Technical Drawing and Design

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DEDICATION

In memory of Walter Brown, one of the most dedicated engineering drawing instructors I have ever known A sincere coworker, a dependable coauthor and most importantly an excellent friend

and to

my children Corina Jamie and Angie

Louis Gary Lamit

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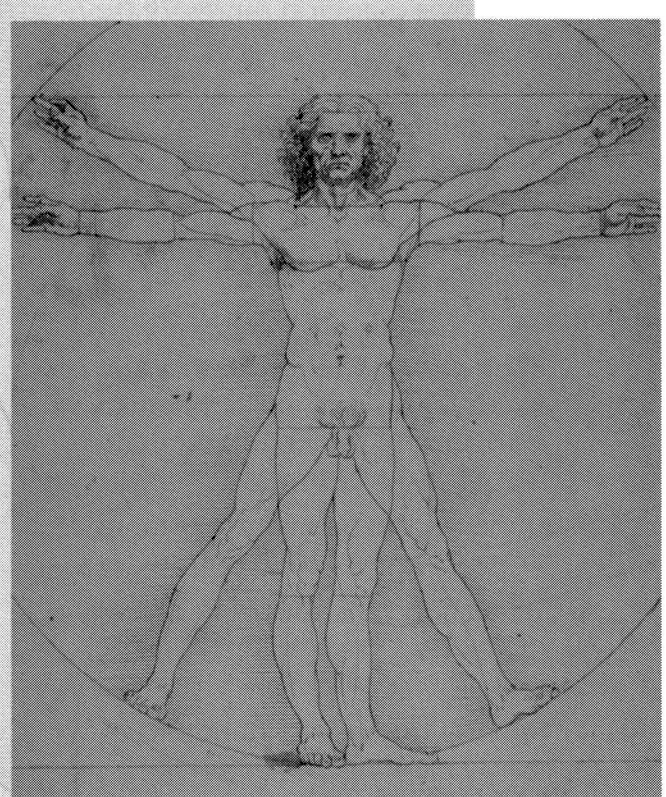
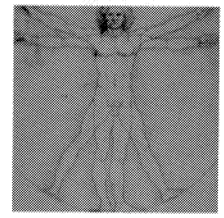
BRIEF CONTENTS

ENGINEERING AND DESIGN



INTRODUCTION TO ENGINEERING GRAPHICS AND DESIGN

Chapter 1



LEARNING OBJECTIVES

Upon completion of this chapter you will be able to:

1. Recognize that engineering graphics allows graphical representation of ideas.
2. Compare career fields in engineering, and understand how engineers and designers use engineering graphics to communicate ideas.
3. Define common terms used in engineering graphics.
4. Understand the transitions in engineering graphics that have taken place from ancient Roman construction projects to modern concurrent engineering projects.
5. Understand and identify technical drawing types and design stages.
6. Understand the role of descriptive geometry in solving three-dimensional problems.
7. Identify the various standards of practice used in engineering graphics and design.

1.1 INTRODUCTION

Engineering graphics and design use graphic language to communicate ideas. This language, developed and used by engineers, designers, and drafters, serves as an essential tool from the beginning of a product's development to its production. How do we communicate ideas graphically? What are the components of this graphic language? What is a good drawing? This text will answer these questions by covering the basics of engineering graphics and engineering design.

Engineering graphics is a *language* or a *tool*, not a specialized field. Engineers use this tool to create and produce a variety of products—from consumer items to highly specialized technical products for the aerospace industry. Engineering drawings play an essential role in design, manufacturing, processing, and production. Every industrial nation employs a large number of engineers and designers. Literally millions of jobs in the United States and Canada depend on technical communication in some way.

Engineering drawings are geometric representations of an idea or product that must be processed, manufactured, or constructed. The engineering and design process is used to define, establish, and create. The engineer, the designer, and the drafter use drawings to communicate technical information to each other and from the design office to the manufacturing floor. All machines, devices, and products are graphically designed before they are manufactured. The cost, the intricacy, and the manufacturability of the item are considered during the beginning of the design stage. Approximately 75% of the cost to produce a part are fixed in the design stage. After the design has been refined, engineering drawings are used to communicate the design data.

You should not look on engineering graphics and design as an end in itself or as an island of information. Design drawings and models are only the first step in the long and

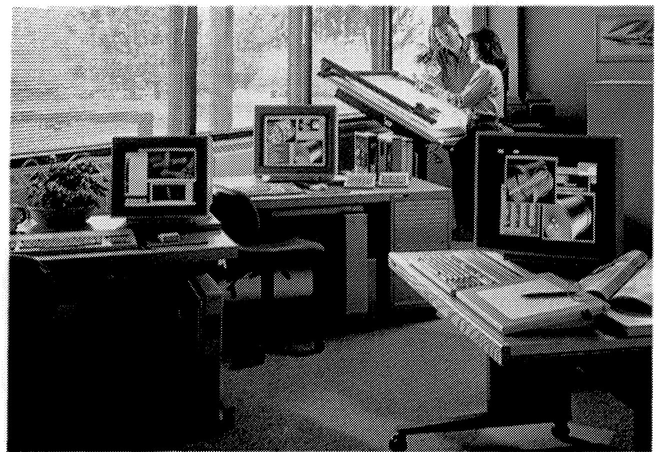


FIGURE 1.1 An Engineering and Design Office

complicated process of product development, production, and manufacture.

Engineering drawings may be prepared either on drafting boards using traditional engineering drawing instruments or with computers. A solid model of the product might be created before any manufacturing is considered. It is not uncommon to see computer-aided design and drafting (CAD) systems interspersed among drafting tables (Fig. 1.1). Some companies still use traditional engineering drawing in portions of their design process. All large companies, such as IBM, General Motors, Hewlett-Packard (Fig. 1.2), and Ford, have converted entirely to computer-aided design/computer-aided manufacturing (CAD/CAM) systems.

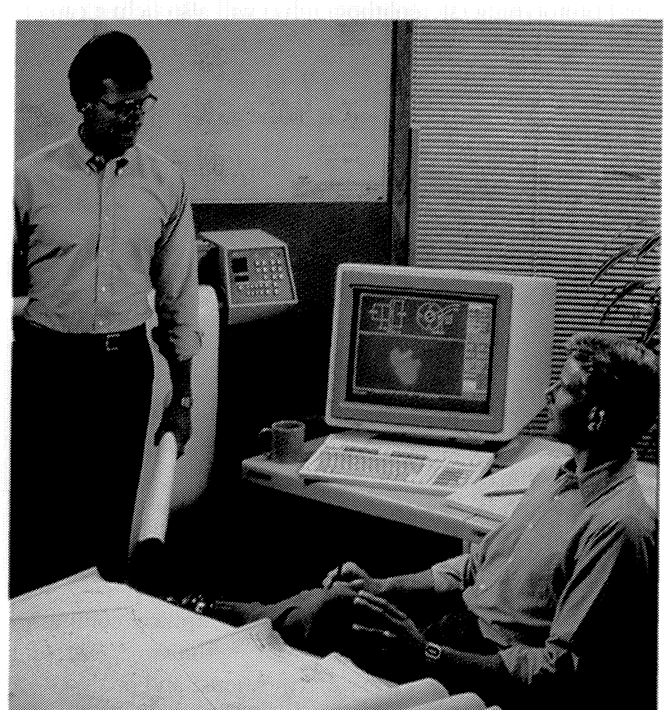


FIGURE 1.2 CAD System

1.2 CAREERS IN ENGINEERING GRAPHICS

There are many sequences you can follow in careers that use engineering graphics and design. Figure 1.3 shows traditional job categories in technical drawing and the path from drafting trainee to design supervisor for a career in drafting and design. The following list shows job categories and responsibilities for various engineering and drafting careers that make use of engineering graphics.

Job Category	*Responsibility*
Chief Engineer	Management
Engineer	Conceptual design
	Ideas
	Calculation and verification
Designer	Design ideas
	Physical layout
Layout designer	Assemblies
	Finalization of design
Detailer	Basic drawings
	Details
	Dimensioning
Checker	Checking of all drawings and designs
Technical illustrator	Presentation drawings
	Manuals
	Publication quality art

The traditional starting point for a career in drafting and design is the *drafting trainee* (Fig. 1.3). The drafting trainee normally has had high school or beginning-level college courses in drafting, math, and related technical subjects. Some drafting trainees start at the apprentice level with no drafting experience.

