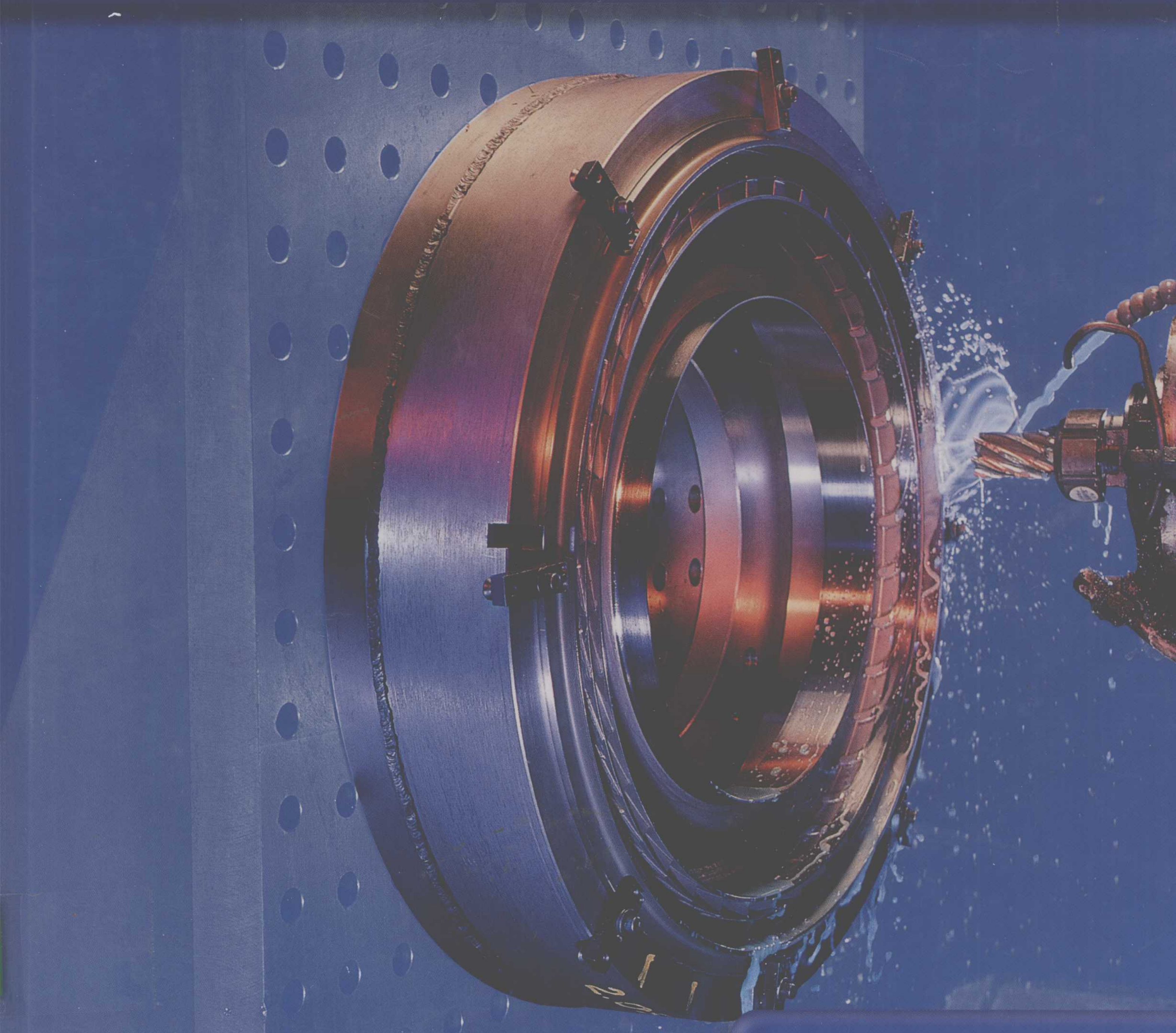
TECHNOLOGY OF MACHINE TOOLS

FIFTH EDITION



Steve F. Krar
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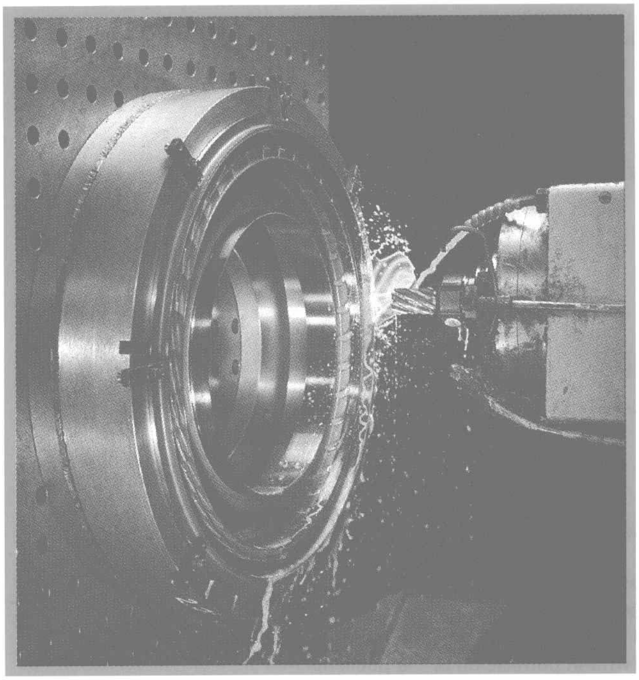

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PREFACE

During the last two or three decades, computers have been applied to all types of 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 even a complete manufacturing plant. Section 14, "Computer-Age Machining" has been expanded to include computer numerical control machine tools such as turning centers, machining centers, and electro-discharge machines. For these new machine tools to reach their full potential, new cutting tools are being developed to produce accurate parts faster and at competitive prices. With this in mind, the authors have 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 that are leaders in their field. Sections of this book were reviewed by key personnel in various manufacturing firms and leading educators so that accurate and up-to-date information is presented. The authors are grateful to Don W. Alexander, Wytheville Community College, Wytheville, VA; James D. Smith, Tennessee Tech Center, Crump, TN; and William L. White, Director of Engineering Laboratories, GMI Engineering and Management Institute, Flint MI for technical and practical suggestions that were incorporated into the text.

The fifth edition of *Technology of Machine Tools* is presented in unit form; each unit is introduced with a set of objectives followed by related theory and operational sequence. Dual dimensioning (inch/metric) is used throughout the book. Because we live in a global society it is important for machine tool technicians to be familiar with both systems of measurement. Each operation is explained in a step-by-step procedure that students can readily follow. Advanced operations are introduced by problems, followed by step-by-step solutions and matching procedures. So this text will be easily understood, each unit contains many new illustrations and photographs with color used to emphasize important points. End-of-unit review questions can be used for review or for homework assignments to prepare students for subsequent operations.

The purposes of this text are to assist instructors in providing the basic training on conventional machine tools; to cover basic programming for CNC machines (such as turning centers, machining centers, and electro-discharge machines); and to introduce new manufacturing technologies and processes. To make this course interesting and challenging for students, videotapes can be used to cover new technologies. They are available on loan or for a small fee from technical societies, manufacturers, and publishers. The instructor's manual includes sources of videotapes along with answers to the review questions in the text. A student workbook is also available.

