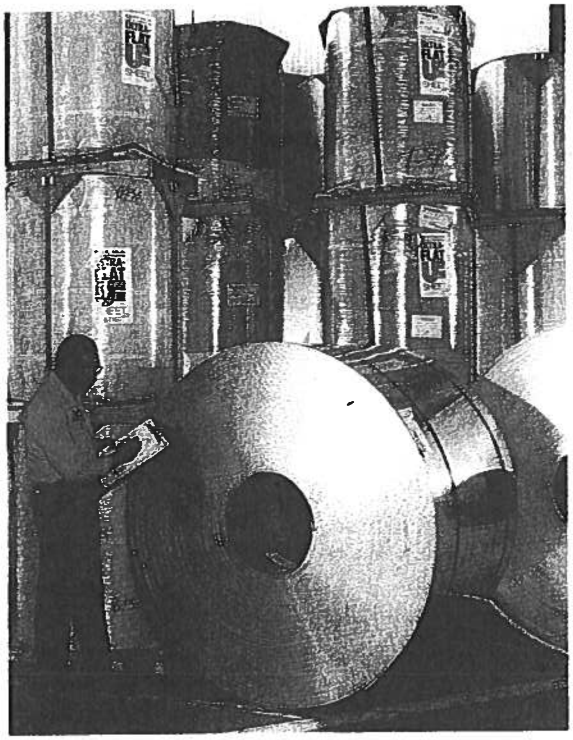


Fig. 1-14 This quality control technician is checking the quality of this rolled aluminum sheet. (Reynolds Metals Company)

director; technical writer; labor relations director; production manager; plant and product designer; and specialist in quality control, facilities planning, cost estimating, and time studies (Fig. 1-14). They may also work in the area of sales as a manufacturer's representative, sales engineer, product analyst, or sales manager or in various capacities in advertising, purchasing, sales and service.

1-10 Engineers

Engineers plan, design, and direct the building of roads, bridges, tunnels, factories, office buildings, waterworks, dams, mines, automobiles, aircraft and spacecraft, ships, railroads, power plants, electrical appliances, electronic equipment, radio and television stations, machinery, and engines. A college education is required to obtain an engineering degree. Engineers must be knowledgeable in **mathematics, drafting, physics,** and **chemistry.**

Engineers specialize in one or more kinds of engineering, such as **mechanical, electrical,** or **chemical** engineering. Many kinds of engineers design metal products, develop and supervise the manufacturing procedures and processes for metal products, and specify the metals to be used in the products they design. Following are some kinds of engineering in which engineers must know and understand the properties of metals and metalworking processes:

1. ***Architectural engineers*** design all types of buildings. These may range from small homes constructed largely of wood, to factories and large buildings constructed of structural metals and masonry.
2. ***Aeronautical*** and ***aerospace engineers*** develop new designs for aircraft, missiles, and space vehicles (Fig. 1-15).
3. ***Civil engineers*** design highways, bridges, dams, waterways, and sanitary systems.

Fig. 1-15 These aircraft engineers are working on the design details of a new aircraft. The model helps them visualize how it will look and function when built. (Textron, Inc.)

4. ***Electrical*** and ***electronics engineers*** design and develop electrical machinery, electrical switches, controls for machines and appliances, radios, televisions, automatic controls for industrial machinery, electric power generators, and many other electronically controlled products.
5. ***Marine engineers*** develop new designs for commercial and military ships, submarines, and other types of marine equipment.
6. ***Mechanical engineers*** design many different kinds of machines, appliances, and mechanical equipment for industrial and consumer use.
7. ***Metallurgical engineers*** develop and improve methods of extracting metals from their ores, refining them, and preparing them for practical use. They also develop new **alloys** with new properties.
8. ***Tool and manufacturing*** or ***industrial engineers*** generally start with the model, or **prototype,** of a product created by a **product engineer.** They analyze and plan the industrial processes needed to economically manufacture the product. They design the special manufacturing machines, equipment, assembly lines, and any packaging system required. They also supervise the construction and installation of the machines and equipment needed for production, and they organize the work force. Finally, they supervise and control production through manufacturing and assembly operations to the finished and packaged product.

REVIEW REVIEW REVIEW REVIEW REVIEW

WORDS TO KNOW

apprentice	heat-treater	metallurgist	skilled worker
boilermaker	inspector	metal patternmaker	steamfitter
carbon monoxide	instrument maker	metal spinner	structural steelworker
coremaker	jeweler	millwright	technician
diemaker	journeyman	molder	technologist
diesinker	layout worker	pipefitter	toolmaker
engineer	lead poisoning	plumber	trade
forge operator	machine operator	polisher	unskilled worker
foundry	machine setup worker	semiskilled worker	welder
gagemaker	machinist	sheet metalworker	

REVIEW QUESTIONS

1. List several factors that you should consider in selecting your occupation.
2. List several school subjects that are generally needed to learn a trade or become a technician, technologist, or engineer.
3. List several kinds of semiskilled metalworking jobs.
4. What is the length of the training period for semiskilled metalworking jobs?
5. List several skilled metalworking trades.
6. In what two government publications can you find further information about skilled trades or occupations?
7. Describe the apprenticeship method of learning a trade.
8. What is a journeyman?
9. What education is required to become a technician? A technologist? An engineer?
10. List several kinds of work done by (1) technicians, (2) technologists, (3) engineers.

UNIT 2
Introducing Metals

What are metals? Usually they are shiny, solid materials that conduct heat and electricity. They come from ores that are mined from the earth, then melted and refined to separate each metal. Except for mercury, most metals are solid and hard at room temperatures.

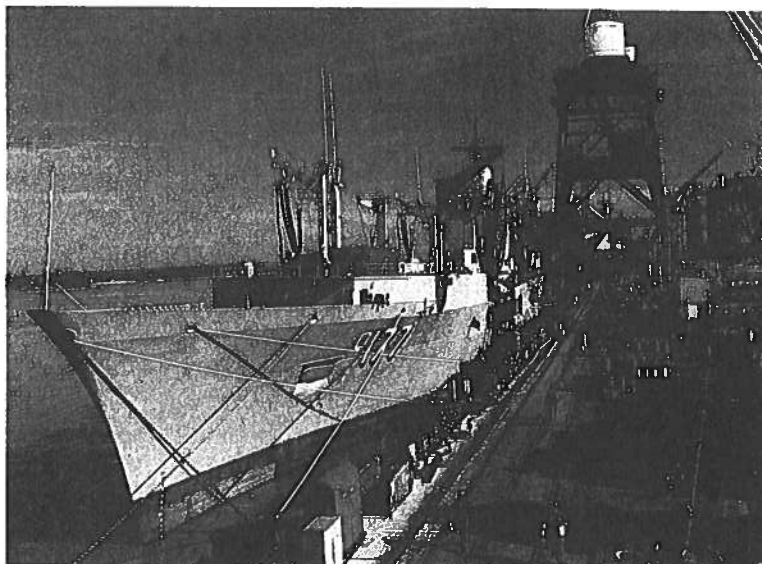
2-1 The Importance of Metals

Metals are essential to the conduct of our daily lives, to our industrial society, and to our national defense (Fig. 2-1). Metals are everywhere around us. They are widely used in the manufacture of aircraft and spacecraft, automobiles, buses and trucks, railroad cars, bicycles and motorcycles, and ships and submarines. Structural steel and other structural metals are used in the construction of roads, bridges, tunnels, and buildings.

Many metals are used in the construction of home appliances. These include familiar labor-saving devices such as stoves, washing machines, clothes dryers, and dishwashers—and convenience items such as toasters, refrigerators, furnaces, and air conditioners. Also included are entertainment items such as radio and television sets, stereo phonographs, tape recorders, cameras, and projectors.

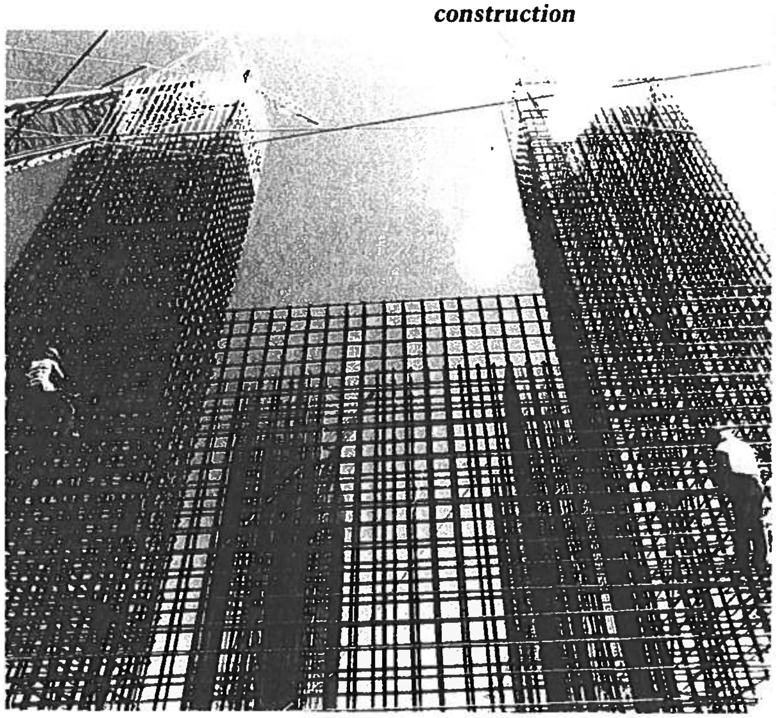
Metals are used extensively in the manufacture of hand tools, portable power tools, machine tools, farm and manufacturing machinery, and roadbuilding equipment. Sports equipment such as fishing reels, pleasure boats, outboard motors, golf clubs, and guns also make use of metals. Valuable or precious metals are often used in making coins, jewelry, tableware, and cutlery.

Fig. 2-1 *Metalworking and metal products are important in every part of modern life.*

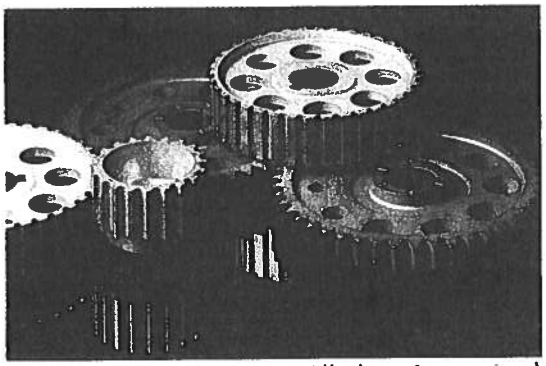


transportation Ogden Corp.

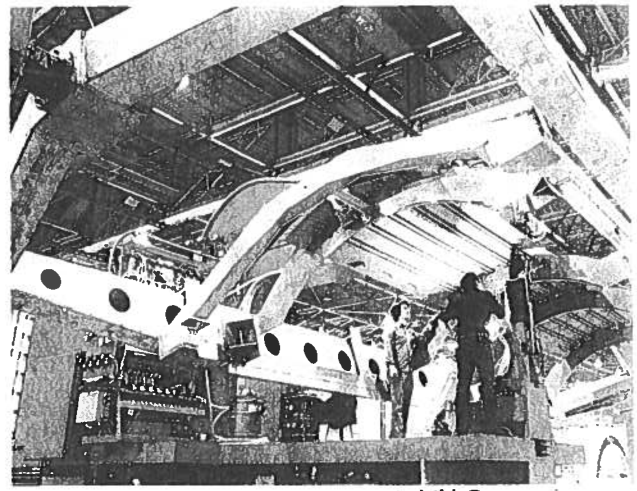
construction



Metalworking and metal products are important to . . .



Allegheny International

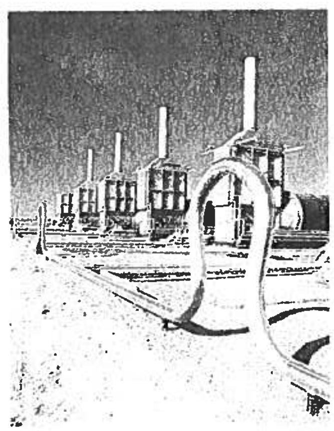


Fairchild Corporation

manufacturing

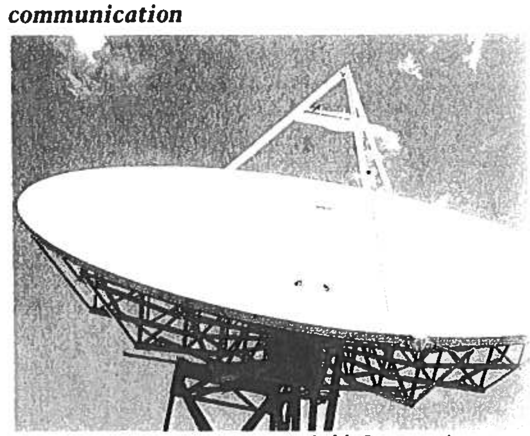
energy

Florida Power & Light Co.



Combustion Engineering, Inc.

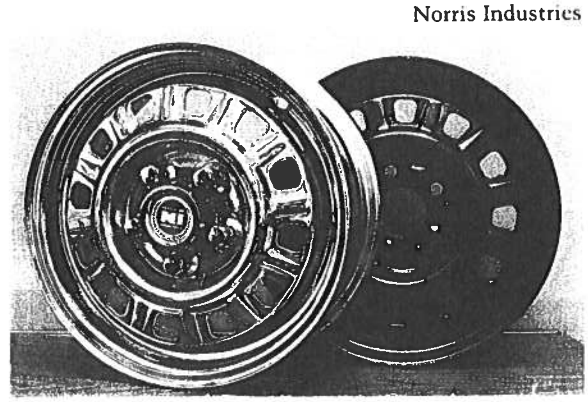
communication



Fairchild Corporation

our daily lives

Talley Industries



Norris Industries

defense

Fairchild Corporation

2-2 Properties of Metals

Metals have different characteristics, called **properties.** When an engineer selects the metals for a product, he selects them on the basis of their properties.

Metal properties fall into three groups:
(1) ***Chemical properties*** are characteristics of the chemical composition of metals and their chemical reactions to other metals. **Corrosion resistance,** for example, is the ability to resist rusting (oxidation) or other chemical actions. Gold, stainless steel, aluminum, and copper are much more corrosion-resistant than iron and steel.
(2) ***Physical properties*** are characteristics of metals when they are not being acted upon by outside forces. Color, density, weight, and electrical and heat conductivity are physical properties. Density is expressed as the weight in grams of one cubic centimeter of material (the mass per unit volume). Conductivity is the ability to absorb and transmit heat or electricity.
(3) ***Mechanical properties*** are characteristics exhibited by metals when outside forces are applied to them. Metalworkers must have an understanding of the mechanical properties of metals when they make or shape metal products.

2-3 Mechanical Properties

Metalworkers are often concerned with the following mechanical properties of metals and how they affect their work.

Hardness means resistance to penetration by other materials. Steel, for example, is much harder than lead or pure aluminum. Hardness may be increased by cold working such as bending, hammering, or rolling at room temperature. Hardness may also be increased or decreased by treating the metal in different ways with heat (Fig. 2-2).

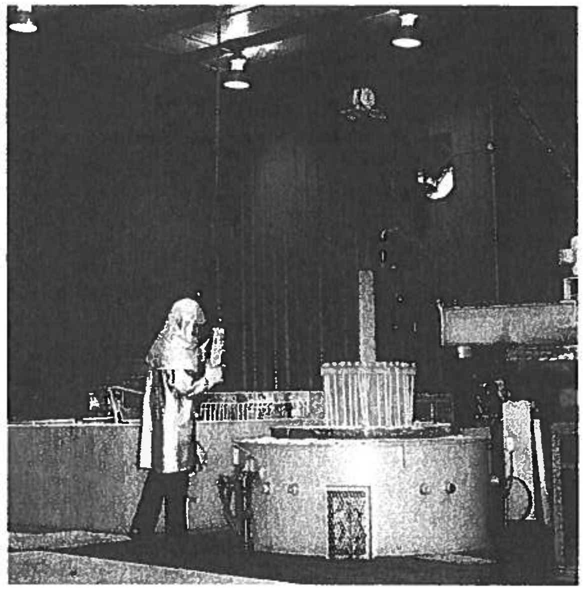


Fig. 2-2 *Drill rods are removed from a heat treating furnace. The heat treatment is being done to stress relieve the rods.* (Allegheny International)

Hardenability is the property of a metal to harden uniformly and completely. A metal with poor hardenability will harden on its surface only, while its center will be left relatively soft.

Brittleness refers to how easily a metal will break with little or no bending. Hardened tool steels and gray cast iron are brittle compared to unhardened steels.

Ductility is the property of a metal to be bent, rolled, or otherwise changed in shape without breaking. Metals high in ductility include soft steel, copper, and aluminum. They can be drawn into fine wire and rolled into thin sheets without breaking.

Malleability permits a metal to be hammered or rolled into shape without breaking. Most malleable metals are ductile. A few metals, such as lead and malleable cast iron, cannot be stretched very far without breaking and are therefore not ductile.

Toughness in metal refers to its ability to withstand sudden shock without breaking **(fracturing).** A metal high in toughness will usually bend or deform before fracturing.

When steel is made extremely hard by heat treatment, it loses much of its toughness. Cutting tools hardened by heat treatment will usually break before they bend very much. However, a special kind of heat treatment, called **tempering,** reduces hardness and increases toughness.

Toughness is often more important than hardness. For example, it is more important for steering knuckles, springs, axles, and other critical auto parts to rank high in toughness than to rank high in hardness.

