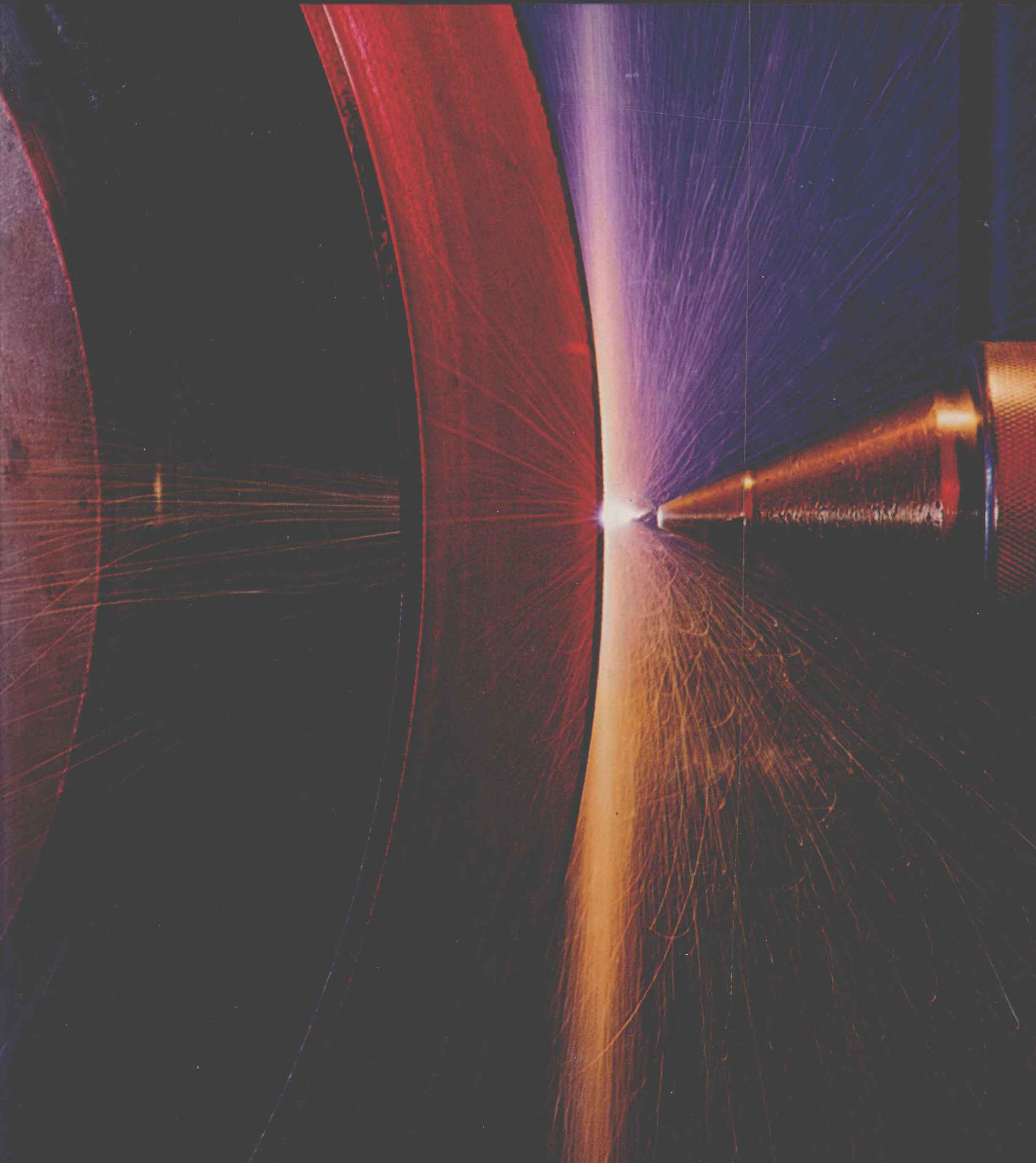
TECHNOLOGY OF MACHINE TOOLS

FOURTH EDITION



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TECHNOLOGY OF MACHINE TOOLS

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PREFACE

No single invention since the Industrial Revolution has left such an impact on society as the computer. During the last two or three decades, basic computers have been applied to machine tools to program and control various machine operations. Computers have steadily improved until there are now highly sophisticated units capable of controlling the operation of a single machine, a group of machines, or soon even a complete manufacturing plant, therefore a section titled "Computer-Age Machining" is included in this edition. New machine tools and processes have been developed to reduce the large production gap between North American and overseas workers. In order for these new machine tools to reach their full potential, new cutting tools are being continually developed to produce accurate parts more quickly and at competitive prices. With this in mind, the authors have included and expanded machining processes such as Flexible Manufacturing Systems and added new cutting tools and materials such as Polycrystalline Cubic Boron Nitride, Polycrystalline Diamond, and SG Ceramic Aluminum Oxide.

