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Technology of Machine Tools

Eighth Edition

Mc Graw Hill Education

TECHNOLOGY of MACHINE TOOLS

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preface

Today's modern machine shops and tool and die shops are now environmentally controlled with dedicated metrology labs for quality control and inspection. They have integrated the use of more computer numerical control (CNC) machine tools, but they have still retained the ability to use conventional machines. A modern jobbing shop today will still have conventional machines such as mills, lathes, assorted drill presses, saws, and some of the precision equipment used prior to CNC (such as surface grinders, jig borers, and cylindrical and tool and cutter grinders).

Because the technology of machining is changing rapidly, the machinist (student) must learn to operate a wide range of machine tools and understand the unique cutting properties of these different machines, cutting tools, and workpiece materials as well as be able to use conventional hand tools and measuring tools.

The purposes of this text are to assist instructors in providing basic training on conventional machine tools, to cover basic programming for CNC machines (such as turning and machining centers), and to introduce new manufacturing technologies and processes to remain competitive in the global enviroment.

The use of computers continues to change how machine tools are used to manufacture products. Computers have improved until they are now highly sophisticated units capable of controlling the operation of a single machine, a group of machines, or even a complete manufacturing plant. Section 17, "Computer-Age Machining," now includes not only computer numerical control machine tools, such as turning and machining centers, but also newer manufacturing technologies. To increase manufacturing productivity, machine tools have been equipped with modular tooling and work-holding systems, as well as new cutting tools to produce accurate parts faster and at competitive prices.

Today's industries are putting more emphasis on using new manufacturing technologies and manufacturing intelligence systems to improve their productivity and remain competitive in the world. Section 17 gives an overview of 10 technologies or processes that are giving manufacturers an advantage over their competition. A few of these are additive manufacturing, Industry 4.0, cryogenics, and robotics. Through the use of DVDs and online videos, students can learn how the machine tool trade will be changing in the future.

This book is based on the authors' many years of trade experience and experience as specialists in teaching. To keep up-to-date with technological change, the authors have researched the latest technical information available and have visited industries that are leaders in their field. Key personnel in manufacturing firms and leading educators reviewed many sections of this book, so that accurate and up-to-date information is presented. The authors are grateful to the reviewers for the technical and practical suggestions that were incorporated into the text.

The business and manufacturing world today is very different from what it was as little as 5 or 10 years ago. Ever more highly productive advanced technology and global competition are the driving forces behind this never-ending change. It seems that new technological developments are occurring every month, and the days when we used to do the same thing month after month are gone.

Globalization and the fierce competition it has brought have created a need for industry to produce high-quality products quickly and at less cost. This is a real challenge for some industries that have not kept pace with the constant-changing technology and that still hope 5- to 10-year-old technology will keep them in business. In order to survive, we must develop and use manufacturing systems that produce better products, faster, and at lower cost than our competitors. These highly productive systems are available to anyone in the world. Those companies that use them first are very likely to survive, while those that do not will gradually fade away.

To make this course interesting and challenging for students, online videos can be used to cover new technologies. DVDs and videos are also available on loan or for a small fee from technical societies, manufacturers, and publishers. The instructor's manual includes sources of videos, along with answers to the review questions in the text. A student workbook is also available.

Steve F. Krar
Arthur R. Gill
Peter Smid
Jonathan A. Gill
Robert J. Gerritsen

about the authors

STEVE F. KRAR

Steve F. Krar spent 15 years in the trade, first as a machinist and finally as a tool and die maker. After this period, he entered Teachers' College and graduated from the University of Toronto with a Specialist's Certificate in Machine Shop Practice. During these 20 years of teaching, Mr. Krar was active in vocational and technical education and served on the executive committee of many educational organizations. For 10 years, he was on the summer staff of the College of Education, University of Toronto, involved in teacher training programs. Active in machine tool associations, Steve Krar is a Life Member of the Society of Manufacturing Engineers and former associate director of the GE Superabrasives Partnership for Manufacturing Productivity. He was inducted into the Canadian Manufacturers Hall of Fame in March 2009.

Mr. Krar's continual research over the past 50 years in manufacturing technology has involved many courses with leading world manufacturers and an opportunity to study under Dr. W. Edwards Deming. Mr. Krar spent a week researching Nanotechnology at leading research centers, universities, and industry in Switzerland. He is coauthor and consultant of over 80 technical books, such as *Machine Shop Training, Machine Tool Operations, CNC Simplified, Superabrasives—Grinding and Machining,* and *Exploring Advanced Manufacturing Technologies,* some of which have been translated into 5 languages and used throughout the world.

ARTHUR R. GILL

Arthur R. Gill served an apprenticeship as a tool and die maker. After 10 years in the trade, he entered the Ontario Community College system. Mr. Gill served as a professor and coordinator of precision metal trades and apprenticeship training for 30 years at Niagara College in St. Catharines. He was a member of the Ontario Precision Metal Trades college curriculum committee for apprenticeship training and Heads of Apprenticeship Training. Mr. Gill is a member of the Society of Manufacturing Engineers and worked closely with industry to continually improve manufacturing technology.

Mr. Gill has coauthored a number of textbooks, including *CNC Technology and Programming, Computer Numerical Control Simplified,* and *Exploring Advanced Manufacturing Technology* with Steve Krar. In 1991, he was invited by China to assist in developing a Precision Machining and Computer Numerical Control (CNC) training facility at Yueyang University in Hunan Province.

Other Highlights (Krar and Gill)

- Consulting editor, manufacturing technology, for Industrial Press, New York, and contributing editor, *Advanced Manufacturing Magazine,* Burlington, Ontario
- Judge at the annual SkillsUSA competition for CNC programming and machining, held in Kansas City
- Research in new developments in Manufacturing Technology in North America and Nanotechnology at universities, industries, and the IBM Research Lab in Switzerland

PETER SMID

Peter Smid graduated from high school with a specialty in machine shop training. He then entered industry, completed an apprenticeship program, and gained valuable experience as a machinist skilled on all types of machine tools. Mr. Smid immigrated to Canada in 1968 and spent the next 26 years employed in the machine tool industry as a machinist and tool and die maker.

In the early 1970s, he became involved in Computer Numerical Control (CNC) as a programmer/operator and devoted the next 18 years to becoming proficient in all aspects of computerized manufacturing. In 1989, he became an independent consultant, and hundreds of companies have used Mr. Smid's CNC and CAD/CAM skills to improve their manufacturing operations. He also wrote a comprehensive, 500-page CNC programming handbook, which is rapidly becoming the Bible of the trade.

In 1995, he became a consultant/professor of Advanced Manufacturing focusing on industrial and customized training in CNC, CAD/CAM, and Agile Manufacturing. His many years of teaching, training, lecturing, and designing curriculum give him the opportunity to pass along his vast knowledge of modern manufacturing technology to students of all ages.

JONATHAN A. GILL

Jonathan A. Gill graduated from high school with an Ontario Secondary School Diploma. He entered Ryerson University in the industrial engineering program and then went into geographical analysis. Mr. Gill attended Humber College for electronics engineering and then spent 2 years at Mohawk College for computer networking and security analysis.

Mr. Gill is currently an independent contractor employed by Nexas Networks Inc. as an Applications Engineer and Support Manager, providing factory floor networking and information technology for the aerospace and automotive industry, jobbing shops, and production discrete manufacturing facilities.

Mr. Gill assisted the authors with the research, artwork, and final production of manuscript for the textbook *Computer Numerical Control Simplified* and is coauthor of the book *Changing World of Manufacturing*.

ROBERT J. GERRITSEN

Robert J. Gerritsen is a Professor of Mechanical Engineering with the School of Engineering Technology at Mohawk College in Hamilton, Ontario, Canada, where he specializes in the areas of computer-aided design and 3D printing.

Upon graduation from Mohawk College's Mechanical Engineering Design program in 1986, Mr. Gerritsen spent more than 25 years in industry, primarily in engineering design and management. After completing his MBA, Mr. Gerritsen continued to be active in the areas of research and product development before entering academia. Mr. Gerritsen now spends his time educating young engineering students in the areas of CAD/CAM/CAE, mechanical design, 3D printing/additive manufacturing, and virtual and rapid prototyping.

Professor Gerritsen was also the founding faculty member of Mohawk College's Additive Manufacturing Resource Center (AMRC), where he received the President's Award of Excellence in 2015.

NEW TO THE EIGHTH EDITION OF *TECHNOLOGY OF MACHINE TOOLS*

In addition to updating the text to reflect changes in the modern business and manufacturing world today—such as Industry 4.0, nanotechnology, and IDI—an entirely new section on additive manufacturing (Section 17) as a revolutionary way to produce complex parts has been added.

> **Unit 90—Nanotechnology.** Nanotechnology deals with dimensions that are less than 100 nanometers, manipulating and controlling materials at the atomic and molecular level. Nanomanufacturing is a term used to refer to manufacturing at the nanoscale.

> **Unit 93—Additive Manufacturing Technologies.** Additive manufacturing creates parts and prototypes by fusing layers of material to build the part layer by layer from STL data, which describe only the surface geometry of a three-dimensional object.

> **Unit 95—Industry 4.0.** The combination of IoT, IIoT, cybersecurity, machine-to-machine connectivity, and the continuing implementation of lean manufacturing (elimination of waste) will be the basis for Industry 4.0.

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The authors wish to thank all the teachers and industrial reviewers who took their valuable time to offer concrete suggestions for the manuscript, which we were happy to include. Their suggestions will make this book, which is considered to be a world leader, even more valuable as an educational tool.

Our sincere thanks go to the following firms that reviewed sections of the manuscript and offered suggestions that were incorporated to make this text as accurate and up-to-date as possible: ABB Robotics; American Iron & Steel Institute; Cincinnati Machines; Dorian Tool International; FBT Inc.; GE Superabrasives; Moore Tool Co.; Norton Co.; Nucor Corporation; and Stelco, Inc.

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TECHNOLOGY of MACHINE TOOLS

Section 1

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INTRODUCTION TO MACHINE TOOLS

The progress of humanity throughout the ages has been governed by the types of tools available. Ever since primitive people used rocks as hammers or as weapons to kill animals for food, tools have governed our standard of living. The use of fire to extract metals from ore led to the development of newer and better tools. The harnessing of water led to the development of hydropower, which greatly improved humanity's well-being.

With the industrial revolution in the mid-18th century, early machine tools were developed and were continually improved. The development of machine tools and related technologies advanced rapidly during and immediately after World Wars I and II. Since World War II, processes such as computer numerical control, electro-machining, computer-aided design (CAD), computer-aided manufacturing (CAM), and flexible manufacturing systems (FMS) greatly altered manufacturing methods.

Today we are living in a society greatly affected by the development of the computer. Computers affect the growing and sale of food, manufacturing processes, and entertainment. Although the computer influences our everyday lives, it is still important that you, as a student or an apprentice, be able to perform basic operations on standard machine tools. This knowledge will provide the necessary background for a person seeking a career in the machine tool trade.

UNIT 1

History of Machines

OBJECTIVES

After completing this unit, you will be familiar with:

1. The development of tools throughout history
2. The standard types of machine tools used in shops
3. The newly developed space-age machines and processes

The high standard of living we enjoy today did not just happen. It has been the result of the development of highly efficient machine tools over the past several decades. Processed foods, automobiles, telephones, televisions, refrigerators, clothing, books, and practically everything else we use are produced by machinery.

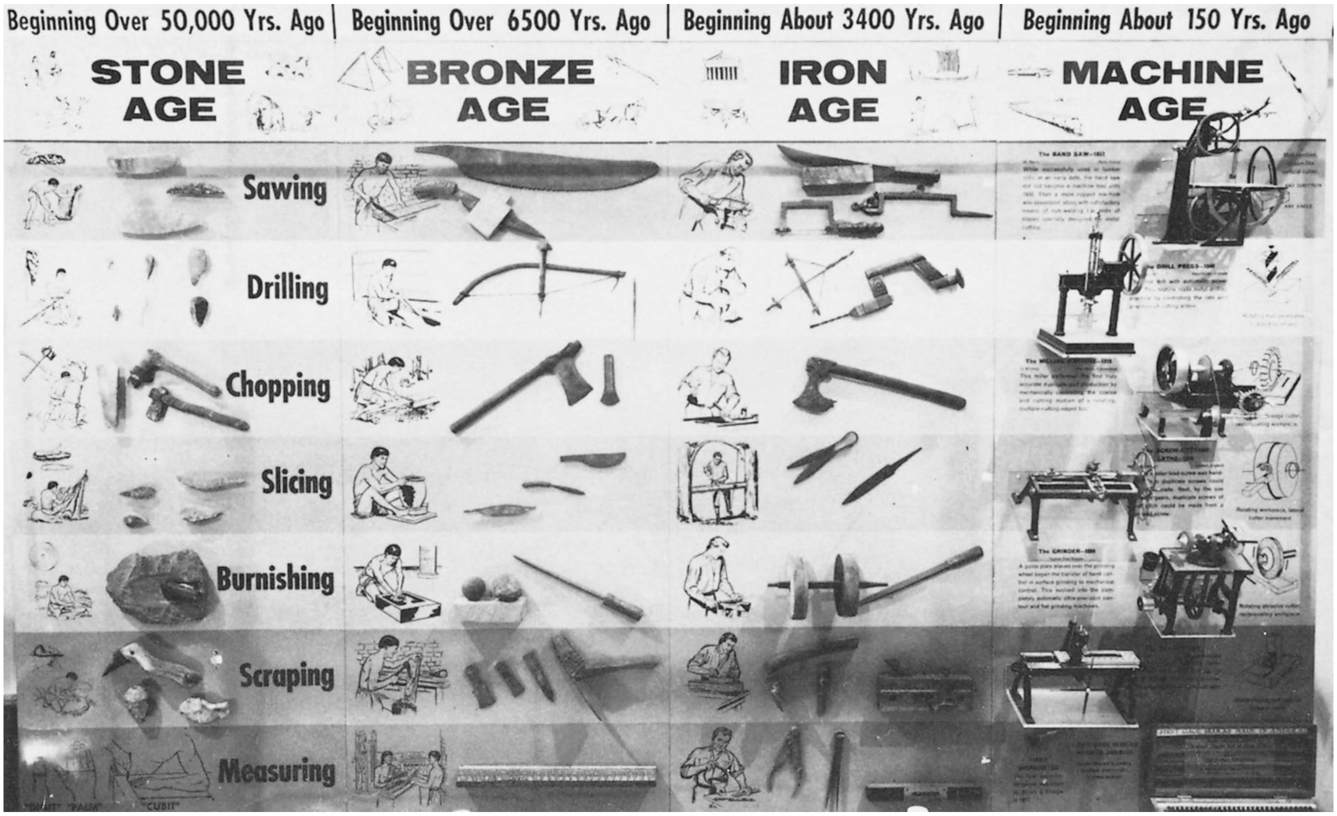
The history of machine tools began during the stone age (over 50,000 years ago), when the only tools were hand tools made of wood, animal bones, or stone (Fig. 1-1 on page 5).

Between 4500 and 4000 B.C., stone spears and axes were replaced with copper and bronze implements, and power supplied by humans was in a few cases replaced with animal power. It was during this bronze age that human beings first enjoyed "power-operated" tools.

Around 1000 B.C., the iron age dawned, and most bronze tools were replaced with more durable iron implements. After smiths learned to harden and temper iron, its use became widespread. Tools and weapons were greatly improved, and animals were domesticated to provide power for some of these tools, such as the plow. During the iron age, all commodities required by humans, such as housing and shipbuilding materials, wagons, and furniture, were handmade by the skilled craftspeople of that era.