Machinability refers to the ease with which metals may be **machined,** or cut by a machine tool (Fig. 2-3). **Machinability ratings** are expressed as a percentage in comparison with AISI 1112 steel, which is rated at 100%.

AISI stands for the American Iron and Steel Institute, a trade association of companies that sell or work with iron and steel. The AISI develops and sets ratings or standards for making, selling, and using different kinds of iron and steel.

Fusibility enables a metal, when in its liquid state, to join easily with another liquid metal. Metals high in fusibility are usually high in **weldability** (Fig. 2-4). Welding is discussed in Unit 26.

Strength is the resistance of a metal to deformation (Fig. 2-5). **Tensile strength** is resistance to being pulled apart. **Compressive strength** is resistance to being squeezed together. **Shear strength** is resistance to cutting or slicing forces. **Torsional strength** is resistance to twisting forces.

Elasticity is the ability of a material to return to its original size and shape after the external force causing a change in shape has been removed. **Elastic limit** is the maximum load per square inch or square centimeter that can be applied to a material without forcing it to change shape permanently.

Fatigue is the characteristic that causes a metal to fracture (break) under a repeated load that is well below the tensile strength of the metal. Parts subjected to repeated bending or vibration sometimes break because of **fatigue failure.**

Fig. 2-3 *Facing, a common machining operation, is done on a lathe. A cutting fluid helps the cutting action of the tool bit. Metals rated high in machinability can be cut more easily, leaving a smoother surface than with harder, tougher metals.*

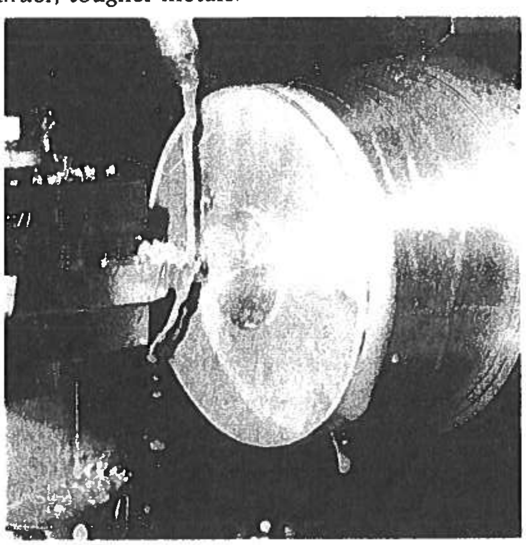
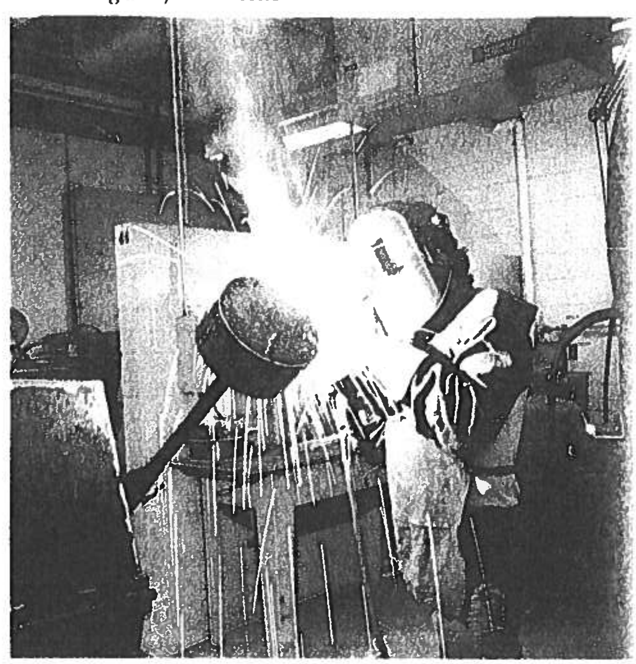


Fig. 2-4 *The fusibility of metal, or the ease with which it may be melted, affects the strength of its welds.*



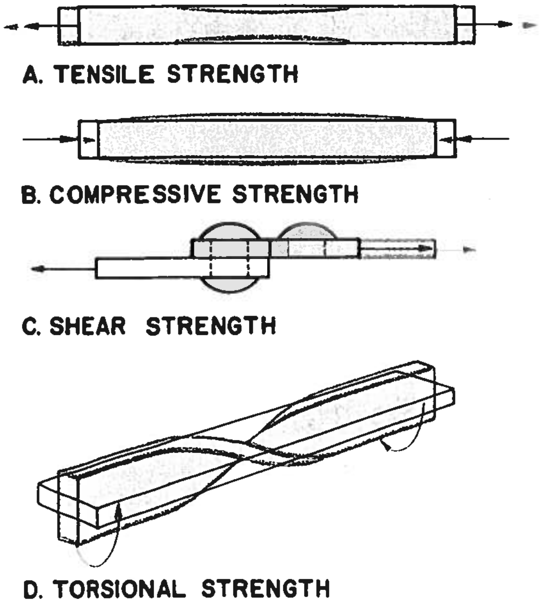


Fig. 2-5 *Types of strength in metals. The colored views show what happens when the stress on a metal exceeds its strength.*

2-4 Classification of Metals

Metals are classified as **pure metals** or as **alloys.**

Pure Metals

A pure metal is a single chemical element that is not combined with any other chemical element. A chemical element is a fundamental substance that cannot be decomposed (broken down) by chemical reaction into substances of simpler composition. The earth is made up of more than 100 elements.

Pure metals are generally too soft, low in strength, or low in some other desired property to be used in many commercial applications. Thus, their use in the pure state is limited to laboratory experiments and a few construction applications.

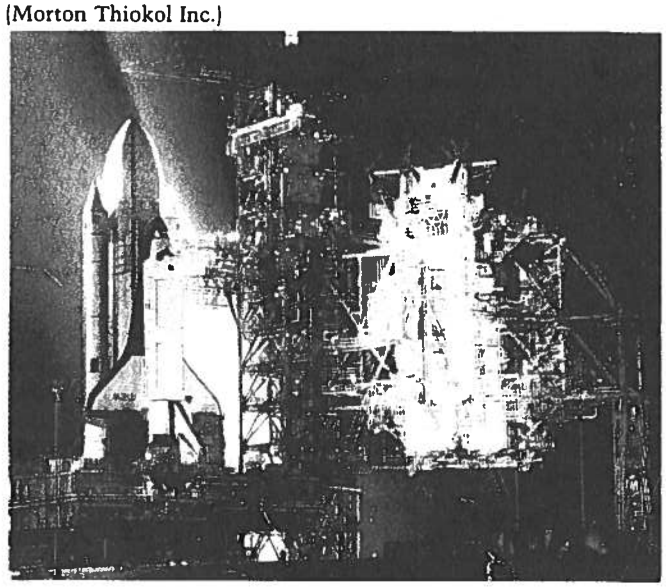
Metals may be further classified as either **ferrous** or **nonferrous** metals. The word "ferrous" is derived from the Latin word "ferrum," which means iron. The main element in all steel is iron. Thus, all steels are called ferrous metals. Examples of nonferrous metals are aluminum, copper, lead, tin, and zinc.

Alloys

The properties of a pure metal can be changed by melting and mixing one or more other pure metals with it. This process produces a new metal which is called an **alloy.** Nonmetallic elements may also be included in alloys. An alloy may have characteristics very different from the pure metals from which it was formed. Stainless steel is a familiar alloy composed of steel, nickel, and chromium. It is strong, tough, and much more corrosion-resistant than plain steel (Fig. 2-6).

The many kinds of alloys may also be classified as either **ferrous alloys** or **nonferrous alloys.** Alloys are named after the main, or **principal,** metal, called the **base metal.** Thus, steels that are intentionally alloyed with nickel, chromium, or tungsten are called steel alloys. When aluminum is alloyed with other metals, **aluminum alloys** are formed. Other metals may also be added to copper to form **copper alloys** or to zinc to form **zinc alloys.**

Fig. 2-6 *Space shuttles and the equipment necessary to launch them contain more than 45 basic metals in several thousand different alloys.* (Morton Thiokol Inc.)



2-5 Selection of Metals

Engineers, product designers, technicians, and skilled workers in metalworking occupations must understand the properties of various metals and their alloys. This knowledge is important to the intelligent selection and processing of metals for each product. For example, various aluminum alloys are used in the construction of spacecraft, aircraft, small engines, lawn furniture, storm windows, and small boats. Aluminum alloys are desirable for these products because they are lightweight, corrosion-resistant, and strong. The

TECHNOLOGIES AND PRACTICES

Showing Off: A Ladder to the Sky

For forty years (1889-1929), the Eiffel Tower in Paris was the tallest structure in the world. Today it is still one of the tallest towers. It was built to show off the new materials and methods used during the first century of the Industrial Revolution. The "new" material was iron. Iron had been used for many years for tools and weapons, but never before had an iron project as great as the Eiffel Tower been attempted.

The tower is named for Gustave Eiffel, the engineer who built it as part of the Paris International Exposition of 1889. The Exposition was a type of industrial fair with exhibits and demonstrations spotlighting new inventions. In the early stages of planning the fair, France's Minister of Commerce and Industry proposed a grand 1000-foot-tall [305 meters] structure that would be a symbol of France's pride and prosperity. A contest was held to find a suitable design. Eiffel's design was chosen after he convinced the Minister that a stone structure of that height would be impractical.

After his design was chosen, Eiffel had only two years to finish the tower. He had to plan every detail carefully and devise whole new building methods to make the grand idea a reality.

One major design problem was to determine the type of metal to be used. Eiffel could choose either cast iron, steel, or wrought iron for the tower's girders. Cast iron was too brittle and lacked tensile strength. Steel was lighter and more flexible, but Eiffel feared that steel's greater elasticity would produce too much sway in high winds. The wind was a very important factor to consider when building a tower that would reach 984 feet [300 meters] into the sky.

Eiffel chose wrought iron as the best material for the 7300 tons [6,636 metric tons] of metal used in the tower. It combined strength with rigidity and still was relatively light.

Eiffel completed the tower in time for it to be used as the entrance to the Paris Exposition. At that time, it was seen as an engineering marvel. While other structures may climb higher today, the Eiffel Tower still stands as a symbol of great technological advances.

(French Government, Tourist Office)

manufacture of tools used for cutting metals requires steels that can be hardened by heat treatment. Steels of this type include plain carbon and alloy **tool steels.** Files, hacksaw blades, drills, chisels, thread-cutting dies and many other cutting tools are made of tool steels.

More than 20,000 different kinds of metal are now available for use in manufacturing. There are hundreds of different grades of structural steels, alloy steels, tool steels, and specialty steels. More than 350 different aluminum alloys and more than 300 copper alloys are also available. Many other kinds of nonferrous alloys are in current use. In fact, there are more than 100 different metals used in the manufacture of a modern automobile.

In other chapters in this book, you will learn more about the different metals, their properties, and how they are produced. At this time, however, it is important to know that there are many different kinds of metals. Each kind of metal was developed to provide certain properties needed in the production of various metal products. You will want to know the principal properties of the common metals when you design and construct metal products in your metalworking course.

REVIEW REVIEW REVIEW REVIEW REVIEW

WORDS TO KNOW

AISI
alloy
base metal
brittleness
compressive strength
corrosion resistance
density
ductility
elastic limit
elasticity
fatigue
ferrous metal
fracture
fusibility
hardenability
hardness
machinability
malleability
nonferrous metal
properties of metal
shear strength
temper
tensile strength
tool steel
torsional strength
toughness
weldability

REVIEW QUESTIONS

1. List ten important products made entirely or largely from metals.
2. Name the three groups of metal properties.
3. Name two principal ways of increasing metal hardness.
4. Name two metals considered to be brittle.
5. Explain the difference between ductility and malleability.
6. In what kinds of metal parts is toughness more important than hardness?
7. What is meant by fusibility in metals?
8. Name and explain each of the four kinds of strength metals may have.
9. What happens to a metal when its elastic limit is exceeded?
10. What are the causes of metal fatigue?
11. Why are pure metals of limited usefulness?
12. How does an alloy differ from a pure metal?
13. Explain the difference between ferrous and nonferrous metals.
14. What is meant by the base metal in an alloy?
15. How many different kinds of metals are now available? Why are there so many?

UNIT 3

Personal Safety in Metalworking

Working safely with metals can be divided into two main topics of concern:

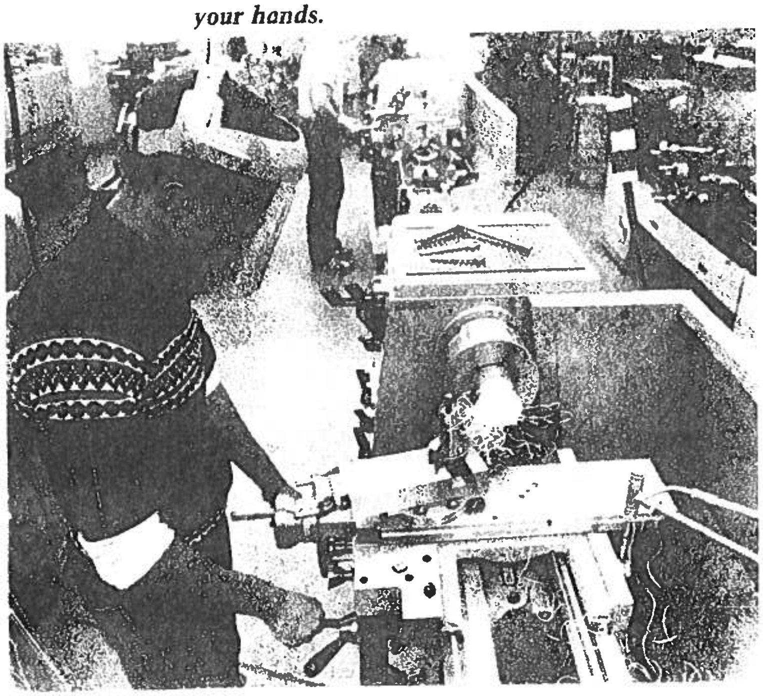
1. protection against personal injury, and
2. prevention of damage to tools, equipment, and machines.

Safe use of tools, equipment, and machines will be dealt with in the units in which these items are discussed. This unit is about personal safety.

When working with metals, you must take great care to avoid personal injury. Solid metals are hard materials that often have sharp edges. Hot, sharp metal chips produced in cutting operations can burn and cut (Fig. 3-1). Grinding wheels can throw abrasive particles into unprotected eyes. Rotating tools and workpieces can catch loose clothing and hair (Fig. 3-2). Harmful rays from electric welding arcs can burn unprotected skin and eyes. Liquid metals can spatter and cause painful burns (Fig. 3-3).

A careless worker can be painfully injured or cause others to be injured. Workers who work safely can avoid being injured. They must dress properly, follow correct work procedures, and work well as a team with fellow workers.

Fig. 3-1 Protect yourself against hot, sharp chips produced by the cutting tools of metalworking machines. ***Never pick up chips with your hands.***



3-1 How To Dress Safely

1. Maximum eye protection requires the wearing of clean, properly fitted safety glasses with side shields, goggles, or a face shield approved by the National Safety Council (Fig. 3-4). State laws require everyone to wear eye protection in school shops,

Fig. 3-2 Long, loose hair can get caught in machinery. ***Keep it in a cap or tie it back securely.***

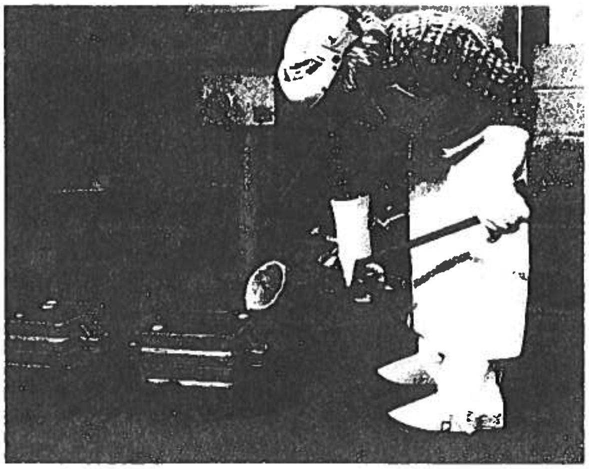


Fig. 3-3 *Handle hot liquid metals carefully and wear the correct safety clothing.*

laboratories, and factories. **Your eyes cannot be replaced. Protect them at all costs.**

2. Close-fitting clothing made of hard, smooth-finished fabrics should be worn. Such fabric will not catch easily on sharp edges or rotating tools. Fuzzy sweaters are especially bad and should only be worn under a hard-finished shop coat or jacket.

   Long shirt sleeves should be close-fitting or rolled up past the elbow. Neckties should be removed or tucked into the shirt. A close-fitting apron or shopcoat will protect street clothes from the usual grime of metalworking (Fig. 3-5).
3. Feet should be protected against hot, sharp chips, heavy falling objects, and hot liquid metals. Safety shoes are best (Fig. 3-6), but ordinary leather shoes offer considerable protection. **Canvas shoes and open-toed sandals offer no protection and should never be worn when doing metalwork.**
4. **Always take off all jewelry before working with metals.** Wrist watches, rings, necklaces, and bracelets can get caught on equipment and cause serious injury.

