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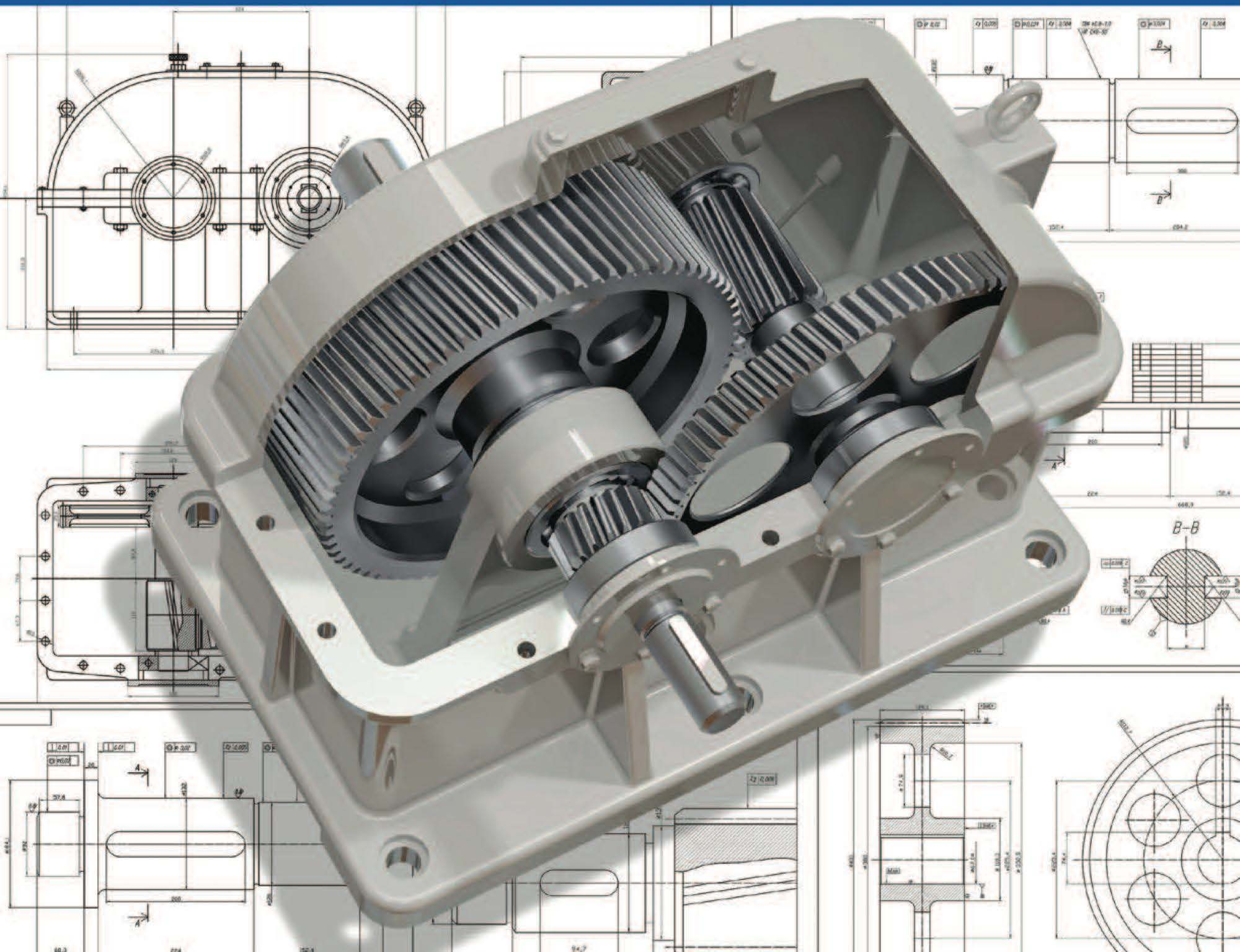
Print Reading for Industry