About 300 years ago, the iron age became the machine age. In the 17th century, people began exploring new sources of energy. Water power began to replace human and animal power. With this new power came improved machines and, as production increased, more products became available. Machines continued to be improved, and the boring machine made it possible for James Watt to produce the first steam engine in 1776, beginning the industrial revolution. The steam engine made it possible to provide power to any area where it was needed. With quickening speed, machines were improved and new ones invented. Newly designed pumps reclaimed thousands of acres of the Netherlands from the sea. Mills and plants which had depended on water power were converted to steam power to produce flour, cloth, and lumber more efficiently. Steam engines replaced sails and steel replaced wood in the shipbuilding industry. Railways sprang up, unifying countries, and steamboats connected the continents. Steam-driven tractors and improved farm machinery lightened the farmer's task. As machines improved, further sources of power were developed. Generators were made to produce electricity, and diesel and gasoline engines were developed.

With further sources of energy available, industry grew and new and better machines were built. Progress

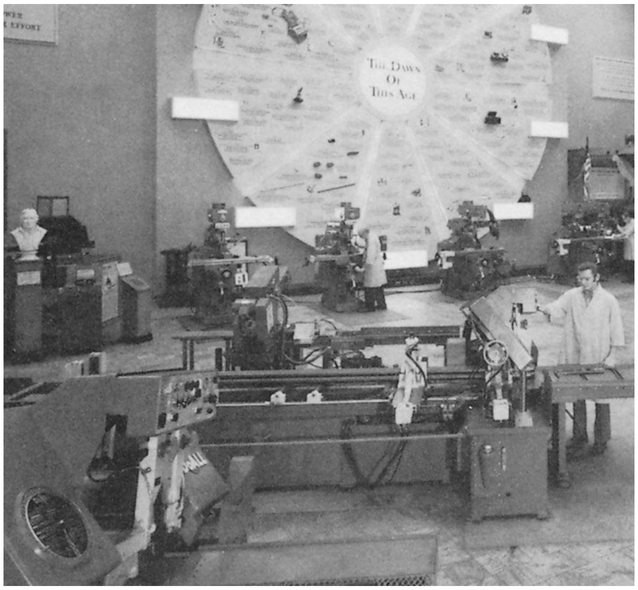


■ **Figure 1-1** The development of hand tools over the years. *(Courtesy of DoAll Company)*

continued slowly during the first part of the 20th century except for spurts during the two world wars. World War II sparked an urgent need for new and better machines, which resulted in more efficient production (Fig. 1-2).

Since the 1950s, progress has been rapid and we are now in the space age. Calculators, computers, robots, and automated machines and plants are commonplace. The atom has been harnessed and nuclear power is used to produce electricity and to drive ships. We have traveled to the moon and outer space, all because of fantastic technological developments. Machines can mass produce parts to millionths of an inch accuracy. The fields of measurement, machining, and metallurgy have become sophisticated. All these factors have produced a high standard of living for us. All of us, regardless of our occupation or status, are dependent on machines and/or their products (Fig. 1-3).

Through constant improvement, modern machine tools have become more accurate and efficient. Improved production and accuracy have been made possible through the application of hydraulics, pneumatics, fluidics, and electronic devices such as computer numerical control to basic machine tools.



■ **Figure 1-2** New machine tools were developed during the mid-20th century. *(Courtesy of DoAll Company)*

Figure 1-3 Machine tools produce tools and machines for manufacturing all types of products. *(Courtesy of DoAll Company)*

Common Machine Tools

Machine tools are generally power-driven metal-cutting or -forming machines used to shape metals by:

- The removal of chips
- Pressing, drawing, or shearing
- Controlled electrical machining processes

Any machine tool generally has the capability of:

- Holding and supporting the workpiece
- Holding and supporting a cutting tool
- Imparting a suitable movement (rotating or reciprocating) to the cutting tool or the work
- Feeding the cutting tool or the work so that the desired cutting action and accuracy will be achieved

The machine tool industry is divided into several different categories, such as the general machine shop, the toolroom, and the production shop. The machine tools found in the metal trade fall into three broad categories:

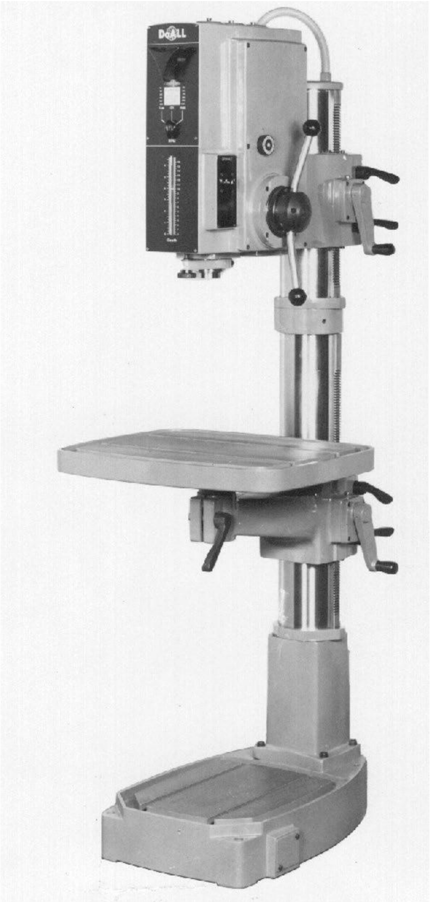
1. *Chip-producing machines,* which form metal to size and shape by cutting away the unwanted sections. These machine tools generally alter the shape of steel-produced products by casting, forging, or rolling in a steel mill.
2. *Non-chip-producing machines,* which form metal to size and shape by pressing, drawing, punching, or shearing. These machine tools generally alter the shape of sheet steel products and produce parts which need little or no machining by compressing granular or powdered metallic materials.
3. *New-generation machines,* which were developed to perform operations that would be very difficult, if not impossible, to perform on chip- or non-chip-producing machines. Electro-discharge, electro-chemical, and laser machines, for example, use either electrical or chemical energy to form metal to size and shape.
4. *Multi-tasking machines,* a combined machining and turning center, can produce virtually any shape of part, starting with a rough piece of material to a finished part in a single machine setup. These machines consist of a turning center with two independent spindles and a vertical machining center having a rotary tool spindle. They combine information technology (IT) and manufacturing technology (MT) for the efficient multiple-face machining of workpieces. Besides the conventional turning and milling operations, it is possible to hob gears, machine molds, harden a workpiece, and cylindrical grind in the same work setup.

The performance of any machine tool is generally stated in terms of its metal-removal rate, accuracy, and repeatability. *Metal-removal rate* depends upon the cutting speed, feed rate, and depth of cut. *Accuracy* is

■ **Figure 1-4** Common machine tools found in a machine shop. *(Courtesy of DoAll Company)*

determined by how precisely the machine can position the cutting tool to a given location once. *Repeatability* is the ability of the machine to position the cutting tool consistently to any given position.

A general machine shop contains a number of standard machine tools that are basic to the production of a variety of metal components. Operations such as turning, boring, threading, drilling, reaming, sawing, milling, filing, and grinding are most commonly performed in a machine shop. Machines such as the drill press, engine lathe, power saw, milling machine, and grinder are usually considered the *basic machine tools* in a machine shop (Fig. 1-4).



■ **Figure 1-5** A standard upright drill press. *(Courtesy of DoAll Company)*

▸▸ Standard Machine Tools

DRILL PRESS

The drill press or drilling machine (Fig. 1-5), probably the first mechanical device developed prehistorically, is used primarily to produce round holes. Drill presses range from the simple hobby type to the more complex automatic and numerical control machines used for production purposes. The function of a drill press is to grip and revolve the cutting tool (generally a twist drill) so that a hole can be produced in a piece of metal or other material. Operations such as drilling, reaming, spot facing, countersinking, counterboring, and tapping are commonly performed on a drill press.

■ **Figure 1-6** An engine lathe is used to produce round work. *(Courtesy of Clausing Industrial, Inc.)*

ENGINE LATHE

The engine lathe (Fig. 1-6) is used to produce round work. The workpiece, held by a work-holding device mounted on the lathe spindle, is revolved against a cutting tool, which produces a cylindrical form. Straight turning, tapering, facing, drilling, boring, reaming, and thread cutting are some of the common operations performed on a lathe.

METAL SAW

The metal-cutting saws are used to cut metal to the proper length and shape. There are two main types of metal-cutting saws: the bandsaw (horizontal and vertical) and the reciprocating cutoff saw. On the vertical bandsaw (Fig. 1-7) the workpiece is held on the table and brought into

■ **Figure 1-7** A contour-cutting bandsaw. *(Source: DoAll Company)*

■ **Figure 1-8** A vertical milling machine. *(©Steve Krar)*

■ **Figure 1-9** A surface grinder is used to grind flat surfaces. *(Source: South Bend Lathe Co.)*

contact with the continuous-cutting saw blade. It can be used to cut work to length and shape. The horizontal bandsaw and the reciprocating saw are used to cut work to length only. The material is held in a vise and the saw blade is brought into contact with the work.

MILLING MACHINE

The horizontal milling machine and the vertical milling machine (Fig. 1-8) are two of the most useful and versatile machine tools. Both machines use one or more rotating milling cutters having single or multiple cutting edges. The workpiece, which may be held in a vise, fixture, accessory, or fastened to the table, is fed into the revolving cutter. Equipped with proper accessories, milling machines are capable of performing a wide variety of operations, such as drilling, reaming, boring, counterboring, and spot facing, and of producing flat and contour surfaces, grooves, gear teeth, and helical forms.

GRINDER

Grinders use an abrasive cutting tool to bring a workpiece to an accurate size and produce a high surface finish. In the grinding process, the surface of the work is brought into contact with the revolving grinding wheel. The most common types of grinders are the surface, cylindrical, cutter and tool, and bench or pedestal.

Surface grinders (Fig. 1-9) are used to produce flat, angular, or contoured surfaces on a workpiece.

Cylindrical grinders are used to produce internal and external diameters, which may be straight, tapered, or contoured.

Cutter and tool grinders are generally used to sharpen milling machine cutters.

Bench or pedestal grinders are used for offhand grinding and the sharpening of cutting tools such as chisels, punches, drills, and lathe and planer tools.

SPECIAL MACHINE TOOLS

Special machine tools are designed to perform all the operations necessary to produce a single component. Special-purpose machine tools include gear-generating machines; centerless, cam, and thread grinders; turret lathes; and automatic screw machines.

Computer Numerical Control Machines

Computer numerical control (CNC) has brought tremendous changes to the machine tool industry. New machine tools, controlled by computers, have allowed industry to produce parts quickly and to accuracies undreamed of only a few years ago. The same part can be reproduced, to the exact accuracy, any number of times if the part program has been properly prepared. The operating commands that control the machine tool are executed with amazing speed, accuracy, efficiency, and reliability. In many cases throughout the world, conventional machine tools operated by hand are being replaced by CNC machine tools operated by computers.

Chucking and turning centers (Fig. 1-10a and b), the CNC equivalent of the engine lathe, are capable of machining round parts in a minute or two that would take a skilled machinist an hour to produce. The *chucking center* is designed to machine parts in a chuck or some form of holding and driving device. The *turning center,* similar to a chucking center, is designed mainly for shaft-type workpieces that must be supported by some type of tailstock center.

The machining centers (Fig. 1-11a and b), the CNC equivalent of the milling machine, can perform a variety of operations on a workpiece by changing its own cutting tools. There are two types of machining centers, the vertical and the horizontal. The *vertical machining center* (Fig. 1-11a), whose spindle is in a vertical position, is used primarily for flat parts where three-axis machining is required. The *horizontal machining center* (Fig. 1-11b), whose spindle is in a horizontal position, allows parts to be machined on any side in one setup if the machine is equipped with an indexing table. Some machining centers have both vertical and horizontal spindles that can change from one to another very quickly.

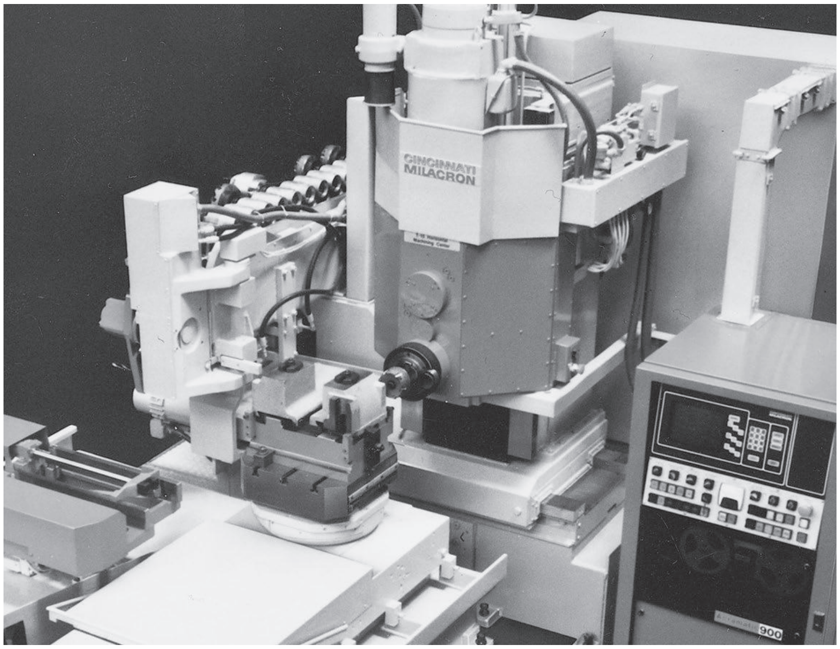
Electrical discharge machines (EDM) (Fig. 1-12) use a controlled spark erosion process between the cutting tool and the workpiece to remove metal. The two most common EDM machines are the *wire-cut* and the vertical *ram type*. The wire-cut EDM uses a traveling wire to cut the internal and external shapes of a workpiece. The vertical ram-type EDM, commonly called the die sinking machine, generally feeds a form tool down into the workpiece to reproduce its form.

(a) (b)

Figure 1-10 Chucking (a) and turning centers (b) are capable of producing round parts quickly and accurately. *(Courtesy of Yamazaki Mazak Corporation)*

(a)

■ **Figure 1-11** (a) The vertical machining center is used primarily for flat parts when three-axis machining is required. *(Source: MAG Industrial Automation Systems)*



(b)

■ **Figure 1-11** (b) The horizontal machining center can machine any side of a part if it is equipped with an indexing table. *(Source: MAG Industrial Automation Systems)*

Electro-discharge machining, electrochemical machining, electrolytic grinding, and *laser machining* have made it possible to machine new space-age materials and to produce shapes which were difficult or often impossible to produce by other methods.

The numerical control principle has also been applied to *robots,* which are capable of handling materials and changing machine tool accessories as easily and probably more efficiently than a person can (Fig. 1-13). *Robotics* has become one of the fastest-growing areas of the manufacturing industry.