Fig. 3-4 *Choose the right equipment to protect your eyes and face. (A) Safety glasses with side shields. (B) Goggles. (C) Face shield for full-face protection.*

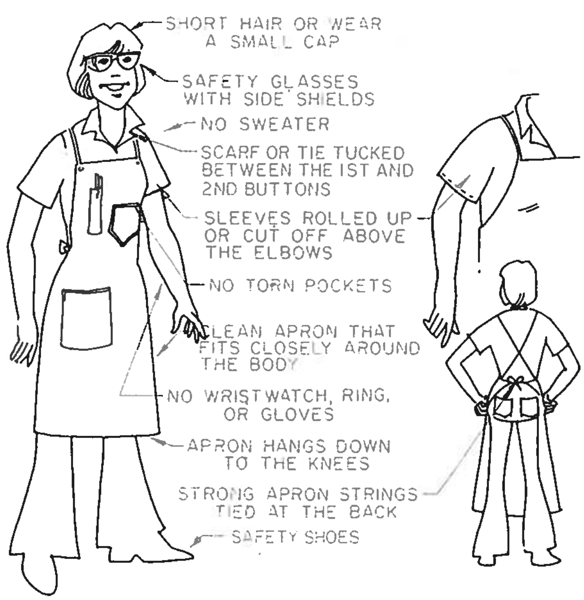


Fig. 3-5 *Dressing safely for metalworking.*

Fig. 3-6 *Safety shoe with steel-reinforced toe.*

5. Long, loose hair can be caught in **rotating tools.** Wear long hair under a close-fitting cap or tie it back tightly.
6. **Never wear gloves when operating metalworking machines.** They are easily caught in moving parts and may cause serious injury to the hands. (Workers **must** wear gloves, however, when handling hot materials or containers and when arc welding.)

3-2 Safe Work Practices

General

1. Get approval from your instructor or supervisor before using any equipment.
2. Make it a habit to stop, look, and think in unfamiliar situations. **When in doubt, ask your instructor or supervisor for help.**
3. Give serious and undivided attention to your work.
4. Do not walk through restricted areas marked by barriers or floor markings.

With Machinery and Machine Tools

1. Be sure all safety devices are in place and working correctly before using any machine or equipment.
2. Be sure to tighten workpieces and cutting tools securely in machine tools, so that cutting pressures cannot loosen them (Fig. 3-7).
3. Always keep hands away from moving machinery.
4. Never use your hands to stop moving machines or parts such as a lathe or drill press chuck.
5. When closing electric switches, use the insulated handle if available. Avoid touching the metal parts of the switch or switch box.
6. Never leave a running machine. Someone else may not expect it to be running and may be injured by it.
7. Always stop a machine before making measurements with tools that may catch in the machinery, such as a caliper.

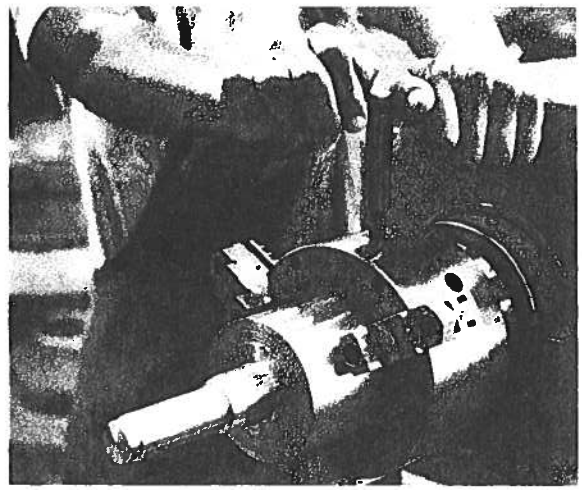


Fig. 3-7 *Cutting tools and workpieces must be tightened securely for safe operation.*

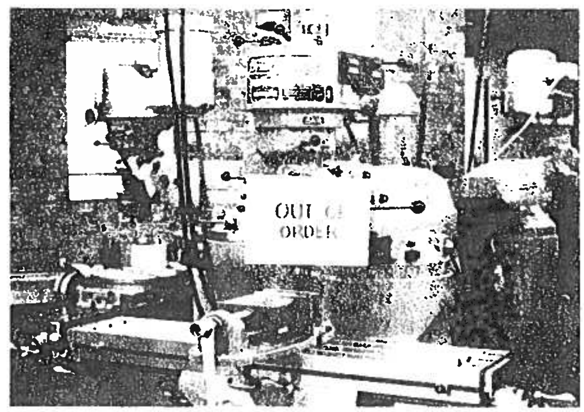


Fig. 3-8 *Mark out-of-order equipment with a blue sign.*

8. Always stop machines to adjust, clean, oil, or repair them. When making hazardous repairs, disconnect the machine from its power source so that it cannot be turned on.
9. Disconnect out-of-order equipment and identify it with a blue sign (Fig. 3-8) as recommended by the National Safety Council.
10. When changing speeds on a cone pulley drive system, wait until the machine comes to a **full stop** before shifting the belt.
11. Replace projecting setscrews on rotating equipment with flush setscrews.

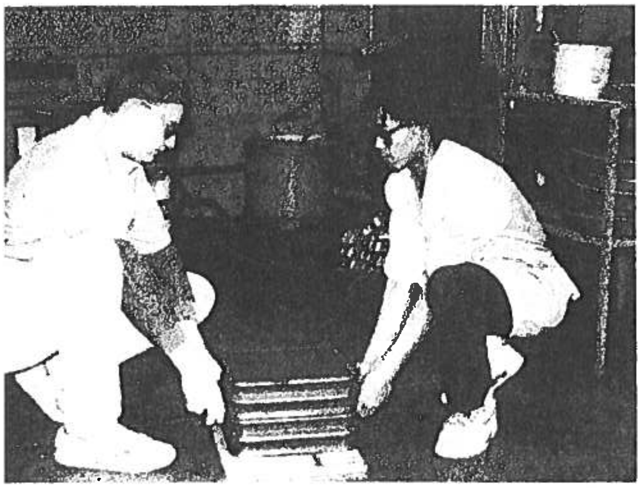


Fig. 3-9 *Learn to lift heavy objects by using the strength in your legs,* ***not your back.*** (Manual High School, Roger Bean)

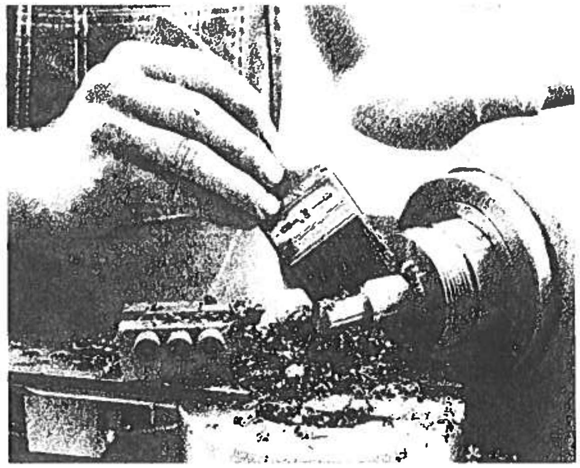


Fig. 3-10 *Brushing is a safe way to remove sharp chips.* ***Never pick up chips with your hands.***

With Shop Materials

1. Handle materials carefully to avoid being cut.
2. Do not touch metal you suspect is hot. Test it first by sprinkling a few drops of water on it.
3. Get help in lifting or moving heavy pieces of metal or machine parts. Remember to lift with your legs, not your back (Fig. 3-9).
4. Get help also when handling long pieces of metal, so as to avoid injuring someone or damaging equipment.
5. Return large pieces of metal to their proper storage racks immediately after cutting off the pieces needed.

With Scrap and Waste

1. Use a brush, a piece of cardboard, or a stick to sweep up or push away sharp metal chips (Fig. 3-10). **Never use your hands.**
2. Never use compressed air to blow metal chips from a machine or work station without approval.
3. Keep aisles clear of small metal pieces, chips, and other waste. These are hazards to safe travel.
4. Keep floors clear of oil, grease, and other liquids that could cause someone to slip and fall.

With Other Students or Co-workers

1. Always try to be alert, patient, courteous, and willing to help. This is especially necessary in school shops where you may have to wait to use a tool or get help from your instructor.
2. When working with someone, agree **beforehand** on how the work will be done and who will do each part so that there will be no confusion that could lead to injury.
3. Do not disturb someone who is actively involved in operating a machine or other potentially hazardous equipment. You may cause them to make a mistake which could cause an accident.

3-3 Safe Use of Hand Tools

The improper use of hand tools frequently results in personal injury. The following safe work practices should be followed when using hand tools:

1. Use the right tool for the job to be performed.
2. See that tools and your hands are clean and free of grease or oil before use so that the tools can be held firmly.

3. Cutting tools should be sharp when using them. Dull tools cause accidents because they require greater force to use them. Dull tools also leave jagged edges that may cut someone.
4. Sharp-edge tools should be carried with their points and cutting edges pointing downward.
5. Heads of cold chisels and punches should not be allowed to mushroom or crack; they should be properly dressed or repaired.
6. When using a chisel, always chip in a direction which will prevent flying chips from striking others.
7. Choose the correct size and type of wrench for the job and use it properly. You can injure your knuckles or hand if the wrench slips.
8. When using a file, be sure that it is equipped with a snug-fitting handle. Otherwise, the sharp tang on the file could injure your hand.
9. When you hand tools to others, give them with the handle first (Fig. 3-11).
10. Always report damaged tools to the instructor. Damaged tools can cause injuries.
11. Tools should always be wiped free of grease or dirt after use and then returned to the proper storage place.

Fig. 3-11 *When you give a tool to someone, always offer it handle first. The scriber being handed to the student in this picture is needle sharp and hard enough to cut steel.*

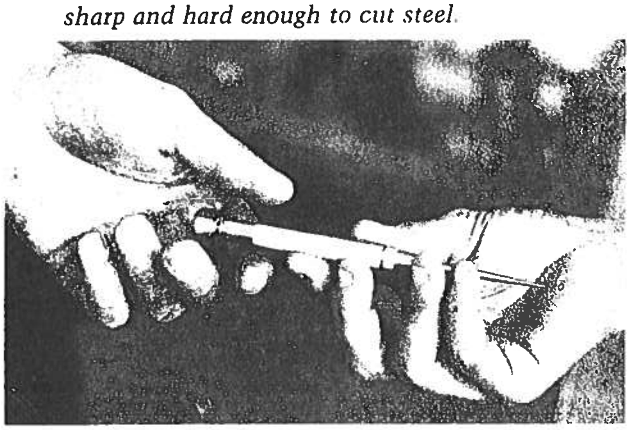


Fig. 3-12 *Get first aid for injuries* ***right away.***

3-4 First Aid

1. Always notify the instructor immediately when you or another student are injured, no matter how slight the injury.
2. Get first aid as soon as possible (Fig. 3-12). It is good practice to let slight or moderate cuts bleed for a few moments before stopping the flow of blood. Free bleeding carries infectious particles out of the wound. **Severe cuts or bruises should receive the immediate attention of a doctor.**
3. Burns should also be treated promptly. A first-degree burn is one in which the skin is merely reddened. In a second-degree burn, the skin is blistered. In a third-degree burn, the skin is charred. Treat first-degree burns with applications of ice or cold water. Then apply a sterile dry bandage. **Second- and third-degree burns should receive a doctor's attention immediately.**
4. If you are concerned about an injury or an illness, don't be foolishly brave and "tough it out." Get professional help as soon as possible.

Fig. 3-13** Always store oily rags in approved **metal containers.

3-5 Fire Prevention

1. Learn the location of the nearest fire alarm as well as the nearest fire exit.
2. Learn the location and use of fire protection equipment in the building. Fire extinguishers which use a **dry chemical** or **carbon dioxide** should be readily available at all times.
3. Place oily rags or waste in proper metal containers (Fig. 3-13). This guards against possible fire from **spontaneous combustion.**
4. Always close containers of inflammable materials such as paints or oils after use. Return them to their proper metal storage containers.

REVIEW REVIEW REVIEW REVIEW REVIEW

WORDS TO KNOW

abrasive particle	carbon dioxide extinguisher	mushroom heads	safety glasses
arc welding rays		rotating tools	safety shoes

REVIEW QUESTIONS

1. What are the state laws on eye protection in school shops, laboratories, and factories?
2. Why shouldn't sweaters or loose clothing be worn while a person is around machinery?
3. What kinds of shoes offer best foot protection for metalworking?
4. Why is long hair a potential hazard around machinery?
5. Why shouldn't jewelry be worn when working with metals?
6. Why is it a good rule not to try to get the attention of a person who is operating a machine until that person has finished the particular operation or process being worked on?
7. Describe a simple way to test whether a piece of metal is too hot to pick up with bare hands.
8. Why should oil or grease be removed from the floor or cleaned from hand tools?
9. List two safety rules or safe practices regarding first aid and the reporting of injuries.
10. Why is it important that oily rags be stored in metal containers?

PART 2

Getting Acquainted with Metals

Safety precautions have always played a major role in metalworking. But it is only recently that educators have offered courses leading to degrees in industrial safety. Deborah Pisoni is one of three safety administrators for one of the largest and most versatile steel mills in Pennsylvania. She began her preparation with a B.S. in Physical Education. Many of her courses, particularly first-aid, drew her attention to accident prevention. So she decided to continue her schooling until she earned an M.A. in Safety Management.

The steel mill where Deborah works covers 727 acres. Different departments handle steel from its manufacture to its processing into products such as pipe, steel coils, and beams. Deborah has to be familiar with the safety aspects of all operations.

Deborah works mainly in the tubular pipe division of the steel works. The job is both physically and mentally demanding. She may walk from furnace to furnace and climb ladders to check cranes. She writes reports on her findings. And she may be "on call" after hours.

Steelmaking has great potential for industrial accidents, but Deborah feels that steel plants have actually become very safe places. The emphasis on safety, from management to employees throughout the mill, has never been greater. Should a serious accident occur, she or a co-worker is immediately called to the scene to discover the cause. Most of the injuries are minor and are caused not by machinery but by a worker's lapse in concentration. Deborah's biggest challenge is to motivate workers to be always alert.

She has been with the company seven years and is pleased to report a noticeable reduction in the number of accidents. She feels that enthusiasm, creativity, and concern for people are the basic qualifications for safety administrators.

Deborah Pisoni
Safety Administrator

Name ______________________

Score __________

UNIT 1
Careers in Metalworking

1-12. Multiple Choice. Write the letter of the correct response to each statement or question in the space at the left.

_____ 1. A book published by the U.S. Department of Labor that provides current information about all types of careers is the
- A. Dictionary of Occupational Titles
- B. Occupational Outlook Handbook
- C. Career Quarterly
- D. Career Outlook Review

_____ 2. There are over 20,000 occupational titles described in the U.S. Department of Labor book called the
- A. Dictionary of Occupational Titles
- B. Occupational Outlook Handbook
- C. Career Quarterly Handbook
- D. Annual Survey of Occupational Titles

_____ 3. The length of time usually required to train an engineer or a machinist is
- A. 2 years
- B. 3 years
- C. 4 years
- D. 5 years

_____ 4. Workers in occupations that require little or no training are classified as
- A. unskilled
- B. semi-skilled
- C. skilled
- D. technicians

_____ 5. An example of a semi-skilled occupation would be a(n)
- A. engineer
- B. floor sweeper
- C. machine tool operator
- D. technologist

_____ 6. An example of a skilled occupation is
- A. technician
- B. technologist
- C. engineer
- D. tradesperson (such as machinist)

_____ 7. A person learning a trade in a systematic way under a master of the trade or under the direction of a company is called a(n)
- A. beginner
- B. learner
- C. trainee
- D. apprentice

_____ 8. Becoming a skilled tradesperson without the benefit of a formal educational program is called
- A. the pickup method
- B. on-the-job training
- C. an apprenticeship
- D. an internship

(Continued on next page)

______ 9. Workers whose occupations require two years of technical education beyond high school are called

A. engineers
B. technologists
C. technicians
D. skilled workers

______ 10. Which occupational classification requires four years of college and prepares industrial workers for either technical or middle-management positions?

A. journeyman
B. technician
C. technologist
D. engineer

______ 11. The occupational classification requiring the highest level of education in mathematics, physics, and chemistry is

A. technician
B. engineer
C. technologist
D. skilled tradesperson

______ 12. The kind of engineer who organizes people, materials, and machines for mass production in an industrial plant is the

A. tool engineer
B. manufacturing engineer
C. industrial engineer
D. all of the above

Name ____________________

Score __________

UNIT 2
Introducing Metals

1-16. Multiple Choice. Write the letter of the correct response to each statement or question in the space at the left.

_____ 1. Characteristics of metals when they are **not** being acted upon by outside forces are called
A. chemical qualities
B. attributes
C. physical properties
D. traits

_____ 2. Characteristics of the chemical composition of metals are called
A. mechanical properties
B. physical properties
C. chemical properties
D. molecular properties

_____ 3. Characteristics that describe how metals behave when outside forces are applied are called
A. mechanical properties
B. physical properties
C. chemical properties
D. molecular properties

_____ 4. What property of metal refers to its ability to resist penetration?
A. hardness
B. toughness
C. elasticity
D. elastic limit

_____ 5. What property of metal refers to its ability to withstand shock without cracking?
A. hardness
B. toughness
C. strength
D. elasticity

_____ 6. The property that causes metal to break with little or no bending is
A. hardness
B. toughness
C. fatigue
D. brittleness

_____ 7. The property of metal that refers to its resistance to being pulled apart is
A. ductility
B. toughness
C. tensile strength
D. compressive strength

_____ 8. Metals high in weldability are usually high in
A. fusibility
B. ductility
C. malleability
D. meltability

_____ 9. The property that causes metal to fracture under a repeated load that is less than the tensile strength of the metal is called
A. elastic limit
B. brittleness
C. toughness
D. fatigue

(Continued on next page)

______ 10. Ferrous metals are metals that contain

A. copper
B. iron
C. aluminum
D. zinc

______ 11. A combination of two or more metals, one of which is intentionally added to the base metal, is called a(n)

A. mixture
B. compound
C. blend
D. alloy

______ 12. Steels that can be hardened to make such items as files, drills, wrenches, and hammers are called

A. alloy steels
B. structural steels
C. specialty steels
D. tool steels

______ 13. About how many different kinds of metals and metal alloys are now available?

A. 1,000
B. 10,000
C. 20,000
D. 30,000

______ 14. About how many different kinds of aluminum alloys are available?

A. 400
B. 350
C. 300
D. 250

______ 15. About how many kinds of copper alloys are available?

A. 100
B. 200
C. 300
D. 400

______ 16. About how many different kinds of metals are used in a modern automobile?

A. 50
B. 100
C. 150
D. 200

Name ______________________________

Score ____________

UNIT 3
Personal Safety in Metalworking

1-13. Short Answer. In the spaces provided below, write 13 things that the boy pictured needs to correct to be dressed safely for work.