Typically the first step on the path to a career in drafting and design is to obtain a certificate at a technical school or a one- to two-year associate degree at a community or technical college that offers a drafting and design degree. With this education you enter the job market as a *drafter/detailer* or a *junior drafter*. The entry level depends on the quality of the degree program and the graduate's experience. The junior drafter is required to know considerably more than the drafting trainee. Mastery is essential in the use of instruments, materials, and drafting techniques, including lettering, geometric construction, freehand sketching, projection techniques, sectioning, dimensioning, and tolerancing. The primary responsibility of the junior drafter is to prepare detail drawings.

The *senior drafter* (or *layout designer*) position requires a minimum of two to five years experience in a particular engineering discipline. Layout designers refine the engineer's and designer's sketches, including investigating alternate design possibilities. Layout designers are required to understand drafting conventions and standards, know how to determine clearances and fits, and make the calculations

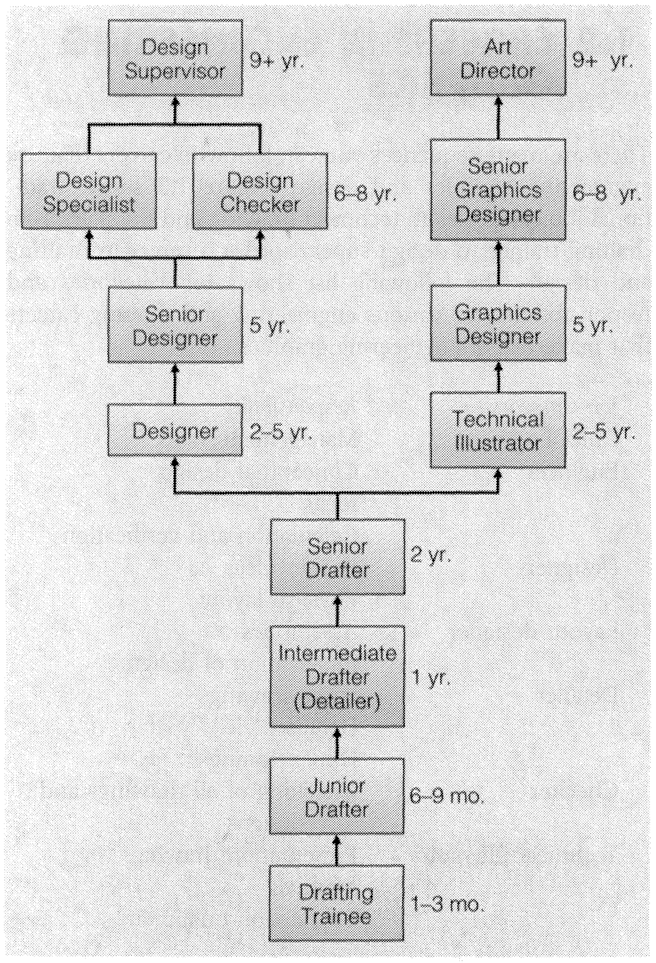


FIGURE 1.3 Flowchart for a Career in Drafting and Design

necessary for an accurate design. Knowledge and understanding of shop practices, procedures, manufacturing techniques, and basic production methods are important. After two to seven years experience, the layout designer may qualify as a junior designer or a designer. A designer is called on to refine designs established by engineers.

Senior designers are in charge of a design group. The senior designer has between six and twenty years of experience as a designer in a particular field. The senior designer works directly with engineers and checkers.

Checkers are responsible for the accuracy of the finished drawings. They review the drawings for clarity, completeness, production feasibility, and cost effectiveness. Checkers review all mathematical computations. A checker is schooled in all standards and conventions for a particular engineering discipline. The checker takes the original design sketches, drawing layouts, and detail drawings of the project and makes sure they are consistent, accurate, and complete.

The ultimate legal responsibility for a project rests with the *engineering team*. Engineers graduate in four or five years from degree programs specific to particular disciplines: mechanical, civil, electrical, chemical, metallurgical, etc. Engineers typically complete at least one course or course sequence in engineering graphics before graduation. Many engineers today go on to complete advanced degrees in their discipline. Engineers must be *registered* in their state to certify certain projects. The *design supervisor* coordinates, supervises, and schedules work assignments.

Computers have changed the way engineers do engineering. Today it is not uncommon for an engineer to be working on a CAD station to complete an initial solid model design for a project. **Parametric** CAD programs are found increasingly in all stages of design engineering. The concurrent engineering environment calls for design for manufacturing (DFM) to be considered during the initial design phase. Parametric CAD programs facilitate this effort. Engineers, industrial designers, technologists, and drafters work together from project inception to ensure a high quality manufacturable product.

The basic knowledge required for a particular engineering project is acquired through a combination of schooling and industrial experience. The technology used in today's engineering design environment is changing rapidly. New features are constantly added to each design program. The pressure to compete in world class manufacturing has pushed the need to complete projects from engineering design to production in a much shorter time. A product late to market is often worthless in today's face paced environment.

You should attempt to gain exposure and training on different CAD software and hardware packages. Pay particular attention to both two-dimensional (2D) and three-dimensional (3D) CAD packages. Experience in solid modeling and parametric design are also particularly important today. A knowledge of computer aided manufacturing and rapid prototyping (stereolithography) will also help a career. Of course strong written and oral communication skills are essential for a successful engineering career.

1.3 TERMS OF THE PROFESSION

This text uses terms that are common in engineering and design. Some of the most important terms follow.

Computer-aided design and drafting or computer aided design (CAD) The use of the computer to design a part and to produce engineering drawings. Two-dimensional CAD is confined to the layout and graphic representation of parts using traditional standard industry conventions. Drawings are *representations* of a part plotted on paper. Whereas 2D CAD is limited to detailing and drafting, 3D CAD, or solid modeling, is usually the starting point for design (Fig. 1.4).

Engineering design graphics The use of graphical communication in the design process. Engineering drawings represent design ideas, configurations, specifications, and analyses for many different kinds of engineering projects.

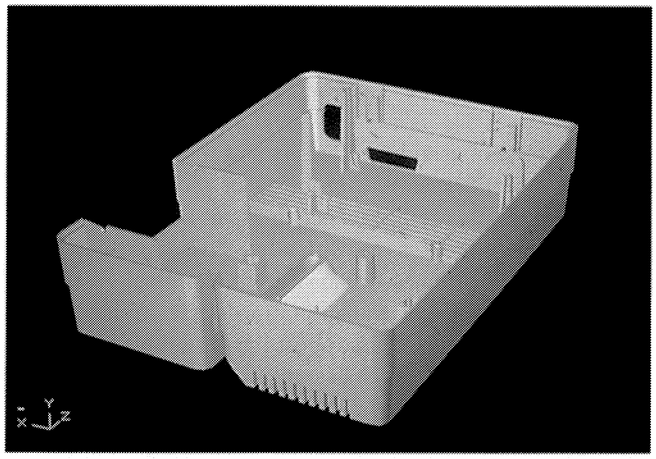


FIGURE 1.4 3D Mold Design

Manual drafting (instrument drawing) The kind of drafting done on a drafting board using paper, pencil, and drawing instruments. Each chapter in the text covers a specific area of manual and CAD procedures used in engineering graphics. In this text, *manual drafting* is confined to the creation of drawings via traditional instruments, not a computer.

