technical DRAWING for ENGINEERING communication

SEVENTH EDITION

DAVID L. GOETSCH AND RAYMOND L. RICKMAN

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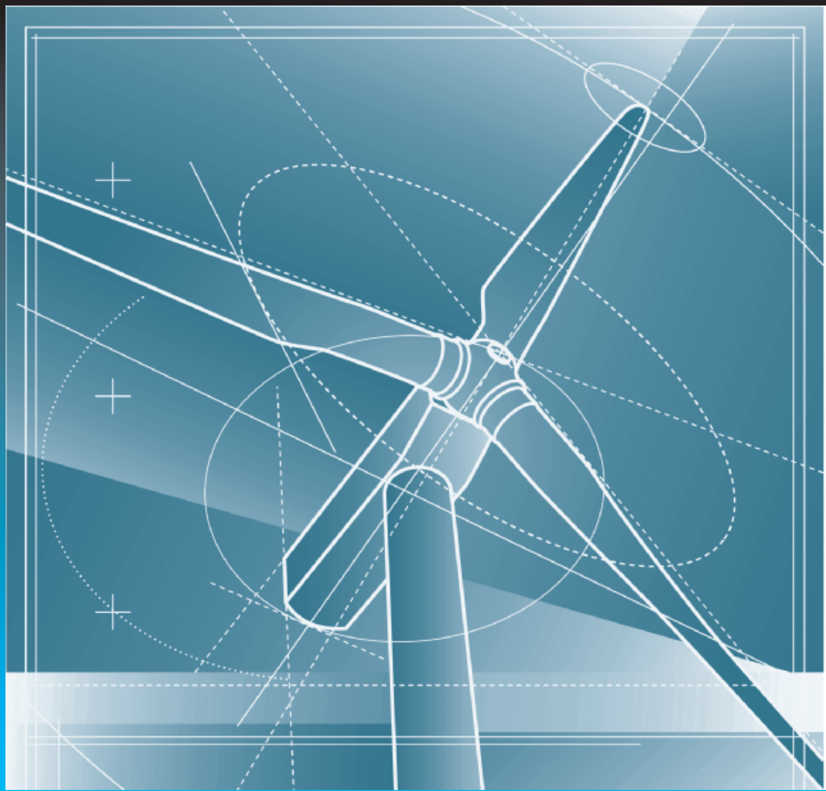

DAVID L. GOETSCH AND RAYMOND L. RICKMAN

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Technical Drawing for Engineering Communication, 7e
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preface

Purposes

Technical Drawing for Engineering Communication is intended for use in such courses as basic and advanced drafting, engineering graphics, descriptive geometry, mechanical drafting, machine drafting, tool and die design and drafting, and manufacturing drafting. It is appropriate for those courses offered in comprehensive high schools, area vocational schools, technical schools, community colleges, trade and technical schools, and at the freshman and sophomore levels in universities.

Prerequisites

There are no prerequisites. The text begins at the most basic level and moves step by step to the advanced levels.

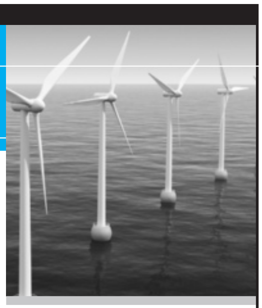
It is as well-suited for students who have had no previous experience with technical drawing as it is for students with a great deal of prior experience.

how to use this book

Technical Drawing for Engineering Communication is a comprehensive teaching and learning tool that contains several special features to promote the student's development and to make learning easier. Students and instructors can make use of the following features:

Career Profiles located in the Section Opener focus on the occupations of specific individuals. These profiles were chosen as representative of the types of jobs that students could acquire after completing an education in drafting. The career profiles also relate directly to the content covered in the section.

CAREER PROFILE


career profile

Jon Whitney

In college, Jon Whitney studied English. On a whim, he applied to graduate school for architecture, and it ended up being the right decision.

After the three-and-a-half-year program, he began as a drafter at Goshow Architects in New York City. This meant he was responsible for turning architects' visions into dimensioned schematics. He would often go on-site to take measurements and then bring them back to insert into the AutoCAD program. After a superior reviewed his drawings, Whitney served as a drafter for three years, a typical amount of time for someone just out of an architecture master's program (although many drafters choose to keep drafting indefinitely).

While serving as a drafter, Whitney accumulated credits toward his internship development program (IDP); when you get enough credits, you can begin the year-long testing process to get your architecture license. Whitney is currently in the midst of that testing. Now that he is a junior project manager, he is still drafting, but he also coordinates multiple projects, each of which can be in a different stage of the process.

The first stage is the schematic phase. At this predesign stage, Whitney is likely to create a not-to-scale schematic by hand, making bubble diagrams to give a broad, general look at the project. For instance, how would a loft space look if it was adapted for office use? Often this stage is conceptual and artistic.

The next stage is design development, at which point the drawing starts to become more technical. This involves refining the schematic, starting to put down dimensions and materials. How big will the walls dividing offices be? Will they be made of masonry or steel? Do they need windows? Whitney may also call in subcontractors (hazmat, mechanical engineers, landmark conservancy consultants, etc.) if necessary.

Next, Whitney and his team will create construction documents, the technical drawings that are given to the contractor at the start of the project. These must be as clear as possible; in fact, Whitney says, this stage is never completed. One can always go one level deeper with detail. Therefore, you should do as much as possible in the allotted time. As a drafter, Whitney used to work primarily in this phase. Now, most mornings he will spend a few hours reviewing drawings (done either by himself or one of his drafters) with a red pen, looking for everything from spelling errors to technical problems. He must also look for clarity and any misleading information. In essence, the client is paying for the comprehensive and accurate packet of drawings and specifications developed here.

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Being a project manager has been a big—but exciting—change for Whitney. He's gotten to step outside the tunnel vision required of drafters and has been able to get a broader look at each project. As a result, he sees each plan go from an artistic idea to a technical reality.