10th Edition

Write-In Text

Walter C. Brown / Ryan K. Brown



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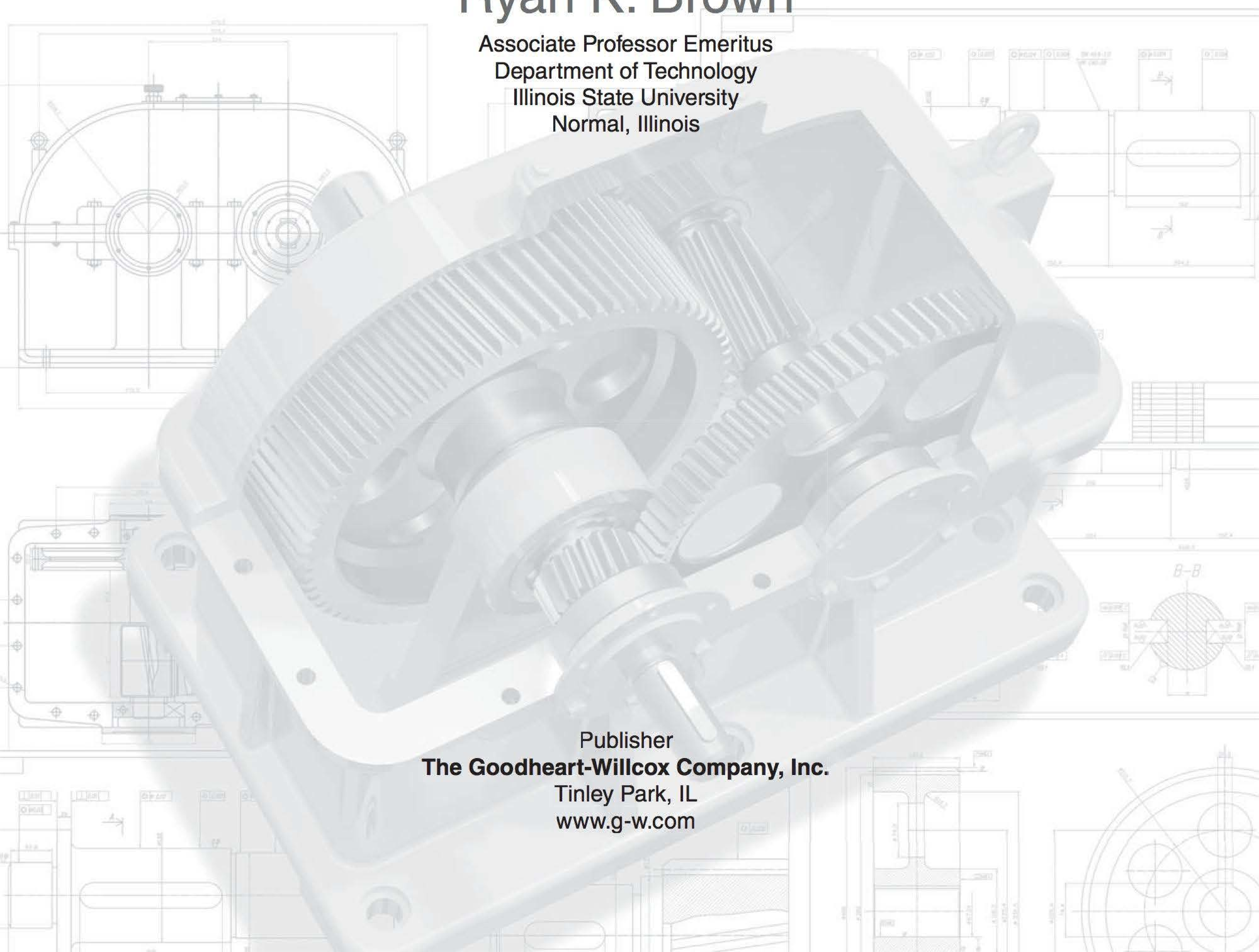
by

Walter C. Brown

Ryan K. Brown

Associate Professor Emeritus
Department of Technology
Illinois State University
Normal, Illinois



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Preface

Print Reading for Industry is a robust text that focuses on interpreting and visualizing drawings and prints used in industrial settings. It is designed to assist beginning through intermediate students and those receiving on-the-job training to build the skills necessary to read and understand "the language of industry." It is ideally suited for teaching semester long courses. This text may also be used in apprenticeship programs.

Print Reading for Industry uses actual prints from various industries as examples so that students can become comfortable with real world common practices. The many prints found in the text are supplemented with the accompanying Large Prints Packet containing 28 C-size prints for even more hands-on learning. In order to provide real-life print reading experiences, actual variations from the national standards have been retained on the prints in the textbook and in the Large Prints Packet. Many of these prints are available as PDFs for classroom display and discussion, and can be found on the Instructor's Resource CD, Online Instructor's Resources, and G-W Online.

Additionally, *Print Reading for Industry* provides coverage of several foundational skills needed for print reading success, including basic mathematics, geometry principles, reading engineering drawings, measurement tools, and the design process. Coverage of specialized parts and prints, including applications for fasteners, gears, cams, plastic parts, and precision sheet metal parts, is also included.

In order to reflect modern trends in the manufacturing industry, this revised edition also includes new content that discusses the role of prints in the digital age, updates the coverage of geometric dimensioning and tolerancing to current standards, and provides the latest information on additive manufacturing and rapid prototyping. Another important change to this edition of *Print Reading for Industry* was the addition of new spatial visualization tools. These visualization exercises help build students' spatial reasoning skills, making them better print readers. Some other changes to this edition include the following:

- The addition of new images and updated art throughout the text.
- Additional content related to computer-generated prints and the automatic generation of multiview drawings, section views, auxiliary views, and screw thread representations.
- New content on drawings for precision sheet metal parts and the automatic generation of flat patterns.
- Updated information to match latest ASME and AWS standards.

Print Reading for Industry is organized into sections based on a progression of concepts from simple to complex. A list of learning objectives and technical terms are located at the beginning of each unit, providing an overview of the content. Review questions, review activities, industry print exercises, and bonus print reading exercises based on the prints found in the Large Prints Packet provide ample means of assessing student progress. The write-in text workbook format with perforations allows students to tear practice prints out of the book, complete the review assignments, and turn them in directly to the instructor.

This textbook will provide the reader with a solid foundation necessary to read prints in an industrial setting and find success in any career where prints are found.