Modeling As used throughout the text, describes the design stage of constructing a 3D physical model or an electronic 3D model of a part. A model can be created via physical modeling (Fig. 1.5) and/or by computer modeling (Figs. 1.6 and 1.7) using 3D CAD systems and parametric modelers. With 3D CAD models, you can investigate a variety of designs, model the mechanical response of the designs on the system, and complete other analyses (Fig. 1.8). Physical modeling is used to create a lifelike scale model of the part

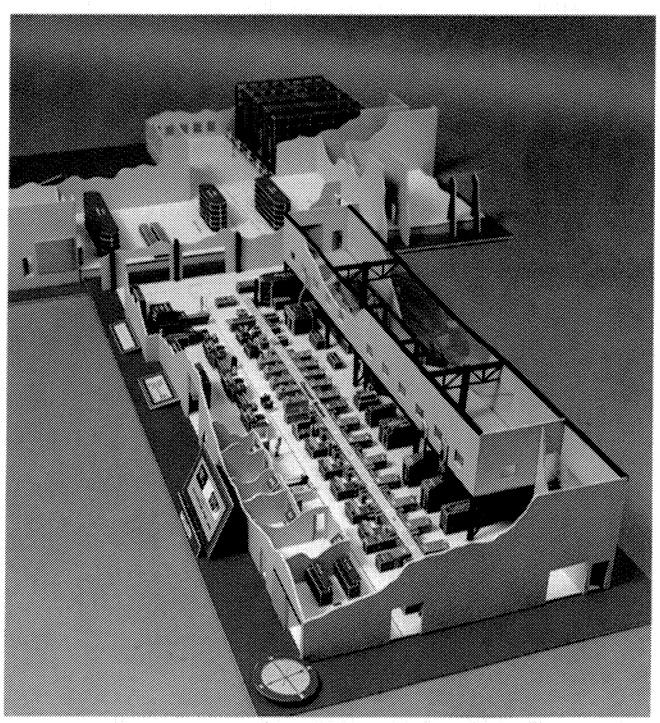


FIGURE 1.5 Scale Physical Model of the Advanced Electronics Assembly Facility

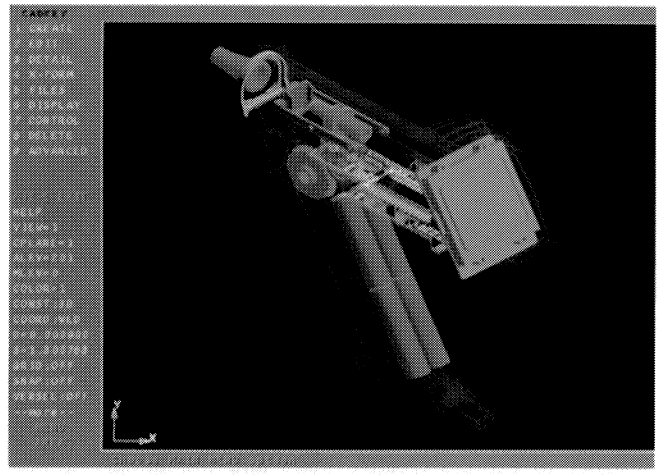


FIGURE 1.6 Solid Model of an Assembly

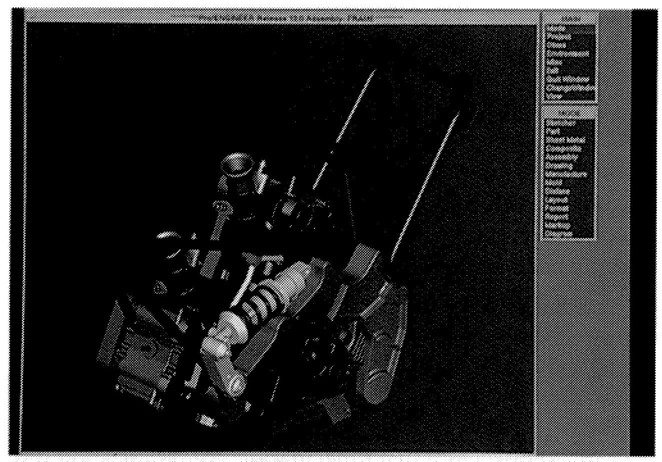


FIGURE 1.7 Shaded Solid Model

FIGURE 1.8 3D Design Model Used for Engineering Analysis

Technical drawing Encompasses all forms of graphic communication: manual, mechanical, freehand, instrument and computer-generated drawings used by the engineer designer, or drafter to express and to develop technical designs for manufacturing, production, or construction.

Technical illustration The use of artistic methods and pictorial techniques to represent a part or a system for use by nontechnical personnel. Technical illustrations are used widely in service, parts, owner's, and other types of manuals Sales and advertising also use technical illustrations

Technical sketching The use of freehand graphics to create drawings and pictorial representations of ideas It is one of the most important tools available to the engineer and designer to express creative ideas and preliminary design solutions

1.4 THE HISTORY OF ENGINEERING DRAWING

Technical drawings have been employed throughout history to communicate ideas. Some of the earliest evidence of the use of drawings comes from the construction of the ancient pyramids and temples, with drawings dating to as far back as 1400 B.C. Drawings were used in ancient Rome to display bridge designs and other construction projects. Leonardo DaVinci employed pictorial sketches to develop and explore different inventions and designs.

The beginning of modern technical drawing dates back to the early 1800s Until that time graphic communication was more artistic in nature and used pen ink and color washes to display pictorial graphic images of a product or construction projects. By the 1900s, drawings were used for the production and manufacture of a wide variety of industrial products. Engineers were learning how to mass-produce products and how to communicate engineering designs more effectively with engineering drawings.

A series of standards and conventions was established to aid the transfer of information between the engineering/design department and manufacturing/production or construction. Communication between companies, industries, and countries was also made easier by standardization. Today, we have a very strict, standardized method of displaying graphic information.

Before the mid-1800s, instruments for graphical representation were limited to measuring scales, the compass, dividers, paper, and ink. Ink was replaced by the pencil The T-square evolved into the parallel bar and then into the drafting machine The newest tool in engineering design and drafting is 2D and 3D CAD systems

1.5 TYPES OF DRAWINGS: ARTISTIC AND TECHNICAL

Drawing is a tool used by engineers and industrial designers to design a product solve a problem, or produce a product. Almost everything around us began as an idea and then as a drawing: the buildings in which we live and work, the appliances in our homes—dishwashers, can openers dryers, toasters; our means of transportation -cars, trains ships, airplanes; our systems that support life -plumbing, electricity; even what we wear was conceived and brought into being by the effective use of engineering drawings. Few items get manufactured or produced without an engineering drawing

There are two types of drawings artistic and technical Artistic drawings are outside the scope of this text Though technical illustrations (Figs 1 9 and 1 10) use artistic techniques an artistic drawing has many techniques and expres

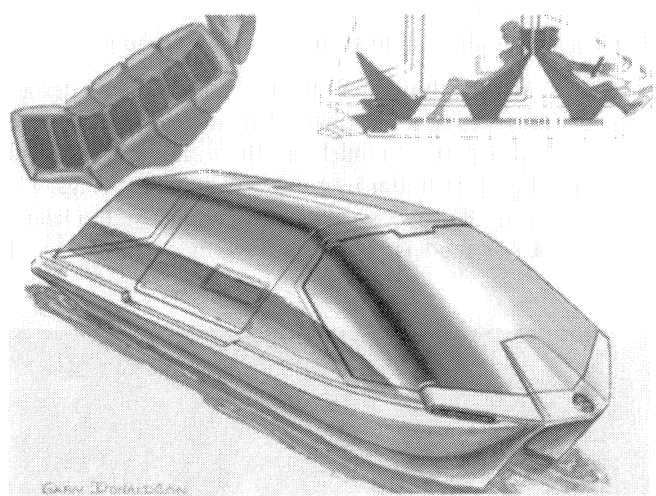


FIGURE 1.9 A Technical Illustration

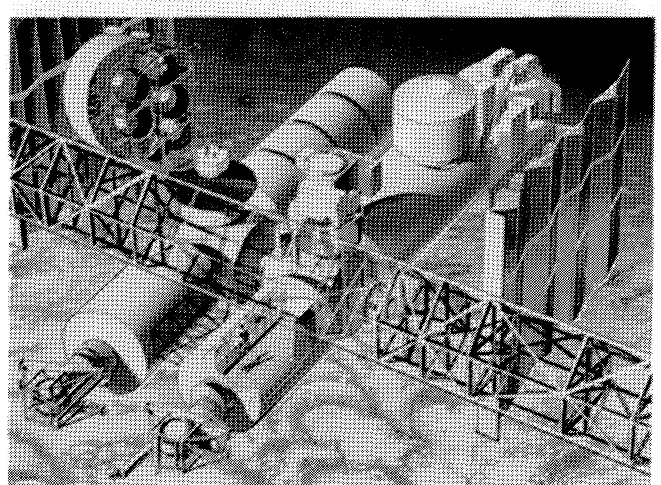


FIGURE 1 10 A Technical Illustration of a Space Station sions not used in technical drawings First of all whereas an artistic drawing is usually interpreted differently by everyone who sees it a technical drawing must communicate the same message to every user or reader of the drawing To limit the interpretation to only one possible conclusion the technical drawing is controlled by accepted standards drawing conventions and projection techniques