1

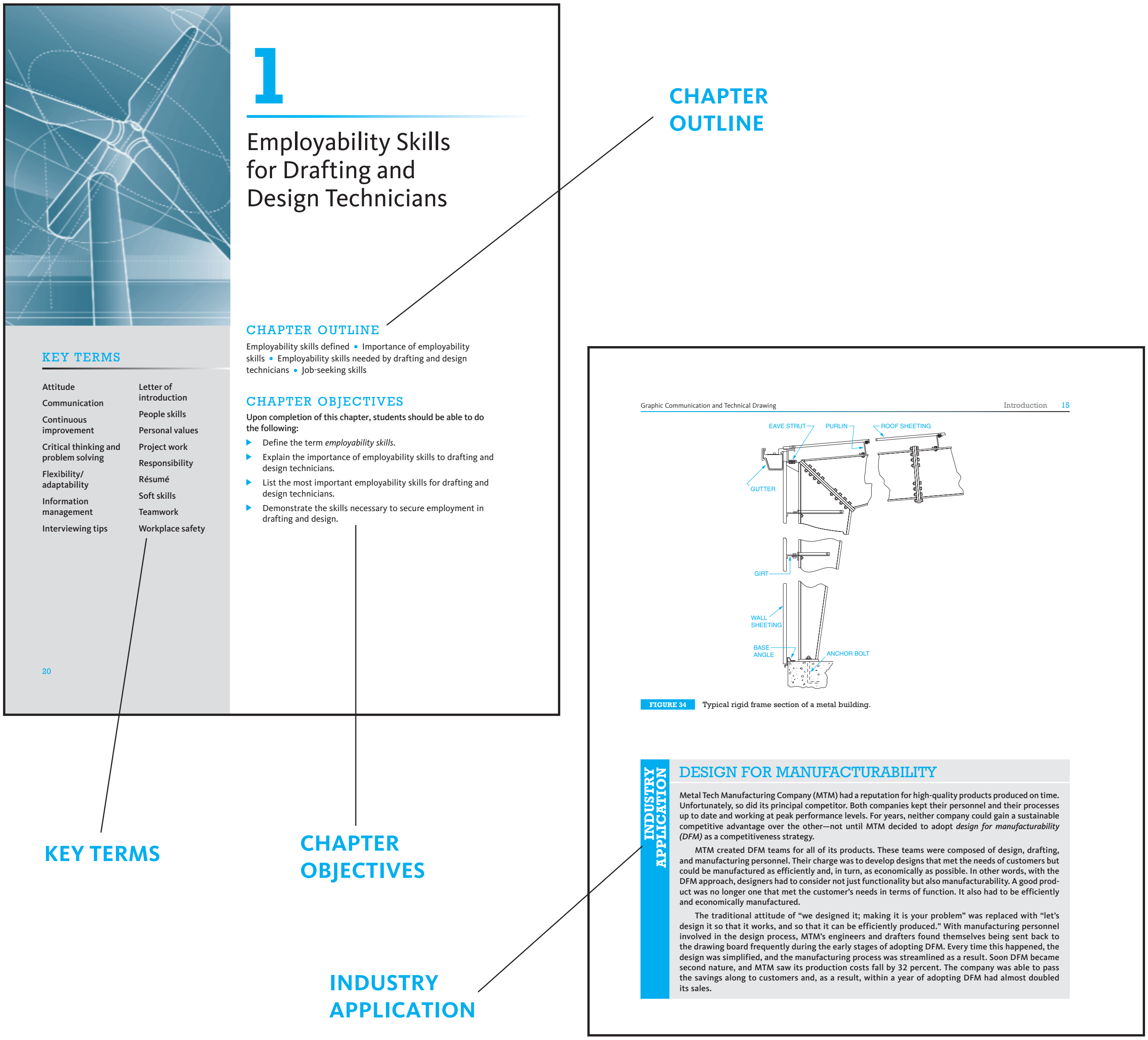
Chapter Objectives at the beginning of each chapter identify the skills and knowledge that students will acquire from reading the material. When students have finished the chapter, they should review the objectives to ensure that they have met each one.

The **Chapter Outline** lists the title of each major topic covered in the chapter. This provides a preview of the content coverage.

Key Terms, listed at the beginning of each chapter, are important words and phrases that students will encounter as they study the chapter. Each key term is highlighted in *italics* at the first significant use in the text and is included in the glossary or index at the back of the book.

Industry Application is a boxed article that explains how the skills and knowledge discussed in the chapter may be applied to a real-world job-related setting. A variety of skills will be covered, including math, science, communications, and computers.

A chapter **Summary** provides a recapitulation of the key topics covered in the chapter. This enables students to reassess their comprehension of the material before proceeding to the end-of-chapter questions and problems.

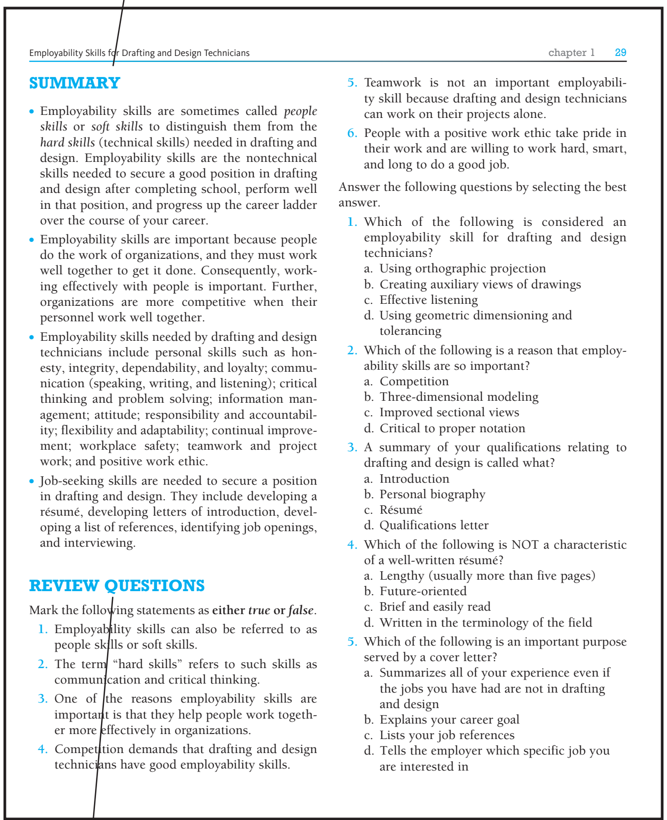


Review Questions are written to ensure that students have adequately read the chapter and that they understand the material. These questions prepare students for class tests given by the instructor and for the certification test offered by the American Design and Drafting Association. (Visit the American Design and Drafting Association website at **www.adda.org** to learn about the certification programs and ADDA membership.) These questions do not require a computer or drafting materials.

Chapter Problems contain drawing projects that allow students to test their drafting skills. Advanced problems are marked by **icons**. These special icons have been placed adjacent to the advanced drawing projects to indicate the engineering and design field the drawing pertains to. These icons call out a specific drafting field or discipline.

SUMMARY

ADVANCED ICON



Employability Skills for Drafting and Design Technicians chapter 1 29

SUMMARY

- Employability skills are sometimes called *people skills* or *soft skills* to distinguish them from the *hard skills* (technical skills) needed in drafting and design. Employability skills are the nontechnical skills needed to secure a good position in drafting and design after completing school, perform well in that position, and progress up the career ladder over the course of your career.
- Employability skills are important because people do the work of organizations, and they must work well together to get it done. Consequently, working effectively with people is important. Further, organizations are more competitive when their personnel work well together.
- Employability skills needed by drafting and design technicians include personal skills such as honesty, integrity, dependability, and loyalty; communication (speaking, writing, and listening); critical thinking and problem solving; information management; attitude; responsibility and accountability; flexibility and adaptability; continual improvement; workplace safety; teamwork and project work; and positive work ethic.
- Job-seeking skills are needed to secure a position in drafting and design. They include developing a résumé, developing letters of introduction, developing a list of references, identifying job openings, and interviewing.

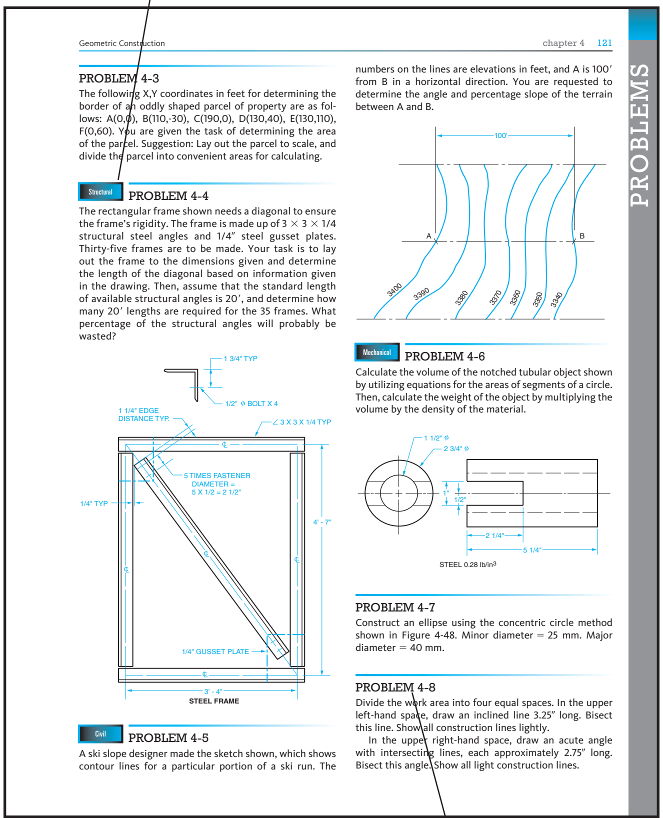
REVIEW QUESTIONS

Mark the following statements as either *true* or *false*.