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________
7. ______________________________
8. ______________________________
9. ______________________________
10. ______________________________
11. ______________________________
12. ______________________________
13. ______________________________

14-24. Multiple Choice. Write the letter of the correct response to each statement or question in the space at the left.

______ 14. Clothing made of which kind of fabric is safest to work in?
- A. soft and smooth
- B. soft and fuzzy
- C. hard and smooth
- D. hard and ribbed

______ 15. Next to safety shoes, what shoes offer good protection for metalworking?
- A. ordinary leather shoes
- B. canvas shoes
- C. open-toe sandals
- D. any of the above

(Continued on next page)

_____ 16. Long hair should be kept close to a worker's head with a
- A. headband
- B. loose-fitting cap
- C. close-fitting cap
- D. either A or C

_____ 17. The safest way to remove sharp metal chips from machines is with
- A. the hands
- B. a brush
- C. a rag
- D. compressed air

_____ 18. Before picking up a piece of metal you suspect is hot, check its temperature
- A. with a thermometer
- B. by sprinkling a few drops of water on it
- C. by looking to see if it is red-hot
- D. by touching it quickly with a wet finger

_____ 19. When is it safe to leave a machine while it is running?
- A. when no cutting is being done
- B. at the beginning of a long cut using power feed
- C. when no one else is near the machine
- D. never

_____ 20. When lifting heavy objects from the floor, what part of the body should provide most of the lifting power?
- A. arms
- B. legs
- C. back
- D. hands

_____ 21. Sharp-edged tools
- A. are safer to use than dull tools
- B. should be carried sharp edge down
- C. should be handed to another person handle first
- D. all of the above

_____ 22. If you injure yourself, even slightly, in the shop or laboratory, the first person you should tell is
- A. your mother
- B. your doctor
- C. the school nurse
- D. your instructor

_____ 23. What kinds of burns should be treated by a doctor?
- A. first-degree burns
- B. second-degree burns
- C. third-degree burns
- D. both B and C

_____ 24. To prevent spontaneous combustion, what kind of container should be used for storing oily rags or waste?
- A. a closed metal container
- B. an open-topped metal container
- C. a wire mesh container
- D. any of the above

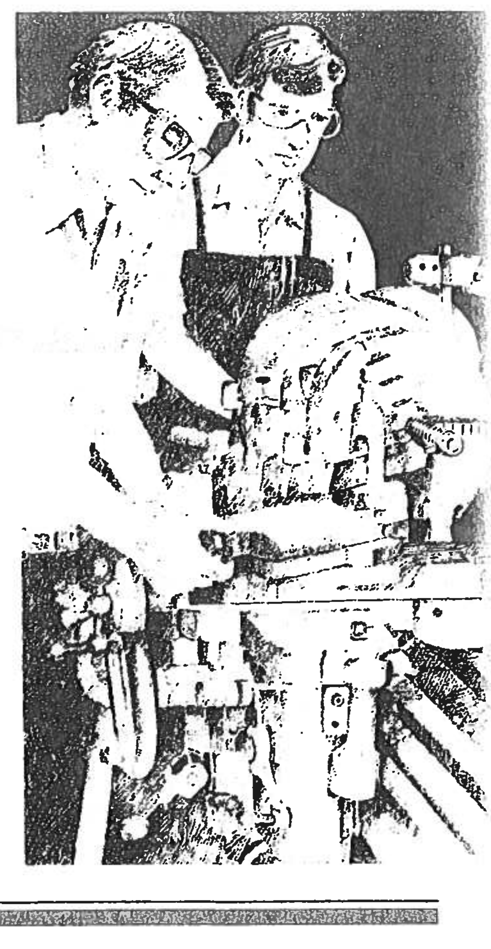
Metals Processes
Week 2

PART 6

As a youngster, Larry Barton was always fixing something or making something. It was easy for him to recognize early in life that he had mechanical ability and enjoyed working with his hands. So in high school he enrolled in shop and vocational programs. He also had the opportunity to participate in a cooperative training program, in which he worked part of the day in a machine shop. Later, of course, he learned many of his skills on the job.

After 22 years in industry, Larry is supervisor of the machine division of a pattern and foundry company, with 17 workers reporting to him. His division is responsible for a wide variety of threading operations, including cutting internal threads on castings and external threads on steel shafts. Although Larry has his share of paperwork to do, he spends most of his time with the machinery and his workers. Larry most enjoys guiding the younger workers gradually up through the ranks, just as he was guided himself. He emphasizes production, but not at the expense of quality. Helping his workers become skilled threaders and machinists is the main satisfaction of his job.

Because Larry works with young people, he has many thoughts for students considering careers in metalwork. He says they will need "lots and lots of math." Electronics and computers are being applied more and more in his business. The company has eight threading machines that use Computer Numerical Control (CNC). And knowing that in business "time is money," Larry advises students to make the best use of their time in every aspect of a project, from planning to finishing. That is the way to stay competitive in industry. And that is the way Larry runs his shop—efficiently and competitively.



Larry Barton
Machine Division Supervisor

UNIT 19

Screw Threads

A screw thread is a ridge of uniform shape that winds at a constant angle around the surface of a cylinder or a cone. Threads on bolts and screws are **external threads** (Fig. 19-1A). Threads on the inside of a hole or a nut are **internal threads** (Fig. 19-1B).

Threads may be **right-hand** or **left-hand.** A nut that is screwed **clockwise** onto a bolt has a right-hand thread (Fig. 19-2A). Most threads are right-hand. A nut that is screwed **counterclockwise** onto a bolt has left-hand threads (Fig. 19-2B).

The shaft on a grinder that has two grinding wheels (Fig. 44-1) has right-hand threads on the right side and left-hand threads on the left side. On working drawings, threads are assumed to be right-hand unless marked **LH** for left-hand.

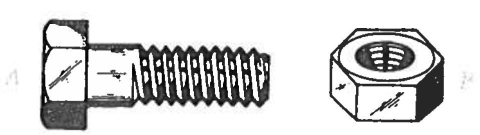
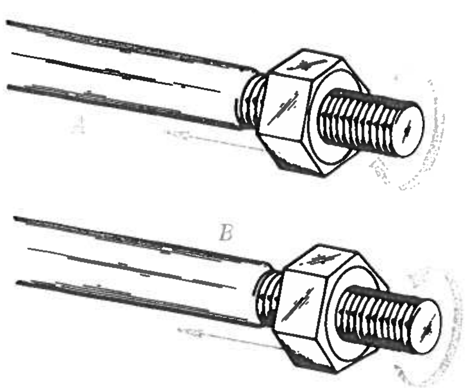


Fig. 19-1 Screw threads. (A) External. (B) Internal.

Fig. 19-2 Threads are either right-hand or left-hand. (A) A right-hand thread advances with clockwise rotation. (B) A left-hand thread advances with counterclockwise rotation.



19-1 Uses of Screw Threads

Screw threads are widely used on fasteners such as bolts, nuts, and screws. They make it easy to put parts together quickly or take them apart. Screw threads are also used to change rotary (turning) motion to straight-line motion. A good example is the lead screw on a metal lathe. As it revolves, it drives the carriage and cutting tool in a straight line. Threads are often used to increase mechanical advantage because they act like a wedge. The screw in a vise provides great mechanical advantage. It multiplies the turning effort of the user to apply great clamping force between the vise jaws. Screw threads are also used to make fine adjustments on instruments, tools, and machinery. The screw in micrometers makes precision measurement possible.

19-2 How Screw Threads Are Made

Hand taps and dies are used to cut threads manually, a process Units 20 and 21 discuss in detail. However, most threads are made with machine tools. Ordinary lathes, turret lathes, automatic lathes, milling machines, drilling machines, and thread-grinding machines all can make threads routinely.

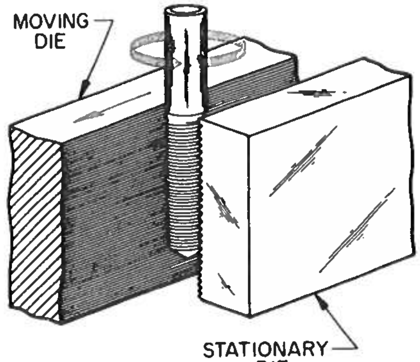


Fig. 19-3 The technique of thread rolling used in cold heading machines.

Most standard threaded fasteners are made from wire on automatic machines called **cold headers**. Cold headers use flat **thread-rolling dies** to form threads (Fig. 19-3). Cylindrical thread-rolling dies are available for use on lathes.

19-3 Screw Thread Terms

The following screw thread terms are adapted from American National Standards Institute (ANSI) definitions:[1]

Major diameter: The largest diameter of a straight external or internal thread (Figs. 19-4 and 19-5). The **nominal,** or **basic size** is similar to the major diameter, and is used for general identification, such as identifying the thread size as ¼" or ½" diameter.

Minor diameter: The smallest diameter on a straight external or internal thread (Figs. 19-4 and 19-5).

Pitch diameter: On a straight thread, the diameter of an imaginary cylinder that passes through the thread profile where the width of the thread and the width of the groove are equal (Figs. 19-4 and 19-5). The amount of clearance between mating threads is controlled by maintaining close tolerances on their pitch diameters.

[1]**Unified Screw Threads** (ANSI B1. 1-1960) Published by the American Society of Mechanical Engineers, New York, NY

Pitch: The distance from a point on one screw thread to a corresponding point on an adjacent thread, measured parallel to the thread axis (Fig. 19-4). The pitch of a thread is a measure of the **size** of the thread. For inch-based threads, pitch is equal to 1 divided by the number of threads per inch. For metric threads, pitch is expressed in millimeters.

The pitch of a thread may be determined with a steel rule or with a **screw pitch gage** (Fig. 19-6). Be sure to use customary inch tools for measuring inch-based threads, and metric tools for measuring metric threads.

Lead: The distance a thread moves along its axis in one revolution. On a single thread, the lead and pitch are the same. On a double thread, the lead is equal to twice the pitch. On a triple thread, the lead is equal to three times the pitch (Fig. 19-7).

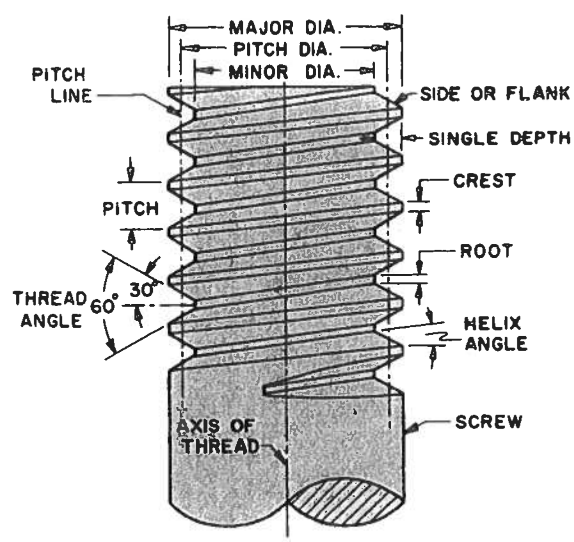
Lead, or helix, angle: Angle made by the **helix** of a thread at the pitch diameter, measured in a plane perpendicular to the axis of the thread (Fig. 19-4).

Multiple thread: A thread having the same thread form produced with two or more helical grooves, such as a double or triple thread (Fig. 19-7).

Crest: The top surface that joins the two sides of a thread (Fig. 19-4).

Root: The bottom surface that joins the two sides of adjacent threads (Fig. 19-4).

Fig. 19-4 The principle parts of a screw thread.



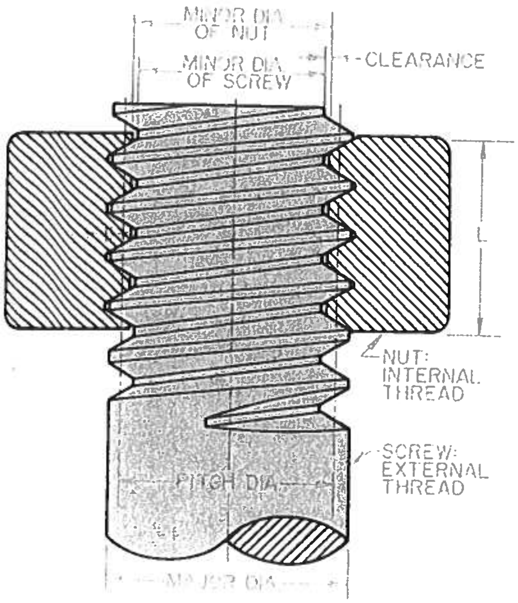
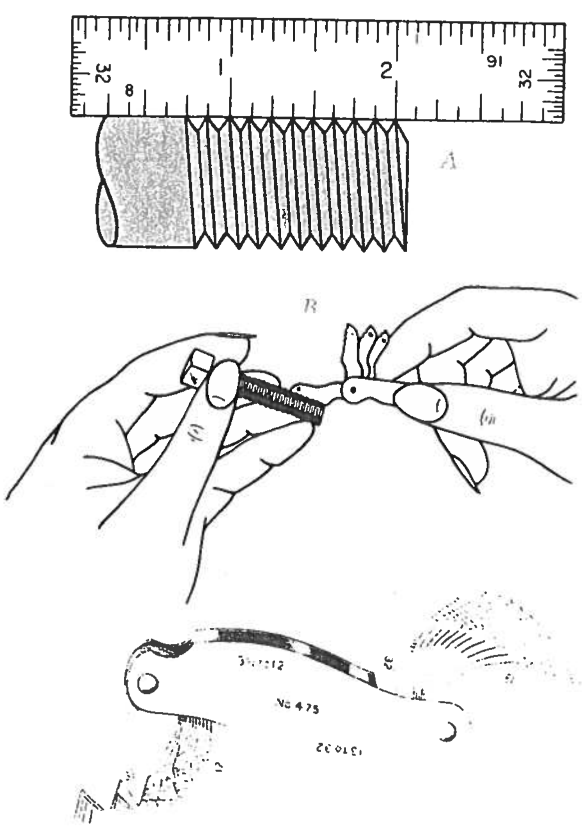


Fig. 19-5 *A comparison between the minor diameters of a screw and a nut, showing the clearance between them. External threads and internal threads of matching bolts and nuts have the same basic pitch diameters.*

Fig. 19-6 *Measuring the number of threads per inch. (A) Using a steel rule. (B) Using a screw pitch gage.*

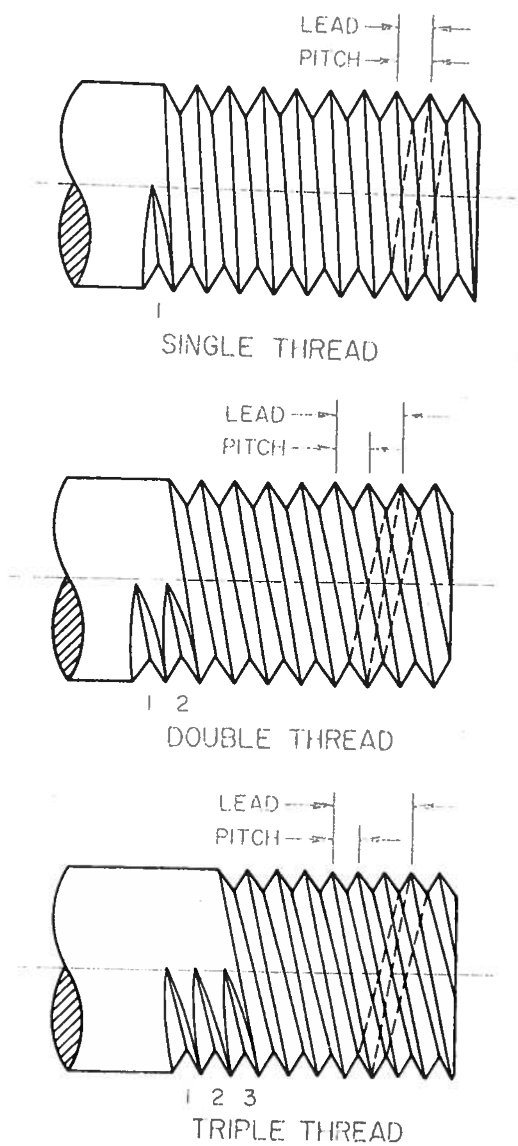


Side or flank: The surface that connects the crest with the root on either side of a thread (Fig. 19-4).

Clearance: The distance between the crest of a thread and the root of a mating thread, measured perpendicular to the thread axis (Fig. 19-5).

Height of thread: (Sometimes called the **single depth** of thread.) The distance between the major and minor diameters of the thread, measured perpendicular to the axis of the thread.

