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# 工程图学（第8版 改编版）

# Engineering Graphics (Eighth Edition)

原著 Giesecke Mitchell Spencer Hill Loving Dygdon Novak

改编 焦永和 韩宝玲 李苏红

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## 内容提要

本书是在 Frederick E. Giesecke 等编著*Engineering Graghics*(Eighth Edition)的基础上，全面考虑近年来我国高校双语教学的实际情况改编而成的。本书是教育科学“十五”国家规划课题——“21世纪中国高等教育人才培养体系的创新与实践”子项目课题“工程图学课程体系与教学内容的研究与实践”的研究成果。

为保证原版教材的风格，对原版教材的内容只进行了删减。针对投影法及制图国家标准方面的问题，在教材后面增加了用中文编写的附录，介绍第一角投影以及相关的制图国家标准。

另外，对Frederick E.Giesecke等编著*Engineering Drawing Problem Series* 2(Tenth Edition)也进行了改编，与本书配套使用，由高等教育出版社同时出版。

本书可作为高等学校机械类专业开展制图课双语教学的教学用书，也可供其他专业师生参考。

# ENGINEERING GRAPHICS

*Eighth Edition*

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# 前　言

双语教学是近年来国内高校的教学改革热点之一，目前不少高校已有多门课程开展了双语教学，制图课程也不例外。但是，相对于数学、物理等公共基础课程而言，制图课程开展双语教学有两大不利因素：首先，我国的制图国家标准中规定采用第一角投影的方法来表达物体，而在欧美国家中采用第三角投影；其次，我国制图标准中的基本规定、图样画法、标准件、零件图与装配图的技术要求等内容也与欧美的标准有所不同。因此，在制图课程开展双语教学时，选择教材就面临着很大的困难。若直接选用欧美原版教材，则无法解决投影法与标准的差异问题，而由我国制图教师编写英文教材，则在语言表达的确切方面，以及专业术语的使用方面难以达到英文原版教材的水平。

为了解决制图课程双语教材的问题，经过两年的分析与研究，决定改编英文原版教材。这里选择了在美国发行量很大的教材——Frederick E.Giesecke等编著*Engineering Graphics*(Eighth Edition)，根据我国的实际情况，对其内容进行了删减，以保证其风格。针对投影法及标准方面的问题，在教材后面增加了用中文编写的附录，介绍第一角投影以及相关的制图国家标准。希望通过这种方法，能够给开展制图课程双语教学的院校提供一本既能保持原版教材风貌，又符合我国实际情况的双语教材。

另外，对Frederick E. Giesecke等编著*Engineering Drawing Problem Series* 2(Tenth Edition)也进行了改编，与本书配套使用。习题集中除保留了部分原版第三角投影的习题外，也增加了一定数量的第一角投影的习题，以满足学生学习第一角投影的需求。

本教材由焦永和、韩宝玲、李苏红改编。焦永和改编第12章至第17章，并承担了附录的编写工作；韩宝玲改编第1章至第5章、第11章；李苏红改编第6章至第10章。樊红丽、张京英、张彤、罗军、罗会甫等参与了部分章节的插图绘制及校对工作。研究生冯欣欣、史向荣、李德龙、房凌辉、丛龙兴、王秋丽、袁焕武绘制了附录中的部分插图。在此表示感谢。

限于编者的水平，书中不当之处在所难免，欢迎广大读者批评指正。

改编者

2005年1月

# Contents

Chapter

1

# The Graphic Language and Design

## OBJECTIVES

After studying the material in this chapter, you should be able to:

1. Describe the role of the engineer on a design team.
2. List two types of drawings.
3. Explain why standards are important.
4. Draw examples of parallel and perspective projection.
5. Define *plane of projection* and *projectors*.
6. Identify uses of the graphic language.
7. Describe the differences between mechanical drawing and sketching.

## OVERVIEW

*A new machine, structure, or system must exist in the mind of the engineer or designer before it can become a reality. This original concept or idea is usually placed on paper or as an image on a computer screen and communicated to others by way of the graphic language in the form of freehand sketches. These first sketches are followed by other, more exact, sketches as the idea is developed more fully.*

*The engineer and drafter for the twenty-first century must understand how to read and write in the graphic language. Everyone on the engineering and design team must be able to communicate quickly and accurately in order to compete in the world market. Like carpenters learning to use the tools of their trade, engineers, designers, and drafters must learn the tools of technical drawing. While CAD has replaced traditional drafting tools for many design teams, the basic concepts of the graphic language remain the same. Those students who can become proficient in graphic communication will succeed and add value to the employer who hires them.*

## ■ INTRODUCTION

The old saying that "necessity is the mother of invention" is still true, and a new machine, structure, system, or device is the result of that need. If the new object is really needed or desired, people will buy it or use it as long as they can afford it.

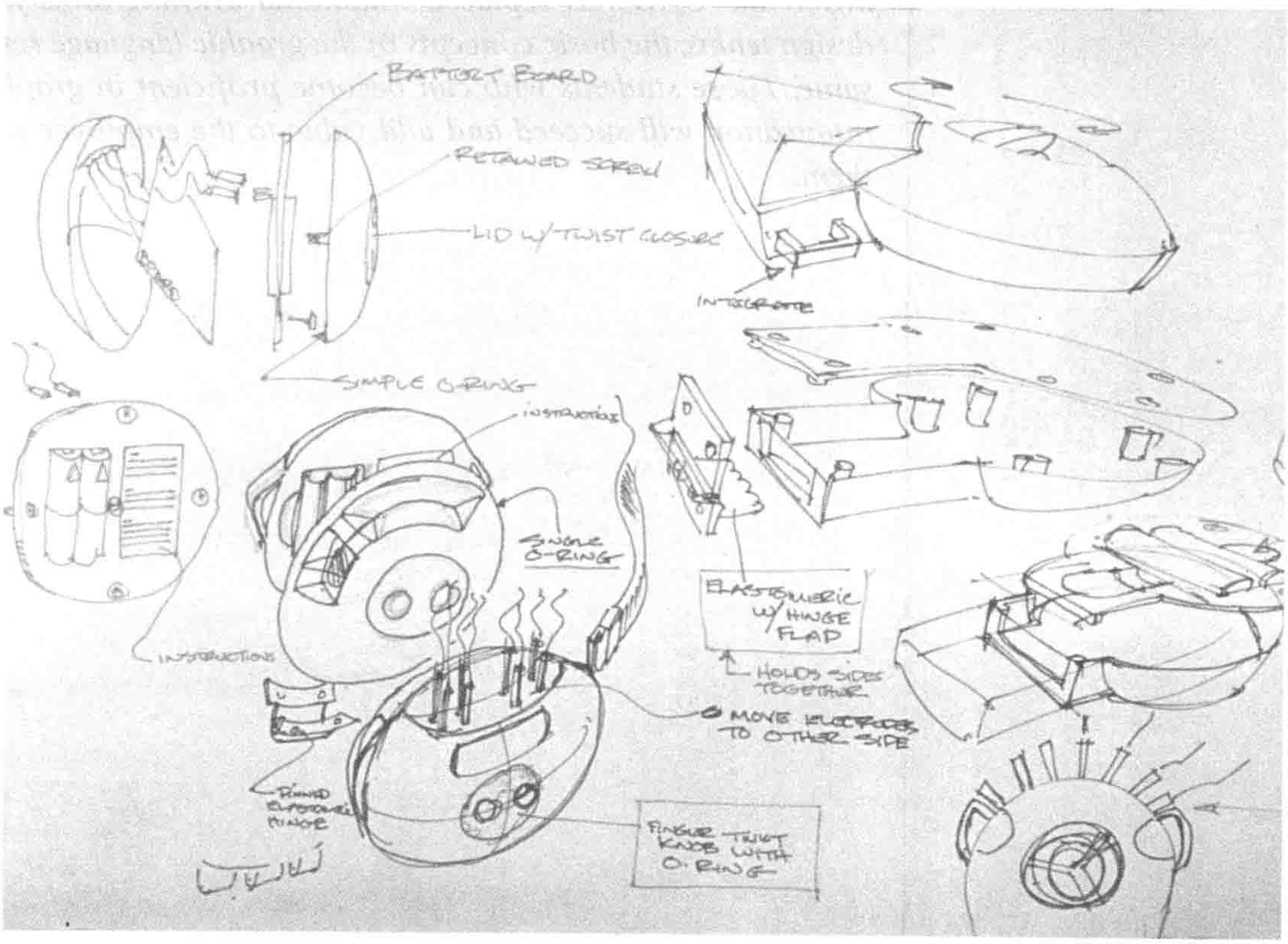
Before a new object of any kind goes into production, certain questions must be answered: What is the potential market for this object? Can the object (device or system) be sold at a price that people are willing to pay? If the potential market is large enough and the estimated selling price seems reasonable, then the inventor, designer, or company officials may choose to proceed with development, production, and marketing plans for the new project.