1. Employability skills can also be referred to as people skills or soft skills.
2. The term "hard skills" refers to such skills as communication and critical thinking.
3. One of the reasons employability skills are important is that they help people work together more effectively in organizations.
4. Competition demands that drafting and design technicians have good employability skills.
5. Teamwork is not an important employability skill because drafting and design technicians can work on their projects alone.
6. People with a positive work ethic take pride in their work and are willing to work hard, smart, and long to do a good job.

Answer the following questions by selecting the best answer.

1. Which of the following is considered an employability skill for drafting and design technicians?
   a. Using orthographic projection
   b. Creating auxiliary views of drawings
   c. Effective listening
   d. Using geometric dimensioning and tolerancing
2. Which of the following is a reason that employability skills are so important?
   a. Competition
   b. Three-dimensional modeling
   c. Improved sectional views
   d. Critical to proper notation
3. A summary of your qualifications relating to drafting and design is called what?
   a. Introduction
   b. Personal biography
   c. Résumé
   d. Qualifications letter
4. Which of the following is NOT a characteristic of a well-written résumé?
   a. Lengthy (usually more than five pages)
   b. Future-oriented
   c. Brief and easily read
   d. Written in the terminology of the field
5. Which of the following is an important purpose served by a cover letter?
   a. Summarizes all of your experience even if the jobs you have had are not in drafting and design
   b. Explains your career goal
   c. Lists your job references
   d. Tells the employer which specific job you are interested in



Geometric Construction chapter 4 121

PROBLEMS

PROBLEM 4-3

The following X,Y coordinates in feet for determining the border of an oddly shaped parcel of property are as follows: A(0,0), B(110,-30), C(190,0), D(130,40), E(130,110), F(0,60). You are given the task of determining the area of the parcel. Suggestion: Lay out the parcel to scale, and divide the parcel into convenient areas for calculating.

Structural PROBLEM 4-4

The rectangular frame shown needs a diagonal to ensure the frame's rigidity. The frame is made up of 3 × 3 × 1/4 structural steel angles and 1/4″ steel gusset plates. Thirty-five frames are to be made. Your task is to lay out the frame to the dimensions given and determine the length of the diagonal based on information given in the drawing. Then, assume that the standard length of available structural angles is 20′, and determine how many 20′ lengths are required for the 35 frames. What percentage of the structural angles will probably be wasted?

Civil PROBLEM 4-5

A ski slope designer made the sketch shown, which shows contour lines for a particular portion of a ski run. The numbers on the lines are elevations in feet, and A is 100′ from B in a horizontal direction. You are requested to determine the angle and percentage slope of the terrain between A and B.

Mechanical PROBLEM 4-6

Calculate the volume of the notched tubular object shown by utilizing equations for the areas of segments of a circle. Then, calculate the weight of the object by multiplying the volume by the density of the material.

PROBLEM 4-7

Construct an ellipse using the concentric circle method shown in Figure 4-48. Minor diameter = 25 mm. Major diameter = 40 mm.

PROBLEM 4-8

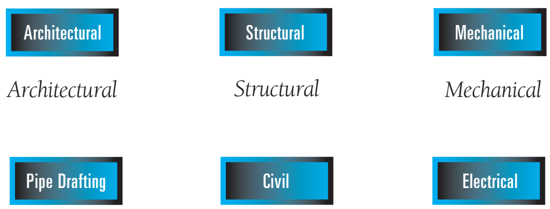
Divide the work area into four equal spaces. In the upper left-hand space, draw an inclined line 3.25″ long. Bisect this line. Show all construction lines lightly.

In the upper right-hand space, draw an acute angle with intersecting lines, each approximately 2.75″ long. Bisect this angle. Show all light construction lines.

CHAPTER PROBLEMS

ICONS

REVIEW QUESTIONS



Architectural | Structural | Mechanical

Pipe Drafting | Civil | Electrical

Content Overview

Chapters 1–18 are to be used to help students develop the design and drafting skills that are fundamental to *all* drafting fields. Instructors are encouraged to use all of these chapters to build a solid footing of design and drafting knowledge for students.

Chapters 19–21 allow students to develop advanced knowledge and skills beyond the fundamentals.

Instructors are encouraged to use these chapters to help their students develop an in-depth understanding of these discipline areas: Welding; Modern Manufacturing: Materials, Processes, and Automation; and Drafting Applications: Pipe, Architectural, and Civil Engineering.

Chapter 21, The Design Process and Advanced Concepts, is important in preparing the student for entry into the job force. The steps of the design process are defined, and the reader is taught how to be creative in analyzing and solving problems. Modern design processes such as DFM, DFA, rapid prototyping, and reverse engineering are addressed.

New Features in the Seventh Edition

The Seventh Edition is based on the concept that "less is more." After polling a wide cross section of instructors who use this textbook, the authors eliminated material reviewers thought was superfluous. This was done so that new material could be added where appropriate without increasing the size of the book and, in turn, the cost. A summary of changes for the Seventh Edition follows:

- The name of the book was changed to reflect the movement in the field away from the traditional name and concept of "drafting." Because technicians in this field prepare drawings and other forms of documentation to communicate engineering concepts and information, the newly adopted title of the book for the Seventh Edition is *Technical Drawing for Engineering Communication*.
- Drawings and photographs were updated throughout the book as needed to reflect the most modern technologies and practices.
- Chapter 1, Employability Skills, is a new chapter that covers the following topics: employability skills defined, importance of employability skills, specific employability skills needed by drafting and design technicians, and job-seeking skills.
- Chapter 2, Drafting Tools: Conventional, CAD, and Solid Modeling, was completely rewritten to present the types of tools drafting and design technicians typically use, ranging from conventional tools that are still used to CAD hardware and software to solid modeling software.
- Old Chapter 10, Dimensioning and Notation, became new Chapter 6 at the request of reviewers to put it in a more logical order for teaching and learning. In addition, the chapter was updated to reflect changes that grew out of the latest revision to ANSI Y14.5.
- Chapter 12, Geometric Dimensioning and Tolerancing, was completely rewritten to bring it in line with the latest revisions to ANSI Y14.5.
- Old Chapter 21, Drafting Applications, was moved to the website and is available there for instructors who use it.
- Old Chapter 22, The Design Process, became new Chapter 21, The Design Process and Advanced Topics. The following new material was added to this chapter: rapid prototyping, parametric design, ISO 9000, and reverse engineering.