Engineering drawings are used to transfer technical information The drawing must contain all information required to bring the concept product or idea into reality Dimensions notes views and specifications are required for a complete drawing Technical drawings must contain everything needed for proper interpretation of the design because design and manufacturing may be located far apart often in different countries

1.6 TYPES OF TECHNICAL DRAWINGS

This text is concerned primarily with engineering drawings of mechanical parts machined parts castings and weldments Various types of drawings are associated with mechanical design and engineering The following are considered standard types of drawings in industry

Design sketches Sketches are initial design ideas requirements calculations and concepts and are used to convey the design parameters to the layout designer

Layout drawings Layout drawings are made to develop the initial design They must show all the information needed to make detail drawings or assembly drawings

Assembly drawings Assembly drawings show a number of detail parts or subassemblies that are joined together to perform a specific function

Detail drawings A detail drawing relays all the information needed to determine the final form of a part It must show a complete and exact description of the part including shapes dimensions tolerances surface finish and heat treatment either specified or implied

Casting drawings Casting drawings are usually not required and the normal practice is to show the necessary casting dimension along with the machining dimensions on the detail drawing When a separate casting drawing is used it contains only information needed for casting but no dimensions for machining or finishing

Fabrication drawings Fabrication drawings are created for parts with permanently fixed pieces The method of fastening is called out on the drawing with symbols or by other standard methods Welded and riveted parts require fabrication drawings

1.7 THE DESIGN PROCESS

The design process (Fig 1 11) starts with a concept or an idea The *first stage* of a project begins with the identification of a particular need for a product Many times the product is identified by a need in industry government the military or the private sector

The *second stage* involves the creation of a variety of options or design ideas These ideas may be in the form of sketches and include mathematical computations The *third stage* is the refinement of the preliminary designs Possible solutions to the problem are identified

The *fourth stage* involves refinement and selection of a particular design Here the project is put in a more formal finalized state using assembly drawings and models This stage requires close attention to how the part is to be manufactured and produced [**design for manufacturability (DFM)**]

In the *fifth stage* detail drawings are prepared The result is a complete set of working drawings The *sixth stage* in the design process is the manufacturing and production of a product or the construction of a system In manufacturing design and layout time is allocated for producing dies tools jigs and fixtures

During the design process the engineers and designers

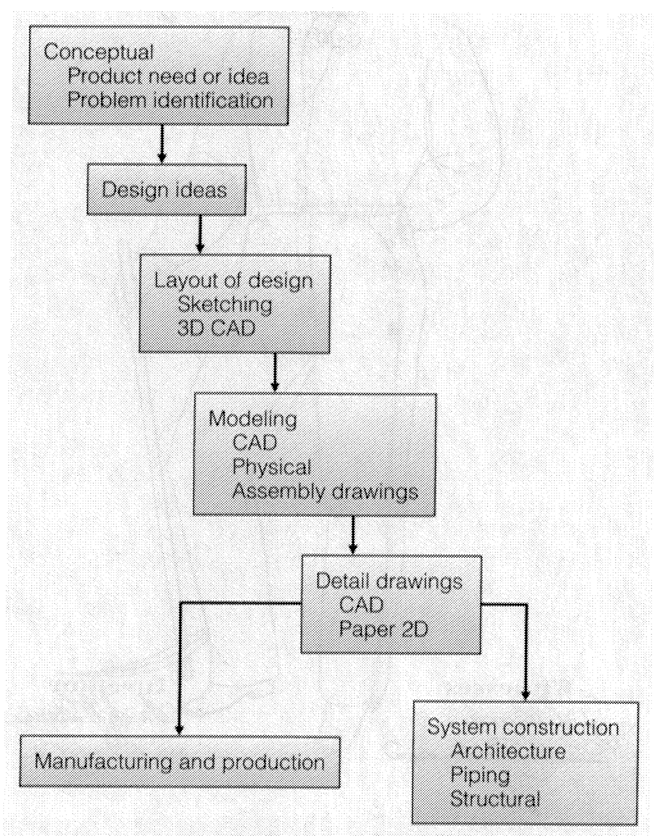


FIGURE 1 11 The Design Process

Focus On . . .

THE DESIGN PROCESS

Even as you read this text, new ideas to give you new sources of pleasure or new sources of frustration are being conceived. Engineers create systems, devices, and processes useful to and sought after by our society. The process by which these goals are achieved in engineering design is a planned sequence of events.

It has been said that "necessity is the mother of invention." Need is the motivating factor in most designs. When Levi Strauss first made what became known as blue jeans, they didn't have the rivets at the pockets. In 1872, Levi was contacted by a tailor from Reno, Nevada, who had started riveting the pants he made for his customers. The two men decided to patent this new innovation and in 1873 were awarded the first patent for pocket rivets.

The patent certificate for rivets on jeans.

Sometimes design is an accident. In 1878, a Procter & Gamble worker forgot to turn off the machine that stirred the soap. The soap that resulted had a lot of air bubbles and was so light it could float. He had just invented Ivory soap, by accident!

Curiosity sometimes drives design. The design of the microwave oven came about because Percy Spencer was curious about the amount of heat that was generated from magnetrons, the tubes used in radar during World War II. He could warm his hands by holding them close to the magnetrons. It was not until he found candy melted in his coat pocket that the idea of using the microwave to cook entered his mind. Many experiments later, the *high-frequency dielectric heating apparatus*—a microwave oven!—was invented. Spencer obtained a patent for it in 1953. Today, microwave ovens are an integral part of home, work, and school—all because Spencer was curious.

For years, we have dreamed about "smart homes." Imagine all the electrical appliances in your home connected so they electronically communicate with each other. As you return home, your house "senses" your arrival, opens the garage door, unlocks the house, turns on the lights, and turns on the television to your favorite program. As we approach the age when this is indeed possible, it is also easy to imagine the amount of information and technology that is needed to produce such a system.

If a design is to be a success and not a frustration, it must be simple and easy to operate, no matter how much information or technology is used. The designer must be able to transmit precise, clear instructions to the user. Much of our technology today makes devices simpler to use, but requires reams of documentation in the development stage. Information management and our ability to communicate will determine whether our future designs are a joy or a frustrating mess of words and wires.

The microwave was born out of curiosity.

encounter many situations where traditional visualization techniques and a mastery of the principles of projection are used in the solution of complex engineering and technical problems. The ability to analyze a specific problem, visualize its spatial considerations, and translate the problem into a viable graphic projection is essential for the engineer. Descriptive geometry is important to this process.

1.8 DESCRIPTIVE GEOMETRY

Descriptive geometry (see Part Six) uses orthographic projection to solve 3D problems with a 2D graphics procedure. Descriptive geometry applications establish the proper representation and relationships of geometric features. These views provide an accurate graphic method to establish information such as true shape and true length. Figure 1.12 shows a descriptive geometry solution to calculating the angle formed by two intersecting planes. The relationship of elements, such as the true distance between a line and a point or the angle between two planes, is a typical descriptive geometry problem.

Engineering graphics, technical drawing, and descriptive geometry share many of the same techniques and are not distinctly different, since each includes and encompasses the others. Two-dimensional mechanical drawing is actually elementary descriptive geometry. Constructions in descriptive geometry are done using orthographic projection techniques. Descriptive geometry has been part of most engineers' education for many years. Gaspard Monge developed the principles of descriptive geometry as a set of projection methods and techniques that are the basis for technical

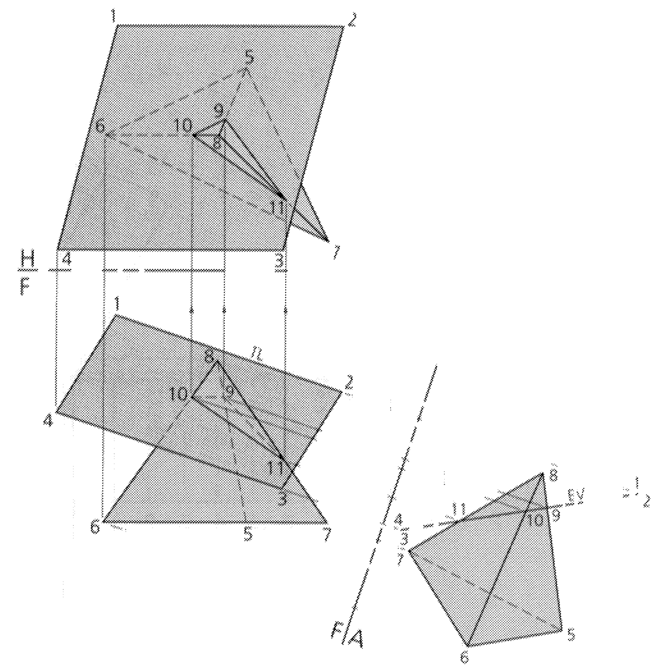


FIGURE 1.13 Intersection Problem

drawing education. A text on engineering graphics, therefore, is a book based on the principles of descriptive geometry.