This book is based on the authors' many years of practical experience as skilled workers in the trade and as specialists in teaching. To keep abreast of rapid technological change, the authors have researched the latest technical information available, and have visited industries which are leaders in their field. Many sections of this book were reviewed by key personnel in various manufacturing firms, so that the most accurate and up-to-date information is presented. The authors appreciated the opportunity to incorporate into the text the suggestions and recommendations made by these people.

The fourth edition of *Technology of Machine Tools* is presented in unit form with each unit introduced with a set of objectives followed by related theory and operational sequence. Each operation is explained in a step-by-step procedure which students can readily follow. Advanced operations are introduced by problems, followed by step-by-step solutions and matching procedures. Review questions at the end of each unit can be used for review or for homework assignments to prepare students for subsequent operations. To make this text easily understood, each unit contains many new illustrations and photographs. Color has been used throughout to emphasize important points and to make the illustrations more meaningful.

Throughout the text, dual dimensioning (U.S. Customary: inch; SI: metric) is used. The need for a working knowledge of the metric system cannot be overstressed, because most of the countries in the world are already on or in the process of converting to the metric system. Since those involved in the machine shop trade will have to be familiar with both the metric and inch systems during the changeover period, wherever possible, metric tools and information are included. All inch dimensions or quantities in this book have been generally rounded to the nearest metric equivalent, which is shown in brackets following each dimension or quantity.

The purpose of this text is to assist instructors in giving students basic training in the operation of machine tools, and in helping students understand the latest machining processes and developments. The material is organized so that instructors may easily select those topics that are most suitable for class projects, or that suit the individual differences of students.

A technician in the machine shop trade should be neat, develop sound work habits, and have a good knowledge of mathematics, print reading, and computers. To keep up to date on technological changes, technicians must continue to expand their knowledge by reading specialized texts, trade literature, and magazine articles in this field.

Steve F. Krar
J. William Oswald

About the Authors

STEVE F. KRAR majored in Machine Shop Practice and spent fifteen years in the trade, first as a machinist and finally as a tool and diemaker. After this period he entered Teachers' College and graduated from the University of Toronto with a Specialist's Certificate in Machine Shop Practice. During his nineteen years of teaching, Mr. Krar was active in Vocational and Technical education and served on the executive of many educational organizations. For ten years he was on the summer staff of the University of Toronto, involved in teacher training programs. Active in machine tool associations, Steve Krar has been a senior member of the Society of Manufacturing Engineers for over thirty years. He is a co-author of the McGraw-Hill text *Machine Tool Operations.* He is also co-author of the following McGraw-Hill Ryerson Ltd. publications: *Machine Shop Training, Machine Shop Operations,* and the overhead transparency kits: *Machine Tools, Measurement and Layout, Threads and Testing Equipment,* and *Cutting Tools.*

J. WILLIAM OSWALD served an apprenticeship in machine shop, and after sixteen years in the trade attended Teachers' College at the University of Toronto. After graduation, he received a Specialist's Certificate in Machine Shop Practice and taught machine shop work for twenty-five years. During this time he attended several up-grading courses in the operation of the latest machine shop and testing equipment. For several years Mr. Oswald served on the teacher-training staffs at the University of Toronto and the University of Western Ontario. He had also worked with various technical educational committees and organizations. He is a co-author of the McGraw-Hill text *Machine Tool Operations.* Mr. Oswald is also a co-author of *Machine Shop Operations,* and the overhead transparency kits: *Machine Tools, Measurement and Layout, Threads and Testing Equipment,* and *Cutting Tools.*

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SECTION 1

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 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 even entertainment. Although the computer influences our everyday lives, it is still important that you as a student or 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

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.

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 history of machine tools began during the stone age (over 5000 years ago), when the only tools were hand tools made of wood, animal bones, or stone (Fig. 1-1).

Between 2000 and 2500 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 craftsmen 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 continued slowly during the first part of the 20th century except for spurts during the two world wars. The Second World War 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 very sophisticated. All these factors have produced a high standard of living for us. All