Fig. 19-7 *The pitch and leads of multiple threads are related as shown here.*



19-4 Development of Screw Threads in the United States

The cross-sectional shape of a screw thread is called its **profile** or **form.** Early threads had no flat crests. To overcome the objections to this sharp V-thread form, the United States Standard Form Thread was developed (Fig. 19-8). It was developed during the 1860s, and was first adopted by the United States Navy in 1868. This thread form was widely adopted by American industries. Some manufacturers, however, continued to make threads according to their own systems. Often, bolts made by one manufacturer would not fit nuts made by another.

TECHNOLOGIES AND PRACTICES

William Sellers: Standard Setter of American Manufacturing

Imagine that you have lost an important metal part—say, the nut that holds your bicycle tire to the frame. You go to the bicycle shop and find that none of the nuts they have will fit your bike. In fact, youı lost part is one of a very limited number of parts, and it will be very difficult to get another one. Maybe you'll never be able to get your bike back together!

This imagined scene will give you some idea of what American manufacturing was like in the mid-1800s. Mass production had begun, but the industrial system had a lot of "bugs" in it. For one thing, there were no standards for screw threads, so a part made by one manufacturer often wouldn't fit a machine made by another. The lack of a standard thread greatly troubled those who were concerned about precision and quality in machine tool production.

One of these people was manufacturer William Sellers (1824-1905). Trained as a machinist and mechanical engineer, Sellers opened and operated a machine tool manufacturing plant in Philadelphia. He insisted on accuracy in all of the company's work. If a measurement was off by even a "hair's breadth," he saw that it was adjusted.

In 1864 Sellers proposed to standardize screw threads. He suggested that all screw threads be made with a sixty-degree angle. He also said that threads should be made with flat crests and roots instead of with the sharp V-shaped form then common.

Sellers' two ideas were used in designing the Standard Form Thread, which was adopted by the U.S. Navy in 1868. Within ten years, Sellers' screw thread was used all over the country. By 1894, this screw thread had become the standard for international use.

Sellers set other trends in machine tool manufacturing, including simple, practical designs and added weight for durability. Machines made by Sellers' company gained a reputation for excellent performance. His insistence on precision, standardization, and simplicity helped advance the general standard of manufacturing. And it was Sellers' influence that made shopping for replacement parts a simple task, instead of a cause for alarm.

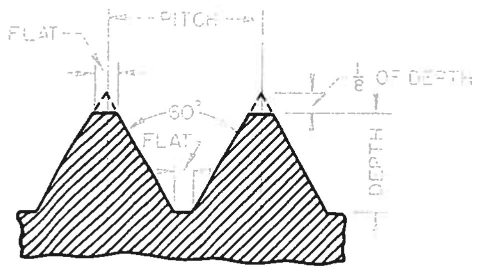


Fig. 19-8 The American National Standards Institute (ANSI) Form for an external thread.

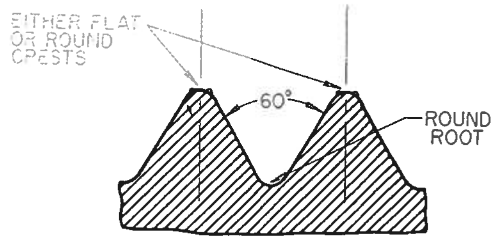


Fig. 19-9 The Unified Screw Thread Form.

During World War I the need arose for more standardization of screw threads. Congress established the National Screw Thread Commission to develop and adopt new screw thread standards.

This committee and other cooperating agencies produced the American National Screw Thread Standard in 1924. The thread profile was named the **American National Form Thread** and was much the same as the United States Standard Form Thread (Fig. 19-8). The Commission also established the **National Fine Thread.** This form was like a thread form the Society of Automotive Engineers (SAE) had recommended in 1911. The SAE **Extra-Fine Thread Series** was added (with modifications) to the American National Screw Thread Standard that the Commission approved in 1933.

In 1948, the United States, Canada, and Great Britain agreed to use the **Unified Screw Thread** so that threaded parts made in each of the countries would be interchangeable. American industry now uses Unified threads instead of the older American National threads.

19-5 Unified Screw Threads

The **Unified Screw Thread** generally has rounded roots and may have either rounded or flat crests (Fig. 19-9). These are the main differences from the American National thread form. American industries use flat crests, while the English prefer rounded crests. The rounded root is optional on both the external and the internal threads for most applications; however, for some applications the root must be rounded.

The calculations for an external **Unified Form** thread may be made with the following formulas (See Figs. 19-8 and 19-9):

$$\text{Pitch} = P = \frac{1}{\text{number of threads per inch}}$$

$$\text{Depth} = D = 0.61343 \times P$$

$$D = \frac{0.61343}{\text{number of threads per inch}}$$

$$\text{Flat at crest} = F = \frac{P}{8}$$

The depth of the external Unified Form Thread is slightly less than the depth for the American National Form Thread. However, these two kinds of threads are essentially the same. Production tolerances permit them to be used interchangeably in most instances.

The depth of the internal Unified Form Thread is equal to 0.51427 × P, or 0.51427 divided by the number of threads per inch. The following common screw thread series are included in the Unified Screw Threads[2]:

1. **Unified National Coarse Thread (UNC):** adopted from the NC thread. (See Table 19–1.)
2. **Unified National Fine Thread (UNF):** adopted from the NF thread. (See Table 19-1.)

[2] **Unified and American Screw Threads** (ANSI B1.1-1949) and later edition, **Unified Screw Threads** (ANSI B1.1-1960), published by the American Society of Mechanical Engineers, New York.

Table 19-1

Unified Screw Threads

Diameter			Threads per inch		
No.	Inch	Decimal Equivalent	UNC (NC) (USS)	UNF (NF) (SAE)	UNEF (NEF) (EF)
0		.0600		80	
1		.0730	64	72	
2		.0860	56	64	
3		.0990	48	56	
4		.1120	40	48	
5	1/8	.1250	40	44	
6		.1380	32	40	
8		.1640	32	36	
10		.1900	24	32	
12		.2160	24	28	32
	1/4	.2500	20	28	32
	5/16	.3125	18	24	32
	3/8	.3750	16	24	32
	7/16	.4375	14	20	28
	1/2	.5000	13	20	28
	9/16	.5625	12	18	24
	5/8	.6250	11	18	24
	11/16				24
	3/4	.7500	10	16	20
	13/16				20
	7/8	.8750	9	14	20
	15/16				20
	1	1.0000	8	14	20

3. **Unified National Extra-Fine Thread (UNEF):** adopted from the NEF thread. (See Table 19-1.)
4. Other less-common series, such as the **8-thread series (8UN)**, the **12-thread series (12UN)**, and the **16-thread series (16UN)** are also included.

19-6 Unified Thread Classes

Six **classes** of threads, formerly called **fits**, are used with Unified screw threads. The six classes include three external classes and three internal classes. The external thread classes are designated **1A, 2A,** and **3A.** The internal classes are designated **1B, 2B,** and **3B.** "Thread fit" means the degree of tightness between mating threads. Normally, class 2A and class 2B threads are mated. However, any Unified class of external thread may be mated with any internal class, as long as the product meets the necessary tightness requirements. The following classes of mated threads have tolerances that result in the following types of fit:

Classes 1A and 1B: loose fit
Classes 2A and 2B: free fit
Classes 3A and 3B: close fit

When classes 2A and 3B are mated, the tolerances permit an intermediate fit ranking between the free and close fits.

19-7 Other Common Thread Forms

Square Thread

A square thread is formed like a square (Fig. 19-10). The depth and width of the groove are equal. The height and width of each ridge between the grooves are also equal. Thus, the groove and ridge form two squares. The screw is very strong and is used in house jacks and similar applications.

Acme Thread

Acme threads are usually used on the **lead screw** of a lathe. They are also used on many other kinds of machine tools. The angle of the thread is 29° (Fig. 19-11). Handbooks for machinists have information about pitches, fits, tolerances, and allowances for acme threads.

Pipe Threads

American National Standard pipe threads are used for assembling pipes and pipe fittings. Plumbers and pipefitters use four types of standard pipe threads.

American National Standard Taper Pipe Threads (NPT) are used for pipe-fitting jobs that require a low-pressure seal against liquid or gas leakage. A pipe compound or sealant is normally used with this type thread. The NPT threads are tapered 3/4" per foot (62.48 mm per meter) on the diameter (Fig. 19-12). The angle

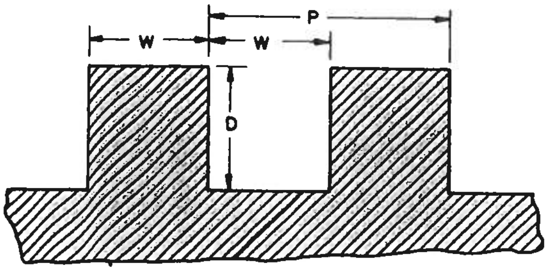


Fig. 19-10 *The square thread.*

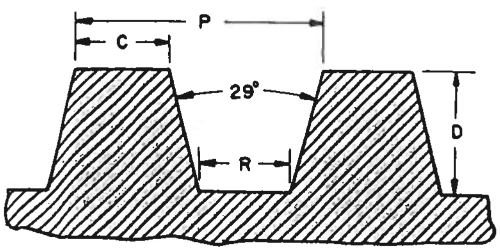


Fig. 19-11 *The Acme thread.*

between the sides of the thread is 60°. The farther the tapered threads are screwed together, the tighter the joint becomes. Table 19-2 provides basic data for different sizes of pipe.

American National Standard Railing Joint Taper Pipe Threads (NPTR) make a rigid, mechanical, tapered thread joint for use in railing construction.

American National Standard Straight Pipe Threads (NPS) have several types:

1. The **NPSC** thread is used in pipe couplings.
2. The **NPSM** thread is designed for use in free-fitting mechanical joints.
3. The **NPSL** is for use in loose-fitting mechanical joints with locknuts.
4. The **NPSH** is for loose-fitting mechanical joints in hose couplings.

American National Standard Dryseal Taper Pipe Threads (NPTF) are used in applications that require a gas or liquid tight thread joint without the use of pipe compound or sealant. The four forms of Dryseal threads are listed below:

NPTF—Dryseal Standard Pipe Thread
PTF-SAE Short—Dryseal SAE Short Taper Pipe Thread
NPSF—Dryseal Standard Fuel Internal Straight Pipe Thread
NPSI—Dryseal Standard Intermediate Internal Straight Pipe Thread

Further information about the different types of pipe threads is available in handbooks for machinists.

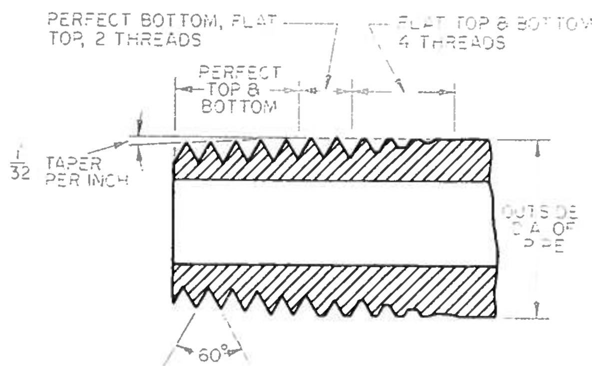


Fig. 19-12 *Taper pipe threads (NPT).*

Table 19-2

Pipe Threads, Pipe Dimensions, and Tap Drill Sizes

Pipe diameters				
Nominal Size inches	Actual inside	Actual outside	Threads Per inch	Tap drill size
1/8	0.270	0.405	27	11/32
1/4	0.364	0.540	18	7/16
3/8	0.494	0.675	18	19/32
1/2	0.623	0.840	14	23/32
3/4	0.824	1.050	14	15/16
1	1.048	1.315	11 1/2	1 5/32
1 1/4	1.380	1.660	11 1/2	1 1/2
1 1/2	1.610	1.900	11 1/2	1 23/32
2	2.067	2.375	11 1/2	2 3/16
2 1/2	2.468	2.875	8	2 5/8

19-8 ISO Metric Threads

In 1949, the **International Standards Organization (ISO)** recommended worldwide adoption of three series of metric threads. These threads are based on the same 60-degree thread form adopted for the **ISO Inch** (Unified) threads, (Fig. 19-9). The three series are (1) **ISO Metric coarse pitch,** (2) **ISO Metric fine pitch,** and (3) **ISO Metric constant pitch. ISO Metric and ISO Inch threads have the same thread form but are not interchangeable because of differences in diameters and pitches.**

Figure 19-13 compares the ISO Metric coarse series thread sizes with the Unified National (ISO Inch) coarse series thread sizes. Table 19-3 gives a complete listing of ISO Metric coarse and fine pitch thread sizes.

Only ISO Metric coarse pitch threads are commonly used on fasteners. ISO Metric fine pitch threads are used mostly on precision tools and instruments. The constant pitch series threads are used mainly on machine parts, but are also used on all spark plugs.

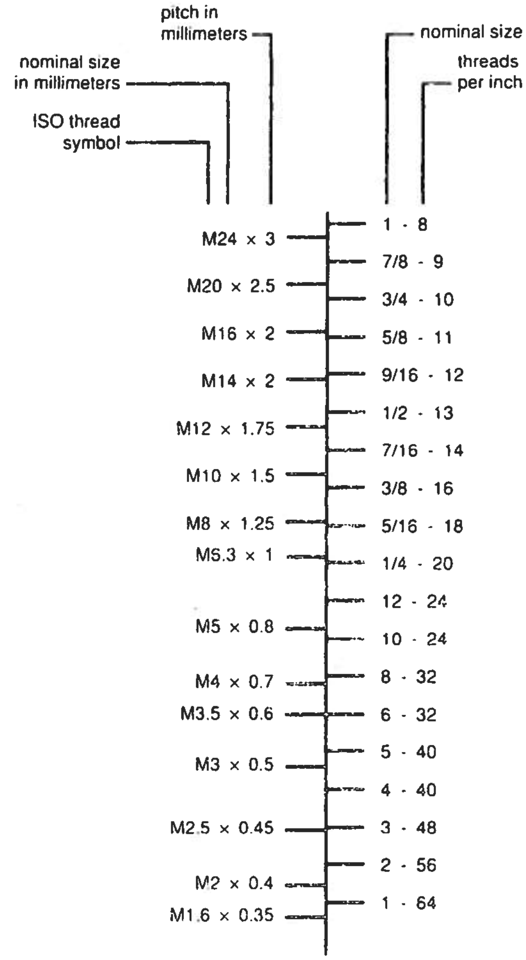


Fig. 19-13 A comparison of the common sizes of ISO Metric Coarse threads with Unified National (ISO Inch) Coarse threads.

Classes of ISO Metric Threads

Basically, there are three ISO Metric classes of fit: **fine, medium,** and **coarse.** The classes of fit are more accurately identified by giving the **tolerance grade** and the **tolerance position** of the mating threads. Tolerance grades are specified by a number that can be applied to both pitch and major diameter. Tolerance position is specified with a lower case (small) letter for external threads and with a capital letter for internal threads as follows:

External Threads:	Internal Threads:
e = large allowance	**G** = small allowance
g = small allowance	**H** = no allowance
h = no allowance	

Table 19-4 shows the tolerance classes for external and internal threads, and matches them with the three classes of fit.

Thread Designation

All ISO Metric thread designations begin with the capital letter "M." Next, the major diameter in millimeters is given. This is followed by the thread pitch in millimeters, separated from the first number by a "times" mark (×). The pitch may be omitted when designating coarse threads. Therefore, an ISO Metric 16 mm coarse thread with a pitch of 2 mm would simply be designated M16. The same diameter in a fine thread would be designated M16 × 1.5. Complete designations for ISO Metric threads include identification of the tolerance class.

Additional information on ISO Metric threads can be found in handbooks for engineers and machinists.

Table 19-3

ISO Metric Threads

Nominal size mm	Pitch mm	Tap drill mm	Clearance drill mm	Pitch mm	Tap drill mm
Coarse series				Fine series	
Approximately 75% thread					
1.4	0.3	1.1	1.55	—	—
1.6	0.35	1.25	1.8	—	—
2	0.4	1.6	2.2	—	—
2.5	0.45	2.05	2.6	—	—
3	0.5	2.5	3.2	—	—
4	0.7	3.3	4.2	—	—
5	0.8	4.2	5.2	—	—
6	1.0	5.0	6.2	—	—
8	1.25	6.75	8.2	1	7.0
10	1.5	8.5	10.2	1.25	8.75
12	1.75	10.25	12.2	1.25	10.50
14	2	12.00	14.2	1.5	12.50
16	2	14.00	16.45	1.5	14.50
18	2.5	15.50	18.20	1.5	16.50
20	2.5	17.50	20.50	1.5	18.50
22	2.5	19.50	22.80	1.5	20.50
24	3	21.00	24.60	2	22.00
27	3	24.00	27.95	2	25.00

Table 19-4

ISO Tolerance Classes of Threads Identified with the Class of Fit

Class of fit	Tolerance class: External threads	Tolerance class: Internal threads
Fine	4h	5H
Medium	6g	6H
Coarse	8g	7H

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WORDS TO KNOW

acme thread
class of thread
depth of thread
dies
double thread
Dryseal thread
external threads
internal threads
ISO Inch threads
ISO Metric threads
lead of thread
left-hand thread
major diameter
minor diameter
multiple thread
nominal size
pipe compound
pitch diameter
pitch of thread
right-hand thread
root diameter
screw-pitch gage
single thread
square thread
tapered
taps
thread designation
tolerance class
triple thread
Unified Form thread

(Review Continued)

Review Questions

1. Are most screw threads right-hand or left-hand?
2. How can you tell whether the thread on a bolt is right-hand or left-hand?
3. What is a double thread? Triple thread? Multiple thread?
4. What is meant by major diameter?
5. What is meant by minor diameter?
6. What is the pitch diameter?
7. What is the pitch of a thread?
8. What is the lead of a thread? What is the difference between lead and pitch?
9. Describe two ways to measure the pitch of a thread.
10. Describe a square thread and give an example of where it is used.
11. Describe an Acme thread and give an example of where it is used.
12. List the four types of pipe threads. Which is used for general purpose plumbing?
13. How do NPT threads differ from Unified screw threads?
14. Why aren't ISO Metric threads interchangeable with Unified National threads?
15. Explain how ISO Metric threads are designated.
16. Where can additional information be obtained on screw threads?