A new machine, structure, or system, or even an improvement of an existing system, must exist in the mind of the inventor, engineer, or designer before it can become a reality. This original concept is usually placed on paper or as an image of a computer screen. It is then communicated to others by way of the *graphic language* in the form of freehand *idea sketches*, or *design sketches* (Figs. 1.1 and 5.1). As the idea is developed more fully, these original sketches are followed by other sketches, such as *computation sketches*.

Engineers and designers must be able to create idea sketches, calculate stresses, analyze motions, size parts, specify materials and production methods, make design layouts, and supervise the preparation of drawings and specifications that will control the numerous details of product manufacture, assembly, and maintenance. To perform or supervise these many tasks, engineers make liberal use of freehand sketches. They must be able to record and communicate ideas quickly to associate and support personnel. Both facility in freehand sketching (Chapter 3) and the ability to work with computer-controlled drawing techniques require a thorough knowledge of the graphic language. Engineers and designers who use a computer for drawing and design work must be proficient in drafting, designing, and conceptualizing.

Typical engineering and design departments are shown in Figs. 1.2 and 1.3. Such staffs include people who have considerable training and experience as well as recent graduates who are gaining experience. There is much to be learned on the job, and inexperienced people must start at a low level and then advance to more responsible positions as they gain experience.

■ **FIGURE 1.1** ■ An Initial Idea Sketch. *Courtesy of Ratio Design Lab, Inc.*



■ FIGURE 1.2 ■ Engineers Work to Have an In-Depth Understanding of a Product's Design. *Courtesy of AC Engineering, Inc.*

## 1.1 ■ THE GRAPHIC LANGUAGE

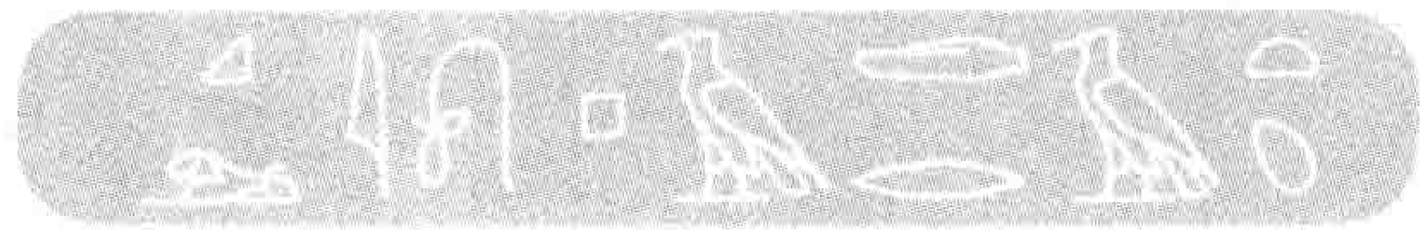
Although people around the world speak different languages, a universal graphic language has existed since the earliest of times. The earliest forms of writing were through picture forms, such as the Egyptian hieroglyphics (Fig. 1.4). Later these forms were simplified and became the abstract symbols used in our writing today.

A drawing is a graphic representation of a real thing, an idea, or a proposed design for later manufacture or construction. Drawings may take many forms, but the graphic method of representation is a basic natural form of communication of ideas that is universal and timeless.

## 1.2 ■ ARTISTIC AND TECHNICAL DRAWINGS

Graphic representation has been developed along two distinct lines, according to purpose: (1) artistic and (2) technical.

■ FIGURE 1.3 ■ Part of a Typical Engineering Design Department. *Courtesy of Hewlett-Packard Company.*



■ FIGURE 1.4 ■ Egyptian Hieroglyphics.

From the beginning of time, artists have used drawings to express aesthetic, philosophic, or other abstract ideas. People learned by conversing with their elders and by looking at sculptures, pictures, or drawings in public places. Everybody could understand pictures, and they were a principal source of information.

The other line along which drawing has developed has been the technical. From the beginning of recorded history, people have used drawings to represent the design of objects to be built or constructed. No trace remains of these earliest drawings, but we know that drawings were used, for people could not have designed and built as they did without using fairly accurate drawings.