Tested and Proven Features

- An enhanced Instructor Companion Website contains electronic instructional material.
- Chapter 21, The Design Process and Advanced Topics, covers modern design practices and standards.
- Discipline-specific icons highlight the drawing problems, enabling the reader to quickly choose problems pertaining to his or her drawing field.
- Review questions are formatted as multiple-choice and true/false for rapid testing and grading.
- New drawing problems are contained in the primary drawing chapters.
- Boxed articles covering real-world applications exist in all chapters. This reinforces the relevance of the chapter content to today's job environment.
- New math problems are contained in selected chapters for additional practice.
- Step-by-step explanations of drawing procedures and techniques are provided.

- The book is written in language students will understand; technical terms are defined as they are used.
- Unique black and rust color format depicts isometric views more clearly than "flat" black-and-white drawings.
- Text and illustrations are located in *direct* relationship to each other wherever possible.
- Real-world techniques are highlighted in the Industry Application boxed articles.
- Although the emphasis is on mechanical drafting, other pertinent drafting subjects are included for a comprehensive, well-rounded approach to technical drawing.
- The book contains in-depth drafting applications in architectural, structural, civil, and piping drafting.

The Learning Package

The complete Instructor Companion Website supplements package was developed to achieve two goals:

1. To assist students in learning the essential information needed to prepare for the exciting field of drafting.
2. To assist instructors in planning and implementing their instructional programs for the most efficient use of time and other resources.

The *Technical Drawing for Engineering Communication* package was created as an integrated whole. Supplements are linked to and integrated with the text to create a comprehensive supplement package that supports students and instructors, beginning or veteran. The package includes:

Instructor Companion Website—The ICW is an educational resource that creates a truly electronic classroom. The website contains tools and instructional resources that enrich your classroom and make your preparation time shorter. The elements of the ICW link directly to the text and tie together to provide a unified instructional system. With the ICW, you can spend your time teaching, not preparing to teach.

Features contained on the Instructor Companion Website include:

- **Syllabus:** Lesson plans created by chapter. You have the option of using these lesson plans with your own course information.
- **Chapter Hints:** Objectives and teaching hints that provide the basis for a lecture outline that helps you to present concepts and material. Key points and concepts can be graphically highlighted for student retention.
- **Answers to Review Questions:** These solutions enable you to grade and evaluate end-of-chapter tests.
- **PowerPoint® Presentation:** These slides provide the basis for a lecture outline that helps you to present concepts and material. Key points and concepts can be graphically highlighted for student retention.
- **Computerized Test Bank:** Over 800 questions of varying levels of difficulty are provided in true/false and multiple-choice formats so you can assess student comprehension.

Cengage Learning Testing (CLT)

Powered by Cognero, CLT is a flexible, online system that allows you to:

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- Create multiple test versions in an instant.
- Deliver tests from your LMS, your classroom, or wherever you want.

Contact Cengage Learning or your local sales representative to obtain an instructor account.

Accessing an Instructor Companion Website from SSO Front Door

1. Go to http://login.cengage.com and log in, using the instructor e-mail address and password.
2. Enter author, title, or ISBN in the Add a Title to Your Bookshelf search.
3. Click Add to My Bookshelf to add instructor resources.
4. At the Product page, click the Instructor Companion site link.

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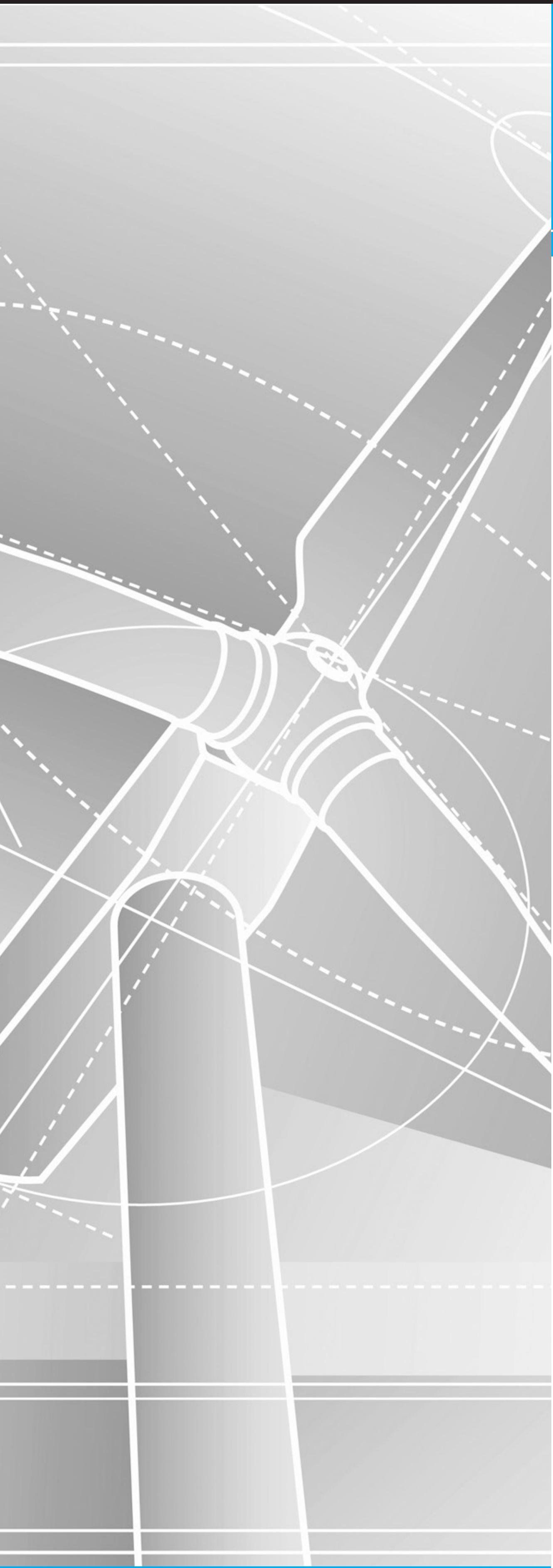
David L. Goetsch is Emeritus Vice President and Professor of Design, Drafting, Quality, and Safety at Northwest Florida State College in Niceville, Florida. His drafting and design program has won national acclaim for its pioneering efforts in the area of computer-aided drafting (CAD). In 1984, his school was selected as one of only 10 schools in the country to earn the distinguished U.S. Secretary of Education's Award for an outstanding Vocational Program. Professor Goetsch is a widely acclaimed teacher, author, and lecturer on the subject of drafting and design. He won Outstanding Teacher of the Year honors in 1976, 1981, 1982, 1983, and 1984. In 1986, he won the Florida Vocational Association's Rex Gaugh Award for outstanding contributions to technical education in Florida. In 2003, Dr. Goetsch was selected as the University of West Florida's Distinguished Alumnus. In 2007, he was named one of the University of West Florida's top 40 alumni in its first 40 years of operation. He entered education full time after a successful career in design and drafting in the private sector, where he spent more than eight years as a Senior Drafter and Designer for a subsidiary of Westinghouse Corporation. He was elected Florida's Outstanding Economic Development person in 1992, 1996, and 2007.

Raymond L. Rickman is chairman of the Manufacturing and Technology Department and Professor of Design and Drafting at Northwest Florida State College.