Walter C. Brown

Ryan K. Brown

About the Authors

Dr. Ryan K. Brown is an Associate Professor Emeritus of the Department of Technology at Illinois State University, Normal, Illinois, where, for over 25 years, he taught various drafting and design topics. His teaching experiences also include four years as a faculty member at his alma mater, Eastern Kentucky University, and five years teaching drafting at the junior and senior high level. His work experiences include short term and summer positions in a wide array of drafting and graphics-based applications, such as steel detailing, plant layout, robotic simulation, and civil engineering drawings. He also conducted several workshops for companies in the field of geometric dimensioning and tolerancing, most extensively for IBM. He continues to serve as an author for secondary-level drafting competitions in Illinois and provides architectural drafting services to local organizations. Feel free to contact him at rkbrown@ilstu.edu with respect to the textbook and related materials.

During his career, Dr. Walter C. Brown was a leading authority in the fields of drafting and print reading. He served as a consultant to industry on design and drafting standards and procedures. He authored several books in the fields of drafting, print reading, and mathematics, and was a professor in the Division of Technology at Arizona State University, Tempe, Arizona.

Reviewers

The author and publisher wish to thank the following industry and teaching professionals for their valuable input into the development of *Print Reading for Industry*.

Brian Bennett
Welding Coordinator
Hill College
Cleburne, TX

Rick Calverley
CNC Manufacturing Supervisor
Lincoln College of Technology
Grand Prairie, TX

Stephanie Gustin
Drafting Professor
Amarillo College
Amarillo, TX

Leon Kassler
Technology Faculty Professor
York County Community College
Wells, ME

Jack Krikorian
Manufacturing Technology Professor
William Rainey Harper College
Palatine, IL

Thomas Looker
Mechanical Engineering Technology Assistant Professor
Edison Community College
Piqua, OH

Tony Micallef
Instructor
Oakland Community College
Auburn Hills, MI

John Shepherd
Instructor—Manufacturing Technology (Retired)
Mt. San Antonio College
Upland, CA

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Images and Prints Used in the Text

Throughout the text are images and illustrations based on actual industry prints. The companies that have supplied images and prints for this text appear in the following list. The publisher and authors thank these companies for their assistance.

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AIR Corporation
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Barko Hydraulics
Barton Manufacturing
BC Design and Associates
Bell Aerosystems
Boston Gear Group
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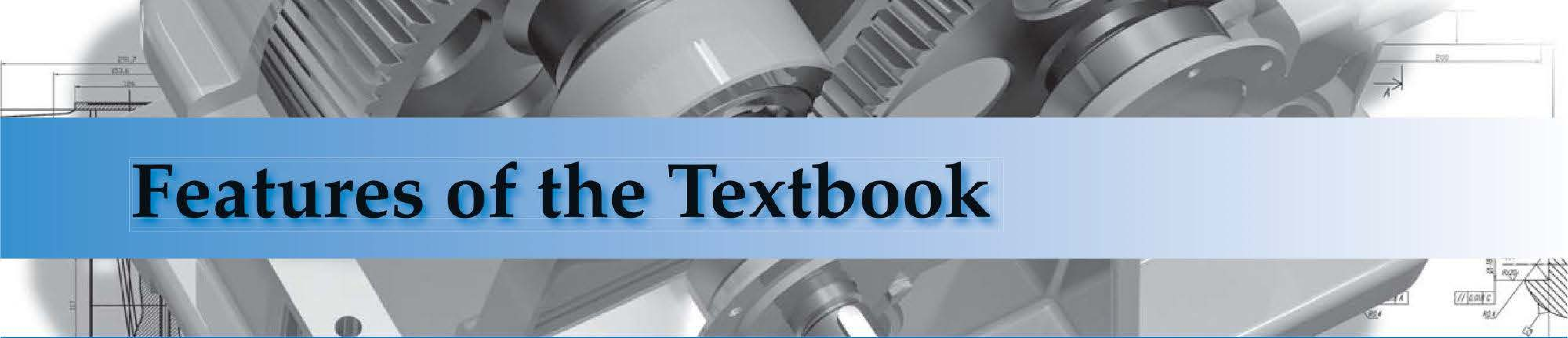
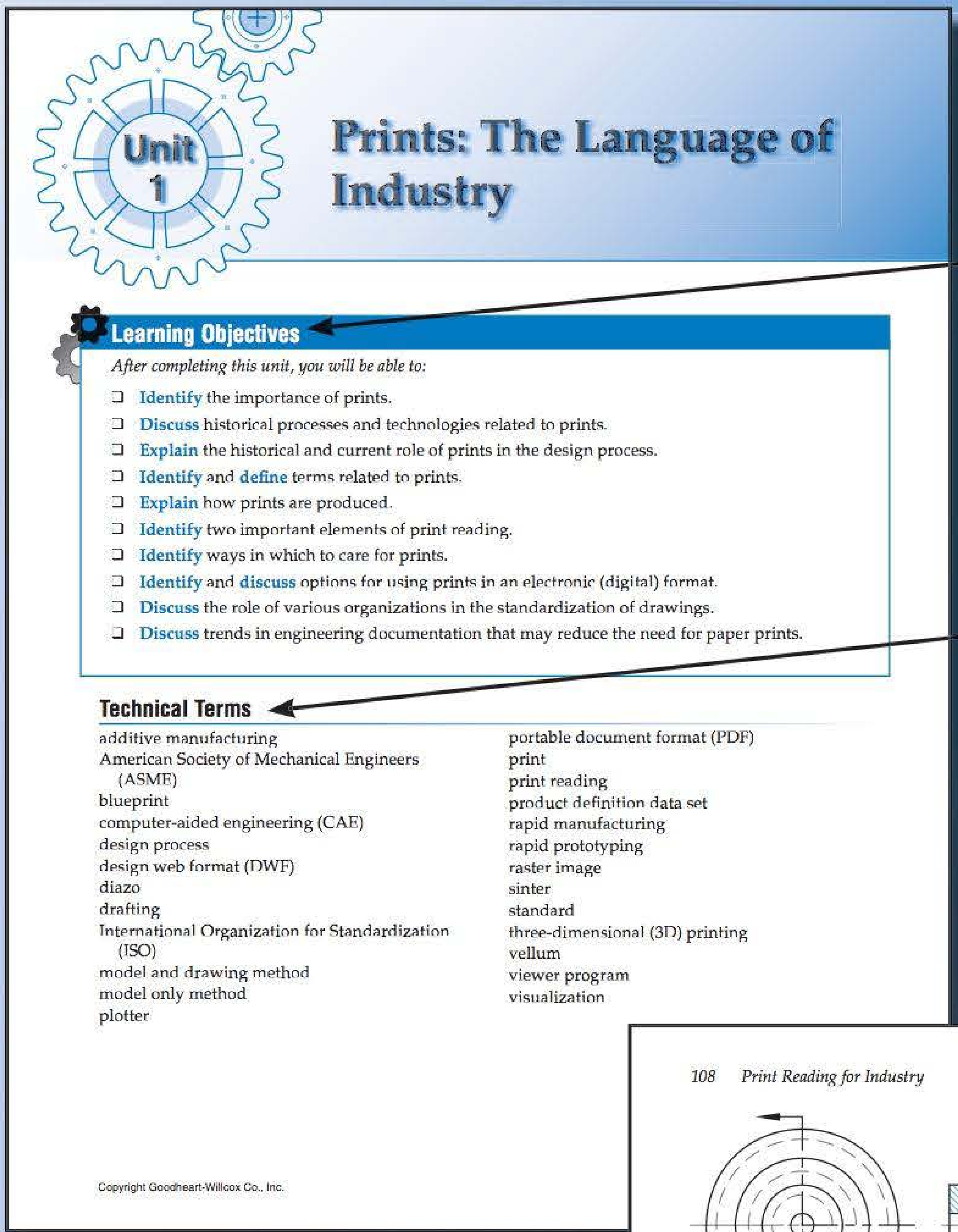