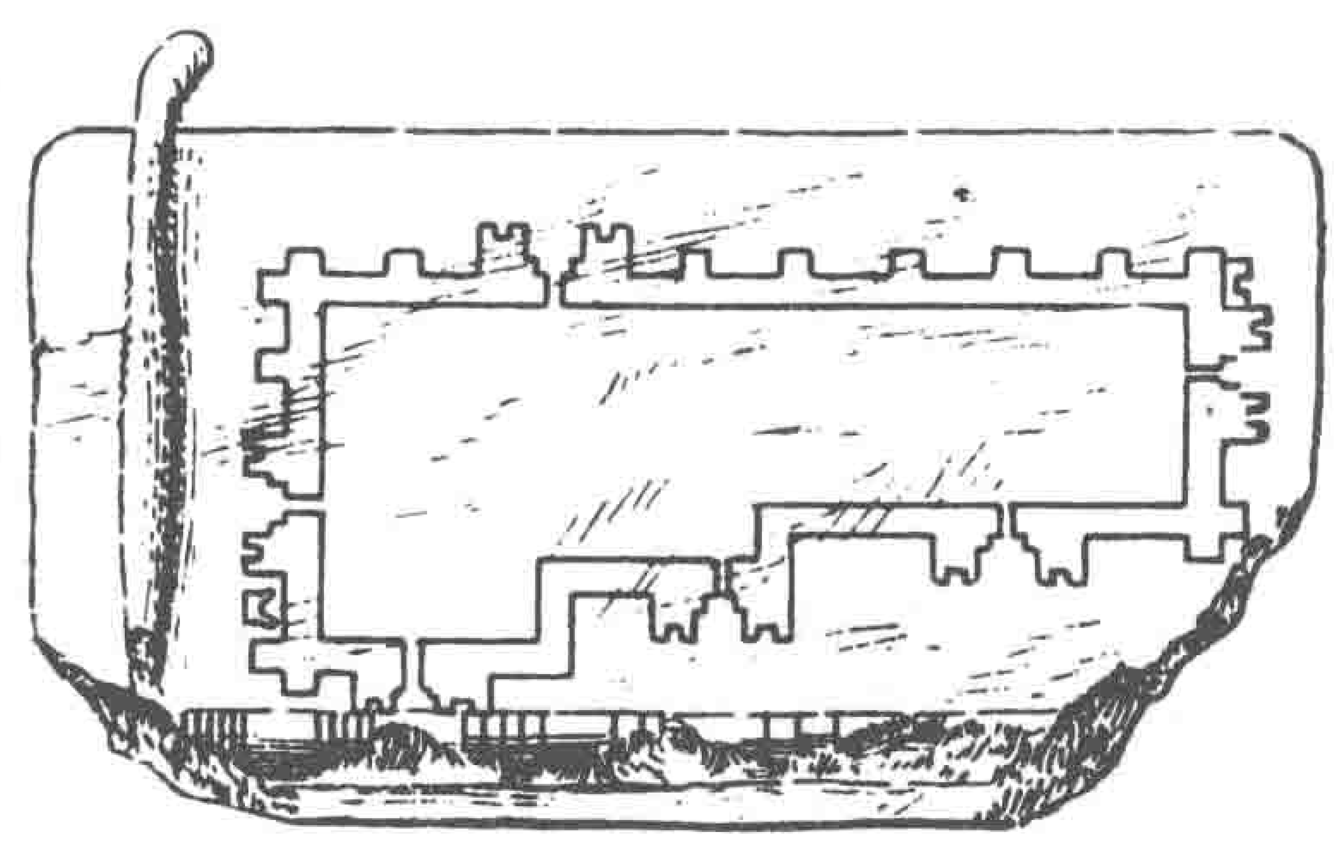
## 1.3 ■ EARLY TECHNICAL DRAWING

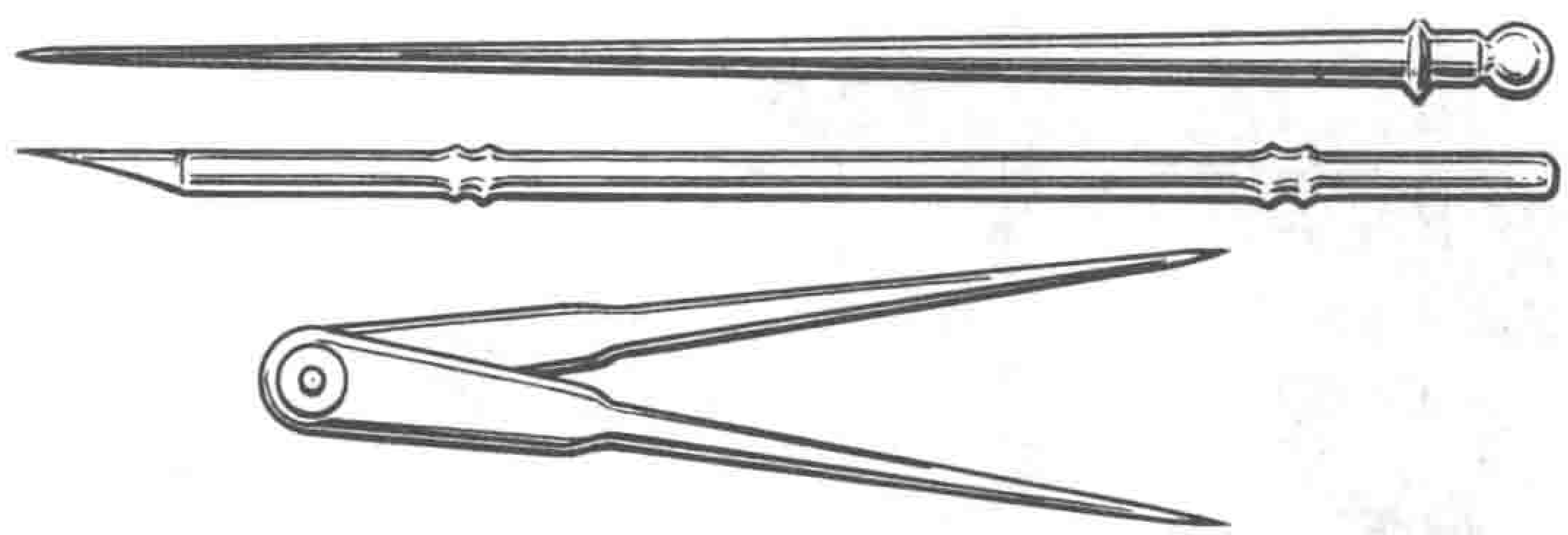
Perhaps the earliest known technical drawing in existence is the plan view for a design of a fortress drawn by the Chaldean engineer Gudea and engraved on a stone tablet (Fig. 1.5). It is remarkable how similar this plan is to those made by modern architects, although it was "drawn" thousands of years before paper was invented.

In museums we can see actual specimens of early drawing instruments. Compasses were made of bronze and were about the same size as those in current use. As shown in Fig. 1.6, the old compass resembled the dividers of today. Pens were cut from reeds.