Professor Rickman has extensive experience in the private sector and the classroom and is a consultant on the subject of geometric dimensioning and tolerancing. He was a member of the ANSI Y14.5 technical committee and is the co-author of several career mathematics textbooks.



section 1

Basics

career profile

Jon Whitney

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Introduction

Graphic Communication and Technical Drawing

KEY TERMS

Axonometric projections
Cabinet
Cavalier
Design for manufacturability
Design process
Drafters
Drafting
Drafting technicians
Drawing
Graphic communication
Oblique projections
Orthographic projections
Parallel projection
Perspective projections
Projection
Projector
Technical drawing

OUTLINE

Graphic communication • Drawings described • Types of drawings • Types of technical drawings • Purpose of technical drawings • Applications of technical drawings • Regulation of technical drawings • What students of technical drawing, drafting, and CAD should learn • Technical drawing and quality/competitiveness • Summary • Review questions • Introduction problems

OBJECTIVES

Upon completion of this introduction, students should be able to do the following:

- Explain the concept of graphic communication.
- Define the term *drawing*.
- Differentiate between artistic and technical drawings.
- List and explain the types of technical drawings.
- Explain the purpose of technical drawings.
- Explain the different applications of technical drawings.
- Explain the concept of the regulation of technical drawings.
- Describe the role of design and drafting in promoting quality and competitiveness.

Graphic Communication

Graphic communication involves using visual material to relate ideas. Drawings, photographs, slides, transparencies, and sketches are all forms of graphic communication. Most children are able to draw before they are able to write. This is graphic communication. When one person sketches a rough map in giving another directions, this is graphic communication. Any medium that uses a graphic image to aid in conveying a message, instructions, or an idea is involved in graphic communication. One of the most widely used forms of graphic communication is the drawing.

Drawings Described

A *drawing* is a graphic representation of an idea, a concept, or an entity that actually or potentially exists in life. The drawing itself is: (1) a way of communicating all necessary information about an abstraction, such as an idea or a concept, or (2) a graphic representation of some real entity, such as a machine part, a house, or a tool, for example.

Drawing is one of the oldest forms of communication, dating back even farther than verbal communication. Cave dwellers painted drawings on the walls of their caves thousands of years before paper was invented. These crude drawings served as a means of communicating long before verbal communications had developed beyond the grunting stage. In later years, Egyptian hieroglyphics were a more advanced form of communicating through drawings.

The old adage “one picture is worth a thousand words” is still the basis of the need for technical drawings.

Types of Drawings

There are two basic types of drawings: artistic and technical. Some experts believe there are actually three types: the two mentioned and another type that combines these two. The third type is usually referred to as an illustration or rendering.

Artistic Drawings

Artistic drawings range in scope from the simplest line drawings to the most famous paintings. Regardless of their complexity or status, artistic drawings are used to express the feelings, beliefs, philosophies, or abstract ideas of the artist. This is why the layperson often finds it difficult to understand what is being communicated by a work of art.

In order to understand an artistic drawing, it is sometimes necessary to first understand the artist. Artists often take a subtle or abstract approach in communicating through their drawings. This gives rise to the various interpretations often associated with artistic drawings.

Technical Drawings

The technical drawing, on the other hand, is not subtle or abstract. It does not require an understanding of its creator, but only an understanding of technical drawings. A *technical drawing* is a means of clearly and concisely communicating all of the information necessary to transform an idea or a concept into reality. Therefore, a technical drawing often contains more than just a graphic representation of its subject. It also contains dimensions, notes, and specifications.

The mark of a good technical drawing is that it contains all of the information needed by individuals for converting the idea or concept into reality. The conversion process may involve manufacturing, assembly, construction, or fabrication. Regardless of the process involved, a good technical drawing allows the conversion process to proceed without having to ask designers or drafters for additional information or clarification.

Figures 1 and **2** contain samples of technical mechanical drawings that are used as guides by the people involved in various phases of manufacturing the represented parts. Notice that the drawings contain a graphic representation of the part, dimensions, material specifications, and notes.

Illustrations or Renderings

Illustrations or renderings are sometimes referred to as a third type of drawing because they are neither completely technical nor completely artistic; they combine elements of both, as shown in **Figures 3**, **4**, **5**, and **6**. They are technical in that they are drawn with mechanical instruments or on a computer-aided drafting system, and they contain some degree of technical information. However, they are also artistic in that they attempt to convey a mood; an attitude; a status; or other abstract, nontechnical feelings.

Types of Technical Drawings

Technical drawings are based on the fundamental principles of projection. A *projection* is a drawing or representation of an entity on an imaginary plane or planes. This projection plane serves the same purpose in technical drawing as is served by the movie screen in a theater.

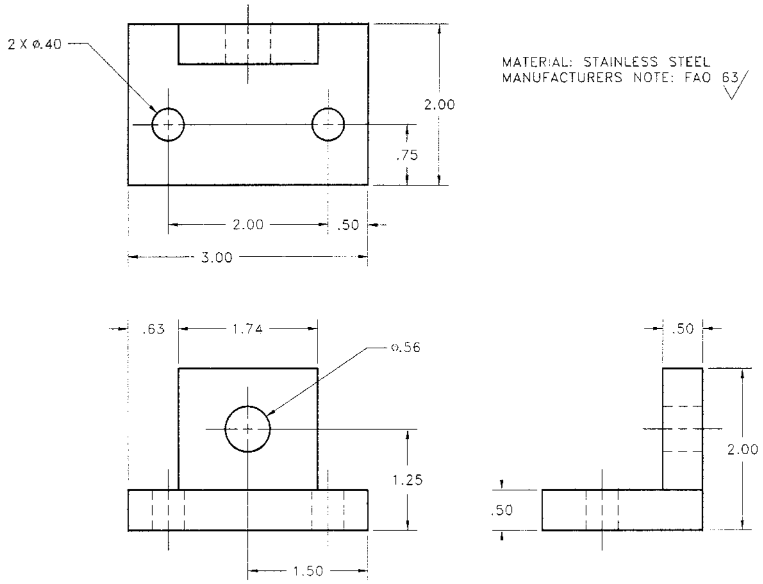

FIGURE 1 Technical drawing (mechanical).

As shown in **Figure 7**, a projection involves four components: (1) the actual object that the drawing or projection represents, (2) the eye of the viewer looking at the object, (3) the imaginary projection plane (the viewer's drawing paper or the graphics display in a computer-aided drafting system), and (4) imaginary lines of sight called *projectors*.

Two broad types of projection, both with several subclassifications, are parallel projection and perspective (converging) projection.

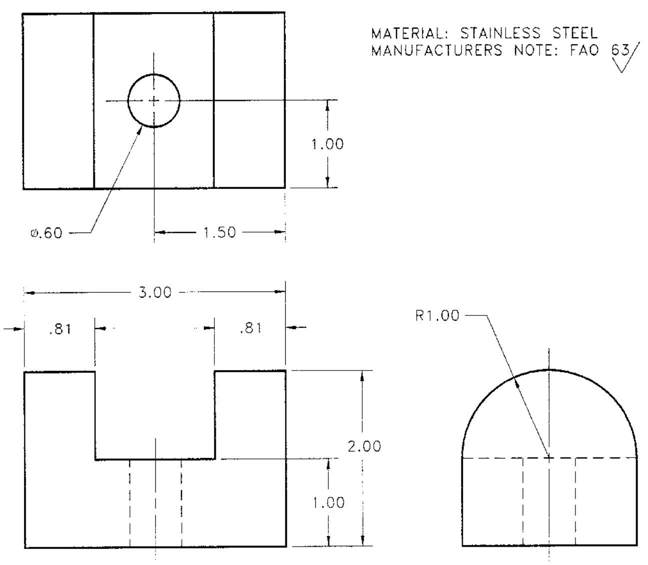

FIGURE 2 Technical drawing (mechanical).