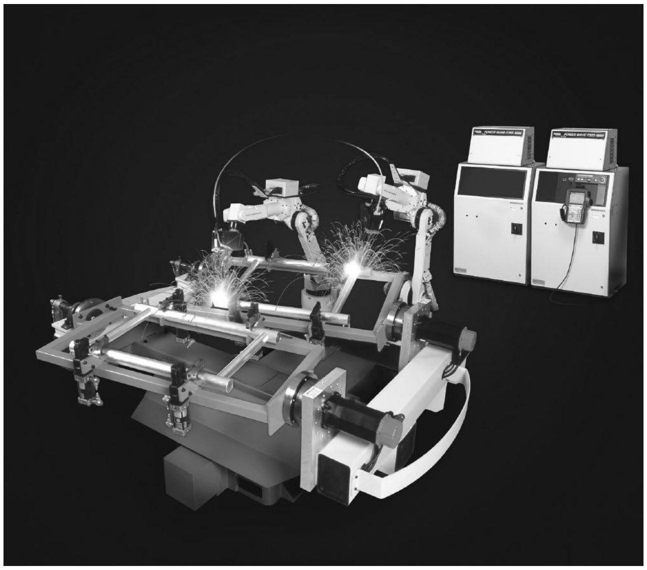
Since its development, the *laser* has been applied to several areas of manufacturing. Lasers are now used increasingly for cutting and welding all types of

■ **Figure 1-12** EDM machines remove metal by an electric spark-erosion process. *(Courtesy of Charmilles Technology Corp.)*

metals—even those that have been impossible to cut or weld by other methods. Laser beams can pierce diamonds and any other known material and are also used in extremely accurate measuring and surveying devices, and as sensing devices.

With the introduction of numerous special machines and special cutting tools, production has increased tremendously over that attained with standard machine methods. Many products are produced automatically by a continuous flow of finished parts from these special machines. Product control and high production rates allow us to enjoy the pleasure and convenience of automobiles, power lawn mowers, automatic washers, stoves, and scores of other modern products. Without the basic machine tools required for mass production and automation, the costs of many luxuries that we now enjoy would be prohibitive.

Additive manufacturing is the technology that allows the building of a 3D object by adding successive layers of material in a layer-by-layer process to complete the fabrication of the 3D object (see unit 93) (Fig. 1-14 on page 12).



■ **Figure 1-13** Robots are finding ever-increasing applications in industry. *(©Steve Krar)*

■ **Figure 1-14** The additive manufacturing machines create 3D components. *(Courtesy of SLM Solutions NA)*

Major Developments in Metalworking over the Past Century

Prior to the 20th century, manufacturing methods changed very slowly. Mass production had not developed nearly to the stage that we know now. It wasn't until the early 1930s that new and outstanding developments in manufacturing began to affect manufacturing processes. Since then, progress has been so rapid that now some of the newer developments astound most of us. It is because of this progress over the past 60 years or so that we in North America enjoy one of the highest standards of living in the world.

Manufacturing prior to 1932 was done on standard types of machine tools with little or no automation. Engine lathes, turret lathes, drill presses, shapers, planers, and horizontal milling machines were the common machine tools of the day. Most of the cutting tools were made of carbon steel or early grades of high-speed steel, which were not very efficient by today's standards. Production was slow and much of the work was finished by hand. This resulted in the high cost of the items produced in relation to wages paid to the workers.

In the early 1930s, machine tool manufacturers took advantage of the lull in production and sales caused by the Great Depression to upgrade their machines by improving flexibility and controls. Thus began the trend leading to the machines of the present.

According to the Society of Manufacturing Engineers and the AMT (Association for Manufacturing Technology), the following chronology lists the most important developments in metalworking during the past half century.

1942: *Heliarc welding* was a new process developed for welding magnesium on a production basis.

1943: *Air gaging* provided a means of gaging parts more quickly and accurately than was previously possible.

1944: The *60,000 r/min grinder motor* was developed to provide small grinding wheels (1/8 in. diameter or less) with sufficient speed for efficient grinding.

1945: *Man-au-trol control* was the first hydraulic-electric control system introduced for automatic machine control.

1946: The *ENIAC digital computer* was the first all-electronic general-purpose computer introduced and would eventually help with design problems.

1947: *Automatic size control* provided a means of automatically boring, honing, and gauging the size of engine block cylinders.

1948: *Cardamatic milling* used punch cards to automatically control the cycle of a milling machine.

1949: *Ultrasonic inspection* provided a nondestructive method of testing materials by means of extremely high-frequency sound waves.

1950: *Electronic hardness testing* was a quick and accurate type of test based on the magnetism retention of a part against a standard.

1951: *Method X electrical discharge machining* provided a means of removing metal from the workpiece by means of a spark of high density and short duration.

1952: *Numerical control* introduced a system attached to a milling machine whereby the table and cutting-tool movements were controlled by punched tape.

1953: *Project tinkertoy* was a system developed to automatically manufacture and assemble electronic circuit elements.

1954: *Indexible insert tooling* introduced a throwaway type of carbide cutting-tool insert, which could be turned over and used on both sides. This eliminated the need for expensive cutting-tool maintenance.

1955: The *numericord system* was the first completely automatic control for machines, provided by means of electronic control and magnetic tape.

1956: The *gear-honing process* provided a method used after heat treating to remove nicks and burrs from a gear and form it to its correct specifications.

1957: *Manufactured diamond* was developed by the General Electric Co. for grinding and machining hard, abrasive nonferrous and nonmetallic materials. It was produced by subjecting a form of carbon and a metal catalyst to high pressure and high temperature.

1958: The *machining center* introduced a computer-controlled machine with a tape-controlled toolchanger capable of performing milling, drilling, tapping, and boring on a workpiece as large as an 18-in. cube.

1959: The *APT (automatically programmed tool)* programming language was a 107-word computer language used by programmers to write programs using data from engineering drawings.

1960: *Ultra-high-speed machining* was based on the principle that at extremely high cutting speeds (2500 sf/min and higher) the tool temperature and horsepower required to machine a workpiece drop. Speeds of 18,000 sf/min were used and speeds of up to 36,000 sf/min were planned.

1961: The *industrial robot* provided a single-armed device that can manipulate parts or tools through a sequence of operations or motions as controlled by computer programs.

1962: *Computer-controlled steelmaking* introduced a system in which every steelmaking variable, from order and raw-material requirements to the finished product, is computer controlled.

1963: The *ADAPT programming language* provided a program compatible with APT language, used only about half of APT's vocabulary words, and was designed for use with small computers to control machine operations.

1964: *DAC-1, design augmented by computers,* was a computer system that allowed the computer to read drawings from paper or film and to generate new drawings by use of the keyboard and a lightpen.

1965: *System/360* introduced a large mainframe computer capable of responding in billionths of a second and became the standard in industry for the next decade.

1966: The *single-layer metal-bonded diamond grinding wheel* was a diamond-impregnated grinding wheel, contoured to the profile of the workpiece, and reduced the grinding time required for certain parts from 10 hours to 10 minutes.

1967: *Computer numerical control* provided a computer control system that combined the functions of separate tape preparation equipment, numerical control, and program and part verification into one unit.

1968: *Direct numerical control* allowed the operation of machines directly from the mainframe computer without the use of tapes.

1969: The *programmable controller* was a smaller, single-purpose computer that could control as many as 64 machines using APT-created programs.

1969: *CBN (cubic boron nitride),* an extremely hard abrasive, was developed by the General Electric Co. for grinding and machining hard, abrasive ferrous metals. It was produced by subjecting hexagonal boron nitride along with a catalyst to high pressure and high temperature.

1970: *Polycrystalline superabrasive cutting tool blanks* consist of a layer of diamond or CBN (cubic boron nitride) bonded to a cemented carbide substrate. They are used to cut hard, abrasive, nonferrous and nonmetallic materials (diamond) and ferrous materials (CBN).

1970: *System GEMINI* provided a system whereby a supervisory computer and a distribution computer control several machines in the total manufacture of a part. This system was the forerunner of the automatic factory.

1971: *Robotic sensory capabilities* permitted a robot to "feel" for objects by means of a sensor applied to the robot's gripping fingers or vacuum cup.

1972: The *Hummingbird press* was a 60-ton automated press with speeds of up to 1600 strokes per minute and a feed rate of 400 ft/min.

1973: *Robotic vision* was a robot system that utilized a television camera and image processing equipment to permit the robot to "see" and prevent the arm from bumping other parts as it travels to the desired location.

1974: *Remote machine diagnostics* allowed diagnosis of CNC machine problems in a plant by a computer in the manufacturer's head office by tying both computers into the telephone system.

1974: *Group technology (GT)* is a system of classifying parts on the basis of their similarities and physical characteristics so that they can be grouped together for manufacturing using the same process. This improves manufacturing productivity by the better use of machine tools and the efficient flow of parts through the machines.

1975: *Computer integrated manufacturing (CIM)* is an information system where computers integrate all manufacturing functions such as CNC, process planning, resource planning, and CAD/CAM with processes such as finance, inventory, payroll, and marketing. The CIM system controls all data flow within a company.

1975: The *super CIMFORM grinding wheel* was a long-life vitrified aluminum oxide grinding wheel developed for high production. It cut grinding costs by 25%.

1976: *CAM-I automated process planning,* when a part is required, allows the computer to determine the "family" the part belongs to, calls up the drawing, makes any necessary modifications, and then directs the production of the part in the shop.

1977: *Distributed plant management systems* allowed a DNC computer system in a plant to be controlled and programmed by a remote computer that may not even be located in the same plant.

1978: *Automated programmable assembly systems* were designed to increase production by the use of several programmed robots to assemble component parts into a unit.

1979: *YMS-50 flexible manufacturing systems* linked standard NC machine modules with a parts-handling device and provided total computer control of the system.

1980: The *variable mission automatic toolhead changer* stores and installs cutting tools, as programmed, on as many as 18 multiple spindle heads.

1980: *Adaptive control* uses the power of the computer to monitor a machining operation and make adjustments to the speed and feed rates to optimize a machining operation. It can be used to sense tool wear, the geometry of the cut, the hardness and rigidity of the workpiece, and the position of the tool in relation to the workpiece.

1981: The *grinding center* provides computer-controlled grinding that can be programmed for as many as 48 different grinds on a workpiece.

1982: *Just-in-time manufacturing,* a concept developed to improve productivity, reduce costs, reduce scrap and rework, use machines efficiently, reduce inventory and work-in-process (WIP), and make the best use of manufacturing space. It involves having the right materials, tools, and machines available at the time they are required for production.

1983: *Artificial intelligence (AI)* is a field of computer science that deals with computers doing humanlike functions such as interpretation and reasoning. It uses robots, vision systems, expert systems, and language and voice recognition to perform operations normally requiring human understanding.

1986: *Manufacturing automation protocol (MAP)* is a 7-layer broadband, token-bus communications protocol for the factory floor to achieve real-time cost monitoring, real-time quality monitoring, and real-time production monitoring. It is designed to accommodate a broad range of manufacturing environments and makes communication possible among computer-controlled factory floor equipment.

1988: *Microcrystalline aluminum oxide grinding wheels,* commonly called seeded gel or SG wheels, contain a submicron crystal structure with billions of particles in each grain. This feature allows grains to resharpen themselves, resulting in fewer wheel dressings and increasing productivity while lowering the cost per part.

1989: *Direct ironmaking and direct steelmaking processes* are in the developmental stage to produce iron and steel in one step. The aim is to develop environmentally sound procedures that reduce manufacturing time, require less energy, and lower the manufacturing cost.

1989: *Net shape manufacturing* involves the production of components by billet forming, precision and die casting, sheet forming, injection molding, and die making that are close to the finished size required.

1989: *Rapid prototyping and manufacturing,* also called stereolithography, combines the technologies of CAD, computers, and lasers to produce solid prototype models from a 3-dimensional technical drawing.

1990: *CVD (chemical vapor deposition)* was developed to provide a thin, long-wearing diamond film on cutting tools, wear parts, heat sinks and electronic substrates, optical devices, etc.

1991: *Concurrent engineering* is the integration of product design, manufacturing processes, and related technology to provide early manufacturing input into the design process.

1992: *Agile manufacturing,* the newest form of manufacturing, combines the state-of-the-art fabrication and product-delivery technologies to custom-make products to suit customers' specifications without increasing the price. This process is especially designed to quickly respond to continuously changing market conditions.

1993: The *octahedral hexapod* is a radical machine tool design for machining centers. It consists of a six-legged structure that connects the bed to the head and the spindle virtually floats in space. The hexapod has 6-axis contouring capability, five times the rigidity and is two to 10 times more accurate than conventional machines.

1994: *High-velocity manufacturing* uses a new axis drive system, *high-force linear motors,* to move machine axes. It is 10 times faster than ball screws, increases velocity rates three to four times higher, with greater accuracy and reliability. Spindle speeds range from 0 to 15,000 r/min on machining centers.

1995: *Combination conventional/programmable machines,* such as vertical mills, lathes, and surface grinders, can be used as conventional machine tools and have limited programming features for repetitive steps or operations. These machines can be taught to record a manual path and as a result increase productivity and part accuracy when doing repetitive operations on smaller lot jobs.

1996: *Artificial intelligence* is a manufacturing tool that is having a great effect in the areas of artificial vision, expert systems, robotics, machine control, natural language understanding, and voice recognition. It is also finding applications in product design, diagnostics, inspection, planning, and scheduling.

1997: *e-Manufacturing* is the technology of networking and controlling machine tools over the Internet through hardware and software technology. Machine tools are turned into Web servers, and they are integrated into the supply chain in ways limited only by the manufacturing imagination. Any process that contributes to a machine tool's effectiveness and productivity can see dramatic efficiency improvements within the InterNetwork.

1998: *The Direct Metal Deposition (DMD)*™ process involves the blending of five common technologies: lasers, computer-aided design (CAD), computer-aided manufacturing (CAM), sensors, and powder metallurgy. It is a form of rapid prototyping that makes parts and molds from metal powder that is melted by moving a laser back and forth, under CNC control, and tracing out a pattern controlled by a computerized CAD design.

1999: *Virtual reality (VR)* uses computers, hardware, and software to create objects and/or even alternate worlds. VR allows a person to create, manufacture, manipulate, look at, and play with something that is totally real in every respect, except it does not physically exist. Immersion provides the ability to believe that the user is present in the virtual world and can navigate through it and function within the simulated environment as if it were real.

2000: *Step NC* is a worldwide standard, developed by the International Standards Organization (ISO), to extend STEP (**St**andard for the **E**xchange of **P**roduct) model data so that it can be used to define data for NC (numerical control) machine tools. STEP is an extensible, comprehensive, international data standard for product data, created by an international team to give a clear and complete representation of product data throughout its life cycle.

2001: *Nanotechnology* is the technology that applies to the controlling of the structure of materials down to a few atoms or molecules. Researchers have a vision of synthetic molecular nanomachines made of mechanical parts consisting of actual gears and axles on a molecular scale. When these tiny (subminuscule) parts are planned as self-replicating nanorobots, they would push atoms and molecules together to build a wide variety of essential materials.

2002: *Cyber management systems* is where all manufacturing information is digitized and accessible to all departments—Engineering, Production, Sales, Distributors, On-line Support, and Administration—through a Central Dataway. Sharing data between all departments and using the Internet realize the absolute minimum time between the start of product design and shipment of finished products to customers.

2003: *Direct digital manufacturing* used by the automotive, medical, and aerospace industry as a part of additive fabrication to build assembly aids, by orthopedic surgeons to create customized metal joint implants, by video game designers to develop the latest in gaming characters.

2004: *Ultracapacitors* also called super-capacitors are the new emerging energy storage technology. Currently being used for applications such as DC motor drives, UPS systems, and electric vehicles. Ultra-capacitors are incredibly efficient and can be recycled over 500,000 times without degradation. They can store amazing amounts of energy in a relatively small space, are safe, and can recharge devices in seconds instead of hours. The perfect storage device for solar energy in the home.