The study of descriptive geometry includes intersections and developments. Intersections can be completed manually (Fig. 1.13) or on a CAD system using surface models (Fig. 1.14) or solid models. Developments are constructed manually (Fig. 1.15), or the process can be automated via advanced CAD systems. Intersections and developments are covered in detail in Chapters 27 and 28.

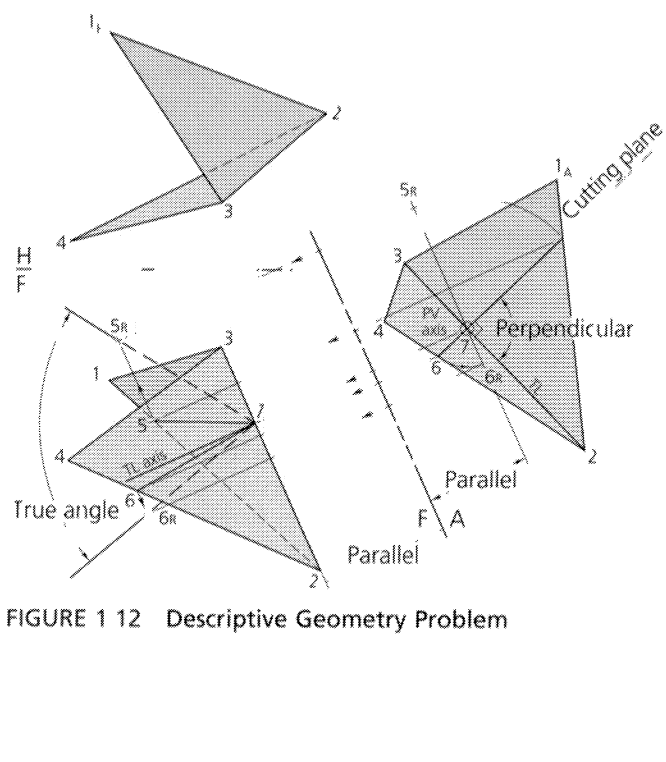


FIGURE 1.12 Descriptive Geometry Problem

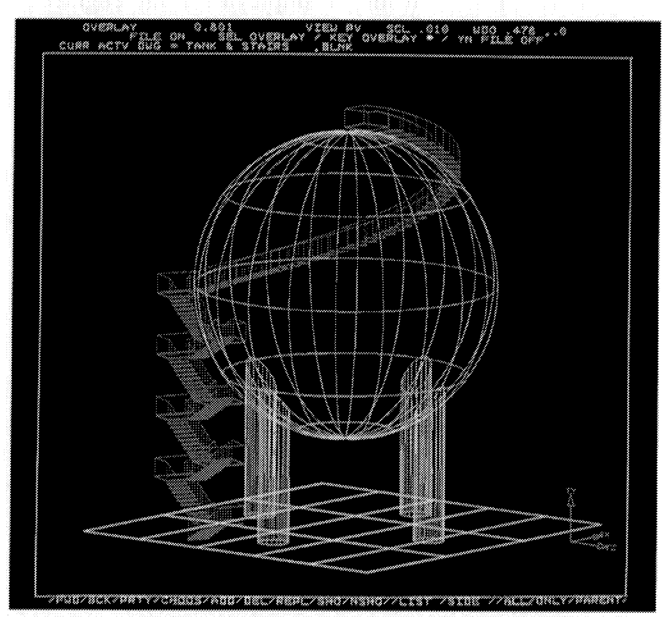


FIGURE 1.14 3D Design of a Holding Tank. Surface modeling was used to solve for the intersection of the four cylindrical legs and the spherical tank.

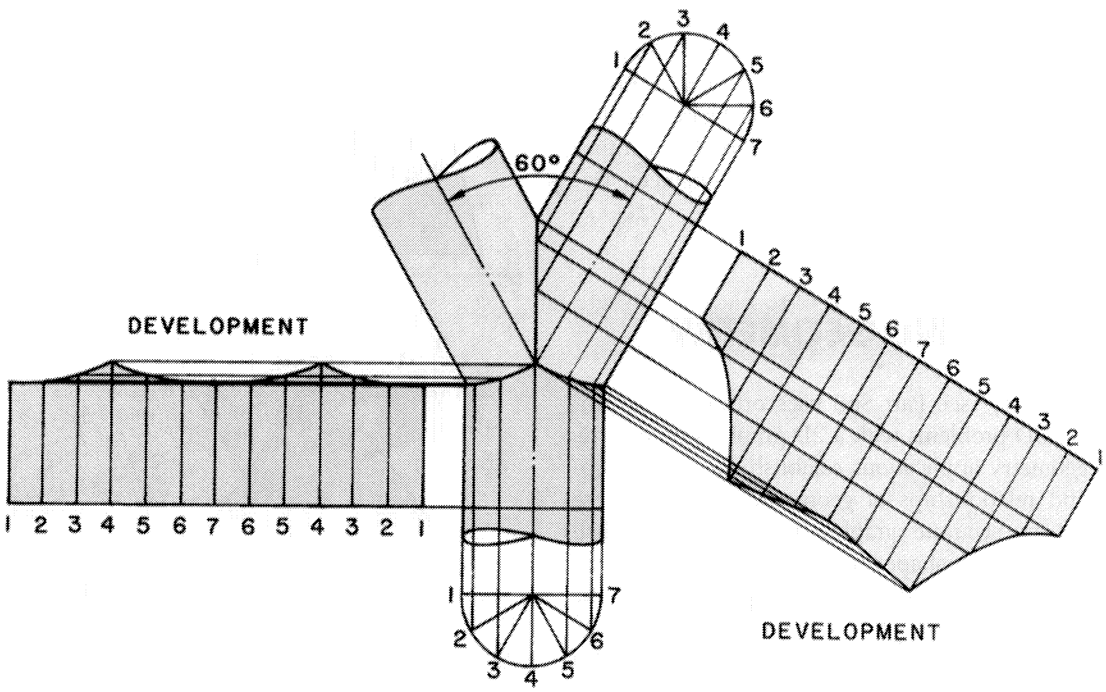


FIGURE 1 15 Development Problem

1.9 CAREER FIELDS IN INDUSTRY

Engineers and designers are employed in a variety of engineering fields civil, electronic chemical ceramic manufacturing mechanical nuclear, solar petrochemical mining and metallurgical engineering All of these fields employ designers and drafters to refine ideas and bring the design to completion The following list provides an overview of the possible fields of employment for engineers designers, and drafters:

Mechanical
Product design
Manufacturing design: jigs and fixtures, dies, assemblies, and details

Electronic-Electrical
Circuits, printed circuit boards
Integrated circuits
Electrical, electromechanical
Computers

Applications for Electronic and Mechanical Design
Marine
Aerospace
Transportation
Mining

Architectural, Engineering, and Construction (AE&C)
Civil: facilities, dams, airports, roads, mapping
Structural buildings, plants power generation
Piping solar nuclear, chemical, process, power hydroelectric
Architecture Commercial residential landscape

Technical Illustration
Product literature advertising sales presentation service manuals display

In mechanical engineering designers and engineers make assembly drawings of jigs fixtures dies and other types of manufacturing aids to create and produce machine parts and new mechanical designs (Fig 1 16) This is one of the largest employment areas for an engineer or a designer The mechanical engineer is concerned with the conceptual development and the engineering calculations (designs) involved in creating and developing mechanical devices including items to be used in machinery automobiles, mechanical equipment (Fig 1 17) and aerospace products (Fig 1 18)

Architectural engineering and construction is comprised primarily of civil engineering structural design piping design and architecture Civil engineering and mapping employ engineers and designers to develop highways, roads railways and airports Sewage treatment plants water systems and dams are all created by civil engineers Piping design includes such diverse fields as fossil fuel power plant design nuclear power plants (Fig 1 19) solar power and a wide range of other areas that require industrial piping systems used in the production of chemicals petrochemical products (Fig 1 20) food and beverages