Parallel Projection

Parallel projection is divided into the following three categories: orthographic, oblique, and axonometric projections.

Orthographic projections are drawn as multiview drawings that show flat representations of principal views of the subject (**Figure 8**). *Oblique projections* actually show the full size of one view and are of three varieties: *cabinet* (half-scale), *cavalier* (full-scale), and general (between half- and full-scale). **Figures 9** and **10** show cavalier and cabinet projections. *Axonometric projections* are three-dimensional drawings and are of three different varieties: isometric, dimetric, and trimetric, as shown in **Figures 11, 12, and 13**.

Perspective Projection

Perspective projections are drawings that attempt to replicate what the human eye actually sees when it views an object. That is why the projectors in a perspective drawing converge. There are three types of perspective projections: one-point, two-point, and three-point projections, as shown in **Figures 14, 15, and 16**.

Purpose of Technical Drawings

To appreciate the need for technical drawings, one must understand the design process. The design process is an orderly, systematic procedure used in accomplishing a needed design.

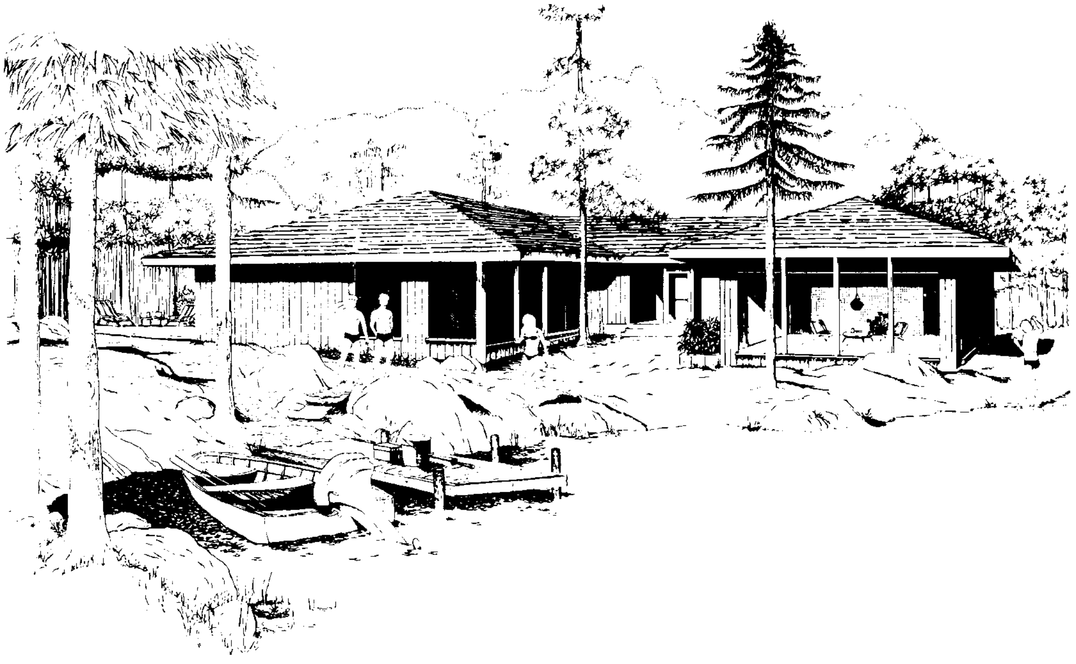

FIGURE 3 Rendering.

FIGURE 4 Rendering.

Any product that is to be manufactured, fabricated, assembled, constructed, built, or subjected to any other type of conversion process must first be designed. For example, a house must be designed before it can be built. An automobile must be designed before it can be manufactured. A printed circuit board must be designed before it can be fabricated.

The Design Process

The *design process* is an organized, step-by-step procedure in which mathematical and scientific principles, coupled with experience, are brought to bear in order to solve a problem or meet a need. The design process has five steps. Traditionally, these steps have been:

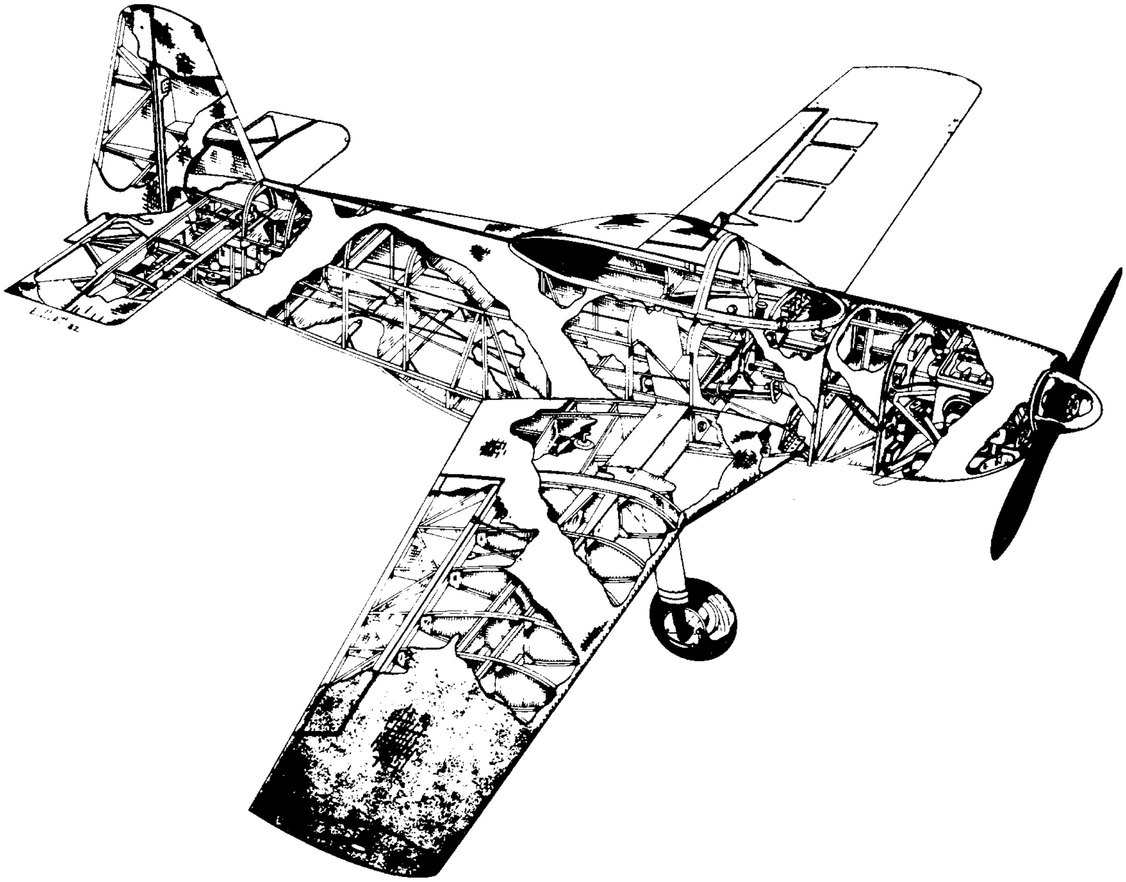

FIGURE 5 Mechanical illustration (Courtesy Ken Elliott).