2005: *Self-assembling nanotechnology* was used by IBM to enhance conventional computer chip manufacturing. This ever-changing technology makes it possible for objects, devices, and even systems to form other structures without external prodding or manipulation.

2006: *Autonomous navigation technology* integrates data from multiple types of sensors such as wheel encoders, laser range finders, and vision systems. With real time calculations performed on the sensor data this technology offers an extraordinary level of navigation autonomy as well as high-precision positioning. It provides safe motion in a human environment, human-friendly man-machine interface, and high-speed obstacle avoidance with wireless Ethernet communications.

2007: *Intelligent device integration (IDI)* is currently used in personal and handheld computers. IDI offers unprecedented visibility into and management of equipment, products, and consumer interactions by combining sensor data with two-way wireless communications. Real-time views of activities and objects will make for a faster response time and the ability to predict manufacturing incidents before they happen.

2008: *Integrated 3-D simulation and modeling/desktop super computers* have revolutionalized computer modeling. These super computers enable the user to see any part or segment instantly with as much detail as required with 3-D impact and full rotation. They will make it possible for the computer to be used as a microscope, telescope, and time machine to manage, view, and tool a complete manufacturing system.

2009: *Micro machining* has been around for some time, but today's companies are pushing the technology to new limits with the manufacture of micro-turned parts with diameters between .1574 and .0039 inches with variances in microns and a parts defect rate of 0 PPM (pieces per million).

2010: *3D printing or additive manufacturing* is the process of making three-dimensional objects from a digital file by placing one thin layer of material on top of another until the object is completed. Inexpensive models have made 3D printing very popular for home and office.

2014: *IoT, or the internet of things,* is a concept that virtually connects everything to each other (machine-to-machine communications) through a network of nodes on the machine, person or anything that transmits data via the internet.

IIoT, or industrial internet of things, specifically applies to industrial applications that monitor and control production processes while capturing data. This will enable efficient management of entire supply chains.

2015: *Artificial intelligence (AI)* experts predict that (AI) will be responsible for the next Industrial Revolution. Computerization of manufacturing.

2016: *Smart Factory* is a vision of what manufacturing processes will look like in the future; the manufacturing processes will be organized with a complete production chain from the supplier to logistics to the life cycle management of a part or product.

2017: *New additive manufacturing systems* and materials are being used in manufacturing facilities around the world. Subtractive and additive machining go together because every critical part that is made additively is also likely to be a precision part with tolerances that only machining can achieve.

2020: *Technology* will continue to change manufacturing techniques and processes. Innovative, and improved workpiece materials and cutting tools.

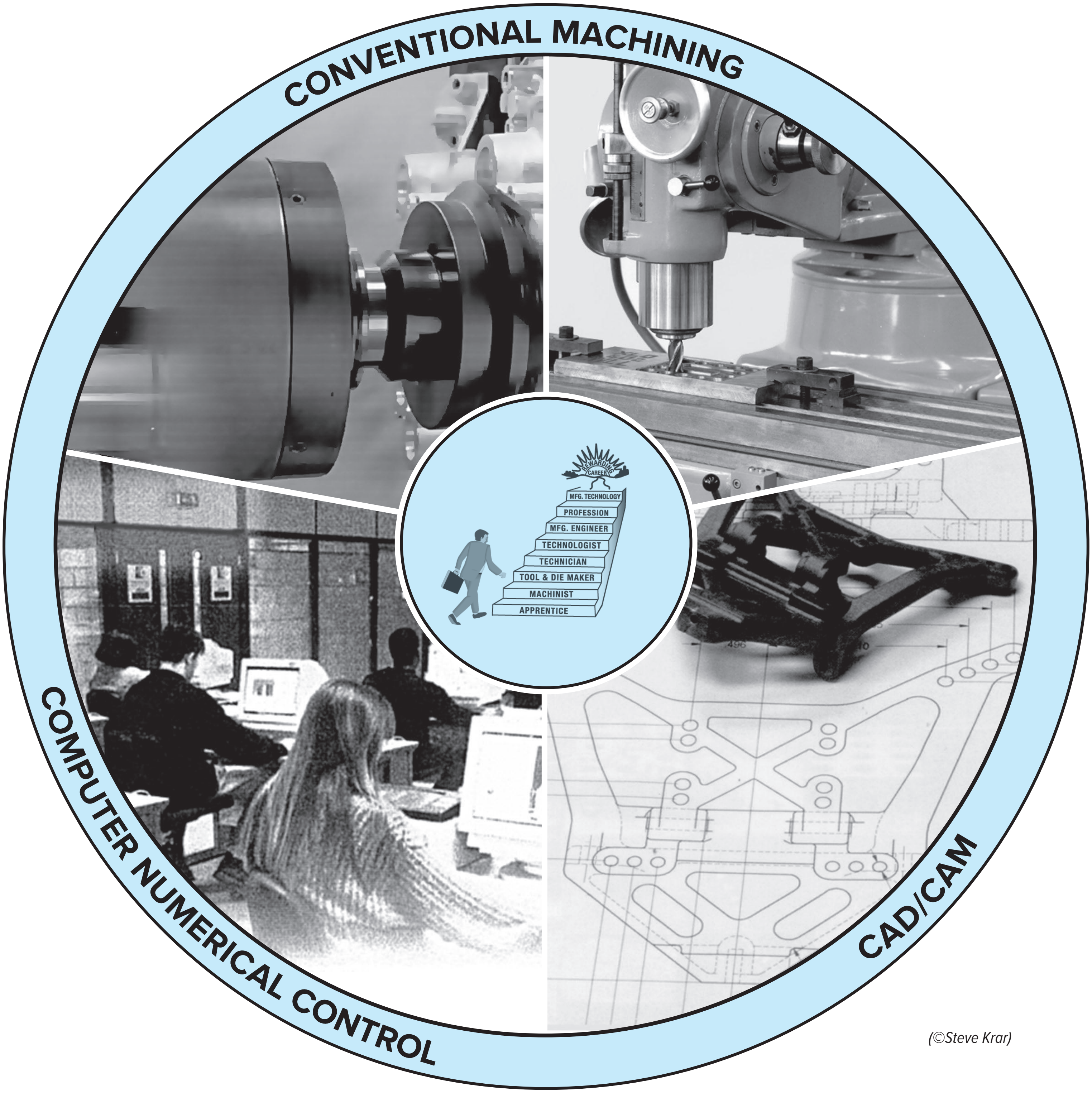
2025: *Will see technologies* such as smart software and robotics create a more productive and competitive environment for manufacturers. Machines will be smart, providing machine data in real time and thus reducing maintenance and manufacturing problems.

2050: *Manufacturing in 2050* will look very different from 2025 and be virtually unrecognizable from that of today. A highly skilled and agile workforce will be required to produce the transportation vehicles, domestic appliances, and consumer electronics that will be created in a virtual world, using smartphones and other electronic devices.

unit 1 review questions

1. Briefly trace the development of tools from the stone age to the industrial revolution.
2. Why are machine tools so important to our society?
3. How have improved production and accuracy been achieved with basic machine tools?
4. Name four categories of machine tools used in metalworking.
5. List five operations that can be performed on each of the following:
   a. Drill press
   b. Lathe
   c. Milling machine
6. Name four types of grinders found in a machine shop.
7. List four advantages of CNC machine tools.
8. What is the difference between a chucking center and a turning center?
9. Name two types of machining centers.
10. What is the purpose of a:
    a. wire-cut EDM machine?
    b. ram-type EDM machine?
11. What is the importance of the electro-machining processes?
12. What effect have computer numerical and computer control had on manufacturing?
13. State two applications of robots.
14. What is the importance of lasers in modern industry?
15. Define the term additive manufacturing.

Section 2



(©Steve Krar)

MACHINE TRADE OPPORTUNITIES

Almost all products used by people, whether in farming, mining, manufacturing, construction, transportation, communication, or the professions, are dependent on machine tools for their manufacture. Constant improvements to and efficient use of machine tools affect the standard of living of any nation. Only through machine tools have we been able to enjoy the automobile, airplane, computers, home furnishings, appliances, personal electronics devices, and many other products on which we rely in our daily lives. Through constant improvement, modern machine tools have become more accurate and efficient. Improved production and accuracy have been made possible through the application of hydraulics and electronic devices such as numerical control, computer numerical controls, direct numerical control, wireless communications, and lasers to machine tools.

UNIT 2

Careers in the Metalworking Industry

OBJECTIVES

After completing this unit, you will be familiar with:

1 The various types of jobs available in the metal-working industry

2 The type of work each job entails

The world is becoming increasingly complex, where success is driven not only by what you know, but by what you can do with this knowlege. Manufacturers across the country are facing a skills gap crisis. Workers do not possess the necessary skills to fill specialized manufacturing positions. It is becoming more important than ever that we have the knowledge and skills to gather and evaluate information to solve difficult problems. These are the skills that will be learned by studying science, technology, engineering, and math, subjects known as STEM.

Advancing technology, new ideas, new products, and special processes and manufacturing techniques are creating new and more specialized jobs. To advance in the machine trade, a person must keep up-to-date with modern technology. A young person leaving school may be employed in an average of five jobs in his or her lifetime, three of which do not even exist today. Industry is always on the lookout for bright young people who are conscientious and do not hesitate to assume responsibility. To be successful, do the job to the best of your ability and never be satisfied with inferior workmanship. Always try to produce quality products, at a reasonable price, in order to compete with foreign products which are of serious concern to North American industry.

New Technologies

Technology is a tool that makes it possible to produce better quality goods at lower prices. Our standard of living has always been built on the ability to produce products that are in demand throughout the world. Therefore, it can be said that technology can be used to increase the resources of a nation and generate wealth. It seems that the most progressive and wealthiest countries in the world are those that use the latest manufacturing technologies to make them more productive than other countries.

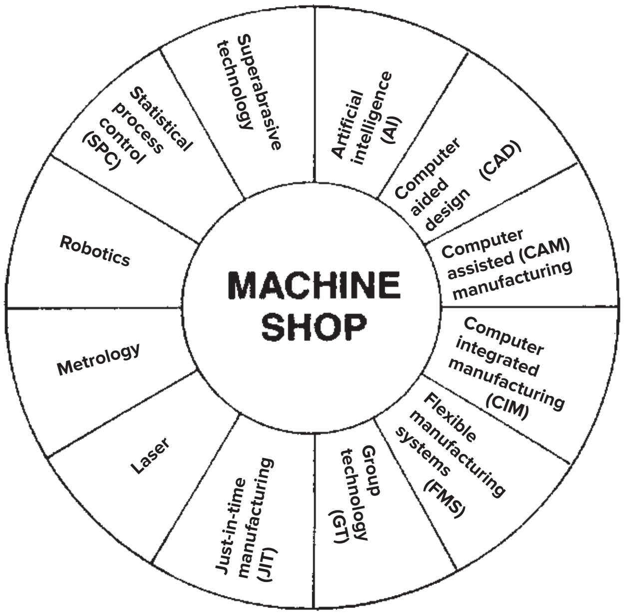
Technology is continually changing and improving, with the amount of technology doubling every three to five years. Machines and manufacturing processes as little as 10 years old can be two generations behind those of the most progressive manufacturing nations of the world. Not only is it important to keep up with the improvements in equipment and processes, it is equally or more important to prepare our students to enter the technological workplace. We cannot expect high technology work from low technology workers; training can make the difference between success and failure. The ever-changing technology means that industrial workers and students in schools must be prepared for continual education (lifelong learning) if they expect to survive in the technological world in which we live.

TECHNOLOGY CURRICULUMS

Rapidly changing technology in the metalworking industry makes it imperative for educators to stay abreast of new improvements and manufacturing processes. To best serve industry and increase the productivity of the nations, educators must continually introduce new material into their curriculum to prepare students to enter the technological world of today. Old “time-proven” methods and processes have been outmoded by new technology. The educational institutions that recognize this and take the appropriate steps will produce graduates who are a credit to their school and make a valuable contribution to the country.

TECHNOLOGY COURSES

Machine shop, which provides the background and groundwork for all manufacturing technologies, is the prerequisite for all students planning to enter the exciting manufacturing world. Along with the knowledge of the basic machining process, a good understanding of computer numerical control (CNC) is essential. In the world today, with approximately 90% of the machine tools manufactured for CNC use, a good knowledge of this area is as important as being able to read and write. A strong background opens up many exciting careers to the progressive student, such as artificial intelligence, computer-aided design, computer-automated manufacturing, flexible manufacturing systems, group technology, just-in-time, lasers, metrology, robotics, statistical process control, superabrasive technology, etc. (Fig. 2-1).



■ **Figure 2-1** A good machine shop background provides the basics for all manufacturing technology careers. *(Source: Kelmar Associates)*

MODULAR TRAINING SYSTEM

A modular training system (Fig. 2-2) offers technical/vocational training covering the skills required for modern manufacturing in the metalworking trade, where computers are playing an ever-increasing role. The training program, developed by a leading machine tool manufacturer and used by many educators throughout the world, consists of individual modules that can readily be incorporated into a technical education curriculum.

The training modules start with the conventional machine tools and processes; progress through the CNC modules; and incorporate skills relating to quality control, machine maintenance, and low-cost automation. In easy-to-learn stages, these modules prepare a student for the complex task of learning how to operate, program, and build a modern flexible manufacturing system.

A brief summary of the main areas of the modular training system follows.

> *Conventional machining* covers the fundamentals of conventional machine tools and the machining processes associated with each machine tool. These skills are necessary so that students learn the basics of machining metal workpieces and develop a feeling for machining the part most efficiently. No metalworking profession or related technology should be without these basic skills.

> *CNC machining* covers the skills and knowledge necessary to program and operate CNC machine tools. This must include the most cost-effective way of producing error-free CNC part programs from the simple to the complex workpiece. CNC training is essential for anyone looking for a rewarding career in manufacturing technology because of the large number of these machines used in industry.

> *CAD/CAM techniques* provide the skills to design parts on a computer and then use this data for machining the parts on CNC machine tools. Without the flexibility, ease of design, and time saving made possible by CAD/CAM techniques, a manufacturer cannot successfully compete today.

> *Quality control* covers the methods and tools used for measuring dimensions, shapes, and surface textures of finished workpieces. The data collected in this process can be used to improve and eliminate errors from manufacturing processes. Quality control is one of the most important parts in the manufacturing process. It plays a vital role in improving the competitive position of the manufacturer.

> *Maintenance* covers the routine upkeep, aligning and adjusting machines, troubleshooting, and repairs of conventional and CNC machine tools. This maintenance, commonly called *preventive maintenance,* ensures that machine tools operate properly to provide a continuous manufacturing operation, with minimum downtime for maintenance.