Features of the Textbook


Unit 1

Prints: The Language of Industry

Learning Objectives

After completing this unit, you will be able to:

- Identify the importance of prints.
- Discuss historical processes and technologies related to prints.
- Explain the historical and current role of prints in the design process.
- Identify and define terms related to prints.
- Explain how prints are produced.
- Identify two important elements of print reading.
- Identify ways in which to care for prints.
- Identify and discuss options for using prints in an electronic (digital) format.
- Discuss the role of various organizations in the standardization of drawings.
- Discuss trends in engineering documentation that may reduce the need for paper prints.

Technical Terms

additive manufacturing	portable document format (PDF)
American Society of Mechanical Engineers (ASME)	print
blueprint	print reading
computer-aided engineering (CAE)	product definition data set
design process	rapid manufacturing
design web format (DWF)	rapid prototyping
diazo	raster image
drafting	sinter
International Organization for Standardization (ISO)	standard
model and drawing method	three-dimensional (3D) printing
model only method	vellum
plotter	viewer program
	visualization

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Learning Objectives clearly identify the knowledge and skills to be obtained when the chapter is completed so students can direct their learning.

Technical Terms list the key terms to be learned in the chapter. Students can review this list after completing the chapter to be sure they know the definition of each term.

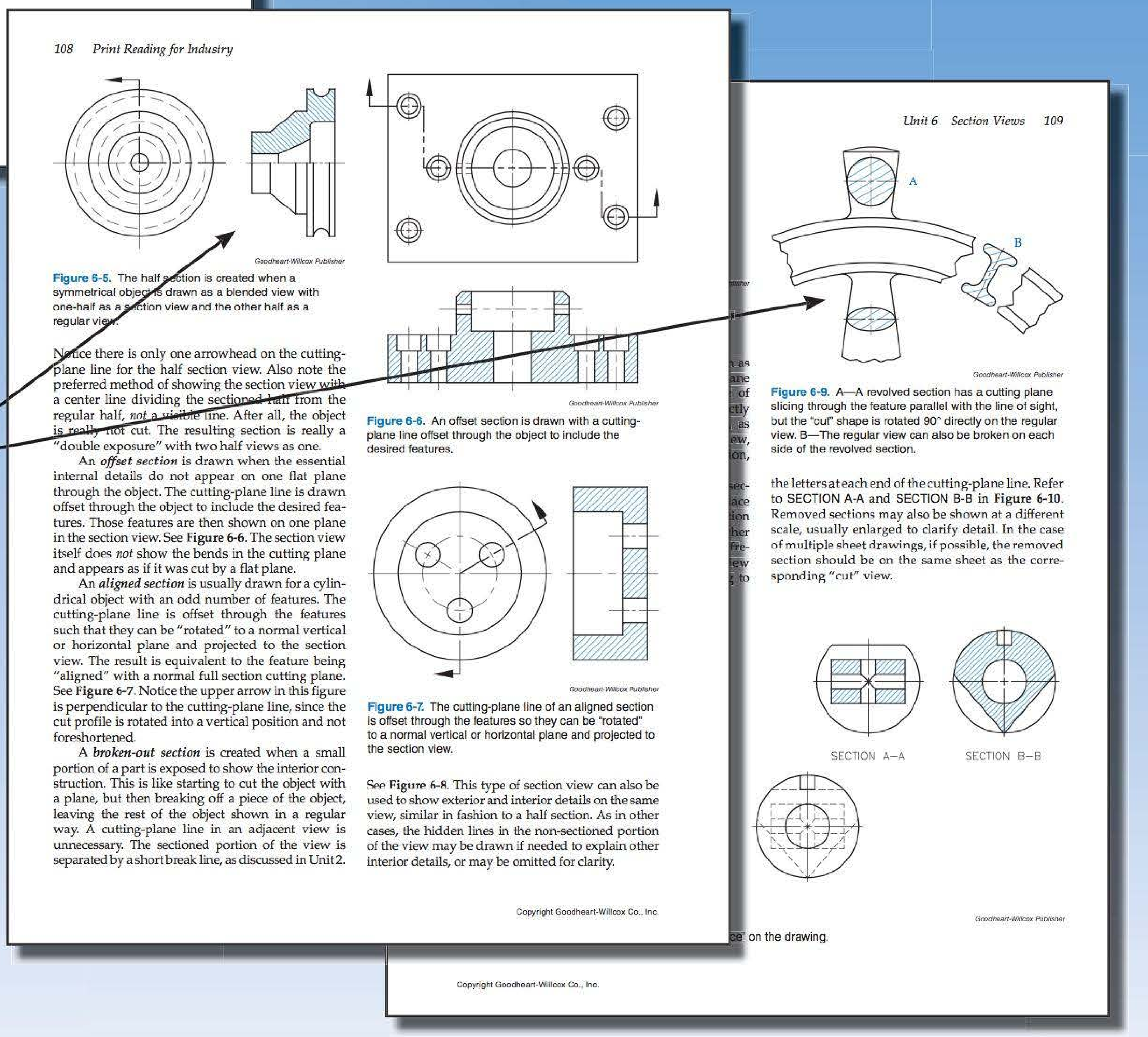
108 Print Reading for Industry

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Figure 6-5. The half section is created when a symmetrical object is drawn as a blended view with one-half as a section view and the other half as a regular view.

Notice there is only one arrowhead on the cutting-plane line for the half section view. Also note the preferred method of showing the section view with a center line dividing the sectioned half from the regular half, *not* a visible line. After all, the object is really not cut. The resulting section is really a "double exposure" with two half views as one.

An *offset section* is drawn when the essential internal details do not appear on one flat plane through the object. The cutting-plane line is drawn offset through the object to include the desired features. Those features are then shown on one plane in the section view. See **Figure 6-6**. The section view itself does *not* show the bends in the cutting plane and appears as if it was cut by a flat plane.

An *aligned section* is usually drawn for a cylindrical object with an odd number of features. The cutting-plane line is offset through the features such that they can be "rotated" to a normal vertical or horizontal plane and projected to the section view. The result is equivalent to the feature being "aligned" with a normal full section cutting plane. See **Figure 6-7**. Notice the upper arrow in this figure is perpendicular to the cutting-plane line, since the cut profile is rotated into a vertical position and not foreshortened.

A *broken-out section* is created when a small portion of a part is exposed to show the interior construction. This is like starting to cut the object with a plane, but then breaking off a piece of the object, leaving the rest of the object shown in a regular way. A cutting-plane line in an adjacent view is unnecessary. The sectioned portion of the view is separated by a short break line, as discussed in Unit 2.

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Figure 6-6. An offset section is drawn with a cutting-plane line offset through the object to include the desired features.

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Figure 6-7. The cutting-plane line of an aligned section is offset through the features so they can be "rotated" to a normal vertical or horizontal plane and projected to the section view.

See **Figure 6-8**. This type of section view can also be used to show exterior and interior details on the same view, similar in fashion to a half section. As in other cases, the hidden lines in the non-sectioned portion of the view may be drawn if needed to explain other interior details, or may be omitted for clarity.

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Unit 6 Section Views 109

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Figure 6-9. A—A revolved section has a cutting plane slicing through the feature parallel with the line of sight, but the "cut" shape is rotated 90° directly on the regular view. B—The regular view can also be broken on each side of the revolved section.

the letters at each end of the cutting-plane line. Refer to SECTION A-A and SECTION B-B in **Figure 6-10**. Removed sections may also be shown at a different scale, usually enlarged to clarify detail. In the case of multiple sheet drawings, if possible, the removed section should be on the same sheet as the corresponding "cut" view.

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...e" on the drawing.