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 current on technological changes, technicians must expand their knowledge by reading specialized texts, trade literature, and magazine articles in this field.

Steve F. Krar
Albert F. Check

ABOUT THE AUTHORS

Steve F. Krar

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 twenty years of teaching, Mr. Krar was active in vocational and technical education and served on the executive committees of many educational organizations. For ten 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.

Mr. Krar's continual research over the past thirty-five years in manufacturing technology has involved many courses with leading world manufacturers and an opportunity to study under Dr. W. Edwards Deming. He is co-author of over forty technical books, such as *Machine Shop Training, Machine Tool Operations, CNC Technology and Programming, Superabrasives—Grinding and Machining,* some of which have been translated into five languages and used throughout the world.

Albert F. Check

Albert F. Check has worked as a machinist, including setup and operation of NC/CNC machine tools. During this period, he pursued his education, attaining an M.S. Ed. degree in Occupational Education from Chicago State University. Mr. Check has been a full-time faculty member at Triton Community College for 20 years and served as the Coordinator for Machine Tool Technology for 16 years. His extensive trade background makes him well suited for teaching industrial in-plant training courses through the Employee Development Institute. Mr. Check keeps up to date with technological developments by attending industrial training seminars offered by the Society of Manufacturing Engineer (SME), industrial machine tool manufacturers, and GE Superabrasives Grinding and Machining Technology.

Mr. Check is a Senior Member of SME, has been a VICA judge for the State of Illinois Precision Machining Skill Olympics, as well as an active participant in the Vocational Instruction Practicum sponsored by the State of Illinois. Mr. Check has mentored a visiting Turkish Educator as part of a World Bank Project. He has served on many college and local elementary education committees and is currently a member of the Educator's Advisory Council of the Industrial Diamond Association's Partnership for Manufacturing Productivity.