Architecture (Fig 1 21) is the design and construction of residential or commercial buildings (larger structures can be included) Structural engineering includes the design and construction of buildings (Fig 1 22) manufacturing facilities airport terminals and power plants to name a few

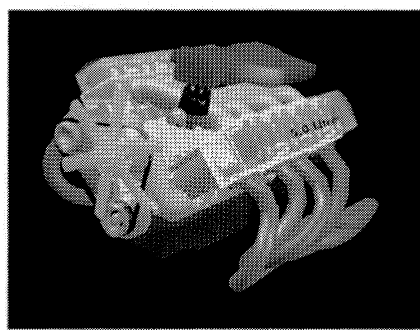


FIGURE 1.16 3D Mechanical Design

FIGURE 1.17 Earthmover Tractor

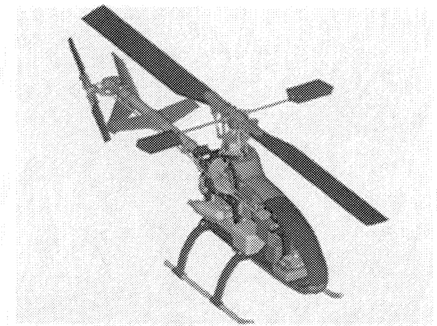


FIGURE 1.18 3D Model of an Experimental Helicopter

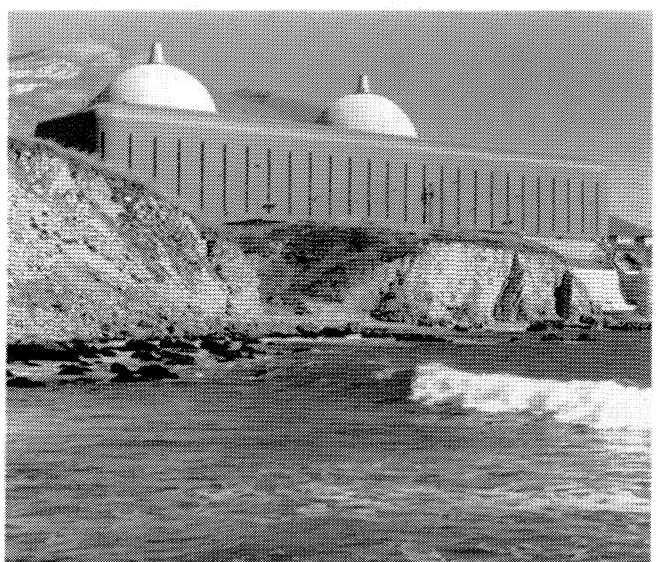


FIGURE 1.19 Diablo Canyon Nuclear Power Plant

FIGURE 1.20 Petrochemical Facility

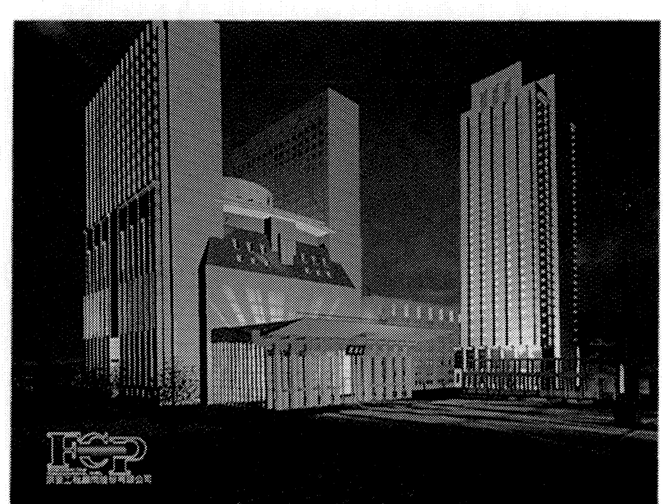


FIGURE 1.21 Architectural Design

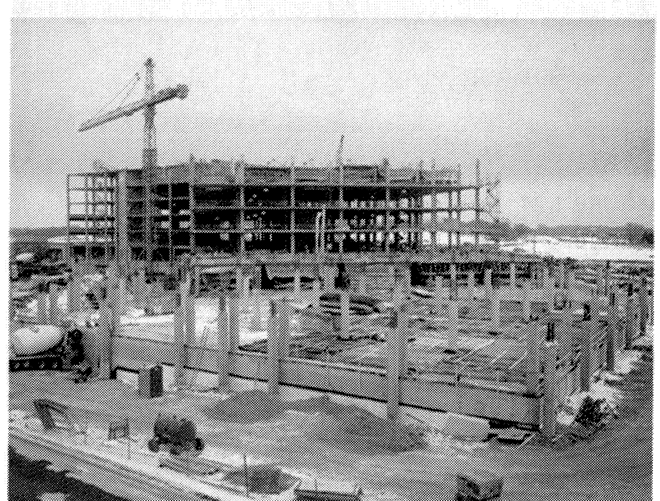


FIGURE 1.22 Construction of a Corporate Office Facility

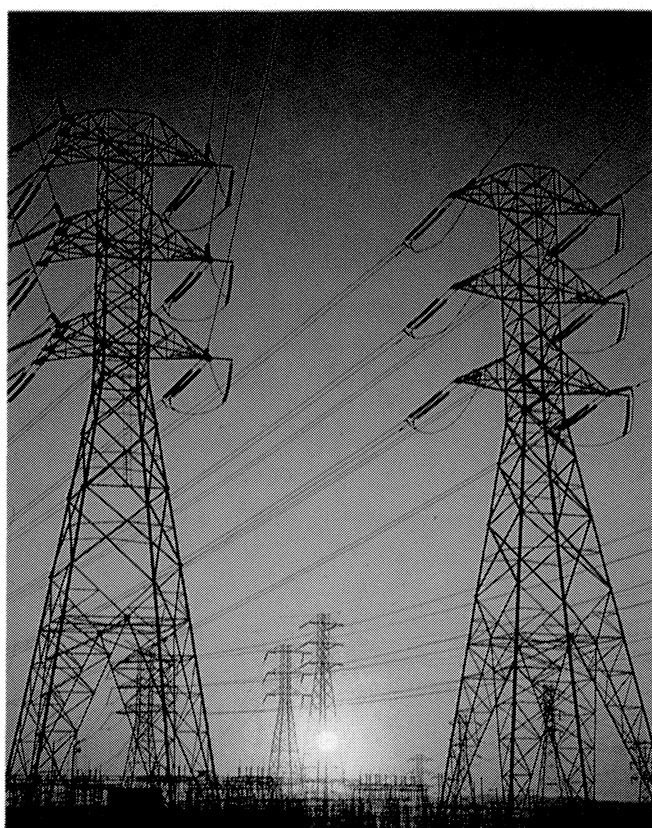


FIGURE 1.23 Power Transmission Lines

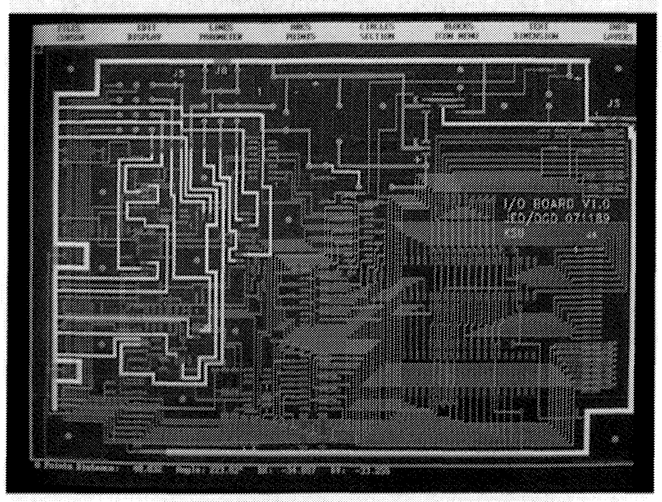


FIGURE 1.24 Printed Circuit Board Design

Electronic and electrical engineering includes the layout of power systems for generation, transmission (Fig. 1.23) and utilization of electrical energy, circuits and the design of printed circuit boards (Fig. 1.24), integrated circuits (Fig. 1.25), and computer products. Electrical engineering concentrates on power generation and the utilization of electrical energy. Electronic engineering, on the other hand, covers smaller devices: consumer electronics, circuit design, embedded microprocessors, integrated circuit design, and computer applications.