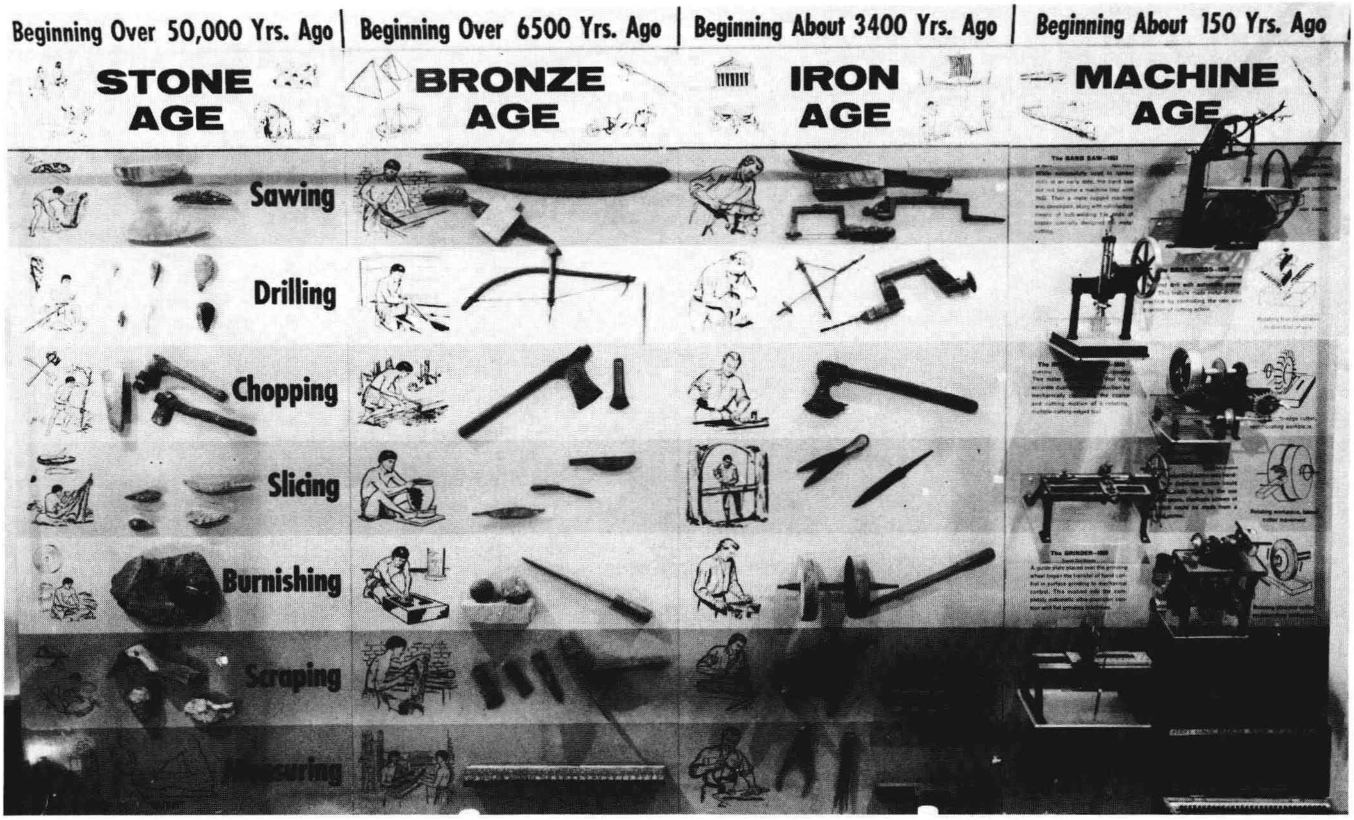

Figure 1-1 *The development of hand tools over the years. (Courtesy DoAll Company.)*

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

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 numerical control to basic machine tools.