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

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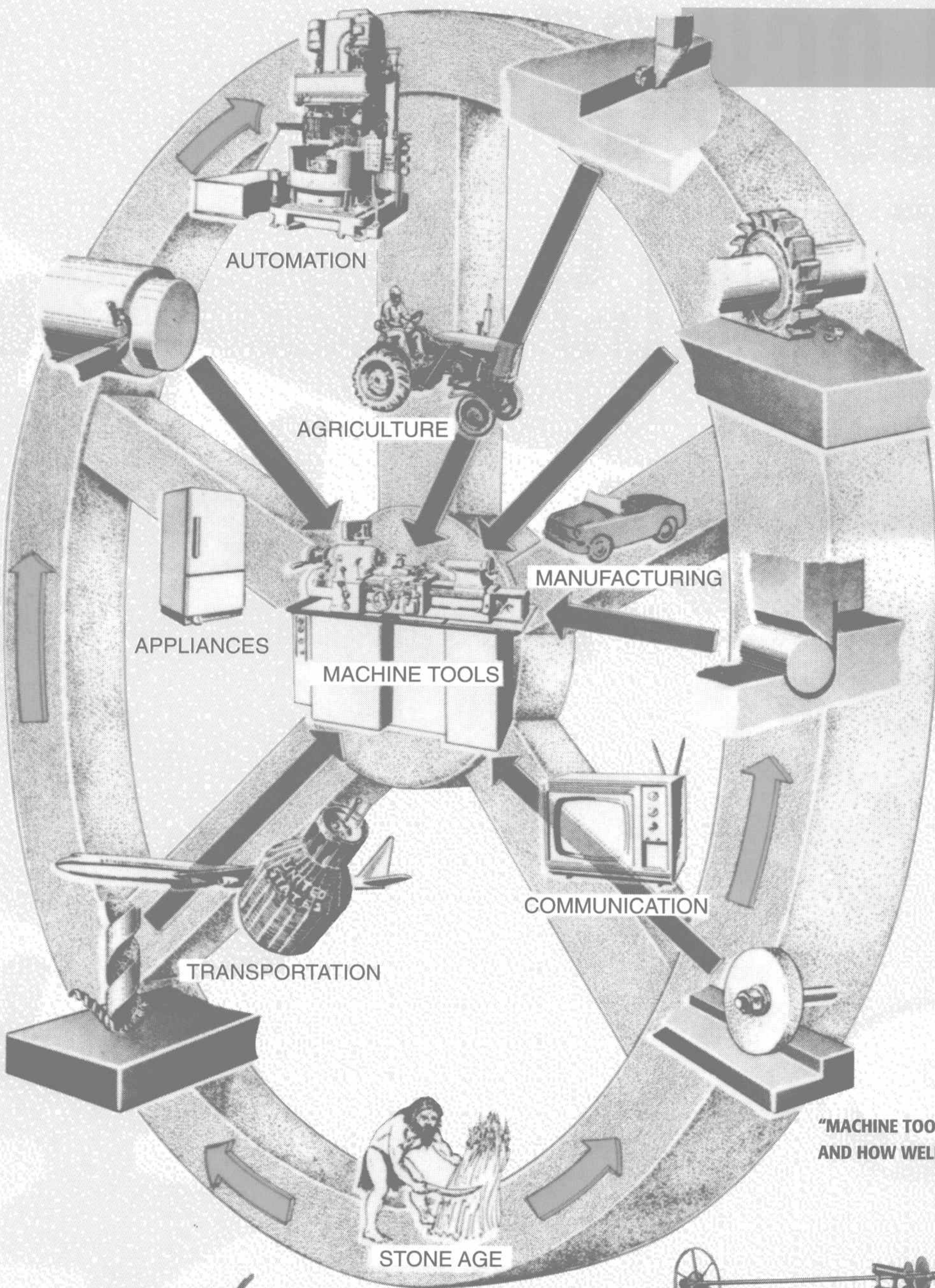
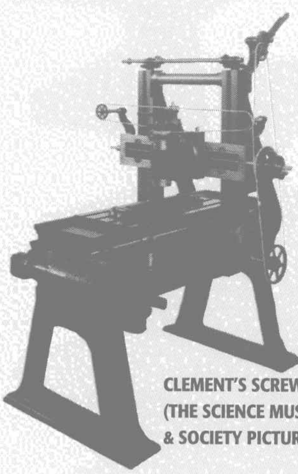


"MACHINE TOOLS DETERMINE HOW MUCH A NATION PRODUCES AND HOW WELL ITS PEOPLE LIVE."