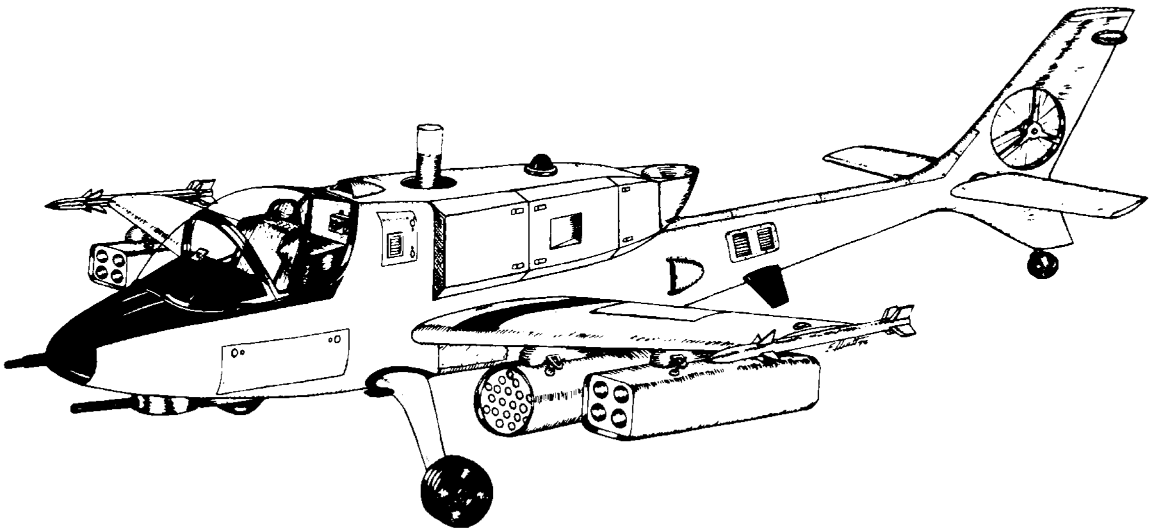

FIGURE 6 Mechanical illustration (Courtesy Ken Elliott).

(1) identification of the problem or need, (2) development of initial ideas for solving the problem, (3) selection of a proposed solution, (4) development and testing of models or prototypes, and development of working drawings (**Figure 17**).

The age of computers has altered the design process slightly for those companies that have converted to computer-aided drafting (CAD). For these companies, the expensive, time-consuming fourth step in the design process—the making and testing of actual models or prototypes—has been substantially altered as shown in **Figure 18**. This fourth step has been replaced with three-dimensional computer models that can be quickly and easily produced on a

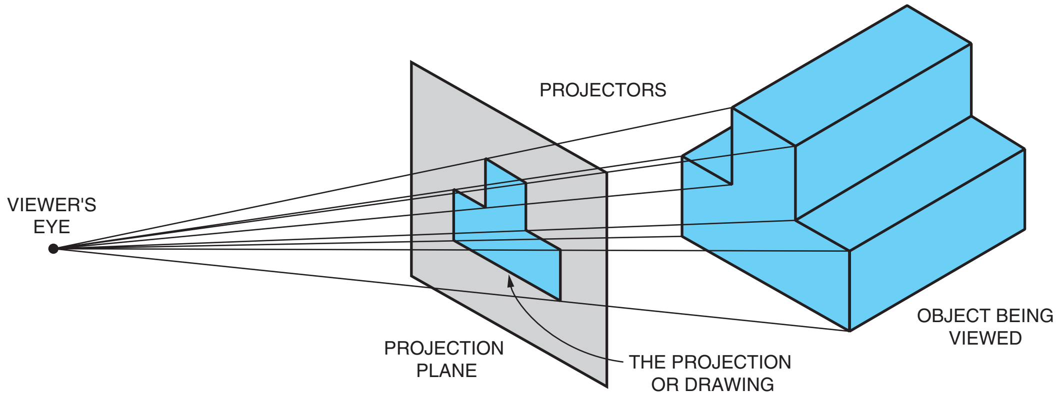

FIGURE 7 The projection plane.

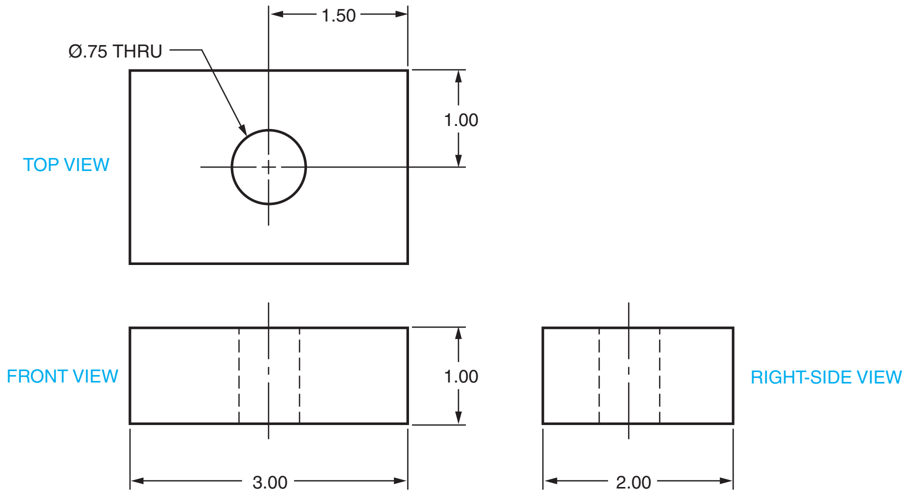

FIGURE 8 Orthographic multiview drawing.

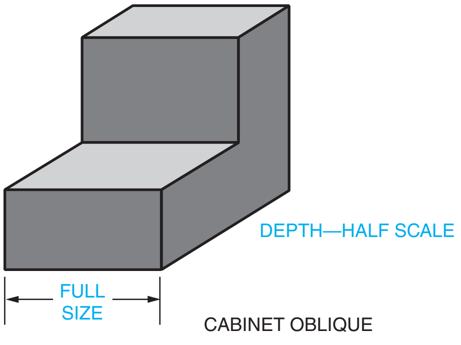

FIGURE 9 Oblique projection (cabinet).

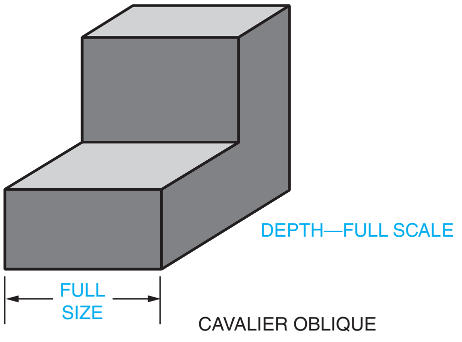

FIGURE 10 Oblique projection (cavalier).

CAD system using the database built up during the first three phases of the design process (Figure 19).

Whether in the traditional design process or the more modern computer version, working drawings are an integral part of the design process from start to finish. The purpose of technical drawings is to document the design process. Creating technical drawings to support the design process is called *drafting*. People who do drafting are known as *drafters*, *drafting technicians*, or CAD technicians (computer-aided drafting technicians). The words “draftsman” or “draughtsman” are no longer used.

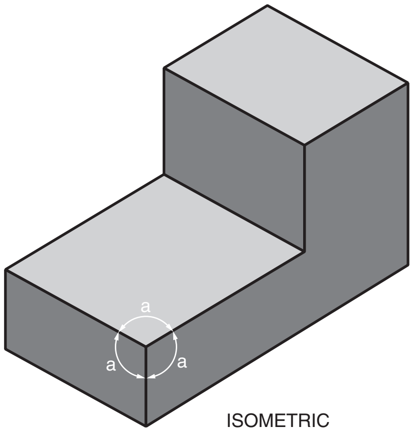

FIGURE 11 Axonometric projection (isometric).