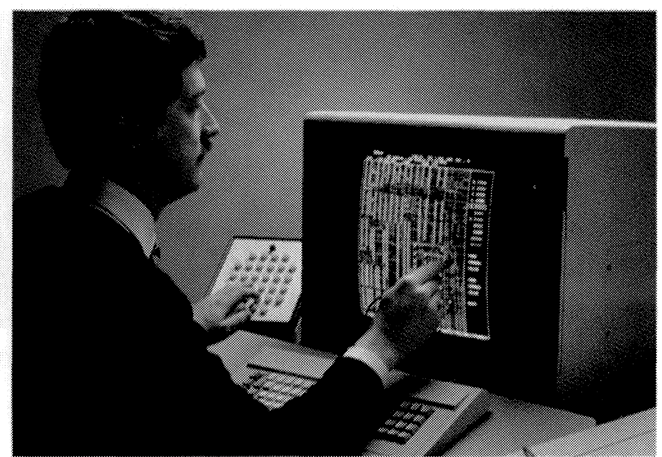


FIGURE 1.25 Integrated Circuit Design

FIGURE 1.26 Technical Illustration

Mining engineering, aerospace engineering, and transportation engineering all use combinations of mechanical, electronic, and electrical designs.

Technical illustration (Fig. 1.26) is an area where the artistic and mechanical aspects of drafting and design merge. Technical illustrations are pictorial drawings, needed for manuals, of products, buildings, or other items.

This text is concerned primarily with mechanical design. Mechanical design and engineering are important because they involve the production of devices and designs for a variety of applications. Marine engineering includes the design and manufacture of marine vessels (Figs. 1.27 and 1.28). Aerospace engineering includes the design of engines and other mechanical devices. Transportation engineering includes the design of automobiles, trucks, buses, and trains and their individual components and requires extensive mechanical design (Fig. 1.29).

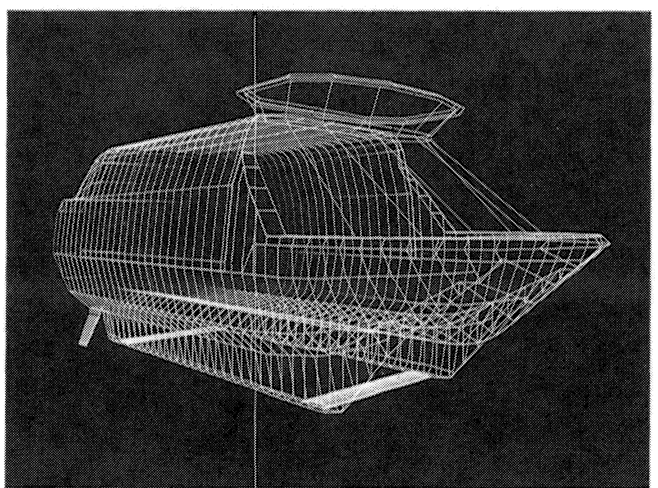
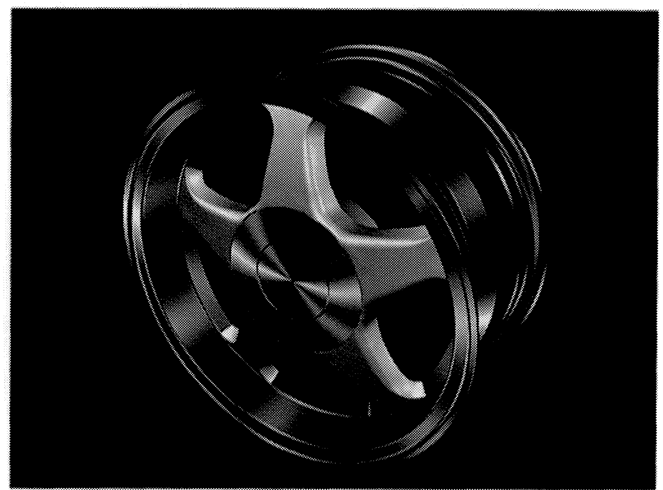
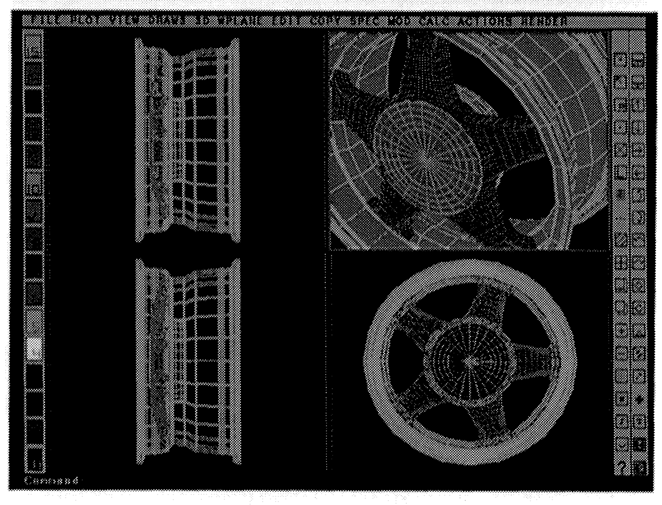


FIGURE 1.27 Marine Vessel Design



(a) Wheel



(b) 3D design of a wheel using CAD

FIGURE 1.29 3D Computer-Aided Design

FIGURE 1.28 Physical Model of a Marine Vessel

1.10 COMPUTERS AND ENGINEERING DRAWING

Computer-integrated manufacturing (CIM) is the integration of all phases of production, from design to manufacturing, using the computer. Computers have changed the way engineers do engineering and has profoundly altered the factory floor (Fig. 1.30). **Computer-aided engineering (CAE)**, **computer-aided manufacturing (CAM)**, and CAD are collectively called **computer-integrated manufacturing (CIM)**. The term **CAD/CAM** refers to the use of computers to integrate the design and production process to improve productivity. CAM includes **numerical control (NC)**, **computer numerical control (CNC)** (Fig. 1.31), and **direct numerical control (DNC)** machining and the use of **robotics** in manufacturing.

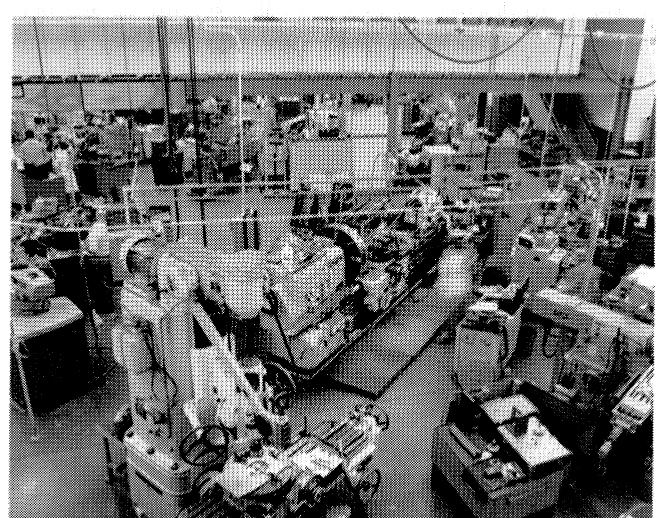


FIGURE 1.30 Computer Control on the Factory Floor

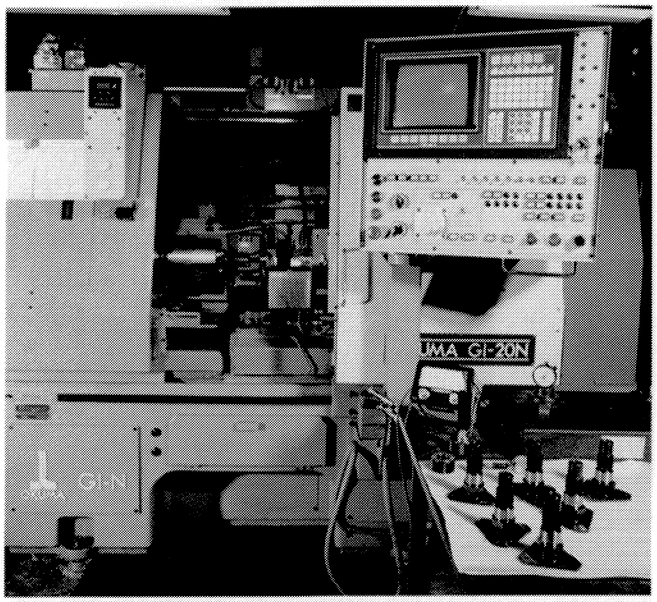


FIGURE 1.31 CNC Machining

FIGURE 1.32 Personal Computer CAD System

The use and integration of computers in all phases of the design-through-manufacturing process and their significance to the new concurrent engineering environment are extremely important to the future of engineering and industrial design. Descriptive geometry, projection techniques, drafting conventions, and dimensioning standards apply to drawings and models completed manually and with the computer. Orthographic projections will still be used on the production floor, regardless of how the part was designed initially. Solid models will continue to aid in the visualization process in the entire design-through-manufacturing process.