> *Automation* provides training in automating the loading and unloading of workpieces for CNC machine tools, material handling, and quality control

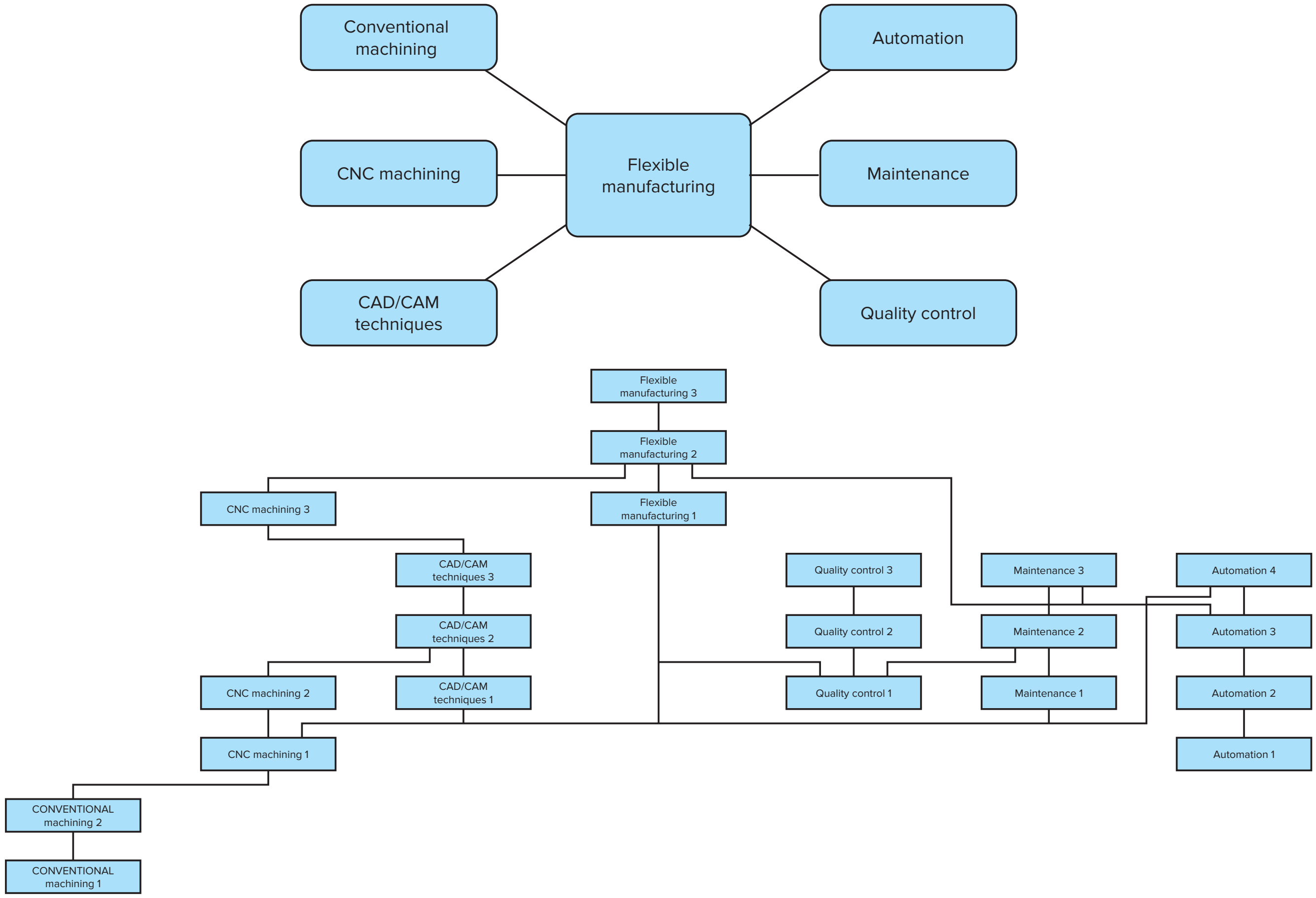


Figure 2-2 Modular training system. *(Source: Emco Maier Corp.)*

of the manufacturing process. This low-cost automation is used by many manufacturers that cannot implement the more complex flexible manufacturing technology.

> *Flexible manufacturing*—This module enables students to identify the elements of a flexible manufacturing system, its programming, the planning of manufacturing processes, and design of the system. (All the prior modules of this program provide the fundamental skills for the flexible manufacturing program.) The flexible manufacturing system is able to adapt to changes in the number of parts required and the type of part machined, accept new or different products, make design changes to parts, and allow them to be expanded quickly.

Many different careers are available in the metalworking industry. Choosing the right one depends on the skill, initiative, and qualifications of an individual. Metalworking offers exciting opportunities to any ambitious young person who is willing to accept the challenge of working to close tolerances and producing intricate parts. To be successful in this trade, the individual must also possess characteristics such as care of self, orderliness, accuracy, confidence, and safe work habits.

Apprenticeship Training

One of the best ways to learn a skilled trade is through an apprenticeship program. An apprentice is a person who is employed to learn a trade under the guidance of skilled tradespeople (Fig. 2-3). The apprenticeship program is set up as a joint agreement between the sponsoring apprentice company, the Department of Labor Federal Bureau of Apprenticeship, and the trade union. It is usually about two to four years' duration and includes on-the-job training and related theory or classroom work. This period of time may be reduced by the completion of approved courses or because of previous experience in the trade.

To qualify for an apprenticeship, the individual should have completed a high school program or its equivalent. Mechanical ability with a good standing in mathematics, science, English writing skills, and mechanical drawing is desirable. Apprentices earn as they learn; the wage scale increases periodically during the training program.

Upon completion of an apprenticeship program, a certificate is granted, which qualifies a person to apply for journeyman status in the trade. Further opportunities in the trade are limited only by the person's initiative and interest. It is quite possible for an apprentice eventually to become an engineer, tool designer, supervisor, or shop owner.

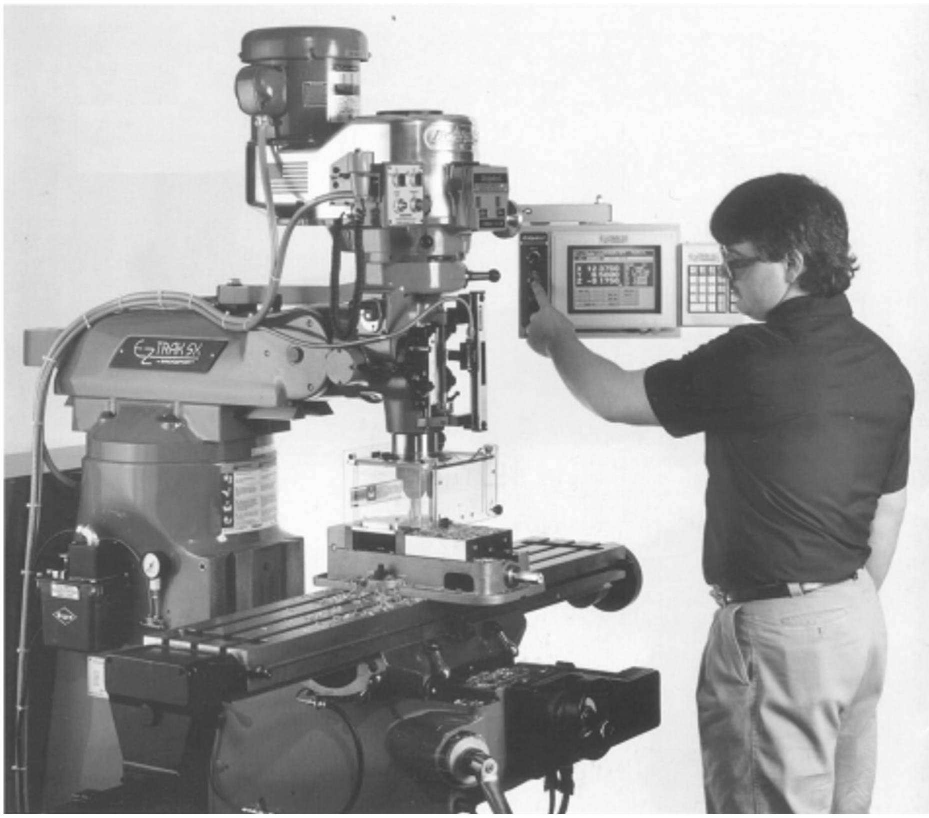
■ **Figure 2-3** An apprentice learns the trade under the guidance of a skilled tradesperson. *(©Monkey Business Images/ Shutterstock)*

Machine Operator

Machine tool operators are classified as semiskilled tradespeople (Fig. 2-4). They are usually rated and paid according to their job classification, skill, and knowledge. The class A operator possesses more skill and knowledge than class B and C operators. For example, a class A operator should be able to operate the machine and:

- Make necessary machine setups
- Adjust cutting tools
- Calculate cutting speeds and feeds
- Read and understand drawings
- Read and use precision measuring tools

With the continued advancement in computer-controlled machines and programmable robots, gradually operators' jobs will be minimized. However, some machine tool operators may qualify with advanced technology courses and remain employed as operators on computer numerical control (CNC) turning centers, machining centers, and CNC robots.



■ **Figure 2-4** A machine operator generally operates only one type of machine. *(©Steve Krar)*

Maintenance Machinist

The maintenance machinist needs a combination of mechanical, rigging, and carpentry skills. The time for apprenticeship varies but usually ranges from two to four years and includes the necessary related theory for the job. During the apprenticeship, the trainee works with qualified tradespeople. A maintenance machinist may be required to:

- Move and/or install machinery, including production lines
- Read drawings and calculate sizes, fits, and tolerances of machine parts
- Repair machines by replacing and fitting new parts
- Dismantle and install equipment

To become a maintenance machinist apprentice, a student should have good technical training and be a high school graduate. A general knowledge of electricity, carpentry, sheet metal, and the machine tool trade is helpful.

The job outlook is good. Most large industries are expected to employ a workforce of maintenance machinists to maintain and install machinery and production lines for the foreseeable future.

Machinist

Machinists (Fig. 2-5) are skilled workers who can efficiently operate all standard machine tools. Machinists must be able to read drawings and use precision measuring instruments and hand tools. They must have acquired enough knowledge and developed sound judgment to perform any bench, layout, or machine tool operation. In addition, they should be capable of making mathematical calculations required for setting up and machining any part. Machinists should have a thorough knowledge of metallurgy and heat treating. They should also have a basic understanding of welding, hydraulics, electricity, and pneumatics and be familiar with computer technology.

Figure 2-5 A machinist is skilled in the operation of all machines. *(©Dmitry Kalinovsky/Shutterstock)*

TYPES OF MACHINE SHOPS

A machinist may qualify to work in a variety of shops. The three most common are maintenance, production, and jobbing shops.

A *maintenance shop* is usually connected with a manufacturing plant, lumber mill, or foundry. A maintenance machinist generally makes and replaces parts for all types of setup and cutting tools and production machinery. The machinist must be able to operate all machine tools and be familiar with bench operations such as layout, fitting, and assembly.

A *production shop* may be connected with a large factory or plant that makes many types of identical machined parts, such as pulleys, shafts, bushings, motors, and sheet-metal pieces. A person working in a production shop generally operates one type of machine tool and often produces identical parts.

A *jobbing shop* is generally equipped with a variety of standard machine tools, CNC machines, and perhaps a few production machines, such as punch and shear presses. A jobbing shop may be required to do a variety of tasks, usually under contract to other companies. This work may involve the production of jigs, fixtures, dies, molds, tools, or short runs of special parts. A person working in a jobbing shop generally is a qualified machinist, toolmaker, or mold maker and is required to operate all types of machine tools and measuring equipment.

Tool and Diemaker

A *tool and diemaker* is a highly skilled craftsperson who must be able to make different types of dies, molds, cutting tools, jigs, and fixtures (Fig. 2-6). These tools may be

Figure 2-6 A tool and diemaker can operate all machine tools and plan procedures for making tools, dies, and fixtures. *(Courtesy of Diamond Innovations, at www.abrasivesnet.com)*

used in the mass production of metal, plastic, or other parts. For example, to make a die to produce a 90° bracket in a punch press, the tool and diemaker must be able to select, machine, and heat treat the steel for the die components. He or she should also know what production method will be used to produce the part since this information will help to produce a better die. For a mold used to produce a plastic handle in an injection molding machine, the tool and diemaker must know the type of plastic used, the finish required, and the process used in production.

To qualify as a tool and diemaker, a person should serve an apprenticeship, have above-average mechanical ability, and be able to operate all standard machine tools. This work also requires a broad knowledge of shop mathematics, print reading, machine drafting, principles of design, machining operations, metallurgy, heat treating, computers, and space-age machining processes.

CNC Machine Operator/Programmer

The wide use of CNC machine tools in the metalworking industry creates a big demand for a person skilled in computer numerical control (Fig. 2-7). The duties of a CNC machine operator will vary from shop to shop. In some shops, the person will be responsible only for the setup and operation of the machine tool, while in others it may also involve preparing the computer program.

A *CNC machine operator* must be able to:

- Visualize a CNC program
- Understand machining processes and the sequence of operations
- Make machine setups

Figure 2-7 CNC machine tool operators and programmers are in high demand. *(©Monkey Business Images/Shutterstock)*

- Calculate speeds and feeds
- Select cutting tools

A *CNC programmer* must possess all the skills of a CNC machine operator and must:

- Be skilled in print reading
- Have a good knowledge of computer programming languages and procedures
- Be able to visualize machining processes and operations

Technician

A *technician* is a person who works at a level between the professional engineer and the machinist. The technician may assist the engineer in making cost estimates of products, preparing technical reports on plant operation, or programming a numerical control machine.

Technologist

A *technologist* works at a level between a graduate engineer and a technician. Most technologists are three- or four-year graduates from a community or technical college. Their studies generally include physics, advanced mathematics, chemistry, engineering graphics, computer programming, business organization, and management.

An *engineering technologist* may do many jobs normally performed by an engineer, such as design studies, production planning, laboratory experiments, and supervision of technicians. This permits the engineer to work in other important areas. Technologists are often employed to serve in a middle management position within a large company. A technologist may be employed in many areas, such as quality and cost control, production control, labor relations, training, and product analysis. A technologist may qualify as an engineer by obtaining further education at the university level and by passing a qualifying examination.

Quality Control Inspector

An *inspector* (Fig. 2-8) checks and examines machined parts to determine whether they meet the specifications on the drawing. If the parts are not within the limits shown on the drawing, they will not fit together and function properly when assembled. This task is very important since parts made in one country may be assembled in another or be interchanged with worn or broken parts.

■ **Figure 2-8** Inspectors check the dimensions of finished parts and products. *(©Steve Krar)*

An inspector should have a technical or vocational education and be familiar with measuring tools and inspection processes. On-the-job training may take from several weeks to several years, depending on the job, the items to be inspected, and the technical knowledge required. An inspector may need varying degrees of skill depending on the size, cost, type, and tolerances required on the finished workpiece. A good inspector should be able to:

- Understand and read mechanical drawings
- Make basic mathematical calculations
- Use micrometers, gages, comparators, and precision measuring instruments

Instrument Makers

Instrument makers are highly skilled tool and diemakers who work directly with scientists and engineers. Instrument makers should be able to operate all precision machine tools in order to make measuring instruments, gages, and special machines for testing purposes. Generally, instrument makers must have more training than a machinist or a tool and diemaker. They must work to closer tolerances and limits than a machinist. Also, they usually must perform all the work on the instrument or gage being produced.

Instrument makers generally serve four or five years of apprenticeship. They may also learn the craft by transferring from a toolmaker or machinist trade and further training on the job.

With new processes in manufacturing, the demand for instrument makers will remain fairly close to the demand for skilled tradespeople. Instrument makers are employed by research centers, scientific laboratories, manufacturers of gages and measuring tools, and government and standards organizations.

Professions

Many areas are open to the engineering graduate. Teaching is one of the most satisfying and challenging professions. Graduation from a college, including teacher training course work, is required. On-the-job industrial experience is not always a prerequisite, but it will prove helpful in teaching. However, some states and/or schools require on-the-job experience to qualify for technical and vocational certification. With industrial experience a person may teach industrial arts or in certain subject areas in a technical school, vocational school, or community college.