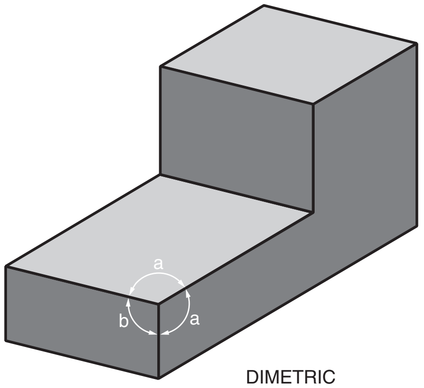

FIGURE 12 Axonometric projection (dimetric).

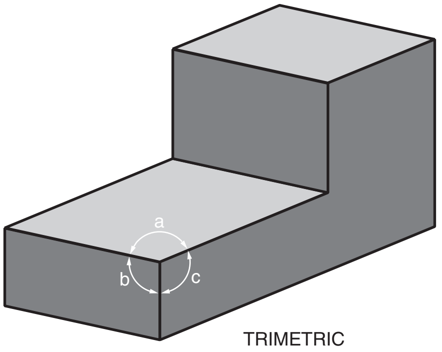

FIGURE 13 Axonometric projection (trimetric).

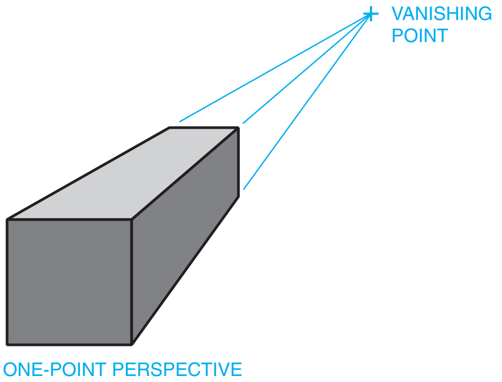

FIGURE 14 One-point perspective projection.

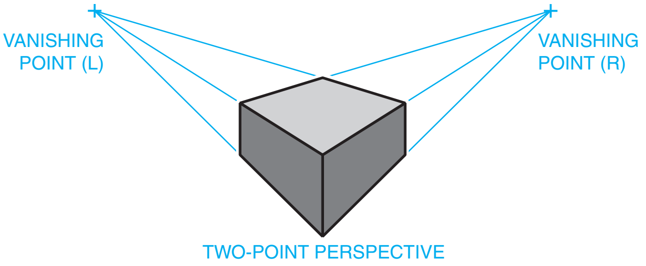

FIGURE 15 Two-point perspective projection.

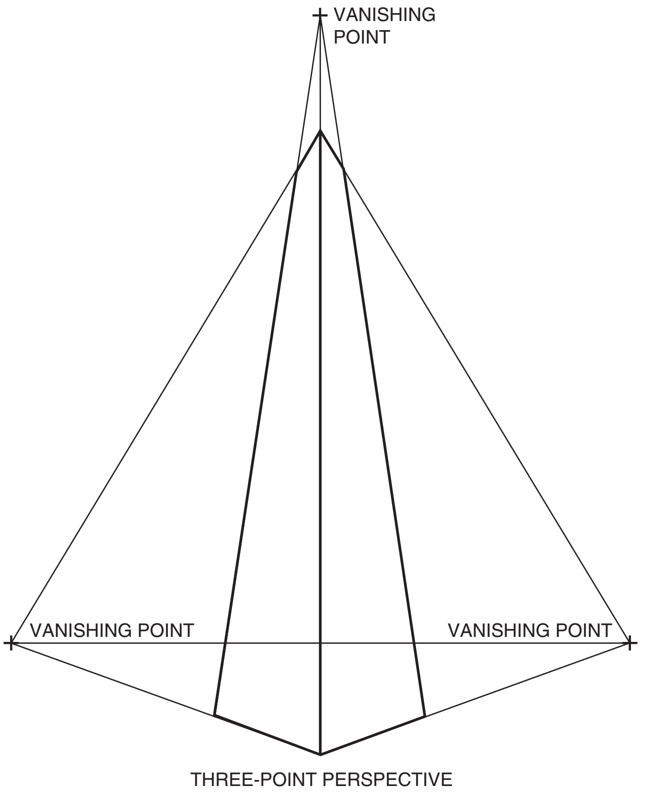

FIGURE 16 Three-point perspective projection.

In the first step of the design process, technical drawings are used to help clarify the problem or the need. The drawings may be old ones on file or new ones created for the purpose of clarification. In the second step, technical drawings—often in the form of sketches or preliminary drawings—are used to document the various ideas and concepts formed. In the third step, technical drawings—again, usually preliminary drawings—are used to communicate the proposed solution.

If the traditional fourth step in the design process is being used, preliminary drawings and sketches from the first three steps will be used as guides in constructing models or prototypes for testing. If the more modern fourth step is being

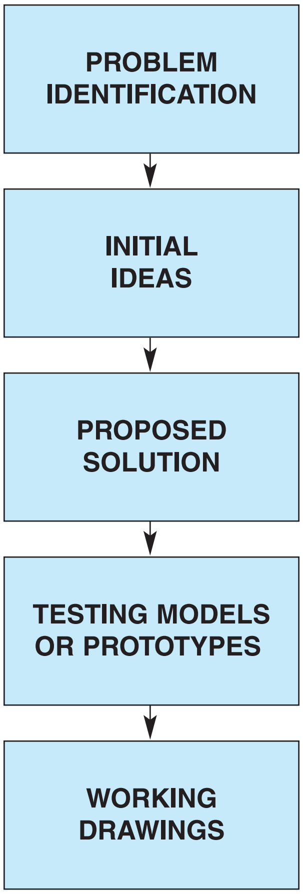

FIGURE 17 The design process (manual).

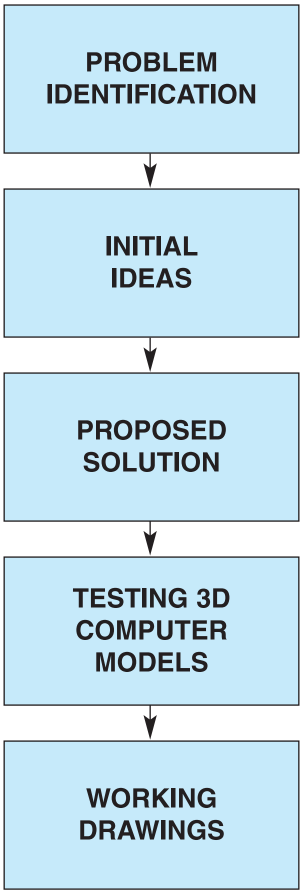

FIGURE 18 The design process (CAD).

used, the database built up during documentation of the first three steps can be used in developing three-dimensional computer models. In both cases, the final step is the development of complete working drawings for guiding individuals involved in the conversion process. **Figure 20** is a working drawing documenting the design of a simple mechanical part. The drawing was produced manually. **Figure 21** is the same drawing produced on a CAD system.

Applications of Technical Drawings

Technical drawings are used in many different applications. They are needed in any setting that involves design and in any subsequent form of the conversion process. The most common applications of technical drawings can be found in the fields of manufacturing, engineering, architecture, and construction, as well as in all of their various related fields.

Architects use technical drawings to document their designs of residential, commercial, and industrial

FIGURE 19 CAD image (Courtesy of Getty Images).