The scriber-type compass gave way to the compass with a graphite lead shortly after graphic pencils were developed. At Mount Vernon we can see the drawing instruments used by the great civil engineer George Washington, bearing the date 1749. This set is very similar to the conventional drawing instruments used

■ FIGURE 1.5 ■ Plan of a Fortress. This stone tablet is part of a statue now in the Louvre, in Paris, and is classified in the earliest period of Chaldean art, about 4000 B.C. *From Transactions ASCE, May 1891.*





■ **FIGURE 1.6** ■ Roman Stylus, Pen, and Compass. *From Historical Note on Drawing Instruments, published by V & E Manufacturing Co.*

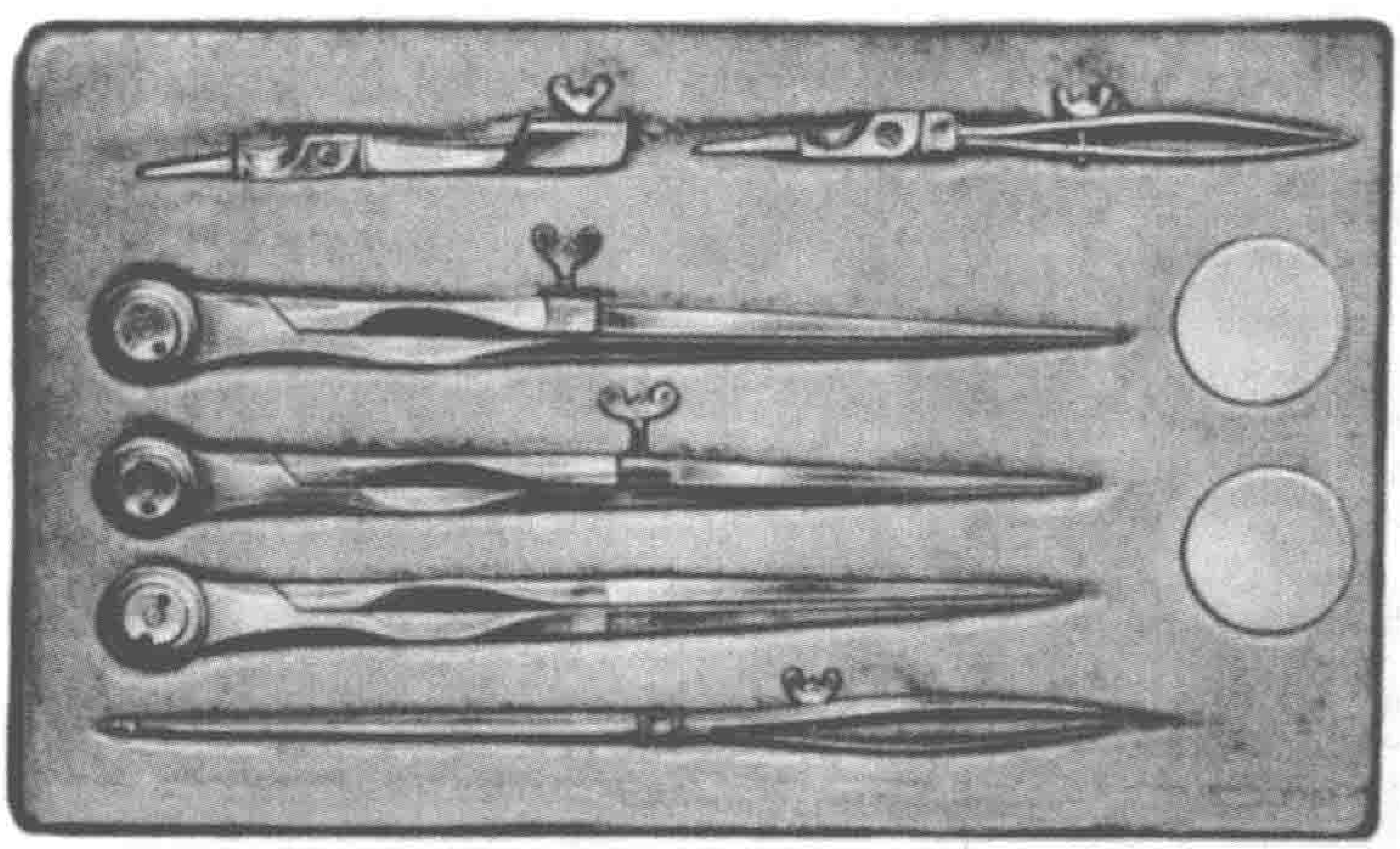
today. It consists of a divider and compass with pencil and pen attachments plus a ruling pen with parallel blades similar to the modern pens (Fig. 1.7).

The theory of projections of objects on imaginary planes of projection (to obtain views; see Chapter 6) apparently was not developed until the early part of the fifteenth century by the Italian architects Alberti, Brunelleschi, and others. It is well known that Leonardo da Vinci used drawings to record and transmit to others his ideas and designs for mechanical constructions, and many of these drawings are still in existence (Fig. 1.8). It is not clear whether Leonardo ever made mechanical drawings showing orthographic views as we now know them, but it is probable that he did. Leonardo's treatise on painting, published in 1651, is regarded as the first book ever printed on the theory of projection drawing; however, its subject was perspective and not orthographic projection.