UNIT 20 External Threading with Dies

Most threads are made with machine tools. However, skilled metalworkers sometimes find it necessary to cut threads by hand with dies.

20-1 Threading Dies

A **threading die** is a tool for cutting **external threads** on a round rod, such as those on a bolt. Small diameter threads are cut with small round dies that are either **solid** or **adjustable** (Fig. 20-1). Larger diameter threads are cut with dies that use **adjustable** and **replaceable** cutters (Fig. 20-2). The main body of this type of die is called a **collet.** The cutters are held in place with a threaded ring called a **guide.** The hole in the center of the guide is a close fit with the rod being threaded. This helps to guide the die so that it will go on the rod squarely.

Rethreading dies are square or hexagonal in shape so they can be turned with an ordinary wrench (Fig. 20-3). They are used only for rethreading of damaged threads.

Left-hand dies cut left-hand threads. They are stamped with either an "L" or an "LH." Right-hand dies are unmarked.

A **screw plate** is a set of threading tools that includes dies, taps, and the tools needed to use them (Fig. 20-4).

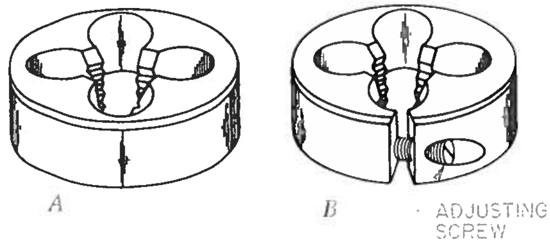


Fig. 20-1 *Threading dies. (A) Solid. (B) Adjustable.*

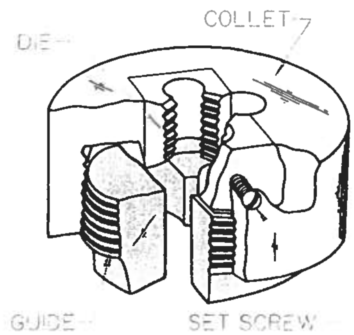


Fig. 20-2 *An adjustable die with replaceable cutters.*

A **diestock** is a tool for holding and turning a threading die (Fig. 20-5). Diestocks are made in several sizes to fit dies of different diameters.

20-2 Sizes of Threading Dies

The diameter and pitch of the thread that is produced are stamped on each die, together with the kind of thread. For example, **¼-20 UNC** means that the die will cut a Unified National Coarse thread with a major diameter of ¼" and 20 threads per inch. The sizes of inch-based threads are given in Table 19-1. A die marked M8 × 1.25 is a metric die that will cut a thread with a major diameter of 8 mm and a pitch of 1.25 mm. The sizes of metric threads are given in Table 19-3.

It should be noted that the diameter of the rod on which a thread is to be cut should be the same as the major diameter of the die.

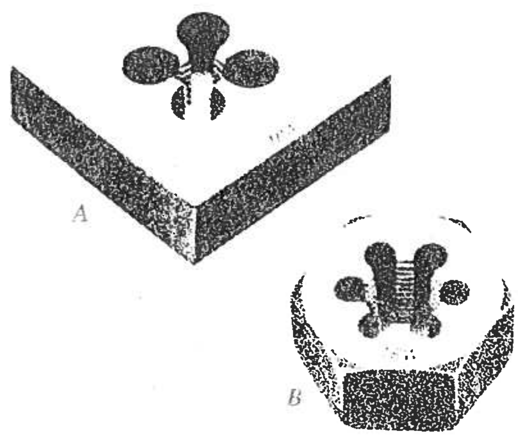


Fig. 20-3 *Rethreading dies. (A) Square. (B) Hexagonal.* (Greenfield Tap & Die/Div. of TRW, Inc.)

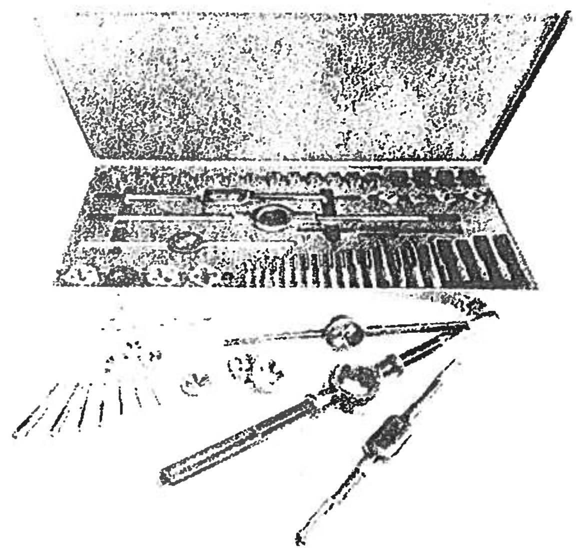
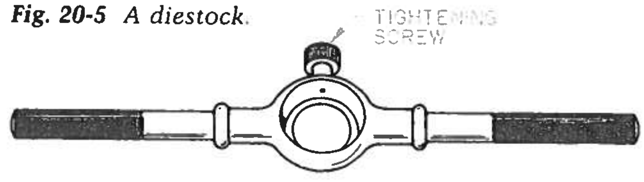


Fig. 20-4 *A screw plate (a set of taps and dies, die stock, and tap wrenches).* (Greenfield Tap & Die/Div. of TRW, Inc.)

Fig. 20-5 *A diestock.*



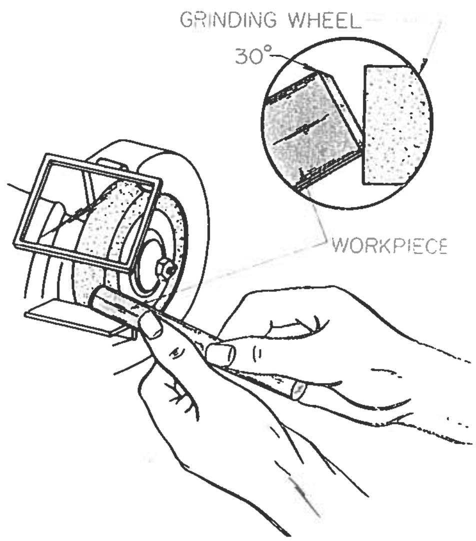


Fig. 20-6 Beveling the end of the workpiece before threading.

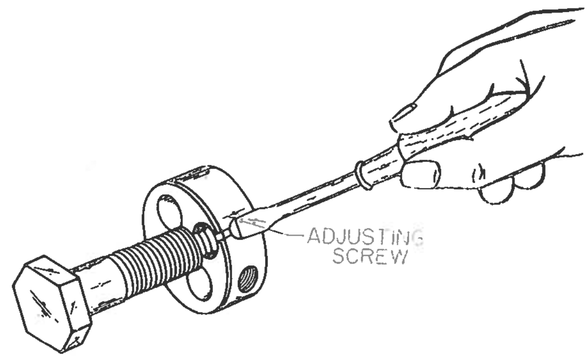


Fig. 20-7 Adjusting a threading die to a standard bolt.

20-3 How to Cut a Thread with a Die and Diestock

1. Bevel the end of the rod to be threaded (Fig. 20-6). ("Bevel" means to slant or taper the edge.) This makes it easier for the die to start the thread.
2. Hold the rod tightly in a machinist's vise so that it cannot turn.
3. Adjust the die to fit a **standard** bolt, that is, a bolt with threads of the same size you want to make (Fig. 20-7).
4. Mount the die in the diestock. Secure it with the **tightening screw** (Fig. 20-5).
5. Place the tapered, or **starting side,** of the die on the rod (Fig. 20-8).
6. Hold the diestock with both hands near the die (Fig. 20-9). **Keep the die as square as possible with the rod.** Press down firmly and at the same time slowly rotate the die **clockwise.** Larger die sizes require more pressure to get the die started. After two or three threads have been cut, heavy pressure on the die is no longer necessary. The die will continue to screw itself onto the rod as it is rotated.
7. Shift the position of your hands to the ends of the diestock, add a little cutting fluid, and continue to cut the thread (Fig. 20-10). Back up the die a half-turn every two or three threads to break and clean away the chips. This helps keep chips from clogging the die and roughening up the thread.

Threading to a shoulder. A shoulder is a diameter larger than the thread diameter. When full threads are needed as close to a

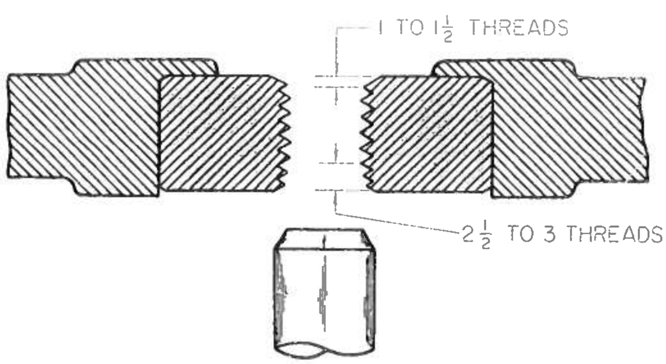


Fig. 20-8 The starting side of the threading die has the most tapered threads.

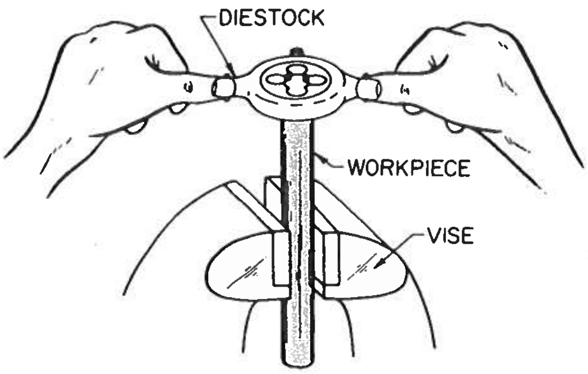


Fig. 20-9 Placing the hands near the die on the diestock is important when starting a thread.

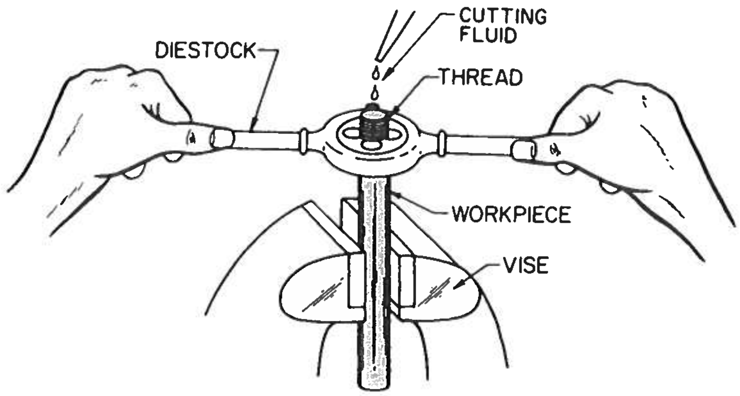


Fig. 20-10 The hands may be moved to the ends of the diestock after cutting several threads.

shoulder as possible, first cut the threads in the usual manner as described above. This will leave several partly cut threads near the shoulder. Then turn the die over and cut the partly finished threads up to the shoulder (Fig. 20-11). **Never cut full threads with the wrong side of the die, since the stress of cutting will usually result in broken die teeth.**

20-4 Cutting Fluids for Threading

When threading steel, use **sulfurized mineral oil** or one of the commercial cutting fluids made especially for threading steel. Special threading fluids are also available for aluminum. Cutting fluid recommendations for other metals are given in Table 50-2.

20-5 External Thread Measurements

External threads must be cut to the correct depth to produce the proper fit or class of thread. If the pitch diameter is too large, the thread fits too tightly. If it is too small, it fits too loosely.

The fit or class of external screw threads can be determined in the following ways:

1. By testing how the threaded piece fits in a standard mating nut or threaded hole.
2. By measuring the pitch diameter either with a thread micrometer (Fig. 14-4) or using the three-wire method with a plain micrometer.
3. With a thread ring gage (Fig. 93-13).
4. With a thread-roll snap gage (Fig. 93-10).

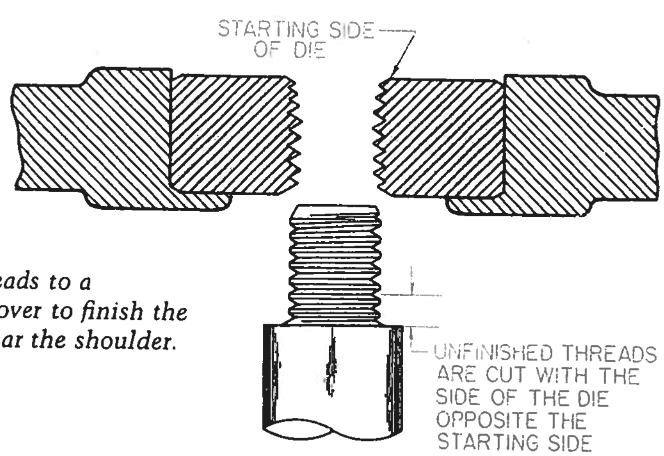


Fig. 20-11 Cutting threads to a shoulder. Turn the die over to finish the partially cut threads near the shoulder.

REVIEW REVIEW REVIEW REVIEW REVIEW

Words to Know

adjustable die
bevel
collet
cutting fluid
diestock
left-hand die
rethreading die
right-hand die
screw plate
solid die
thread micrometer
thread ring gage
threading die
thread-roll gage
starting side

Review Questions

1. What tool is used for cutting external threads?
2. Describe three kinds of dies for cutting new threads.
3. What kind of die is used for recutting damaged threads?
4. What is a screw plate?
5. What does ¼-20 UNC on a die mean?
6. What is a diestock?
7. Why should the end of a rod be beveled before threading?
8. Why is it necessary to back up the die when threading?
9. What kind of cutting fluid should be used when threading steel?
10. List several ways in which the fit or class of thread can be determined.

UNIT 21

Internal Threading with Taps

Most threaded studs, bolts, and screws have mating parts that have a hole with internal threads. Metalworkers sometimes cut these threads by hand with threaded taps. This unit describes the use of taps for internal threading, a necessary skill for most metalworkers.

21-1 Taps

A **tap** is a tool for cutting **internal threads.** It has threads like a bolt with two, three or four **flutes** (grooves) cut across the threads (Fig. 21-1). The edges of the thread formed by the flutes are the cutting edges (Fig. 21-2). The **shank** end of the tap is square so that it can be turned with a wrench.

Taps are made from carbon steel or high-speed steel and are hardened and tempered. A set of taps includes a taper tap, a plug tap, and a bottoming tap (Fig. 21-1).

The **taper tap** has about six threads tapered at the end so that it will start easily. The taper also makes it easier to keep the tap straight as the cut is begun. The threads are cut gradually as the tap is turned into the hole.

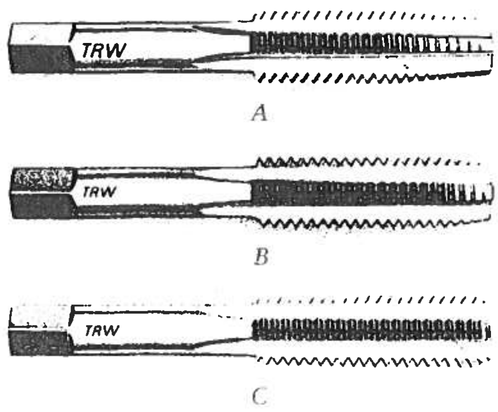


Fig. 21-1 *A set of hand taps. (A) Taper. (B) Plug. (C) Bottoming.* (Greenfield Tap & Die/Division of TRW Inc.)

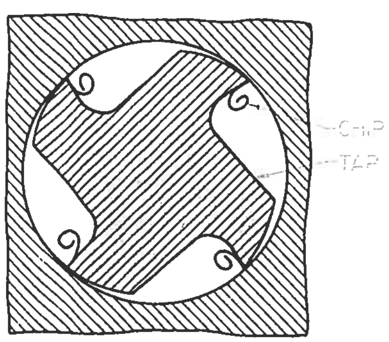


Fig. 21-2 *How the cutting edges of a tap cut.*

The **plug tap** has three or four threads tapered at the end and is used as a starting tap on easily cut metals.

The **bottoming tap** has full threads except for the first thread and is used to cut full threads as close as possible to the bottom of a hole.

21-2 Tap Styles

Taps are made in many styles to suit various hand- and machine-tapping operations.

Hand taps are straight-fluted, have three or four flutes, and have a cutting edge parallel to the center line of the tap (Fig. 21-5A). Chips tend to collect in the flutes of these taps. Unless the tap is backed out to clear it of chips, the tap may bind in the hole and break. **Gun taps** and **helical-fluted taps** are designed for efficient chip removal, thereby permitting rapid thread cutting with a minimum of tap breakage.