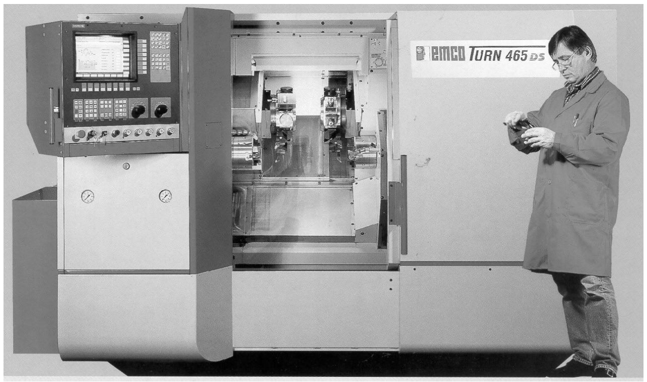
Engineers in industry are responsible for designing and developing new products and production methods and for redesigning and improving existing products. Most engineers specialize in a specific discipline of engineering, such as:

- Industrial
- Metallurgical
- Aerospace
- Mechanical
- Electrical
- Electronics

A bachelor's degree in engineering is usually required to enter the profession. However, in some branches of engineering, such as tool and manufacturing, the individual progresses through a program of practical experience and obtains a certificate after passing a qualifying examination. Because of the variety of engineering jobs available, many women, as well as men, are entering the profession.

A technician should have completed high school and have at least two additional years of education at a community college, technical institute, or university. A technician must also possess a good knowledge of drafting, mathematics, and technical writing.

Opportunities for technicians are becoming more plentiful because of the development of machine tools



■ **Figure 2-9** A technician is often required to check the setup and operation of a machine program. *(Courtesy of Emco Maier Corp.)*

■ **Figure 2-10** A management conference. *(©Matej Kastelic/Shutterstock)*

such as computer numerical control, turning centers, and electro-machining processes. Technicians are usually trained in only one area of technology, such as electrical, manufacturing, machine tool, or metallurgy. Some technicians may need knowledge beyond that of their specialty field. For example, a machine tool technician (Fig. 2-9) should have a knowledge of industrial machines and manufacturing processes to know the best method of manufacturing a product. However, it is not necessary for a technician to perform as a skilled machinist. A technician may qualify as a technologist after at least one year of on-the-job training under a technologist or an engineer.

Trade Organizations

Society today could not exist without manufacturing, and manufacturing could not exist without machine tools, which are the power base of the modern industrial world. The dramatic changes in technology over the past 25 years have made it imperative to learn about and implement new manufacturing technology in order to stay competitive in the world. Two major machine tool–related organizations have been leaders in seeing that their members stay abreast of this rapidly changing world: AMT—The Association for Manufacturing Technology and the Society of Manufacturing Engineers (SME). Both are involved in the continual updating of programs for students, educators, tradespeople, and manufacturing personnel.

AMT—THE ASSOCIATION FOR MANUFACTURING TECHNOLOGY

AMT (formerly the National Machine Tool Builders' Association) is a nonprofit trade association representing U.S. companies in the machine tool building and related manufacturing industries. This association has been preparing its members for the change created by the ever-changing manufacturing technology. Supported by executives of member companies, AMT develops programs to meet member needs in marketing, technology, production, training, communications, and financial administration (Fig. 2-10).

The association has seen the need to develop skilled personnel for all phases of the machine tool industry. An extensive scholarship program is supported by AMT for technical training.

AMT and its member companies provide the machines, tools, and equipment for young machinists to compete in the VICA National Precision Machining Competition at the Skills U.S.A. Championships. Since 1990, it has hosted the International Machining Trials at its biannual International Manufacturing Technology Show (IMTS), to select contestants who will represent the United States in the International Skills Competition. AMT has also developed effective training procedures and textbooks used in vocational schools and technical colleges.

THE SOCIETY OF MANUFACTURING ENGINEERS

The Society of Manufacturing Engineers (SME) is an international society dedicated to advancing the manufacturing profession through the sharing of technical information. Its goal is to advance the knowledge of manufacturing technology of its over 80,000 members throughout the world.

To encourage engineering as a profession among young people in vocational schools, technical institutions, and community colleges, SME sponsors about 300 student chapters with over 9000 members. The society also assists colleges and technical institutions with curriculum development, career guidance resources, and grants for equipment and software. Over the years SME has become a storehouse for the most up-to-date technological knowledge through its publications of technical papers, textbooks, magazines, films, and videotapes. Membership in an organization such as SME is essential to keep up with the ever-changing technology. It is open to students, teachers, machinists, technicians, and manufacturing engineers who wish to advance their careers through lifelong learning.

unit 2 review questions

1. What four effects does technology have on the country and its ability to manufacture goods?
2. Name four of the most important careers available to those with a good background in CNC.
3. List the seven key elements of a modular training system.
4. Define an apprentice.
5. Name three desirable qualities a person should have for apprenticeship training.
6. Explain the difference between a machinist and a machine operator.
7. Briefly explain the difference between a jobbing and a production shop.
8. Define a tool and diemaker.
9. How can a person become a tool and diemaker?
10. How do the duties of a CNC programmer differ from those of a CNC machine operator?
11. Explain the difference between a technician and a technologist.
12. Briefly define the duties of an inspector and an instrument maker.
13. What qualifications must a person have to become a technical teacher?
14. List four areas in industry that require an engineer's qualifications.
15. What skills will be learned by studying the subjects known as STEM?

UNIT 3

Getting the Job

OBJECTIVES

After completing this unit, you will be able to:

1 Prepare a comprehensive résumé

2 Arrange for a job interview

3 Prepare for and follow up on the job interview

After graduation or leaving school, your most important task probably is that of finding a full-time job. *Choosing the right job is very important*.

After consulting with the school guidance counselor, state employment service, and any other agency that may be helpful, start looking into the job that appeals to you. In most areas, aptitude and interest tests are available to help you decide on the career you wish to explore.

Assess Your Abilities

To help determine where your interests lie, ask yourself the following questions:

- What type of work do I like?
- What type of work do I dislike?
- What jobs have I done with some success?
- What skills have I acquired at school?
- What have I done in my part-time work that has been outstanding?
- Do I enjoy taking apart and repairing appliances and items which are not working?

Explore Your Interests

After having narrowed the field, then:

- Research information on the chosen subject(s) (Fig. 3-1).
- Talk to people who do the type of work that you are considering. Ask them about the job and job opportunities.

Figure 3-1 Research as much as possible about a job that appeals to you. *(©Rawpixel.com/Shutterstock)*

- Talk further with your school guidance counselor.
- Consult state or federal employment services.

When you have gathered enough information to discuss reasonably the type of work you are interested in, check the classified ads in the newspapers.

Writing a Résumé

When you have decided on the job you wish to apply for, prepare a résumé listing the following facts in a logical order:

- Your full name
- Address, including zip code, and telephone number, including area code
- Education—schools attended and grade or level completed
- Other special training that may be helpful, for example, first-aid courses
- Special interests and hobbies
- Sports in which you are active or interested
- Any organizations to which you belong or in which you are active
- Previous employment. List the names of firms and places where you have worked and in reverse chronological order. Include the following information:

  Dates of employment

  Type of work and equipment operated (if any)

  Supervisor's name

  A portfolio with copies of certificates or courses you have completed
- A list of at least three persons who can be contacted for character references. Include addresses and telephone numbers. Be sure to ask permission to use their names *before* listing them on an application.

Many state employment services and government agencies have pamphlets that can be used as a guide to prepare résumés. Also available is information on how to get and keep a job, which can be especially valuable to a person looking for that first job.

Facts About Interviews

ARRANGING AN INTERVIEW

After completing your résumé, submit it with a cover letter to the personnel manager of the company you are interested in. Be sure to include a request for an interview. In many cases you may phone the company and make an appointment for an interview. In this case, leave the résumé with the person who interviews you.

Another option when seeking employment is to go through an employment agency. These agencies will take your résumé and do an interview to find out what jobs you would be interested in. They will find potential employers on your behalf and set up interviews for you.

QUESTIONS COMMONLY ASKED DURING AN INTERVIEW

Prior to the interview, consider the following questions, which are often asked by employers, and the probable reason for asking them. You should be prepared with satisfactory answers.

Question: **Why would you like to work here?**
Reason: To see if you have gathered any information about the company before the interview.

Question: **What were your best subjects at school?**
Reason: This will reveal some of your interests and abilities.

Question: **What sports or activities did you participate in when attending school?**
Reason: To find out your interests and abilities outside of school. Also to see if you can work as part of a team.

Question: **What type of job do you hope to have five years from now?**
Reason: To assess your ambition and initiative.

Question: **At what salary would you expect to start?**
Reason: To see if you are familiar with the going rates and to see how you assess your abilities.

Question: **What do you have to offer for the job?**
Reason: To give you a chance to outline your abilities.

Question: **What type of books or plays are you interested in?**
Reason: To assess your interests and often your environment.

Question: **How did you get along with your previous employer?**
Reason: Your answer may reveal whether you are a complainer and a person who is hard to get along with.

Question: **Why are you applying for this job?**
Reason: To see if you have checked into this particular job and aren't just looking for any job.

THE INTERVIEW

When preparing for the interview, you should consider the following:

- Be sure of the address, the office, and the time.
- Know the name and position of the person who will be interviewing you. This information can be obtained by a phone call to the company prior to the interview.
- Be neatly dressed and groomed. Remember, a neat applicant usually commands more attention (Fig. 3-2).

■ **Figure 3-2** Be at ease while you are interviewed. *(©Antonio Guillem/Shutterstock)*

■ **Figure 3-3** Always thank the interviewer—it may pay off! *(©Wavebreakmedia Ltd/Getty Images)*

- Be punctual.
- Display confidence when you introduce yourself to the interviewer.
- During the interview, be honest. Emphasize your good qualities and abilities, but don't bluff.
- Know enough about the company to enter into a discussion with the interviewer.
- Never underestimate the importance of a firm handshake with solid eye contact.

AFTER THE INTERVIEW

- Thank the interviewer and ask when you may expect to hear from him or her (Fig. 3-3).
- If you are offered a job, accept it (or reject it) as soon as possible. Never let the prospective employer await your decision indefinitely. If you aren't interested, explain why.
- The next day, send the interviewer a short letter expressing your appreciation for the valuable time he or she took for the interview.
- If you don't hear from the company in a reasonable time (seven to 10 days) call and ask for the person who interviewed you. Ask if he or she has made a decision yet and, if not, when you might expect one.
- If you don't get the first job, apply to other companies. Don't stop looking.
- Try to learn from each interview, which will eventually help you to get the right job.
- After several unsuccessful interviews, you might seek professional counseling from the Department of Labor, a vocational school, or a community college.

Points to Remember

- The job will not find you. You must find the job.
- Know the type of work that you want and don't offer to take just any job.
- Look for the type of work that you feel will be interesting. You will be more successful if you like your work.
- Potential employers may look into any social media that you may have. It is a good idea to keep your online accounts clean and updated.

unit 3 review questions

1. List four things that you should consider when attempting to assess your abilities.
2. Name four ways to obtain further information about a trade or job.
3. Assume that you are applying for a job; prepare a personal résumé that you would submit to an employer.
4. Name three methods of arranging an interview.
5. List four important points that you must consider in preparing for an interview.
6. Name four important actions that you can take to follow up an interview.

Section 3

HIGH VOLTAGE
DANGER TO HANDS
INFLAMMABLE
POISON
DANGER OF FALLS

SAFETY

Today's modern machine shops are acquiring more computer-controlled equipment and robotics. Under OSHA (Occupational Safety and Health Association) law, employers have a responsibility to provide workers a safe workplace. The need to be able to evaluate unsafe conditions and work habits is essential. Some companies have installed video cameras throughout their facilities to be able to identify and have a visible account of unsafe practices or accidents that may occur. Not only is this valuable information for safety training, but it is a source of information required by OSHA.

There has never been a more meaningful saying than "Safety Is Everyone's Business." Safety is becoming an even greater concern than it was a few years ago. Companies are requiring visitors to sign in at reception and wear proper identification, footwear, and safety glasses before entering the shop areas. To become a skilled craftsperson, it is very important for you to learn to work safely, taking into consideration not only your own safety but the safety of your fellow workers. In general, everyone has a tendency to be careless about safety at times. We take chances every day by not wearing seat belts, walking under ladders, cluttering the work area, and doing many other careless and unsafe things. People tend to feel that accidents always happen to others. However, be sure to remember that a moment of carelessness can result in an accident that can affect you for the rest of your life. A loss of eyesight because of not wearing safety glasses or the loss of a limb because of loose clothing caught in a machine can seriously affect or end your career in the machine tool trade. *Think safe, work safe, and be safe*.

UNIT 4

Safety in the Machine Shop

OBJECTIVES

After completing this unit, you will be able to:

1. Recognize safe and unsafe work practices in a shop
2. Identify and correct hazards in the shop area
3. Perform your job in a manner that is safe for you and other workers

All hand and machine tools can be dangerous if used improperly or carelessly. Working safely is one of the first things a student or an apprentice should learn because the safe way is usually the correct and most efficient way. A person learning to operate machine tools *must first* learn the safety regulations and precautions for each tool or machine. Far too many accidents are caused by careless work habits. It is easier and much more sensible to develop safe work habits than to suffer the consequences of an accident. *Safety is everyone's business and responsibility*.

Safety on the Job

The safety programs initiated by accident prevention associations, safety councils, government agencies, and industrial firms are constantly attempting to reduce the number of industrial accidents. Nevertheless, each year accidents that could have been avoided result not only in millions of dollars' worth of lost time and production but also in a great deal of pain, many lasting physical handicaps, or even the death of workers. Modern machine tools are equipped with safety features, but it is still the operator's responsibility to use these machines wisely and safely.

Accidents don't just happen; they are caused. The cause of an accident can usually be traced to carelessness on someone's part. Accidents can be avoided, and a person learning the machine tool trade must first develop safe work habits.

A safe worker should:

> Be neat, tidy, and safely dressed for the job he or she is performing
> Develop a responsibility for personal safety and the safety of fellow workers
> Think safely and work safely at all times

Safety in the Shop

Safety in a machine shop may be divided into two broad categories:

> Those practices that will prevent injury to workers
> Those practices that will prevent damage to machines and equipment. Too often damaged equipment results in personal injuries.

When considering these categories, we must consider personal grooming, proper housekeeping (including machine maintenance), safe work practices, and fire prevention.

PERSONAL GROOMING

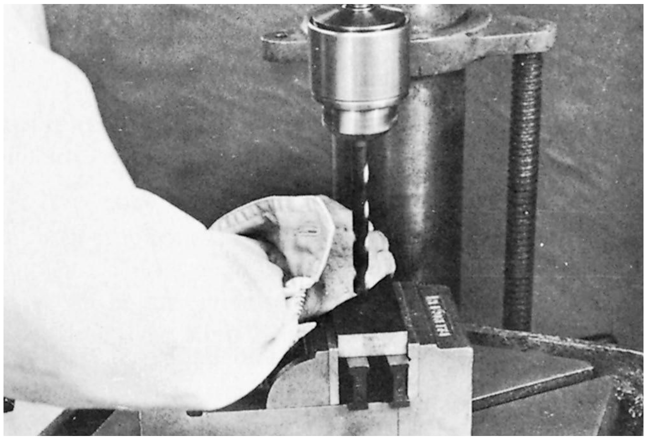
The following rules should be observed when working in a machine shop.