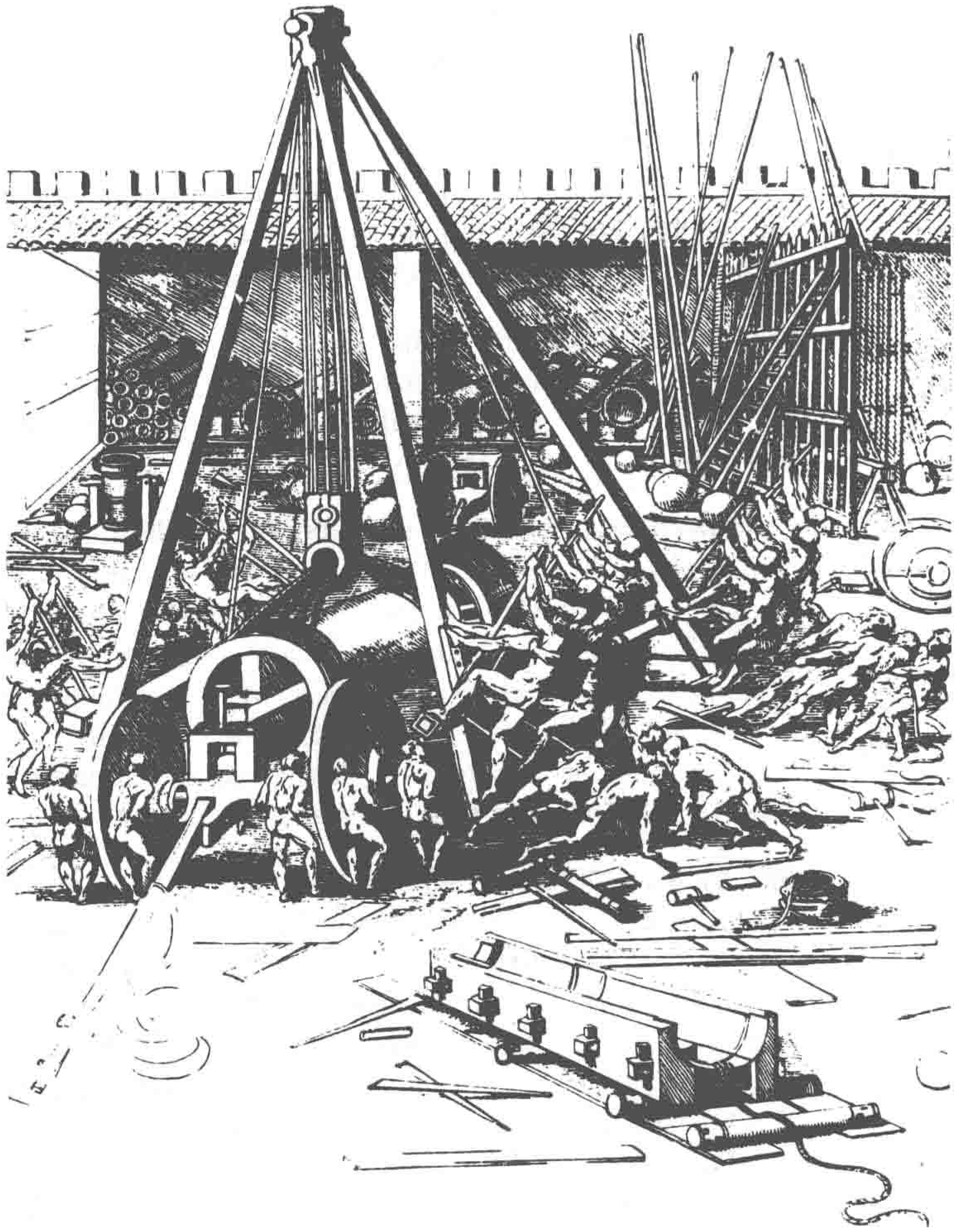
## 1.4 ■ EARLY DESCRIPTIVE GEOMETRY

Descriptive geometry is the science of graphic representation and solution of spatial problems. The beginnings of descriptive geometry are associated with the problems encountered in designs for building construction and military fortifications of France in the eighteenth century. Gaspard Monge (1746–1818) is considered the "inventor" of descriptive geometry, although his efforts were preceded by publications on stereotomy (the art or science of cutting solid bodies, especially stone, into desired shapes), architecture, and perspective, in which many of the principles were used. It was while he was a professor at the Polytechnic School in France near the close of the eighteenth century that Monge developed the principles of projection that are now the basis of our technical drawing. [A view of a part for a design is technically known as a **projection**]. These principles of descriptive geometry were soon recognized to be of such military importance that Monge was compelled to keep his principles secret until 1795, after which they became an important part of technical education in France and Germany and later in the United States. His book, *La Géométrie Descriptive*, is still regarded as the first text to expound the basic principles of projection drawing.

Monge's principles were brought to the United States from France in 1816 by Claude Crozet, an alumnus of the Polytechnic School and a professor at the United States Military Academy at West Point. He published the first text on the subject of descriptive geometry in the English language in 1821. In the years immediately following, these principles became a regular part of early engineering curricula at Rensselaer Polytechnic Institute, Harvard University, Yale University, and others. During the same period, the idea of manufacturing interchangeable parts in the early arms industries was being developed, and the principles of projection drawing were applied to these problems.



■ **FIGURE 1.7** ■ George Washington's Drawing Instruments. *From Historical Note on Drawing Instruments, published by V & E Manufacturing Co.*



■ FIGURE 1.8 ■ An Arsenal, by Leonardo da Vinci.
*Courtesy of the Bettmann Archive.*

## 1.5 ■ MODERN TECHNICAL DRAWING

Perhaps the first text on technical drawing in this country was *Geometrical Drawing*, published in 1849 by William Minifie, a high school teacher in Baltimore. In 1850 the Alteneder family organized the first drawing instrument manufacturing company in the United States (Theo. Alteneder & Sons, Philadelphia). In 1876 the blueprint process was introduced at the Philadelphia Centennial Exposition. Up to this time the graphic language was more or less an art, characterized by fine-line drawings made to resemble copper-plate engraving, by the use of shade lines, and by the use of watercolor "washes." These techniques became unnecessary after the introduction of blueprinting, and drawings gradually were made less ornate to obtain the best results from this method of reproduction. This was the beginning of modern technical drawing. The graphic language now became a relatively exact method of representation, and the building of a working model as a regular preliminary to construction became unnecessary.

Up to about 1900, drawings everywhere were generally made in what is called *first-angle projection*, in which the top view was placed under the front view, the left-side view was placed at the right of the front view, and so on. At this time in the United States, after a considerable period of argument pro and con, practice gradually settled on the present *third-angle projection*, in which the views are situated in what we regard as their more logical or natural positions. Today, third-angle projection is standard in the United States, but first-angle projection is still used throughout much of the world.

During the early part of the twentieth century, many books were published in which the graphic language was analyzed and explained in connection with its rapidly changing engineering design and industrial applications. Many of these writers were not satisfied with the term because they recognized that technical drawing was really a graphic language. Anthony's *An Introduction to the Graphic Language*, French's *Engineering Drawing*, and Giesecke et al., *Technical Drawing*, were all written with this point of view.

## 1.6 ■ DESIGN PROCESS

Design is the ability to combine ideas, scientific principles, resources, and often existing products into a solution for a problem. This ability to solve problems in design is the result of an organized and orderly approach to the problem known as the ***design process***. The design process is not the haphazard operation of an inventor working in a garage or basement, although it might well begin in that manner. Nearly all successful companies support a well-organized design effort, and the vitality of the company depends to a large extent on the planned output of its designers.

The design process leads to manufacturing, assembly, marketing, service, and the many activities necessary for a successful product, and it is composed of several phases. Although many industrial groups may identify them in their own particular way, one procedure for the design of a new or improved product follows these five stages:

1. Problem identification;
2. Concepts and ideas;
3. Compromise solutions;
4. Models and/or prototypes;
5. Production and/or working drawings.

Ideally, the design moves through these stages, but as new information becomes available, it may be necessary to return to a previous stage and repeat a procedure. The design process will be discussed in detail in Chapter 12.

## 1.7 ■ DRAFTING STANDARDS

Modern technical drawing books tended to standardize the characters of the graphic language, to eliminate its provincialisms and dialects, and to give industry, engineering, and science a uniform, effective graphic language. Of prime importance in this movement in the United States has been the work of the American National Standards Institute (ANSI) with the American Society for Engineering Education, the Society of Automotive Engineers, and the American Society of Mechanical Engineers. As sponsors, they have prepared the *American National Standard Drafting Manual—Y14*, which is composed of a number of separate sections that were published as approved standards as they were completed over a period of years.

These sections outline the most important idioms and usages in a form that is acceptable to the majority. They are considered the most authoritative guide to uniform drafting practices in this country today. The Y14 Standard gives the characters of the graphic language, and it remains for the textbooks to explain the grammar and the penmanship (see §1.9 for a definition of penmanship as it applies to technical drawing).

## 1.8 ■ DEFINITIONS

After this brief survey of the historical development of the graphic language, and before we begin a serious study of theory and applications, a few terms need to be defined.