Gun taps are straight-fluted, with two, three, or four flutes depending on the size of the tap (Fig. 21-3). The cutting edges are ground at an angle to the centerline of the tap. The angular cutting edges cause the chips to shoot ahead of the tap. Plug-type gun taps are designed for tapping open, or **through,** holes. Bottoming-type gun taps are designed for tapping blind holes (holes that go only part-way into a workpiece), producing fine chips that can readily escape.

Helical-fluted taps, commonly known as **spiral-fluted taps** (Fig. 21-4), are designed to lift the chips out of the hole being tapped. For

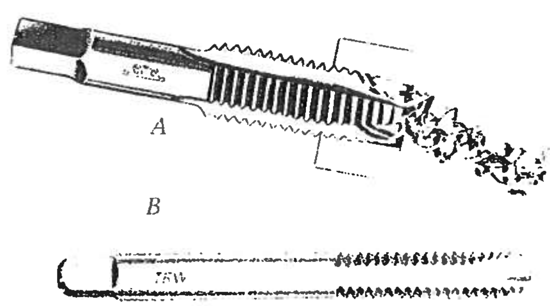
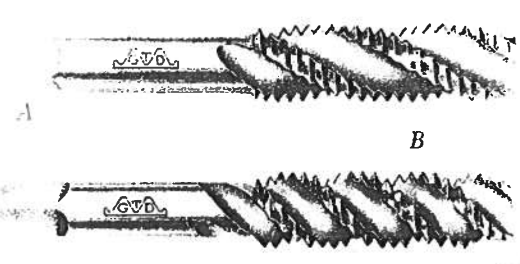


Fig. 21-3 *Gun taps. (A) Plug-type. Note the chip formation. (B) Bottoming-type* (Greenfield Tap & Die/Division of TRW Inc.

Fig. 21-4 *Spiral-fluted taps. (A) Low-angle. (B) High-angle.* (Greenfield Tap & Die/Division of TRW, Inc.)



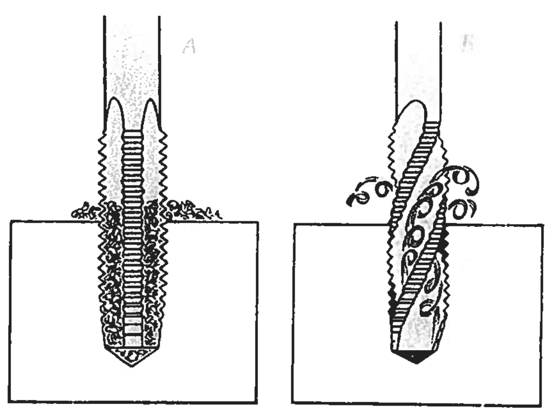
this reason, they are well suited for tapping blind holes. **Low-angle** spiral-fluted taps are best for tapping ductile materials like aluminum, copper, or die-cast metals (Fig. 21-5B). **High-angle** spiral-fluted taps work best on tough metals, such as carbon and alloy steels. They are made with two, three, or four flutes, depending on the tap diameter, and are available in plug and bottoming types.

Serial taps are usually made in sets of three. They have one, two, or three identifying rings cut at the end of the shank (Fig. 21-6). These taps are designed for cutting threads in very tough metals. The taps are similar in appearance to the taper, plug, and bottoming taps, but they differ in **pitch diameter** and **major diameter.** Each tap is designed to remove part of the metal that must be cut away to produce the thread. The No. 1 tap is used first to make a shallow thread, then the No. 2 tap is used, and the No. 3 tap cuts the thread to final size.

Thread-forming taps (Fig. 21-7) have no cutting edges and therefore produce no chips. Threads are formed by forcing the metal to flow around the threads on the tap. This produces a strong thread, because the grain of the metal is forced to follow the thread profile and the surface is somewhat **work-hardened.** Because of the high pressures involved, thread depths are less than those produced by conventional taps. Tap drills used with thread-forming taps (drills used to make the holes to be tapped) must be larger than those used with comparable conventional taps. The manufacturer's tap drill size recommendations should be carefully followed.

Left-hand taps cut left-hand threads. They are stamped with an "L" or an "LH." Right-hand taps are unmarked.

Fig. 21-5 The cutting action of straight-fluted taps compared to spiral-fluted taps. (A) Straight-fluted hand tap. (B) Low-angle, spiral-fluted tap. (Greenfield Tap & Die/Division of TRW, Inc.)



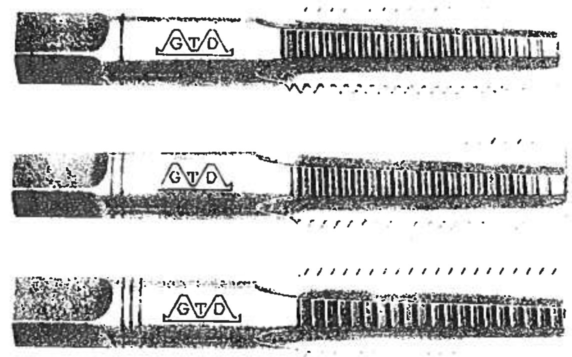


***Fig. 21-6** A set of serial taps.* (Greenfield Tap & Die/Division of TRW, Inc.)

***Fig. 21-7** A thread-forming tap.* (Greenfield Tap & Die/Division of TRW, Inc.)

21-3 Sizes of Taps

Taps are made the same sizes as bolts and screws. The major diameter, pitch, and kind of thread are stamped on the shank of the tap. For example, **¼-20 UNC** means that the outside diameter of the tap is ¼", there are 20 threads per inch, and the thread is Unified National Coarse. Table 21-1 gives the sizes of inch-based taps.

A tap marked **M6 × 1** is a metric tap with an outside diameter of 6 mm and a pitch of 1 mm. The sizes of metric taps are given in Table 19-3.

21-4 Tap Size Limits

The size of the pitch diameter of a tap determines the **depth** and the **fit** of a tapped thread. Internal threads may be tapped for various classes of threads, such as classes 1B, 2B, and 3B. The thread may be either a loose or tight fit, depending on the pitch diameter of the tap.

Taps are available with either **cut** threads or **ground** threads. The ground threads produce tapped threads to a very accurate size. Taps with ground threads are made with **standard, oversize,** or **undersize** pitch diameters. The size limits of the pitch diameter are indicated by a **pitch diameter limit number,** such as L1, H1, H2, or H6, on the shank of ground thread taps. When purchasing taps of this type, the limits code number and the fit or class of thread to be tapped should be specified. If they are not specified, the supplier generally sends taps with pitch diameter limits for either of two sizes. One produces tapped threads for a Class 2 fit for National Form threads. The other produces threads for a Class 2B fit for Unified Form threads. These fits are used on most commercially available bolts, screws, and nuts.

The recommended taps for specific types of threads, including limits code numbers for various thread fits and classes of threads, are given in standard handbooks for machinists. For example, a ⅜-16 UNC ground thread tap for a Class 2B thread would be identified with the letter G and with the additional number H5; for a Class 3B thread, the code number would be GH3.

21-5 Internal Thread Measurement

Internal threads are checked for the correct fit or class of thread with **thread plug gages,** as shown in Unit 93.

21-6 Tap Drills

The hole to be tapped must be the right size. If the hole is too large, the thread will be too shallow; if it is too small, the tap may break. The drill that is used to make the hole before tapping is called the **tap drill.**

The tap drill should be a little larger than the diameter at the bottom, or **root,** of the thread, known as the **minor diameter** (Fig. 21-8). To save the time of figuring, tap drill sizes are put in the form of a table such as Table 21-1. The tap drill recommended for average work produces threads that are about 75% of the depth of external threads.

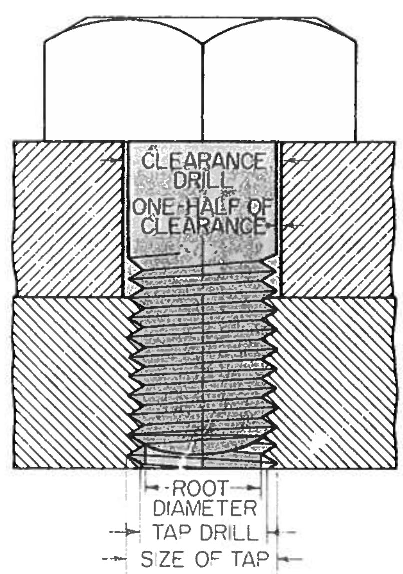


Fig. 21-8 *This drawing shows how the size of a tap, the size of a tap drill, and the minor (root) diameter of the thread compare to each other.*

Table 21-1

Tap Drills[1] and Clearance Drills[2] for Inch-Based Taps

Size of tap				Size of tap drill (in inches) for 75% thread depth			Clearance drill (inches)		
UNC NC (USS)	UNF NF (SAE)	Outside diameter (inches)	Root diameter (inches)	Number and letter drills	Fractional drills	Decimal equivalent	Size	Decimal equivalent	Clearance (inches)
	#0-80	0.0600	0.0438	. . .	3/64	0.0469	#51	0.0670	0.0070
#1-64	. . .	0.0730	0.0527	53	. . .	0.0595	#47	0.0785	0.0055
	#1-72	0.0730	0.0550	53	. . .	0.0595	#47	0.0785	0.0055
#2-56	. . .	0.0860	0.0628	50	. . .	0.0700	#42	0.0935	0.0075
	#2-64	0.0860	0.0657	50	. . .	0.0700	#42	0.0935	0.0075
#3-48	. . .	0.0990	0.0719	47	. . .	0.0785	#36	0.1065	0.0075
	#3-56	0.0990	0.0758	45	. . .	0.0820	#36	0.1065	0.0075
#4-40	. . .	0.1120	0.0795	43	. . .	0.0890	#31	0.1200	0.0080
	#4-48	0.1120	0.0849	42	. . .	0.0935	#31	0.1200	0.0080
#5-40	. . .	0.1250	0.0925	38	. . .	0.1015	#29	0.1360	0.0110
	#5-44	0.1250	0.0955	37	. . .	0.1040	#29	0.1360	0.0110
#6-32	. . .	0.1380	0.0974	36	. . .	0.1065	#25	0.1495	0.0115
	#6-40	0.1380	0.1055	33	. . .	0.1130	#25	0.1495	0.0115
#8-32	. . .	0.1640	0.1234	29	. . .	0.1360	#16	0.1770	0.0130
	#8-36	0.1640	0.1279	29	. . .	0.1360	#16	0.1770	0.0130
#10-24	. . .	0.1900	0.1359	25	. . .	0.1495	13/64	0.2031	0.0131
	#10-32	0.1900	0.1494	21	. . .	0.1590	13/64	0.2031	0.0131
#12-24	. . .	0.2160	0.1619	16	. . .	0.1770	7/32	0.2187	0.0027
	#12-28	0.2160	0.1696	14	. . .	0.1820	7/32	0.2187	0.0027
1/4"-20	. . .	0.2500	0.1850	7	. . .	0.2010	17/64	0.2656	0.0156
	1/4"-28	0.2500	0.2036	3	. . .	0.2130	17/64	0.2656	0.0156
5/16"-18	. . .	0.3125	0.2403	F	. . .	0.2570	21/64	0.3281	0.0156
	5/16"-24	0.3125	0.2584	I	. . .	0.2720	21/64	0.3281	0.0156
3/8"-16	. . .	0.3750	0.2938	. . .	5/16	0.3125	25/64	0.3906	0.0156
	3/8"-24	0.3750	0.3209	Q	. . .	0.3320	25/64	0.3906	0.0156
7/16"-14	. . .	0.4375	0.3447	U	. . .	0.3680	29/64	0.4531	0.0156
	7/16"-20	0.4375	0.3725	. . .	25/64	0.3906	29/64	0.4531	0.0156
1/2"-13	. . .	0.5000	0.4001	. . .	27/64	0.4219	33/64	0.5156	0.0156
	1/2"-20	0.5000	0.4350	. . .	29/64	0.4531	33/64	0.5156	0.0156
9/16"-12	. . .	0.5625	0.4542	. . .	31/64	0.4844	37/64	0.5781	0.0156
	9/16"-18	0.5625	0.4903	. . .	33/64	0.5156	37/64	0.5781	0.0156
5/8"-11	. . .	0.6250	0.5069	. . .	17/32	0.5312	41/64	0.6406	0.0156
	5/8"-18	0.6250	0.5528	. . .	37/64	0.5781	41/64	0.6406	0.0156
3/4"-10	. . .	0.7500	0.6201	. . .	21/32	0.6562	49/64	0.7656	0.0156
	3/4"-16	0.7500	0.6688	. . .	11/16	0.6875	49/64	0.7656	0.0156
7/8"-9	. . .	0.8750	0.7307	. . .	49/64	0.7656	57/64	0.8906	0.0156
	7/8"-14	0.8750	0.7822	. . .	13/16	0.8125	57/64	0.8906	0.0156
1"-8	. . .	1.0000	0.8376	. . .	7/8	0.8750	1-1/64	1.0156	0.0156
	1"-14	1.0000	0.9072	. . .	15/16	0.9375	1-1/64	1.0156	0.0156

[1]If you cannot get the size of tap drill given here, see Table 54-2 "Drill Sizes," to find the size of drill nearest to it. Be sure to get a drill a little larger than the **root diameter** of the thread.

[2]The drill that makes a hole in a workpiece so that a bolt or screw may pass through is called a clearance drill.

21-7 How to Cut Internal Threads with a Tap

1. Drill the hole with the proper size tap drill.
2. Clamp the workpiece in a vise with the hole in an upright position.
3. Install a **taper tap** or a **plug tap** of the correct size in a **tap wrench** (Fig. 21-9). (The **T-handle tap wrench** is used for holding small taps.)
4. Insert the end of the tap in the hole, then grasp the tap wrench with both hands close to the tap (Fig. 21-10). Press down firmly on

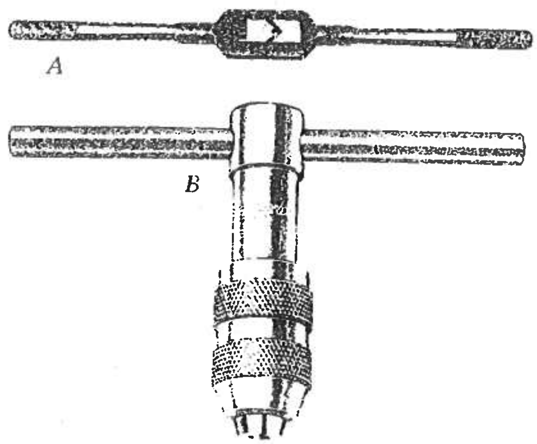


Fig. 21-9 *Tap wrenches. (A) Adjustable. (B) T-handle.* (Greenfield Tap & Die/Division of TRW, Inc.) (L.S. Starrett Company)

the tap while turning it clockwise. Larger taps require more pressure to get the tap started.

5. **It is very important that the tap be started parallel with the hole.** If the hole is 90 degrees to the top of the workpiece, a square or steel rule can be used to check its alignment (Fig. 21-11). A tap that is started at an angle to the hole is forced to cut a deeper and deeper thread on one side of the hole as it gets deeper. This often results in a broken tap.
6. Once several threads have been cut, it is no longer necessary to press down on the tap. Lubricate the tap with an appropriate cutting fluid. Shift your hands to the ends of the tap wrench (Fig. 21-12), and continue to turn the tap until the threads are as deep as required. If a **hand tap** is being used, back the tap up every two or three turns to break the chip. It is not necessary to back up when using a gun, helical, or thread forming tap.

Tapping blind holes. If full threads to the bottom of a blind hole are desired, run the **plug tap** in as far as it will go. Clean out the hole now and then. In this way, the chips collecting in the bottom of the hole will not keep the tap from going to the bottom. Then change to the **bottoming tap,** and finish cutting the partially cut threads at the bottom of the hole.

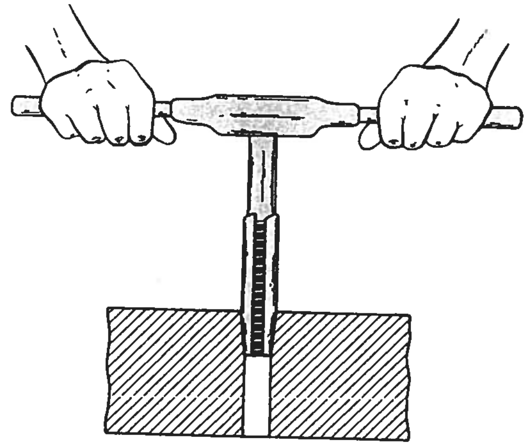


Fig. 21-10 *When starting a thread with a tap, keep your hands near the tap on the tap wrench.*

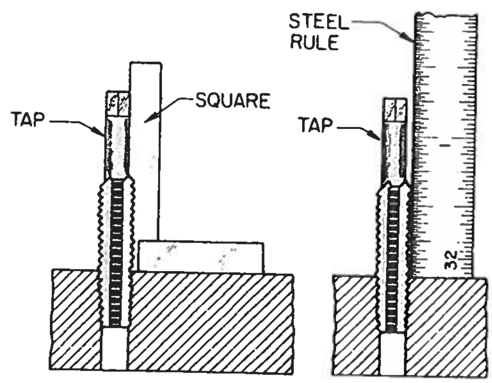
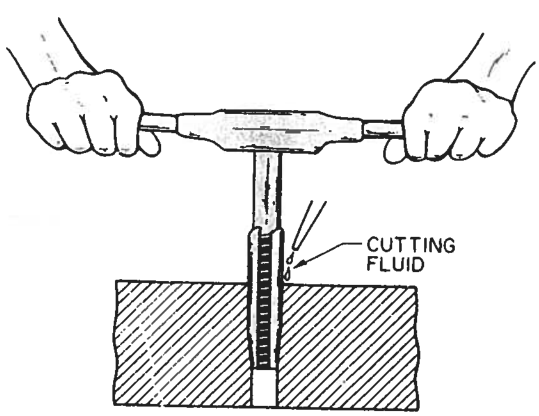


Fig. 21-11 *The tap must be parallel to the hole to minimize the chance of tap breakage.*

Fig. 21-12 *Shift your hands to the ends of the tap wrench after the thread has been started.*



Cutting fluids for tapping. Taps are very hard and brittle and are easily broken. Cutting fluids greatly reduce the strain on the tap, and should be used when tapping most metals. Cutting fluids for tapping are the same as for external threading, and are explained in Unit 20.