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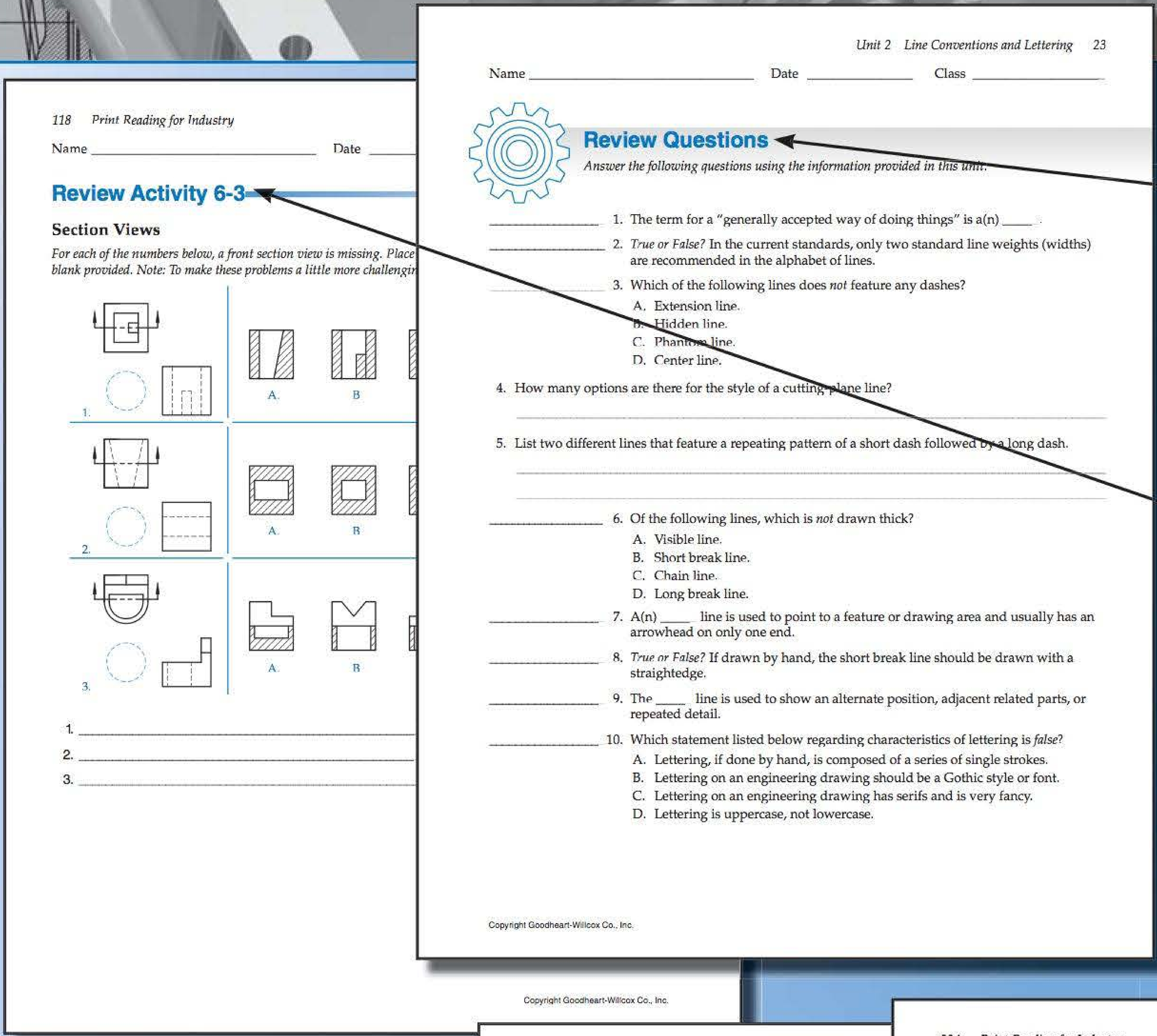
Illustrations have been designed to clearly and simply communicate the specific topic. Photographic images have been updated for this edition.

Features of the Textbook


118 Print Reading for Industry

Name ______________ Date

Review Activity 6-3

Section Views

For each of the numbers below, a front section view is missing. Place … blank provided. Note: To make these problems a little more challengin…

1. ______
2. ______
3. ______

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Unit 2 Line Conventions and Lettering 23

Name ______________ Date ________ Class ________

Review Questions

Answer the following questions using the information provided in this unit.

______ 1. The term for a "generally accepted way of doing things" is a(n) ______.

______ 2. *True or False?* In the current standards, only two standard line weights (widths) are recommended in the alphabet of lines.

______ 3. Which of the following lines does *not* feature any dashes?
A. Extension line.
B. Hidden line.
C. Phantom line.
D. Center line.

4. How many options are there for the style of a cutting-plane line?

5. List two different lines that feature a repeating pattern of a short dash followed by a long dash.

______ 6. Of the following lines, which is *not* drawn thick?
A. Visible line.
B. Short break line.
C. Chain line.
D. Long break line.

______ 7. A(n) ____ line is used to point to a feature or drawing area and usually has an arrowhead on only one end.

______ 8. *True or False?* If drawn by hand, the short break line should be drawn with a straightedge.

______ 9. The ____ line is used to show an alternate position, adjacent related parts, or repeated detail.

______ 10. Which statement listed below regarding characteristics of lettering is *false*?
A. Lettering, if done by hand, is composed of a series of single strokes.
B. Lettering on an engineering drawing should be a Gothic style or font.
C. Lettering on an engineering drawing has serifs and is very fancy.
D. Lettering is uppercase, not lowercase.