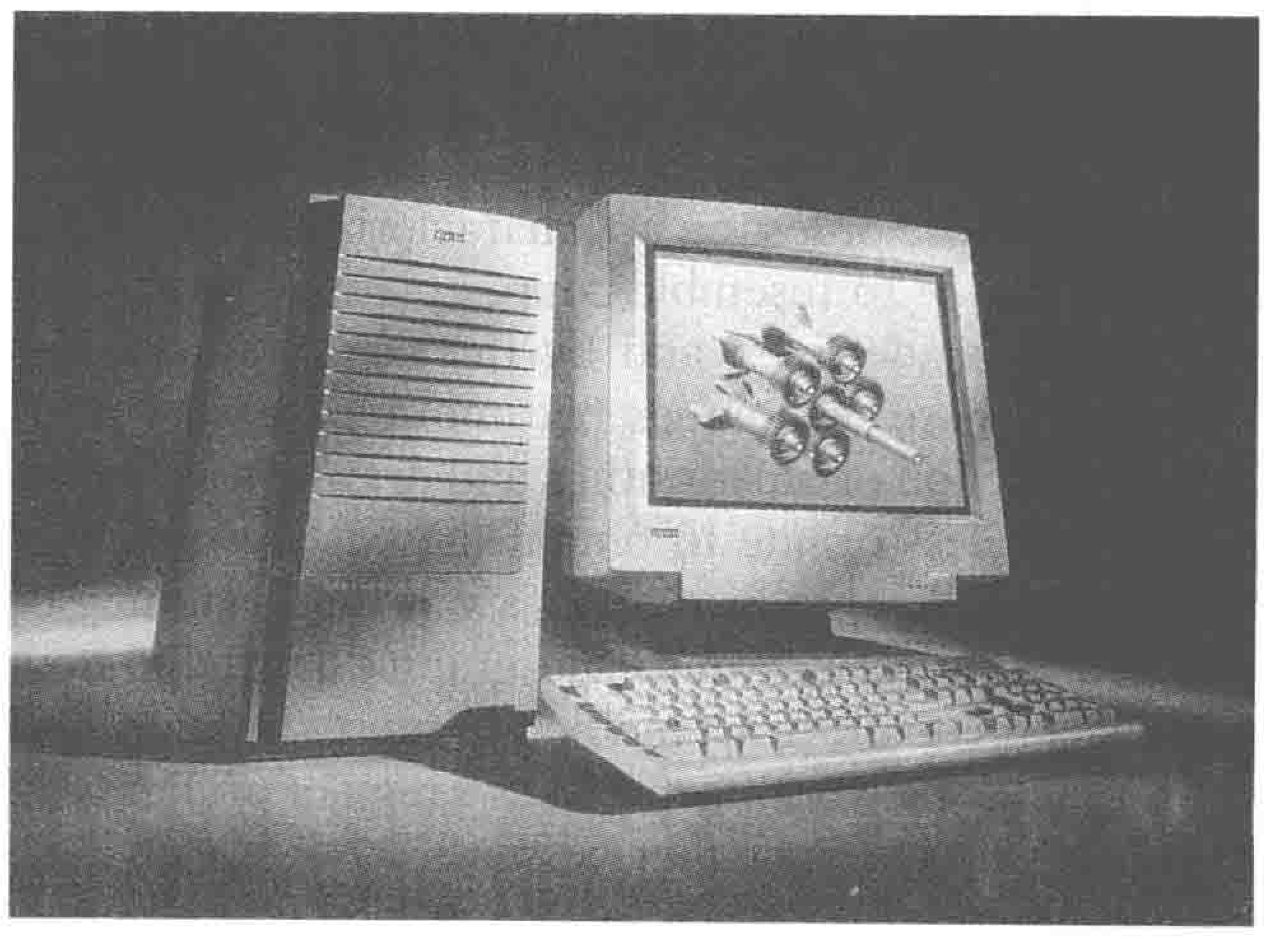
**DESCRIPTIVE GEOMETRY** This is the three-dimensional geometry forming the background for the practical applications of the graphic language and through which many of its problems may be solved graphically.

**INSTRUMENTAL DRAWING OR MECHANICAL DRAWING** These terms properly apply only to a drawing made with drawing instruments. The use of "mechanical drawing" to denote all industrial drawings is unfortunate not only because such drawings are not always mechanically drawn, but also because that usage tends to belittle the broad scope of the graphic language by naming it superficially for its principal mode of execution.

**COMPUTER GRAPHICS** This is the application of conventional computer techniques (with the aid of one of many graphic data processing systems available) to the analysis, modification, and finalizing of a graphical solution. The use of computers to produce technical drawings is called computer-aided design or computer-aided drafting (CAD) and also computer-aided design and drafting (CADD). (See Fig. 1.9.)

You can use CAD to create a useful database that accurately describes the three-dimensional geometry of the machine part, structure, or system you are designing. This database can be used to perform analysis, directly machine parts, or create illustrations for catalogs and service manuals.

**FIGURE 1.9** A CAD Workstation. *Courtesy of Digital Equipment Corporation.*



**ENGINEERING DRAWING AND ENGINEERING DRAFTING** These are broad terms widely used to denote the graphic language. However, since the graphic language is also used by a much larger group of people in diverse fields who are concerned with technical work or industrial production, these terms are not broad enough.

**TECHNICAL DRAWING** This is a broad term that adequately suggests the scope of the graphic language. It is rightly applied to any drawing used to express technical ideas. This term has been used by various writers since Monge's time at least and is still widely used, mostly in Europe.

**ENGINEERING GRAPHICS OR ENGINEERING DESIGN GRAPHICS** These terms are generally applied to drawings for technical use and have come to mean that part of technical drawing that is concerned with the graphical representation of designs and specifications for physical objects and data relationships as used in engineering and science.

**TECHNICAL SKETCHING** This is the freehand expression of the graphic language. Technical sketching is a valuable tool for engineers and others engaged in technical work because through it most technical ideas can be expressed quickly and effectively without the use of special equipment.

**BLUEPRINT READING** This is the term applied to the "reading" of the language from drawings made by others. Actually, the blueprint process has now been replaced by other more efficient processes, but the term "blueprint reading" has been accepted through usage to mean the interpretation of all ideas expressed on technical drawings, whether or not the drawings are blueprints.

## 1.9 ■ WHAT ENGINEERING, SCIENCE, AND TECHNOLOGY STUDENTS SHOULD KNOW

From the dawn of history, the development of technical knowledge has been accompanied, and to a large extent made possible, by a corresponding graphic language. Today the intimate connection between engineering and science and the universal graphic language is more vital than ever before. Thus, training in the application of technical drawing is required in virtually every engineering school in the world.

The old days of fine-line drawings and of shading and "washes" are gone forever; artistic talent is no longer a prerequisite to learning the fundamentals of the graphic language. Instead, today's graphics student needs the same aptitudes, abilities, and computer skills that are needed in science and engineering courses.

The well-trained engineer, scientist, or technician must be able to make and read correct graphical representations of engineering structures, designs, and data relationships. This means that the individual must understand the fundamental principles, or the grammar, of the language and be able to execute the work with reasonable skill (which is penmanship).

Graphics students often try to excuse themselves for inferior results (usually caused by lack of application) by arguing that after graduation they do not expect to do any drafting at all. Such students presumptuously expect, immediately after graduation, to be accomplished engineers concerned with bigger things. They forget that first assignments may involve working with drawings and possibly revising drawings, either on a board or on a computer, under the direction of an experienced engineer. Entering the engineering profession via graphics provides an excellent opportunity to learn about the product, the company operations, and the supervision of others.