1. Always wear approved safety glasses in any area of the machine shop. Most plants now insist that all employees and visitors wear safety glasses or some other eye protection device when entering a shop area. Several types of eye protection devices are available for use in the machine shop:
   a. The most common are *plain safety glasses* with side shields (Fig. 4-1a). These glasses offer sufficient eye protection when an operator is operating any machine or performing any bench or assembly operation. The lenses are made of shatterproof glass, and the side shields protect the sides of the eyes from flying particles.
   b. *Plastic safety goggles* (Fig. 4-1b) are generally worn by anyone wearing prescription eyeglasses. These goggles are soft, flexible plastic and fit closely around the upper cheeks and forehead. Unfortunately, they have a tendency to fog up in warm temperatures.
   c. *Face shields* (Fig. 4-1c) may also be used by those wearing prescription glasses. The plastic shield gives full face protection and permits air circulation between the face and the shield, thus preventing fogging up in most situations. These shields, as well as approved protective clothing and gloves, *must* be worn when an operator is heating and quenching materials during heat-treating operations or when there is any danger of hot flying particles. In industry, some companies provide their employees with prescription safety glasses, which eliminate the need for protective goggles or shields.

STOP **SAFETY PRECAUTIONS Never think that because you are wearing glasses your eyes are safe. If the lenses are not made of approved safety shatterproof glass, serious eye injury can still occur.**


(a)
(b)
(c)

Figure 4-1 Types of safety glasses: (a) plain; (b) plastic goggles; (c) face shields. *((a) ©Stockbroker/SuperStock; (b) ©nullplus/Shutterstock; (c) ©Hill Street Studios/Getty Images)*



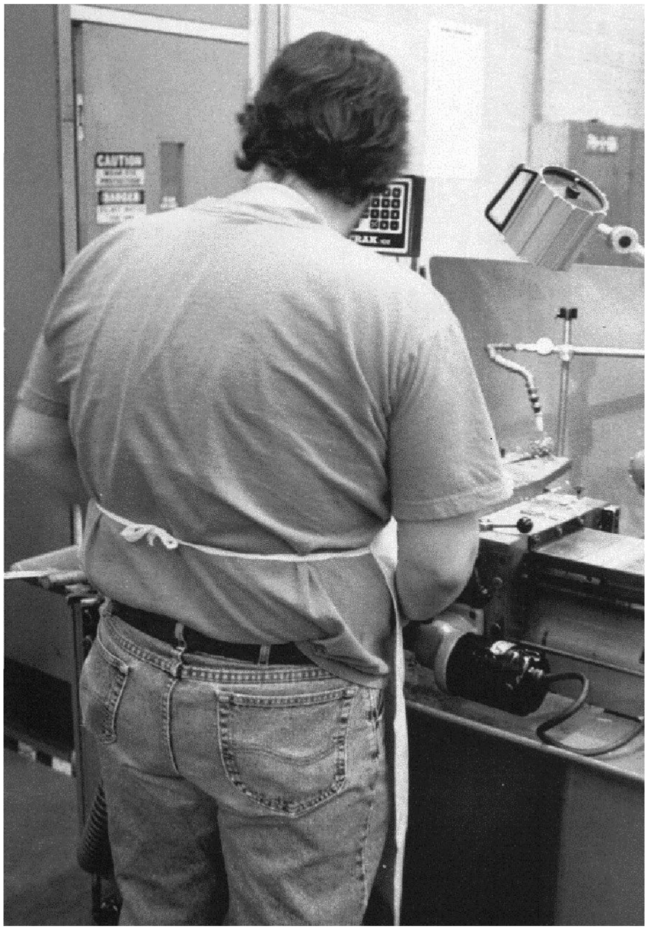
■ **Figure 4-2** Loose clothing can easily be caught in moving parts of machinery. *(©Kelmar Associates)*

2. Never wear loose clothing when operating any machine (Fig. 4-2).
   a. Always roll up your sleeves or wear short sleeves.
   b. Clothing should be made of hard, smooth material that will not catch easily in a machine. Loose-fitting sweaters should not be worn for this reason.
   c. Remove or tuck in a necktie before starting a machine. If you want to wear a tie, make it a bow tie.
   d. When wearing a shop apron, *always tie it at the back* and never in front of you so that the apron strings will not get caught in rotating parts (Fig. 4-3).
3. Remove wrist watches, rings, and bracelets; these can get caught in the machine, causing painful and often serious injury (Fig. 4-4).
4. Never wear gloves when operating a machine.
5. Long hair must be protected by a hair net or an approved protective shop cap (Fig. 4-5). One of the most common accidents on a drill press is caused by long, unprotected hair getting caught in a revolving drill.
6. Canvas shoes or open-toed sandals must *never* be worn in a machine shop because they offer no protection to the feet against sharp chips or falling objects. In industry, most companies make it mandatory for employees to wear safety shoes.

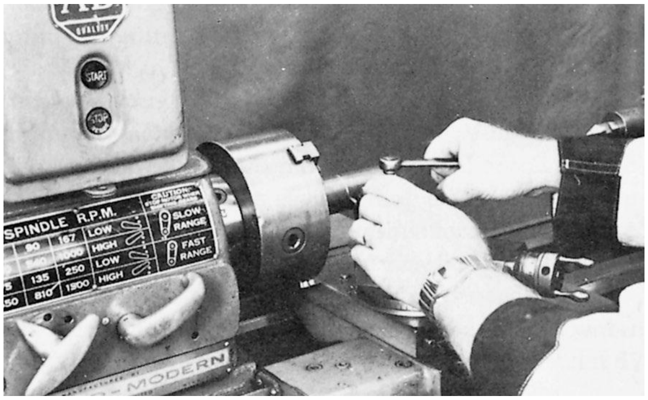
HOUSEKEEPING

The operator should remember that *good housekeeping will never interfere with safety or efficiency*; therefore, the following points should be observed.

1. *Always stop the machine before you attempt to clean it.*



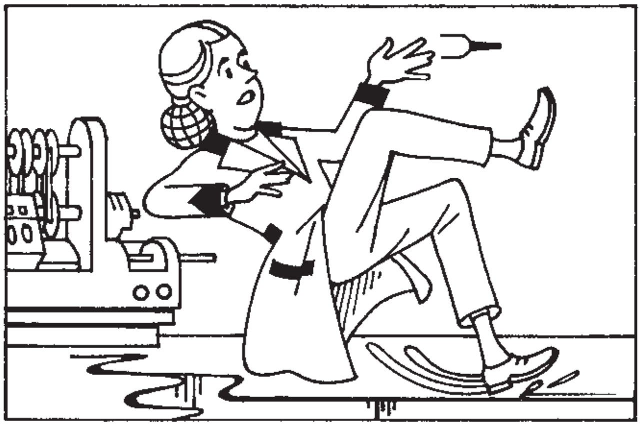
■ **Figure 4-3** Tie aprons behind your back to keep the ties from being caught in machinery. *(©Steve Krar)*



■ **Figure 4-4** Wearing rings and watches can cause serious injury. *(©Kelmar Associates)*

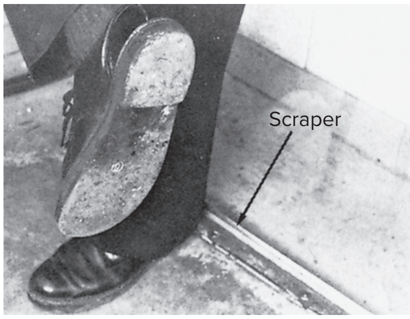
2. Always keep the machine and hand tools clean. Oily surfaces can be dangerous. Metal chips left on the table surface may interfere with the safe clamping of a workpiece.
3. Always use a brush and not a cloth to remove any chips. Chips stick to cloth and can cause cuts when the cloth is used later.

■ **Figure 4-5** Long hair must be protected by a hair net or an approved shop cap. *(©Kelmar Associates)*



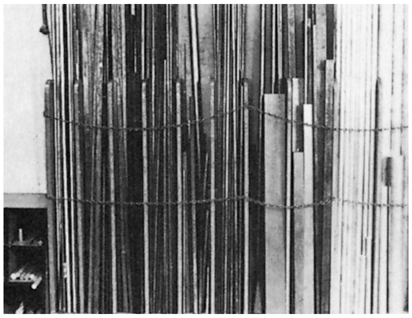
■ **Figure 4-6** Grease and oil on the floor can cause dangerous falls.

4. Clean up all spills and leaks.
5. Do not place tools and materials on the machine table—use a bench near the machine.
6. Keep the floor free from oil and grease (Fig. 4-6).
7. Sweep up the metal chips on the floor frequently. They become embedded in the soles of shoes and can cause dangerous slippage if a person walks on a terrazzo or concrete floor. Use a scraper, mounted on the floor near the door, to remove these chips before leaving the shop (Fig. 4-7).
8. Never place tools or materials on the floor close to a machine where they will interfere with the operator's ability to move safely around the machine (Fig. 4-8).
9. Return bar stock to the storage rack after cutting off the required length (Fig. 4-9).
10. Storage areas should not have an accumulation of material that presents hazards for tripping, fire, explosion, or pests.
11. Never use compressed air to remove chips from a machine. Not only is it a dangerous practice because of flying metal chips, but small chips and dirt can become wedged between machine parts and cause undue wear and damage.



■ **Figure 4-7** Remove chips from the soles of your shoes before leaving the shop. *(©Kelmar Associates)*

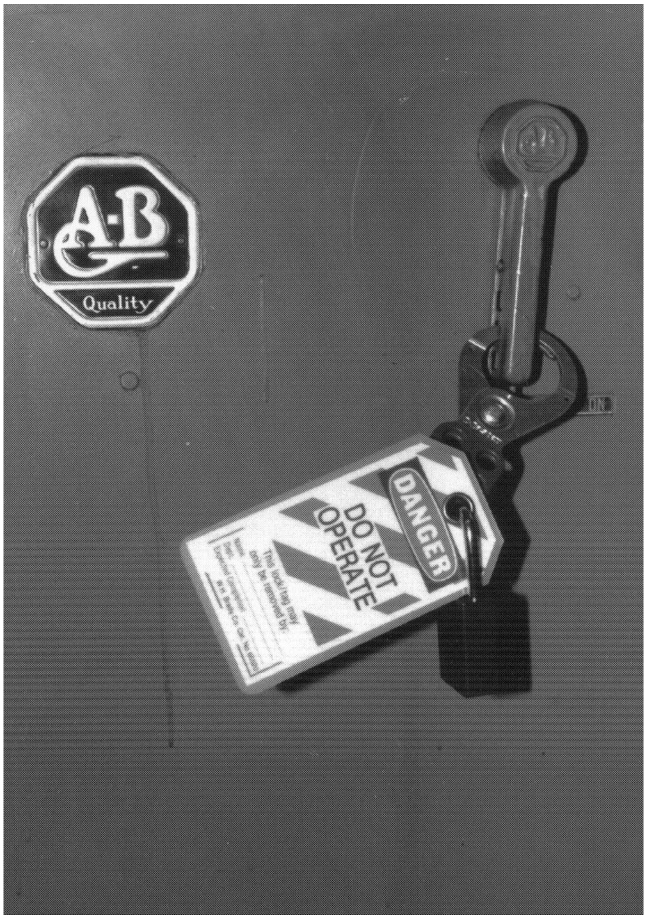
■ **Figure 4-8** Poor housekeeping can lead to accidents. *(©The McGraw-Hill Companies, Inc./Photographer Prographics, Inc.)*



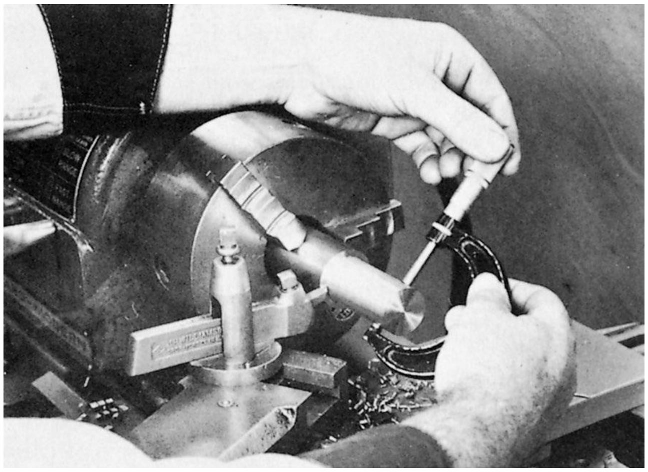
■ **Figure 4-9** Store stock safely in a material stock rack. *(©Kelmar Associates)*

SAFE WORK PRACTICES

1. Do not operate any machine before understanding its mechanism and knowing how to stop it quickly. Knowing how to stop a machine quickly can prevent a serious injury.

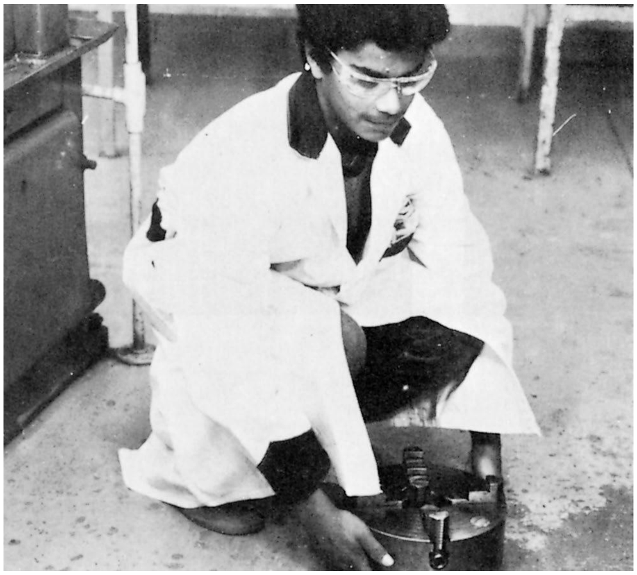


■ **Figure 4-10** Power switches must be locked off before you repair or adjust a machine. *(©Steve Krar)*

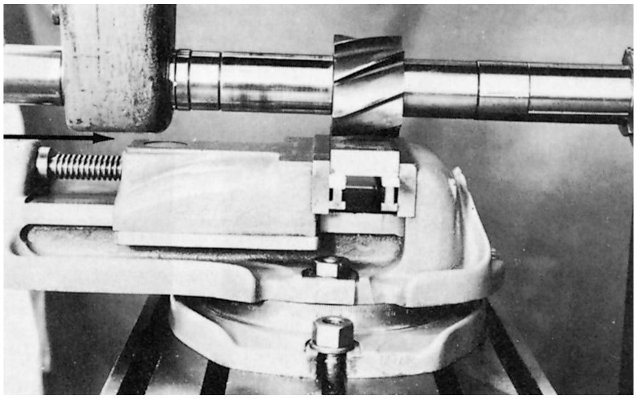


■ **Figure 4-11** The machine must be stopped before you measure a workpiece. *(©Kelmar Associates)*

2. Before operating any machine, be sure that the safety devices are in place and in working order. Remember, safety devices are for the operator's protection and should not be removed.
3. Always disconnect the power and lock it off at the switch box when making repairs to any machine (Fig. 4-10). Place a sign on the machine noting that it is out of order.
4. Always be sure that the cutting tool and the workpiece are properly mounted before starting the machine.
5. *Keep hands away from moving parts.* It is dangerous practice to "feel" the surface of revolving work or to stop a machine by hand.
6. *Always stop a machine before measuring, cleaning, or making any adjustments.* It is dangerous to do any type of work around moving parts of a machine (Fig. 4-11).
7. *Never use a rag near the moving parts of a machine.* The rag may be drawn into the machine, along with the hand that is holding it.
8. *Never have more than one person operate a machine at the same time.* Not knowing what the other person would or would not do has caused many accidents.
9. *Get first aid immediately for any injury, no matter how small.* Report the injury and be sure that the smallest cut is treated to prevent the chance of a serious infection.
10. Before you handle any workpiece, remove all burrs and sharp edges with a file.
11. Do not attempt to lift heavy or odd-shaped objects that are difficult to handle on your own.
12. For heavy objects, follow safe lifting practices:
    a. Assume a squatting position with your knees bent and back straight.
    b. Grasp the workpiece firmly.
    c. Lift the object by straightening your legs and keeping your back straight (Fig. 4-12). This procedure uses the leg muscles and prevents injury to the back.
13. Be sure the work is clamped securely in the vise or to a machine table.
14. Whenever work is clamped, be sure the bolts are placed closer to the workpiece than to the clamping blocks.
15. Never start a machine until you are sure that the cutting tool and machine parts will clear the workpiece (Fig. 4-13).
16. Use the proper wrench for the job, and replace nuts with worn corners.
17. It is safer to pull on a wrench than to push on it.