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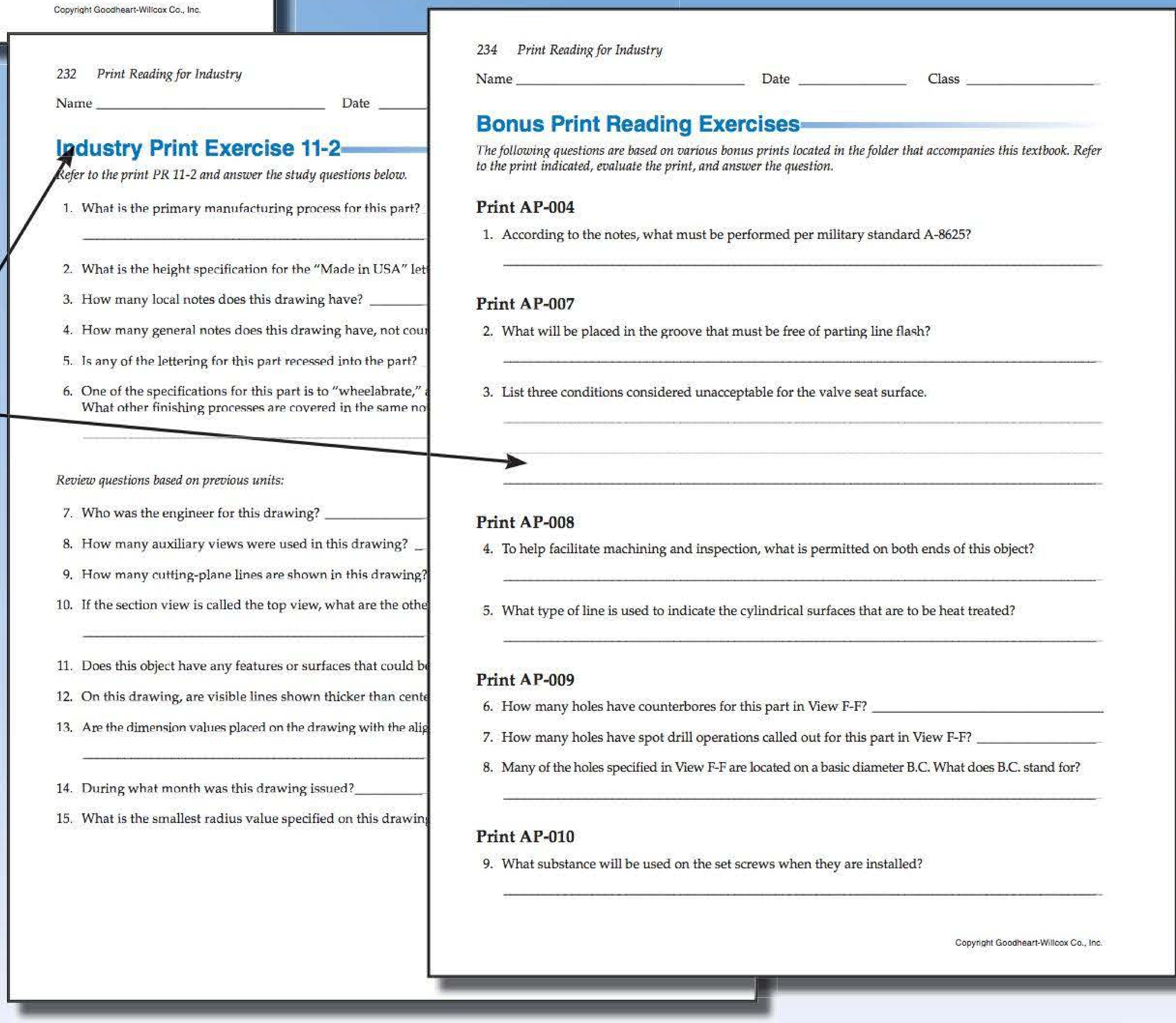
Review Questions are provided in multiple choice, fill-in-the-blank, true or false, and short answer formats designed to aid student mastery.

Review Activities provide students with an additional review tool and an effective way to assess knowledge.


232 Print Reading for Industry

Name ______________ Date

Industry Print Exercise 11-2

Refer to the print PR 11-2 and answer the study questions below.

1. What is the primary manufacturing process for this part?
2. What is the height specification for the "Made in USA" let…
3. How many local notes does this drawing have?
4. How many general notes does this drawing have, not cou…
5. Is any of the lettering for this part recessed into the part?
6. One of the specifications for this part is to "wheelabrate," … What other finishing processes are covered in the same no…

Review questions based on previous units:

7. Who was the engineer for this drawing?
8. How many auxiliary views were used in this drawing?
9. How many cutting-plane lines are shown in this drawing?
10. If the section view is called the top view, what are the othe…
11. Does this object have any features or surfaces that could be…
12. On this drawing, are visible lines shown thicker than cente…
13. Are the dimension values placed on the drawing with the alig…
14. During what month was this drawing issued?
15. What is the smallest radius value specified on this drawing…

234 Print Reading for Industry

Name ______________ Date ________ Class ________

Bonus Print Reading Exercises

The following questions are based on various bonus prints located in the folder that accompanies this textbook. Refer to the print indicated, evaluate the print, and answer the question.

Print AP-004

1. According to the notes, what must be performed per military standard A-8625?

Print AP-007

2. What will be placed in the groove that must be free of parting line flash?
3. List three conditions considered unacceptable for the valve seat surface.

Print AP-008

4. To help facilitate machining and inspection, what is permitted on both ends of this object?
5. What type of line is used to indicate the cylindrical surfaces that are to be heat treated?

Print AP-009

6. How many holes have counterbores for this part in View F-F? ______
7. How many holes have spot drill operations called out for this part in View F-F? ______
8. Many of the holes specified in View F-F are located on a basic diameter B.C. What does B.C. stand for?