CLEMENT'S SCREW-CUTTING LATHE (c. 1820)
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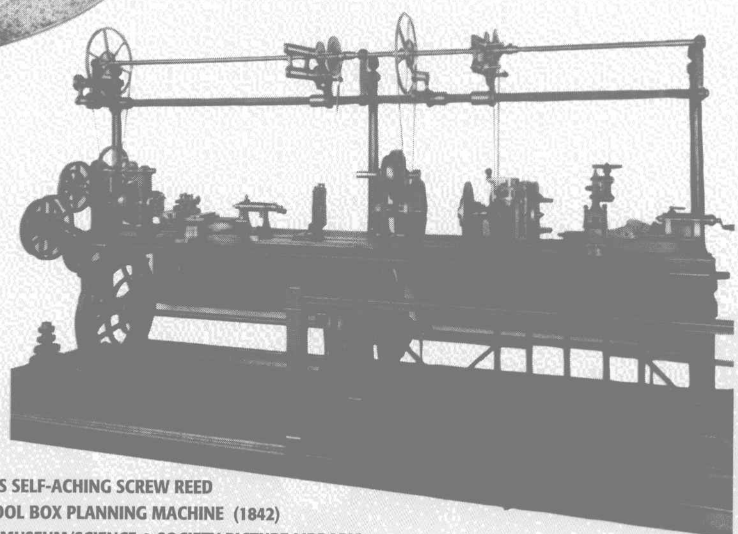

WHITWORTH'S SELF-ACHING SCREW REED REVERSING TOOL BOX PLANNING MACHINE (1842)
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SECTION

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 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 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

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).

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.

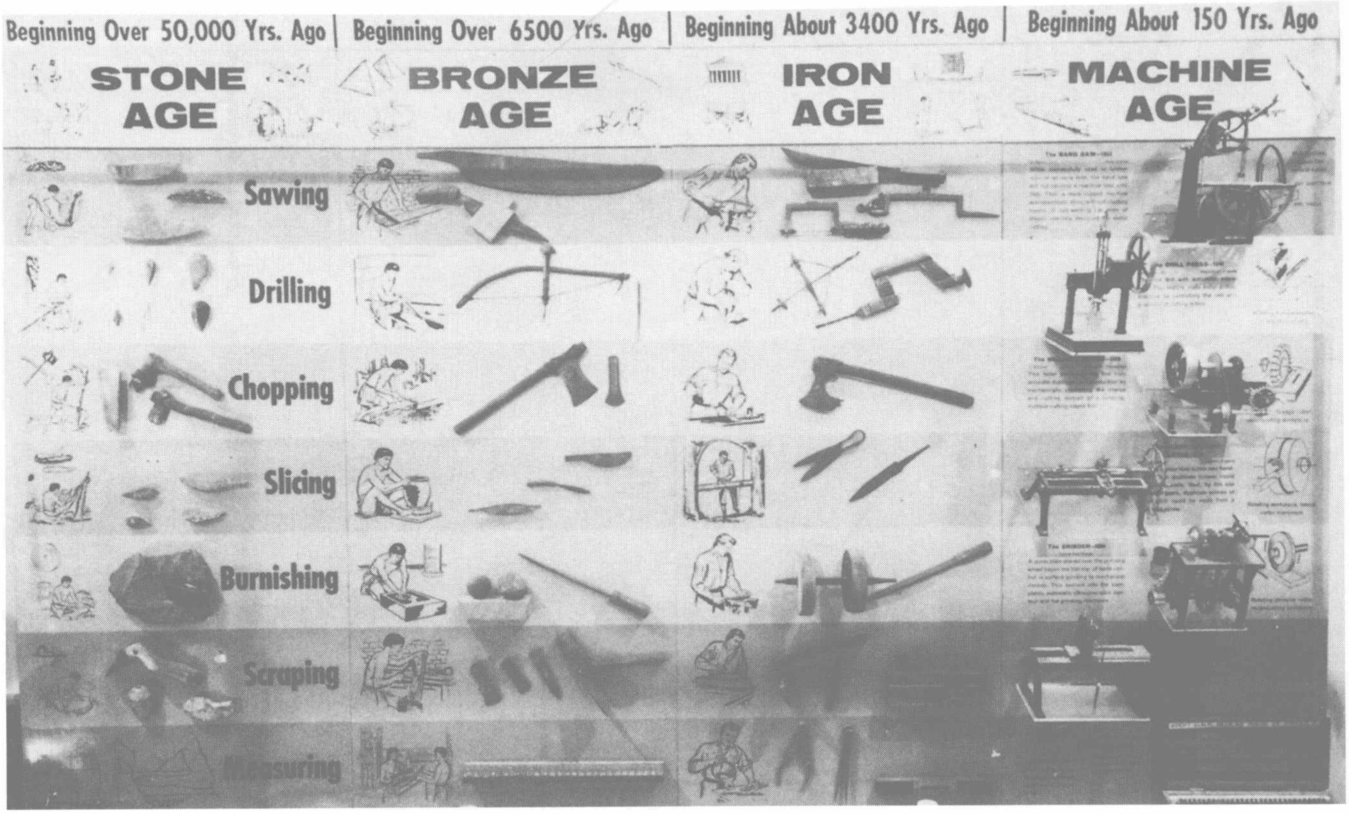

FIGURE 1-1 The development of hand tools over the years. (Courtesy DoAll Company.)