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 tool-

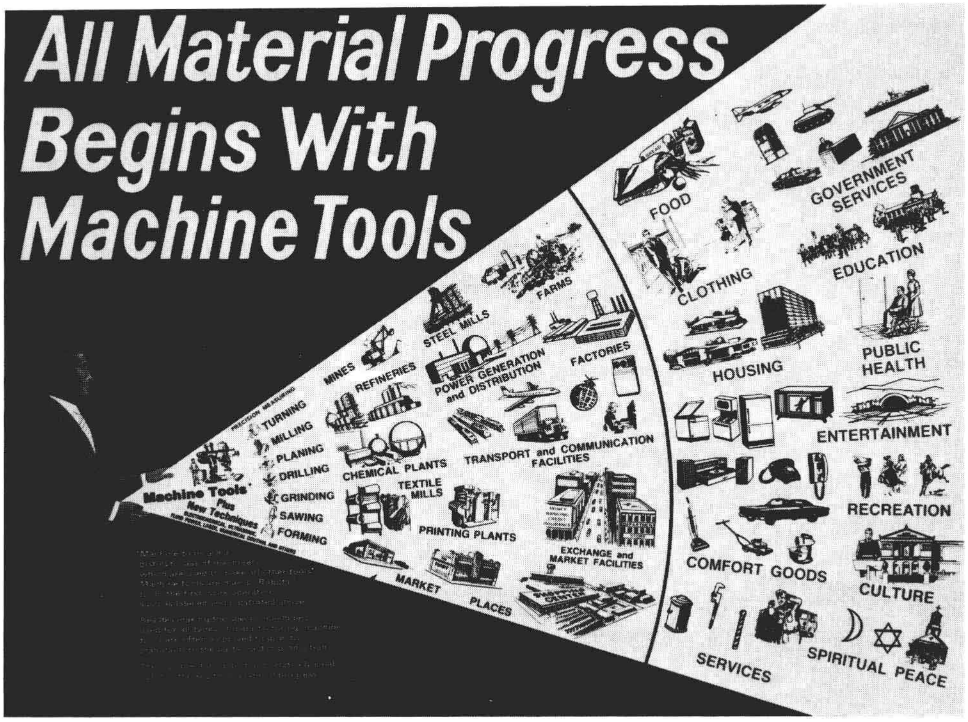

Figure 1-3 *Machine tools produce tools and machines for manufacturing all types of products. (Courtesy DoAll Company.)*

room, 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 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 also 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 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.

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, shaper, milling machine, and grinder are usually considered the *basic machine tools* in a machine shop (Fig. 1-4).

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.

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.

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

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 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 (Fig. 1-8) and the vertical milling machine 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

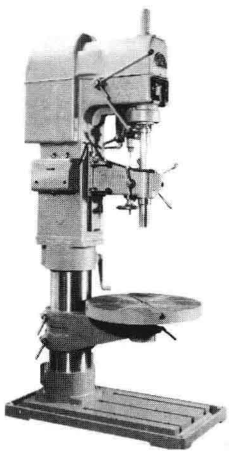

Figure 1-5 *A standard upright drill press.*

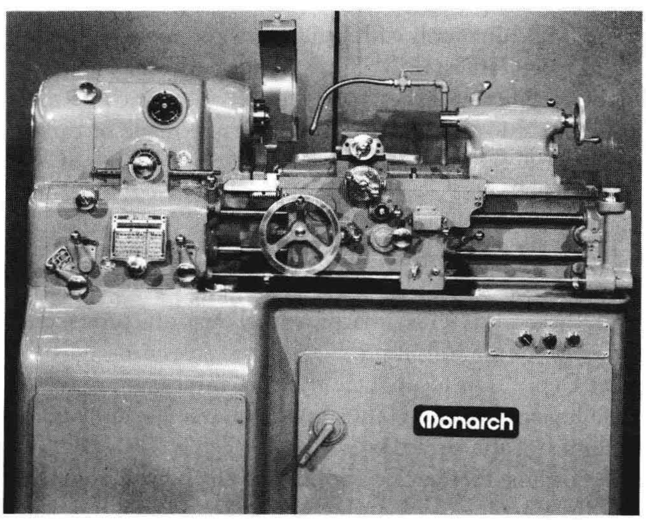

Figure 1-6 *An engine lathe is used to produce round work. (Courtesy Monarch Machine Tool Company.)*

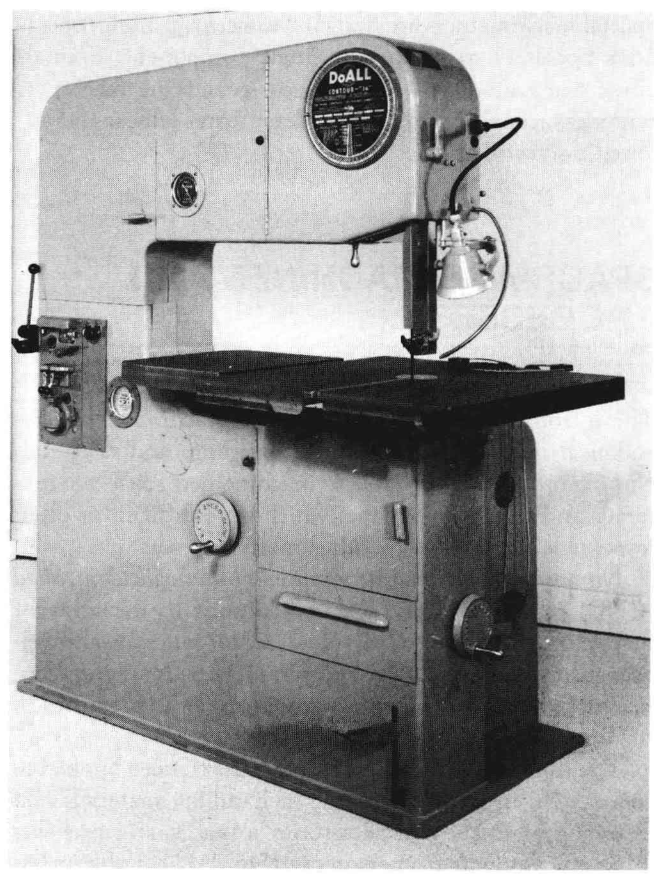

Figure 1-7 *A contour-cutting bandsaw. (Courtesy DoAll Company.)*