Even a young engineer who has not been successful in developing a skillful penmanship in the graphic language will have use for its grammar, since the ability to read a drawing will be of utmost importance. Furthermore, the engineering student is apt to overlook that, in practically all the subsequent courses taken in college, technical drawings will be encountered in most textbooks. The student is often called on by instructors to supplement calculations with mechanical drawings or sketches. Thus, a mastery of a course in technical drawing utilizing both traditional methods and computer systems (CAD) will aid materially, not only in professional practice after graduation but more immediately in other technical courses.

Besides the direct advantages of a serious study of the graphic language, many students learn the meaning of neatness, speed, and accuracy for the first time in a drawing course. These are basic and necessary habits for every successful engineer, scientist, and technician.

The ability to *think in three dimensions* is one of the most important requisites of successful scientists, designers, and engineers. Learning to visualize objects in space, to use the constructive imagination, is one of the principal values to be obtained from a study of the graphic language. Persons of extraordinary creative ability possess the ability to visualize to an outstanding degree. It is difficult to think of Edison, De Forest, or Einstein as being deficient in constructive imagination.

## 1.10 ■ PROJECTIONS

Behind every drawing of an object is a space relationship involving four imaginary things:

1. The observer's eye, or the *station point*;
2. The object;

3. The *plane of projection*;
4. The *projectors*, also called *visual rays* or *lines of sight*.

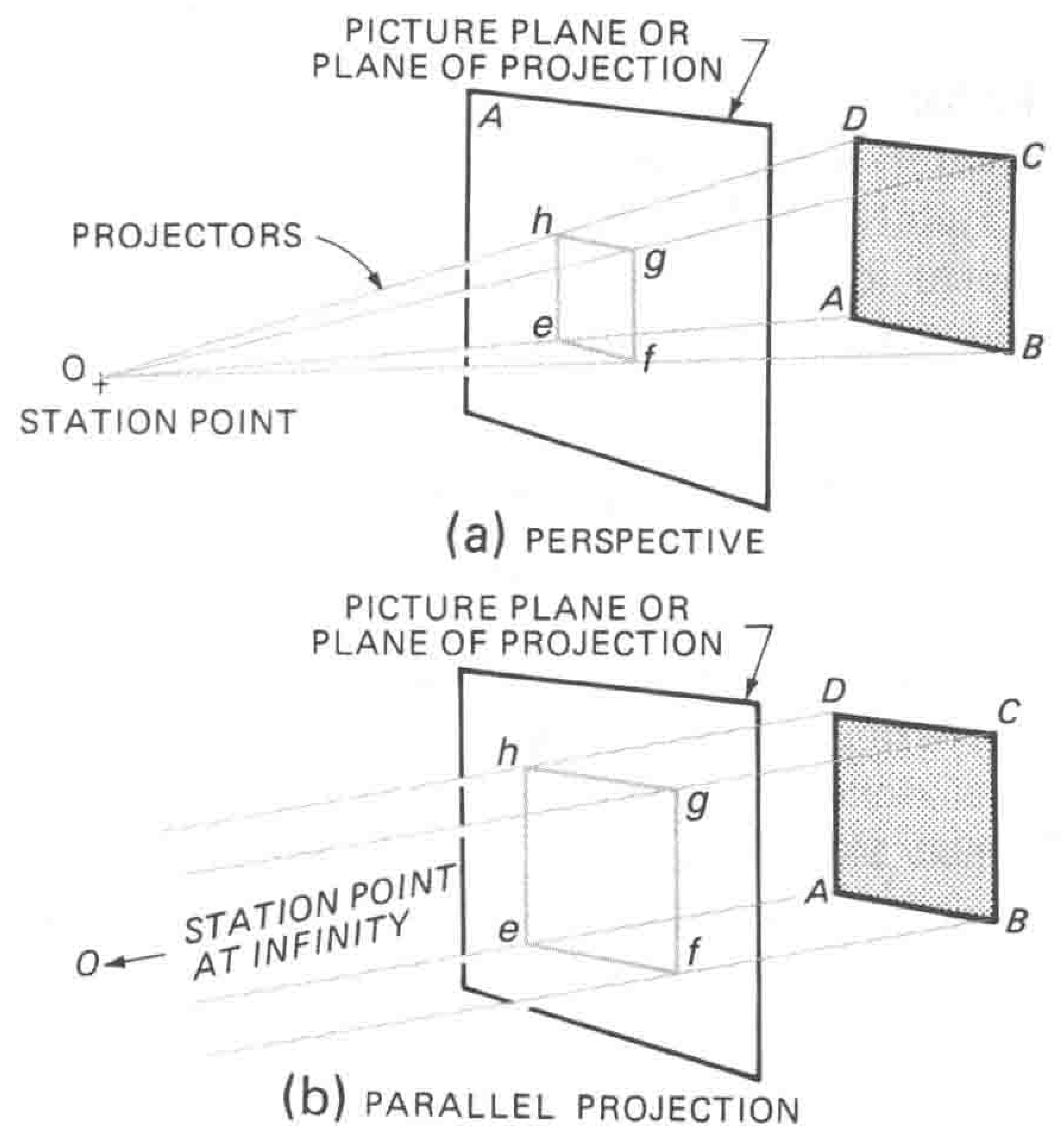
For example, in Fig. 1.10a the drawing efgh is the projection, on the plane of projection A, of the square ABCD as viewed by an observer whose eye is at the point O. The projection or drawing on the plane is produced by the points at which the projectors pierce the plane of projection (*piercing points*). In this case, where the observer is relatively close to the object and the projectors form a "cone" of projectors, the resulting projection is known as a *perspective*.

If the observer's eye is imagined as infinitely distant from the object and the plane of projection, the projectors will be parallel, as shown in Fig. 1.10b; hence, this type of projection is known as a *parallel projection*. If the projectors, in addition to being parallel to each other, are perpendicular (normal) to the plane of projection, the result is an *orthographic*, or right-angle, *projection*. If they are parallel to each other but oblique to the plane of projection, the result is an *oblique projection*.

These two main types of projection—perspective or central projection, and parallel, or central, projection—are further broken down into many subtypes, as shown in Fig. 1.11, and will be treated at length in the various chapters that follow.

A classification of the main types of projection according to their projectors is shown in Table 1.1.