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. 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 on p. 6).

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.

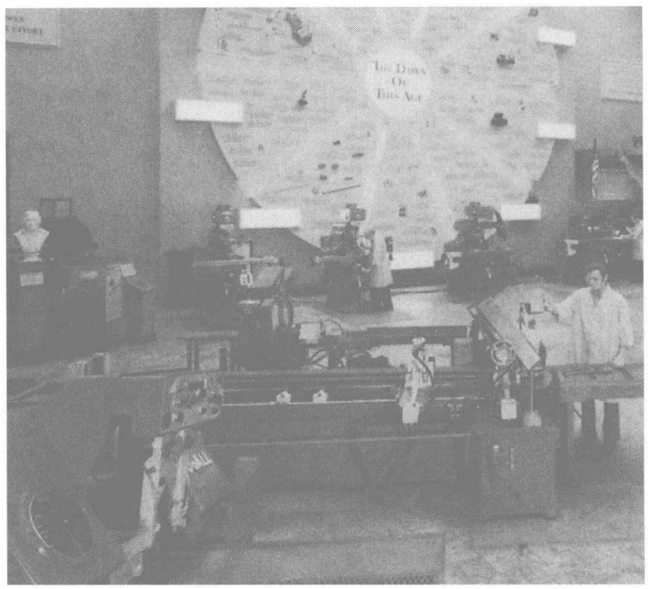

FIGURE 1-2 New machine tools were developed during the mid-20th century. (Courtesy DoAll Company.)

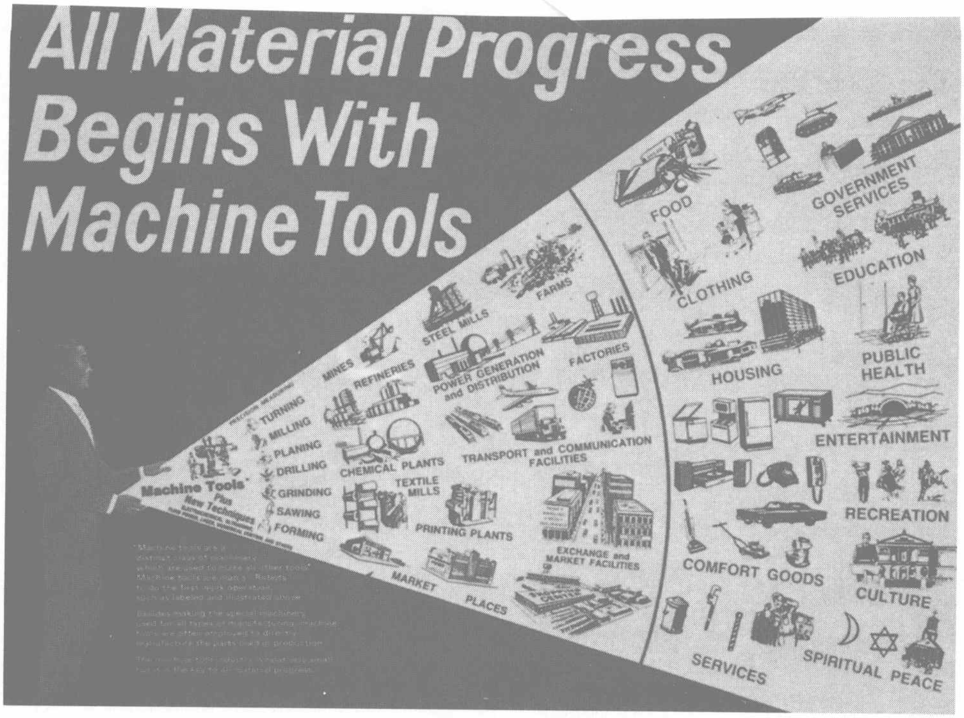

FIGURE 1-3 Machine tools produce tools and machines for manufacturing all types of products. (Courtesy DoAll Company.)

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 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 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.

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 the depth of cut. *Accuracy* is 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).