21-8 Causes of Broken Taps

Taps break for the following reasons:

1. A hole that has been drilled too small forces the tap to remove more metal than it is able to; therefore, it jams and breaks.
2. A tap that is started at an angle to the hole sticks tight and then breaks.
3. The tap wrench acts like a **lever.** With it, a great twisting force can be put upon the tap. Misuse of this force breaks many taps. Applying more pressure to one side of the tap wrench than the other may also break the tap.
4. Lack of cutting fluid where required will cause a tap to stick tight and break.
5. Failure to back up the tap will cause the chips to crowd in front of the cutting edges or to pack tight in the flutes of the tap. More force is then needed to turn the tap, and this extra force is often more than the tap can stand.
6. Turning a tap after the bottom of the hole is reached will cause it to break.

21-9 Removing a Broken Tap from a Hole

A broken tap is usually difficult to remove because the broken part is jammed tightly in the hole.

A tap broken near the top of the hole may sometimes be removed by placing a dull **cape chisel** in the flute of the tap and striking light blows with the hammer, as shown in Figure 21-13. Apply **penetrating oil** first, then work the broken tap both clockwise and counterclockwise until it is loose.

A **tap extractor** is a tool designed to remove broken taps (Fig. 21-14). It is made with slender steel fingers that fit into the flutes of the tap, so that a twisting force can be applied to remove the broken tap.

Electrical discharge machining, explained in Unit 83, can be used to cut away the broken tap if the above methods fail.

21-10 Thread Inserts

Thread inserts are threaded steel **bushings.** They are used to replace worn or damaged threads. They are also used to provide strong wear-resistant threads in low tensile strength metals, such as cast aluminum and magnesium. Special tools are required for installing some types of thread inserts. However, some types of thread inserts are installed without special tooling (Fig. 21-15).

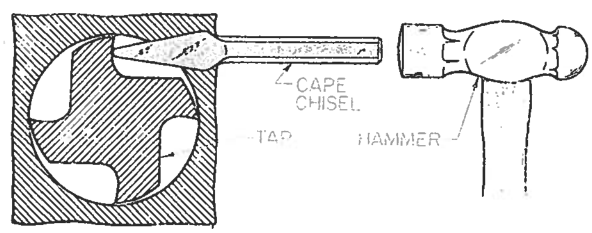
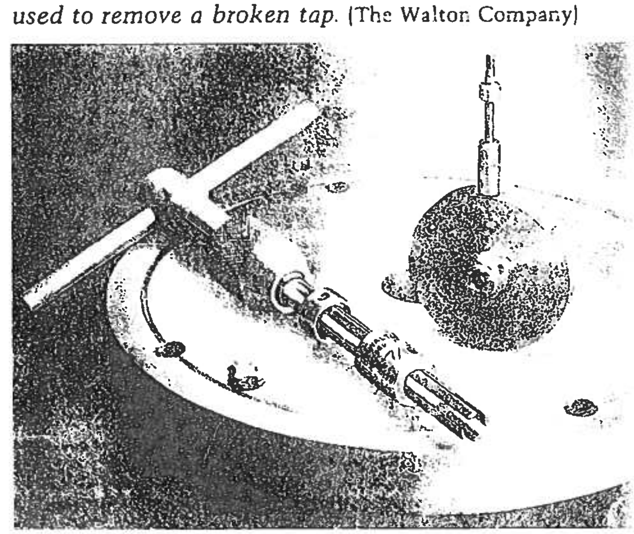


Fig. 21-13 Removing a broken tap with a cape chisel and hammer.

Fig. 21-14 A tap extractor can sometimes be used to remove a broken tap. (The Walton Company)



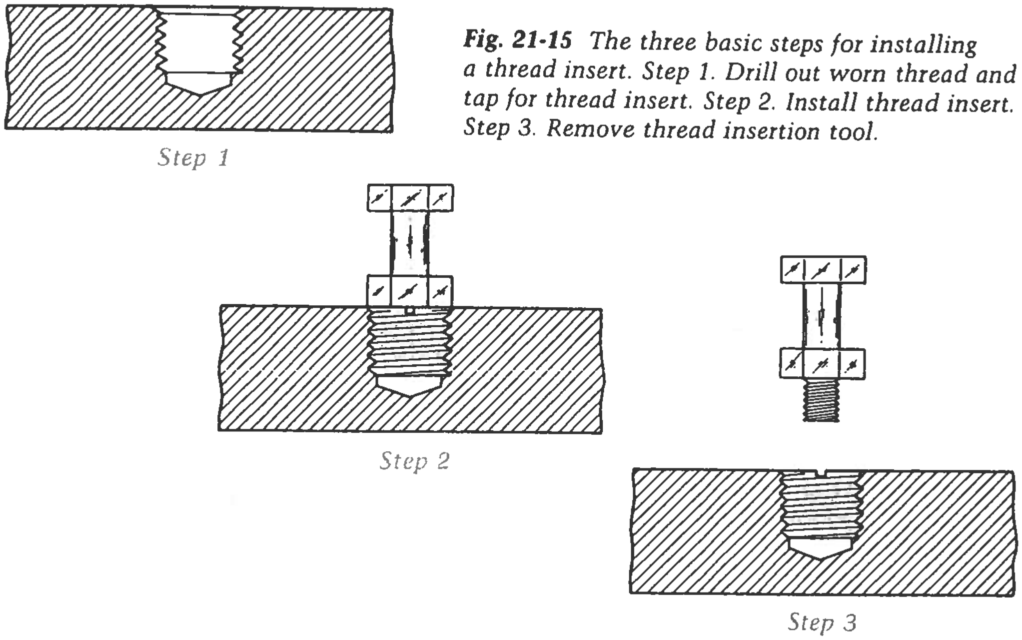


Fig. 21-15 The three basic steps for installing a thread insert. Step 1. Drill out worn thread and tap for thread insert. Step 2. Install thread insert. Step 3. Remove thread insertion tool.

REVIEW REVIEW REVIEW REVIEW REVIEW

WORDS TO KNOW

blind hole
bottoming tap
gun tap
hand tap
left-hand tap
plug tap
right-hand tap
serial taps
tap extractor
taper tap
T-handle tap wrench
thread-forming tap
thread insert

REVIEW QUESTIONS

1. What is the name of the tool used for cutting internal threads?
2. Describe a taper tap; plug tap; bottoming tap. What is each used for?
3. How does a machine tap differ from a hand tap?
4. How do thread-forming taps differ from conventional taps?
5. What does 5/16-18 UNC stamped on the shank of a tap mean?
6. What does M12 × 1.75 stamped on the shank of a tap mean?
7. What is a tap drill?
8. What size tap drill is used for a 1/4"-20 UNC thread? M6 thread?
9. What is a tap wrench? Name two types.
10. When hand-tapping, why should the tap be kept square with the work?
11. What kind of lubricant should be used for tapping steel? Aluminum?
12. Why is it necessary to back up hand taps while tapping?
13. How can a broken tap be removed from a hole?
14. Name six causes of broken taps.
15. What are thread inserts? What are they used for?

PART 7

Fitting and Assembling

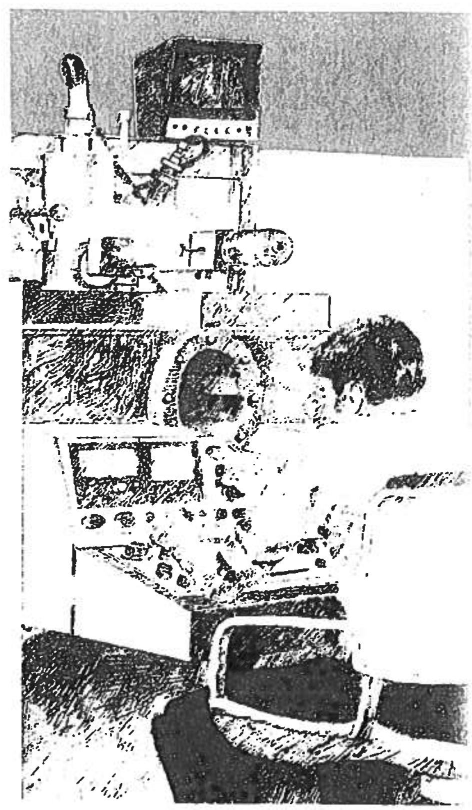
One of the most interesting jobs for a young welder would be to work on the wings of the XB-70 supersonic aircraft or the cone connectors for the Trident missile. Such jobs are common for those who work under Donald Clayton, manager of an electron beam welding (EBW) company. Donald, who spent his younger years on a farm, has been around machinery most of his life. He learned to weld in the Navy, but German-speaking technicians first taught him about EBW machinery.

The company Donald works for imported four EBW machines from Germany. Technical representatives and interpreters accompanied the equipment and taught Donald how to operate it. Later, his company constructed its own EBW machine. Many of the company's products are used in aerospace programs. Donald's welders work on telescopes, fuel lines, tanks, and special antennas for space shuttles. On the other hand, they also weld heart pacemakers and special tools used in brain surgery.

EBW welders are trained to use both hands and both feet to operate the controls of the machine. Sitting outside the box-like hard-vacuum chamber, he or she works levers and pedals that change the position of the workpiece and the intensity of the electron beam.

Electron beam welding is especially good for welding the latest "super-alloys," which are used extensively in spacecraft and aircraft. One potential problem with EBW is its production of X-rays. The box must have heavy shielding to protect the welders. Donald's company, however, has no trouble in meeting safety regulations.

Donald says that students should have the opportunity to learn about the latest types of nontraditional machining methods. He has invested his time and energy in this field, and it has paid off well in job satisfaction.



Donald Clayton
Manager
Electron Beam Welding

Name ______________________

Score ____________

UNIT 19

Screw Threads

1-15. Multiple Choice. Write the letter of the correct answer to each statement or question in the space at the left.

______ 1. The threads on most standard threaded fasteners are made on cold-heading machines with
A. ordinary thread-cutting dies
B. round thread-rolling dies
C. flat thread-rolling dies
D. single-point threading tools

______ 2. The largest diameter of a straight external or internal screw thread is called the
A. outside diameter
B. major diameter
C. inside diameter
D. minor diameter

______ 3. The smallest diameter of a straight external or internal screw thread is called the
A. outside diameter
B. major diameter
C. minor diameter
D. inside diameter

______ 4. The diameter of a screw thread that determines the fit or clearance between mating threads is the
A. major diameter
B. minor diameter
C. pitch diameter
D. actual outside diameter

______ 5. The distance from a point on one thread to a corresponding point on the next thread is called the
A. lead
B. pitch
C. travel
D. gap

______ 6. Two ways to measure the pitch of screw threads are
A. with a plain micrometer and a screw pitch gage
B. with dividers and a micrometer
C. with a rule and a plain micrometer
D. with a screw pitch gage and a rule

______ 7. The thread form that was first adopted by most American industries was the
A. American National
B. Unified National
C. United States Standard
D. ISO Metric

______ 8. The form of screw thread most widely used in the United States today is the
A. American National
B. Unified
C. United States Standard
D. ISO Metric

______ 9. The thread angle of the Unified Screw Thread is
A. 30°
B. 45°
C. 60°
D. 90°

(Continued on next page)

_______ 10. The class of a Unified National Thread has to do with the
A. pitch of the thread
B. fit of the thread
C. smoothness of the finish on the threads
D. lead of the thread

_______ 11. A 29-degree thread used mostly on machine tools is the
A. ISO Metric
B. Unified National
C. Acme
D. pipe thread

_______ 12. The type of pipe thread used for general-purpose jobs that require a low-pressure seal is the American National Standard
A. Taper Pipe Thread
B. Straight Pipe Thread
C. Railing Joint Taper Pipe Thread
D. Dryseal Taper Pipe Thread

_______ 13. ISO Inch and ISO Metric threads are not interchangeable because of differences in their
A. thread angle
B. diameters
C. pitches
D. B and C

_______ 14. Which ISO Metric thread is commonly used on metric fasteners?
A. coarse pitch
B. fine pitch
C. constant pitch
D. variable pitch

_______ 15. How are ISO Metric threads designated on working drawings?
A. with the letters ISO
B. with the letter I
C. with the letter M
D. with the letter m

16-17. Short Answer. Write your answers in the blanks at the left.

_______________ 16. What is the thread designation for a coarse metric thread of 20 mm diameter and 2.5 mm pitch?

_______________ 17. What is the thread designation for a fine metric thread of 12 mm diameter and 1.25 mm pitch?

Name ____________________

Score __________

UNIT 20
External Threading with Dies

1-7. Multiple Choice. Write the letter of the correct answer to each statement or question in the space at the left.

______ 1. Cutting threads by hand on a round bar is done with a tool called a
A. threading tap
B. threading die
C. thread chaser
D. thread cutter

______ 2. A set of taps and dies is called a
A. tap-and-die set
B. threading set
C. thread-cutting kit
D. screw plate

______ 3. The tool for holding and turning the threading die is called a
A. die wrench
B. die lever
C. diestock
D. die holder

______ 4. To make it easier to start a threading die, the end of the rod should be
A. beveled
B. rounded off
C. squared off
D. reduced in diameter

______ 5. The starting side of a die
A. has smaller teeth
B. has three or four tapered teeth
C. has straight teeth
D. has oversized teeth

______ 6. Why is it recommended to back up the die every two or three turns when threading?
A. to break the chip into small pieces
B. to make it easier to turn the die
C. to help make a smoother thread
D. both A and C

______ 7. A good cutting fluid to use for threading steel is
A. soluble oil
B. inactive mineral oil
C. sulfurized mineral oil
D. all of the above

8-11. Short Answer. List four ways of measuring an external thread for correct pitch diameter or fit.

8. ____________________

9. ____________________

10. ____________________

11. ____________________

Name ______________________________

Score ____________

UNIT 21

Internal Threading with Taps

1-10. Multiple Choice. Write the letter of the correct answer to each statement or question in the space to the left.

_____ 1. A tool used to cut threads inside a hole, such as in a nut, is called a
A. tap
B. die

_____ 2. A style of tap that should be backed up a turn every two or three turns in order to break the chip into small pieces is the
A. gun tap
B. hand tap
C. helical-fluted tap
D. cam ground tap

_____ 3. A style of tap that shoots the chip ahead of it and is used for tapping through holes is the
A. gun tap
B. serial tap
C. hand tap
D. helical-fluted tap

_____ 4. A style of tap that lifts the chips out of the hole and is used for tapping of blind holes is the
A. gun tap
B. serial tap
C. hand tap
D. helical-fluted tap

_____ 5. A style of tap designed especially for use in tough materials is the
A. gun tap
B. serial tap
C. hand tap
D. helical-fluted tap

_____ 6. A style of tap that has no flutes and does not produce chips is the
A. hand tap
B. thread-forming tap
C. gun tap
D. serial tap

_____ 7. A tap drill is
A. a special drill for a certain size tap
B. an ordinary drill that is the correct size for a certain size tap

_____ 8. The tool that is used to hold and turn a tap by hand is the tap
A. wrench
B. holder
C. stock
D. tool

_____ 9. A tool made for removing broken taps is the
A. tap remover
B. tap extractor
C. screw extractor
D. tap eliminator

Name ________________________________

Unit 21 (continued)

______ 10. Threaded steel bushings that are used to repair damaged or stripped threads are called thread

A. rings
B. inserts
C. plugs
D. collars

11-17. Matching. Match the taps shown with their names by writing the correct letters in the blanks.

______ 11. Gun tap

______ 12. Taper tap

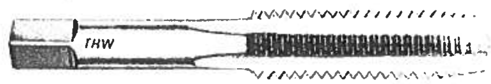
______ 13. Helical-fluted tap

______ 14. Serial tap

______ 15. Plug tap

______ 16. Thread-forming tap

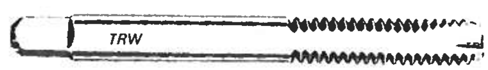
______ 17. Bottoming tap



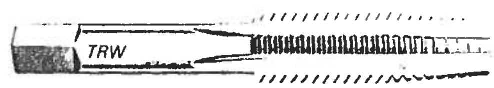
A

B

C



D



E


F

G

18-20. Short Answer. A tap is marked ¼-20 UNC. Explain what the markings mean in the space provided.

18. ¼: ________________________________

19. 20: ________________________________

20. UNC: ________________________________

(Continued on next page)

21-26. Short Answer. List six causes of broken taps.

21. ______________________________

22. ______________________________

23. ______________________________

24. ______________________________

25. ______________________________

26. ______________________________

27-29. Short Answer. Look up the correct tap drill size for each of the following taps. Write the sizes in the blanks at the left.

______________ 27. 1/4-20 UNC tap

______________ 28. 3/8-24 UNF tap

______________ 29. M8 × 1 tap