**FIGURE 1.10** Projections.



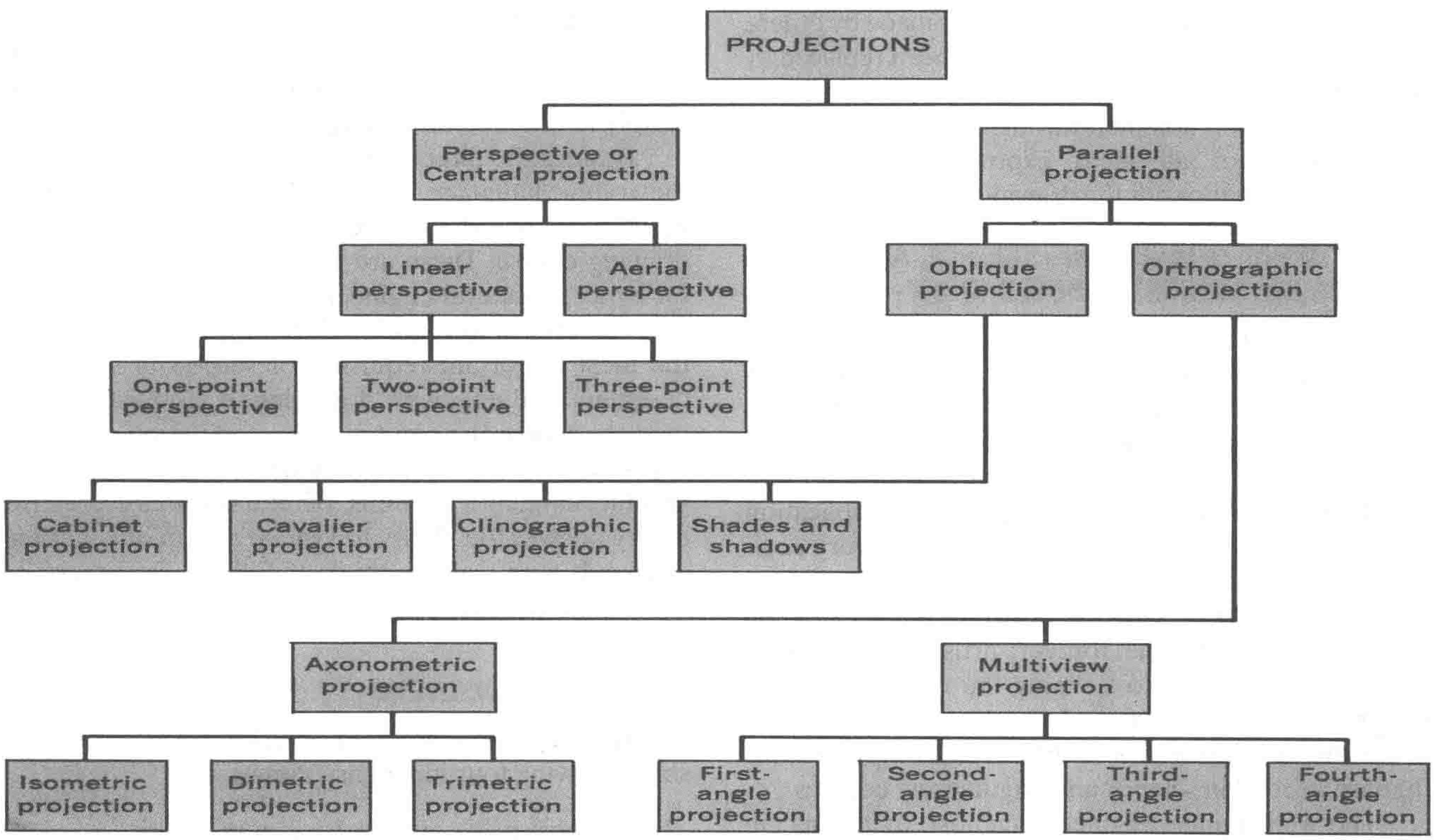




**FIGURE 1.11** Classification of Projections.

**TABLE 1.1** Classification by Projectors.

| Classes of Projection | Distance from Observer to Plane of Projection | Direction of Projectors |
|---|---|---|
| Perspective | Finite | Radiating from station point |
| Parallel | Infinite | Parallel to each other |
| Oblique | Infinite | Parallel to each other and oblique to plane of projection |
| Orthographic | Infinite | Perpendicular to plane of projection |
| Axonometric | Infinite | Perpendicular to plane of projection |
| Multiview | Infinite | Perpendicular to planes of projection |

## KEY WORDS

GRAPHIC LANGUAGE
TECHNICAL DRAWING
DRAWING INSTRUMENTS
COMPUTER GRAPHICS
PERSPECTIVE
DESIGN PROCESS
DESIGN TEAM
DESCRIPTIVE GEOMETRY
STANDARDS
PROJECTION
PLANE OF PROJECTION

## CHAPTER SUMMARY

- The members of the engineering design project team must be able to communicate among themselves and with the rest of the project team in order to contribute to the team's success.
- The graphic language is the universal language used by every engineering team designing and developing products throughout the world.
- There are two basic types of drawings: artistic and technical.
- Technical drawing is based on the universal principles of descriptive geometry, developed in the late eighteenth century in France.
- The design process is the ability to combine ideas, scientific principles, resources, and existing products into a solution for a problem. It consists of five specific stages.
- Every technical drawing is based on standards that prescribe what each symbol, line, and arc means.
- Computers running CAD software are the current tools used by drafters. However, the basic drawing principles are the same ones used for hundreds of years.
- Drawings are based on the projection of an image onto a plane of projection. There are two types of projection: parallel and perspective.
- Successful companies hire skilled people who can add value to their design team. The proper use of equipment and a thorough understanding of the graphic language are two essential skills employers require.

## REVIEW QUESTIONS

1. What is the role of the engineer on the design team?
2. What is the difference between mechanical drawing and sketching?
3. Describe the main difference between parallel projection and perspective projection.
4. When is sketching an appropriate form of graphic communication?
5. Why are standards so important for members of the engineering design team?
6. What is the most important new tool used by drafters?
7. What is a plane of projection?
8. What are projectors and how are they drawn?
9. What is the design process?
10. What are the five phases of the design process?

Chapter

2

# Introduction to CAD

## OVERVIEW

*The use of electronic computers today in nearly every phase of engineering, science, business, and industry is well known. The computer has altered accounting and manufacturing procedures, as well as engineering concepts. The integration of computers into the manufacturing process from design to prototyping, manufacture, and marketing, is changing the methods used in the education and training of technicians, drafters, designers, and engineers.*

*Engineering, in particular, is a constantly changing field. As new theories and practices evolve, more powerful tools are developed and perfected to allow the engineer and designer to keep pace with the expanding body of technical knowledge. The computer has become an indispensable and effective tool for design and practical problem solving. New methods for analysis and design, the creation of technical drawings, and the solving of engineering problems, as well as the development of new concepts in automation and robotics, are the result of the influence of the computer on current engineering and industrial practice.*

## OBJECTIVES

After studying the material in this chapter, you should be able to:

1. List the basic components of a computer-aided drawing workstation.
2. Describe the relationship between computer-aided drawing (CAD) and computer-aided manufacturing (CAM).
3. List the major parts of a computer and describe their function.
4. Describe the purpose of a computer operating system.
5. List several input and output devices.
6. Describe ways in which a computer stores information.
7. Explain the differences between a bit and a byte.
8. Provide hints for selecting and using CAD systems.
9. Understand issues that affect the choice and the use of a CAD system.
10. Explain features common to most CAD software.