■ **Figure 4-12** Follow recommended lifting procedures to avoid back injury. *(©Kelmar Associates)*



■ **Figure 4-13** Make sure that the cutting tool and machine parts will clear the workpiece. *(©Kelmar Associates)*

FIRE PREVENTION

1. *Always* dispose of oily rags in properly covered metal containers that are disposed of daily.
2. Be sure of the proper procedure before lighting a gas furnace.
3. Know the location and the operation of every fire extinguisher in the shop.
4. Know the location of the nearest fire exit from the building.
5. Know the location of the nearest fire-alarm box and its operating procedure.
6. When using a welding or cutting torch, be sure to direct the sparks away from any combustible material.

unit 4 review questions

1. What must be learned before operating a machine tool for the first time?
2. List three qualities of a safe worker.

Personal Grooming

3. Name three types of eye protection that may be found in a shop.
4. State four precautions that must be observed with regard to clothing worn in a shop.
5. Why should gloves not be worn when operating a machine?
6. How must long hair be protected?

Housekeeping

7. Why must a cloth not be used to remove chips?
8. Why should shoe soles be scraped before leaving the shop?
9. State two reasons why compressed air should not be used for cleaning machines.

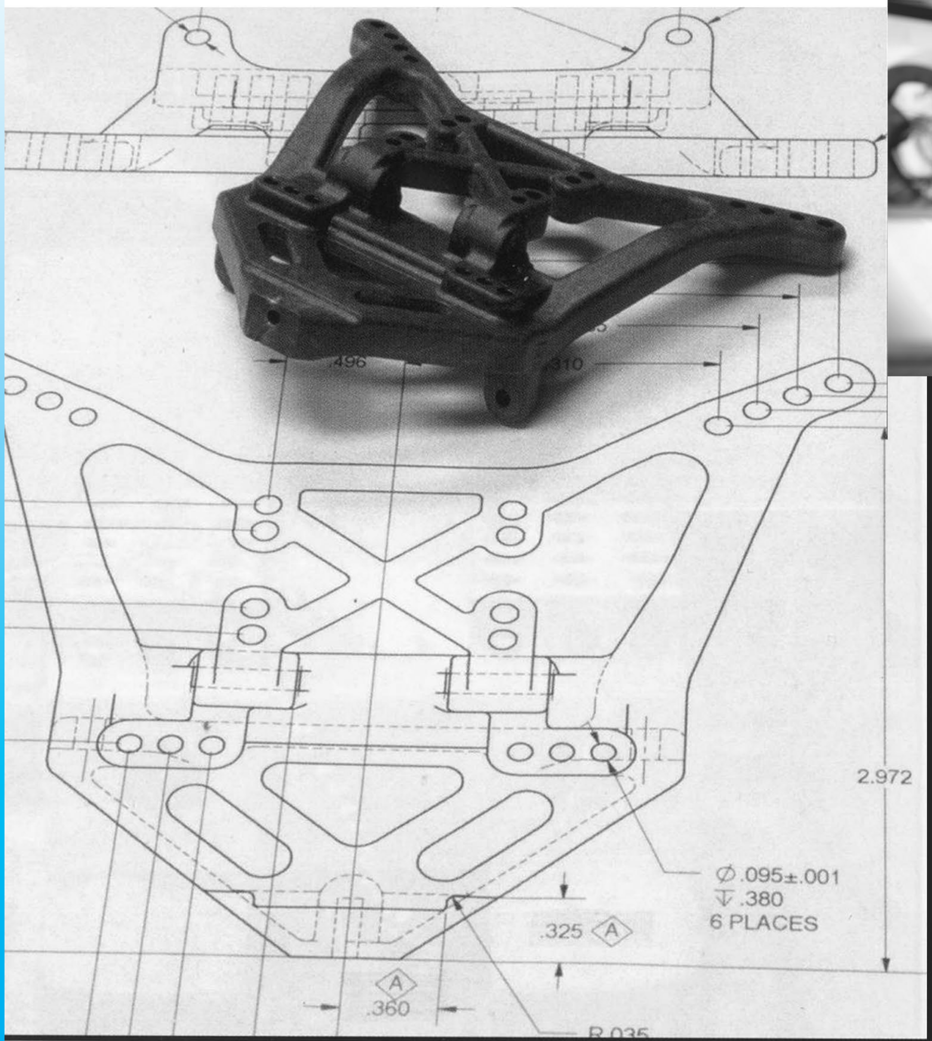
Safe Work Practices

10. State three precautions to observe before operating any machine.
11. Describe the procedure to follow for lifting a heavy object.
12. What should you do immediately after receiving any injury?

Fire Prevention

13. What three fire prevention factors should everyone become familiar with before starting to work in a machine shop?

Section 4



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(©Steve Krar)

JOB PLANNING

Machine shop work consists of machining a variety of parts (round, flat, contour) and either assembling them into a unit or using them separately to perform some operation. It is important that the sequence of operations be carefully planned in order to produce a part quickly and accurately. Improper planning or following a wrong sequence of operations often results in spoiled work.

UNIT 5

Engineering Drawings

OBJECTIVES

After completing this unit, you will be able to:

1 Understand the meaning of the various lines used on engineering drawings

2 Recognize the various symbols used to convey information

3 Read and understand engineering drawings or prints

Engineering drawing is the common language by which draftspersons, tool designers, and engineers indicate to the machinist and toolmaker the physical requirements of a part. Drawings are made up of a variety of lines, which represent surfaces, edges, and contours of a workpiece. By adding symbols, dimension lines and sizes, and word notes, the draftsperson can indicate the exact specifications of each individual part. Geometric dimensioning and tolerancing (GD&T) has become a universal language on engineering (technical) drawings for specifying a part's exact geometry or shape and how the part should be inspected and gaged. The *American ANSI* Y14.5, the American Standard, ASME Y14.5M-1994 (formerly ANSI Y14.5M-1982 R 1988), and the ISO R1 101 standards are very similar with only a few variations.

A complete product is usually shown on an *assembly drawing* by the drafter. Each part or component of the product is then shown on a *detailed drawing,* which is reproduced as copies called *prints.* The prints are used by the machinist or toolmaker to produce the individual parts that eventually will make up the complete product. Some of the more common lines and symbols will be reviewed briefly.

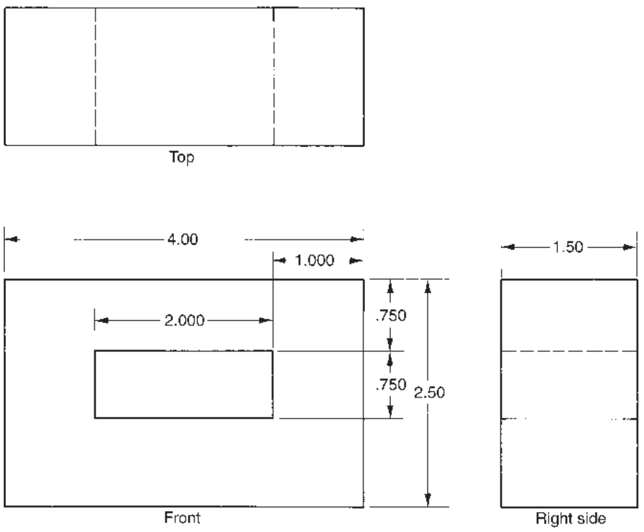
Types of Drawings and Lines

To describe the shape of noncylindrical parts accurately on a drawing or print, the draftsperson uses the *orthographic view* or *projection method.* The orthographic view shows the part from three sides: the front, top, and right-hand side (Fig. 5-1). These three views enable the draftsperson to describe a part or an object so completely that the machinist knows exactly what is required.

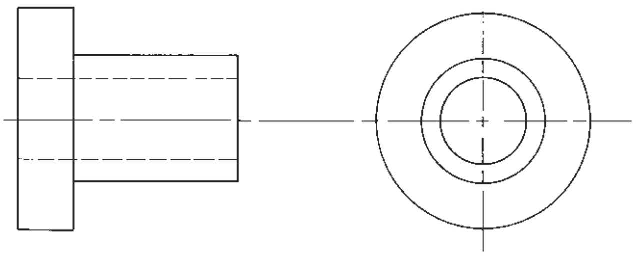
Cylindrical parts are generally shown on prints in two views: the front and right side (Fig. 5-2). However, if a part contains many details, it may be necessary to use the top, bottom, or left-side views to describe the part accurately to the machinist.

In many cases, complicated interior forms are difficult to describe in the usual manner by a draftsperson. Whenever this occurs, a *sectional view,* which is obtained by making an imaginary cut through an object, is presented. This imaginary cut can be made in a straight line in any direction to best expose the interior contour or form of a part (Fig. 5-3).

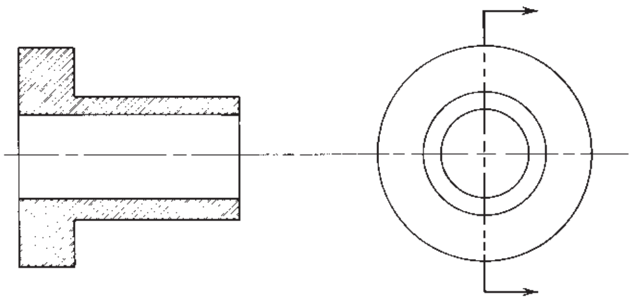
A wide variety of *standard lines* are used in engineering drawings for the designer to indicate to the machinist exactly what is required. Thick, thin, broken,



■ **Figure 5-1** Three views of orthographic projection make it easier to describe the details of a part.



■ **Figure 5-2** Cylindrical parts are generally shown in two views.



■ **Figure 5-3** Section views are used to show complicated interior forms.

wavy, and section lines are used on shop or engineering drawings. See Table 5.1 for examples, including the description and purpose of some of the more common lines used on shop drawings.

Drafting Terms and Symbols

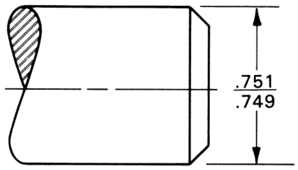
Common drafting terms and symbols are used on shop and engineering drawings for the designer to describe each part accurately. If it were not for the universal use of terms, symbols, and abbreviations, the designer would have to make extensive notes to describe exactly what is required. These notes not only would be cumbersome but could be misunderstood and therefore result in costly errors. Some of the common drafting terms and symbols are explained in the following paragraphs and examples.

Limits (Fig. 5-4) are the largest and the smallest permissible dimensions of a part (the maximum and minimum dimensions). Both sizes would be given on a shop drawing.

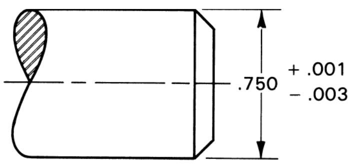
EXAMPLE

.751 largest dimension

.749 smallest dimension



■ **Figure 5-4** Limits show the largest and smallest size of a part.



■ **Figure 5-5** Tolerance is the permissible variation of a specified size.

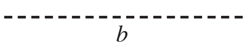
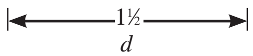
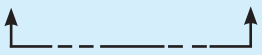
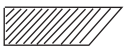
Tolerance (Fig. 5-5) is the permissible variation of the size of a part. The basic dimension plus or minus the variation allowed is given on a drawing.

EXAMPLE

$$.750 \begin{matrix} +.001 \\ -.003 \end{matrix}$$

The tolerance in this case would be .004 (the difference between +.001 oversize or −.003 undersize).

table 5.1 Common lines used on shop drawings

Example	Name	Description	Use
a	Object lines	Thick black lines approximately .030 in. wide (the width may vary to suit drawing size).	Indicate the visible form or edge of an object.
 *b*	Hidden lines	Medium-weight black lines of .125 in. long dashes and .060 in. spaces.	Indicate the hidden contours of an object.
c	Center lines	Thin lines with alternating long lines and short dashes. —Long lines from .500 to 3 in. long. —Short dashes .060 to .125 in. long, spaces .060 in. long.	Indicate the centers of holes, cylindrical objects, and other sections.
 *d*	Dimension lines	Thin black lines with an arrowhead at each end and a space in the center for a dimension.	Indicate the dimensions of an object.
 *e*	Cutting-plane lines	Thick black lines make up a series of one long line and two short dashes. Arrowheads show the line of sight from where the section is taken.	Show the imagined section cut.
 *f*	Cross section lines	Fine, evenly spaced parallel lines at 45°. Line spacing is in proportion to the part size.	Show the surfaces exposed when a section is cut.

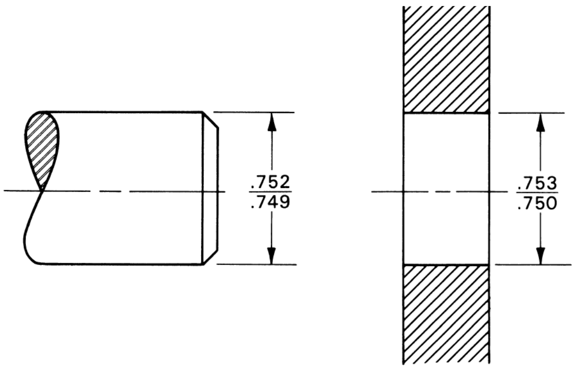


Figure 5-6 Allowance is the intentional difference in the sizes of mating parts.

Allowance (Fig. 5-6) is the intentional difference in the sizes of mating parts, such as the diameter of a shaft and the size of the hole. On a shop drawing, both the shaft and the hole would be indicated with maximum and minimum sizes to produce the best fit.

Fit is the range of tightness between two mating parts. There are two general classes of fits:

1. *Clearance fits,* whereby a part may revolve or move in relation to a mating part
2. *Interference fits,* whereby two parts are forced together to act as a single piece

Scale size is used on most shop or engineering drawings because it would be impossible to draw parts to exact size; some drawings would be too large, and others would be too small. The scale size of a drawing is generally found in the title block and indicates the scale to which the drawing has been made, which is a representative measurement.

Scale	Definition
1:1	Drawing is made to the actual size of the part, or full scale.
1:2	Drawing is made to one-half the actual size of the part.
2:1	Drawing is made to twice the actual size of the part.