1.11 COMPUTER-AIDED DESIGN

CAD involves any type of design activity that uses the computer to develop analyze, modify or enhance an engineering design CAD systems are based on interactive computer graphics. The engineer creates an image on the monitor by entering commands at the computer (Fig 1.32) and by interacting with the computer program. In many systems, the image is formed from basic geometries/entities/primitives—points, lines, circles, arcs, splines, cylinders, boxes, prismatic solids, torroids, etc. The entities can be easily modified—enlarged or reduced in size, moved to another location, rotated, mirrored, copied etc By using different manipulations, the required details of the graphic image are created.

CAD *design* refers to the establishment and definition of the 3D database; CAD *drafting* involves primarily defining refining, and manipulating the *same* database to provide certain kinds of information. CAM and CIM apply and utilize the same database as was initially created. This concept is at the heart of concurrent engineering Concurrent engineering is sometimes called *simultaneous* engineering because manufacturing and design are considered simultaneously.

As an engineer or a designer using a CAD system, you must be able to understand the system's *hardware* configuration and its *software* capabilities. CAD/CAM systems are designed to be operated as purchased, and programming ability is not required. However, you can program them to customize them for your particular needs In any case, you must be familiar with the following:

1. Drafting standards
2. Engineering-discipline-specific conventions
3. Particular industrial applications: mechanical, piping, electrical electronics electromechanical civil structural or architectural
4. Software characteristics of your CAD system

It must be stressed that CAD is an engineering and design *tool* The method of creating engineering graphics has changed, not the content. Regardless of the type of system the most common form of output remains the 'drawing

1.12 STANDARDS

Many agencies control the standards used in engineering and design **American National Standards Institute (ANSI)**, the **Department of Defense (DOD)** standards and the **military standards (MIL)** are the three most used standards in the United States The **International Standards Organization (ISO)** standards and **Japanese standards (JIS)** are also used in many companies

ANSI standards are available to engineers and designers at their place of employment. It is important to become familiar with these standards. ANSI Y14 contains information on drafting practices, dimensioning, projection, descriptive geometry, geometric tolerancing, and a wide variety of other areas associated with engineering and design.

Standards are used because drawings are a standard form of communication between individuals, departments, companies, and countries. They communicate design requirements. If standards are followed, each drawing will mean the same thing to everyone who reads and uses it. The real purpose of a drawing is eventually to get the part made correctly. A drawing that no one understands is worthless.

Some companies have not adopted ANSI standards, are using older standards, or have not updated all of their older drawings to the newer standards. Always be aware of this when reviewing drawings. This text uses ANSI standards as a basis for its drawings, conventions, practices, and instructional methodology. All projects completed from the book are to be drawn using the latest revisions of ANSI standards, conventions, and drawing practices.

1.13 STANDARDS OF MEASUREMENT

The United States is the only major industrial country in the world still using feet, inches, and decimal equivalents. However, many large companies such as Ford, IBM, John Deere, General Motors, Honeywell, and most electronic, medical instrument, and computer manufacturers have converted completely to the metric system that is called **Système Internationale (SI)**. The English system units are now called **U.S. customary units**.

Because you may encounter both measurement systems on the job, this text uses a balanced approach and applies both systems. Piping, architecture, and structural engineering use units of feet, inches, and fractions in most cases. The standard of measurement for metric drawings is the millimeter. The U.S. decimal inch unit is used on many of the illustrations and on many of the exercises and problems at the end of the chapters. In some cases, your instructor may wish you to convert the units of measurement from one system to another.

1.14 ORGANIZATION OF THE TEXT

This text is organized into six parts. Part One covers the basics of engineering and design: introduction to engineering graphics (Chapter 1), design engineering (Chapter 2), the design process (Chapter 3), computers in engineering design and manufacturing (Chapter 4), and parametric design (Chapter 5).

Part Two covers basic graphical materials and procedures: equipment, materials, and techniques for engineering graphics (Chapter 6), lettering and annotation (Chapter 7), geometric constructions (Chapter 8), and sketching (Chapter 9).

Part Three covers drawing basics: multiview drawing (Chapter 10), sections (Chapter 11), auxiliary views (Chapter 12), and pictorials (Chapter 13).

Part Four covers processes and documentation: manufacturing processes (Chapter 14), dimensioning (Chapter 15), and geometric dimensioning and tolerancing (Chapter 16).

Part Five covers mechanical parts, procedures, and layout: threads and fasteners (Chapter 17), springs (Chapter 18), gears, shafts, and bearings (Chapter 19), cams (Chapter 20), fluid power (Chapter 21), welding drawings (Chapter 22), and working drawings (Chapter 23).

Part Six covers engineering graphical analysis: points and lines (Chapter 24), planes (Chapter 25), revolutions (Chapter 26), intersections (Chapter 27), developments (Chapter 28), vector analysis (Chapter 29), and design projects (Chapter 30).

The main body of the text is followed by four appendixes. In Appendix A you will find three glossaries: mechanical, CAD/CAM, and parametric design. Appendix B contains abbreviations: standards and general abbreviations. Appendix C presents catalog parts and reference material: threads, twist drills, bolts, screws, nuts, washers, rivets and retaining rings, pins, bushings, Woodruff keys, sheet metal gages, structural shapes and sizes, fits, and tolerances. Consult the appendixes when working on projects from the text.

Each chapter in the text has the same sequence. They start with an introduction and continue with an explanation of the material to be covered. Chapter objectives introduce the chapter.

At the end of each chapter is a quiz composed of True or False, Fill in the Blanks, and Answer the Following questions. In Chapters 6–29, the quiz is followed by exercises and problems. The exercises are designed to be completed at specific intervals. You will be prompted at certain places within each chapter to complete the corresponding exercises, which test your knowledge of the material just covered. All exercises are presented on a grid format using .25 in. units and can be transferred directly without the use of dimensions to an $8\frac{1}{2} \times 11$ in. A size grid lined sheet of paper. If metrics are preferred, use metric grid paper with appropriate divisions. The problems can be assigned in many different ways—as sketches, ink drawings, manual drawings, or CAD projects. Unlike the exercises, which are confined to an $8\frac{1}{2} \times 11$ in. A size format, the size of paper depends on the project requirements.

QUIZ

True or False

1 CAD systems and drafting boards may be in mixed use in engineering offices and firms
2 Engineering or technical drawings were used to communicate technical ideas only in the twentieth century
3 Artistic drawings are used extensively to communicate ideas in engineering
4 CIM doesn't really involve computers in design or on the manufacturing floor
5 Descriptive geometry and engineering graphics are totally separate fields
6 CAD systems are based on interactive computer graphics
7 An extensive knowledge of computer programming is needed to use CAD effectively
8 There are literally millions of jobs in manufacturing and engineering that depend on engineering graphics in some way

Fill in the Blanks

9   is the term used to describe the use of graphical communication in the design process
10 The two main types of drawings are   and
11   use artistic methods and pictorial techniques to represent a part or system for use by nontechnical personnel
12   is the integration of all phases of production from design to manufacturing using the computer
13 Technical   is the use of freehand graphics to create drawings
14   involves any type of design activity that uses the computer to develop analyze modify or enhance an engineering design
15   and   are three different agencies that control the standards for engineering drawing in the United States
16   is completed on a drafting board using paper pencil and drawing instruments

Answer the Following

17 Describe why CAE CAD CAM and CAD/CAM are collectively called CIM
18 Describe at least two different engineering disciplines and the types of job they entail
19 Explain how technical illustration differs from engineering drawing
20 Explain why standards are important in engineering graphics
21 Explain and describe the basic concepts involved in the design process
22 What types of problems are solved by the use of descriptive geometry techniques?
23 What is the difference between a casting drawing and a fabrication drawing?
24 How has the computer changed engineering and engineering graphics?