Print AP-010

9. What substance will be used on the set screws when they are installed?

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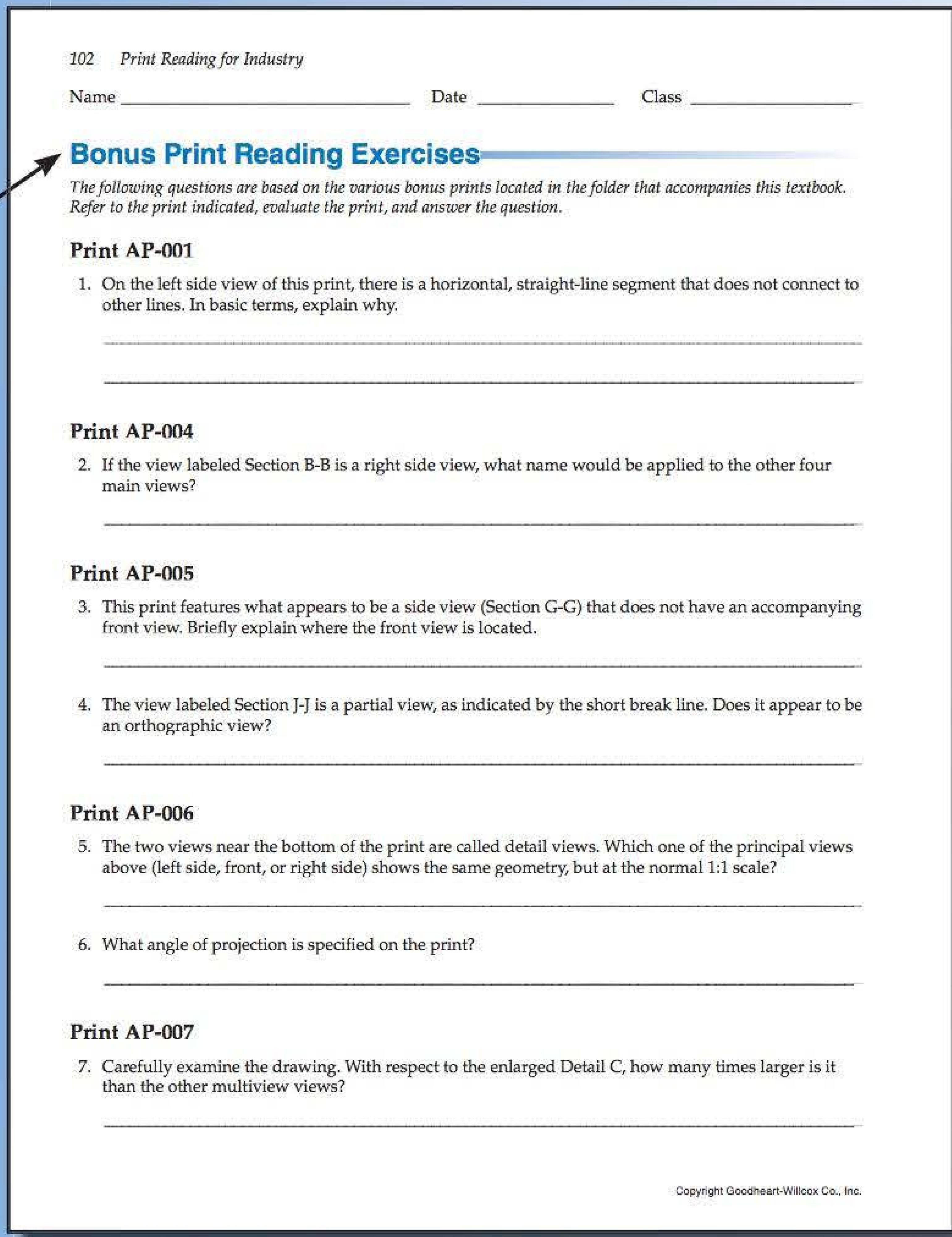
Industry Print Exercises provide minds-on and hands-on print reading activities with actual industrial prints.

Bonus Print Reading Exercises are provided at the end of each unit and correspond to the bonus prints located in the Large Prints Packet that accompanies this textbook. These exercises enable students to powerfully apply real-world knowledge and skills.



102 *Print Reading for Industry*

Name ______________________ Date ______________ Class ______________

Bonus Print Reading Exercises

The following questions are based on the various bonus prints located in the folder that accompanies this textbook. Refer to the print indicated, evaluate the print, and answer the question.

Print AP-001

1. On the left side view of this print, there is a horizontal, straight-line segment that does not connect to other lines. In basic terms, explain why.

Print AP-004

2. If the view labeled Section B-B is a right side view, what name would be applied to the other four main views?

Print AP-005

3. This print features what appears to be a side view (Section G-G) that does not have an accompanying front view. Briefly explain where the front view is located.

4. The view labeled Section J-J is a partial view, as indicated by the short break line. Does it appear to be an orthographic view?

Print AP-006

5. The two views near the bottom of the print are called detail views. Which one of the principal views above (left side, front, or right side) shows the same geometry, but at the normal 1:1 scale?

6. What angle of projection is specified on the print?

Print AP-007

7. Carefully examine the drawing. With respect to the enlarged Detail C, how many times larger is it than the other multiview views?

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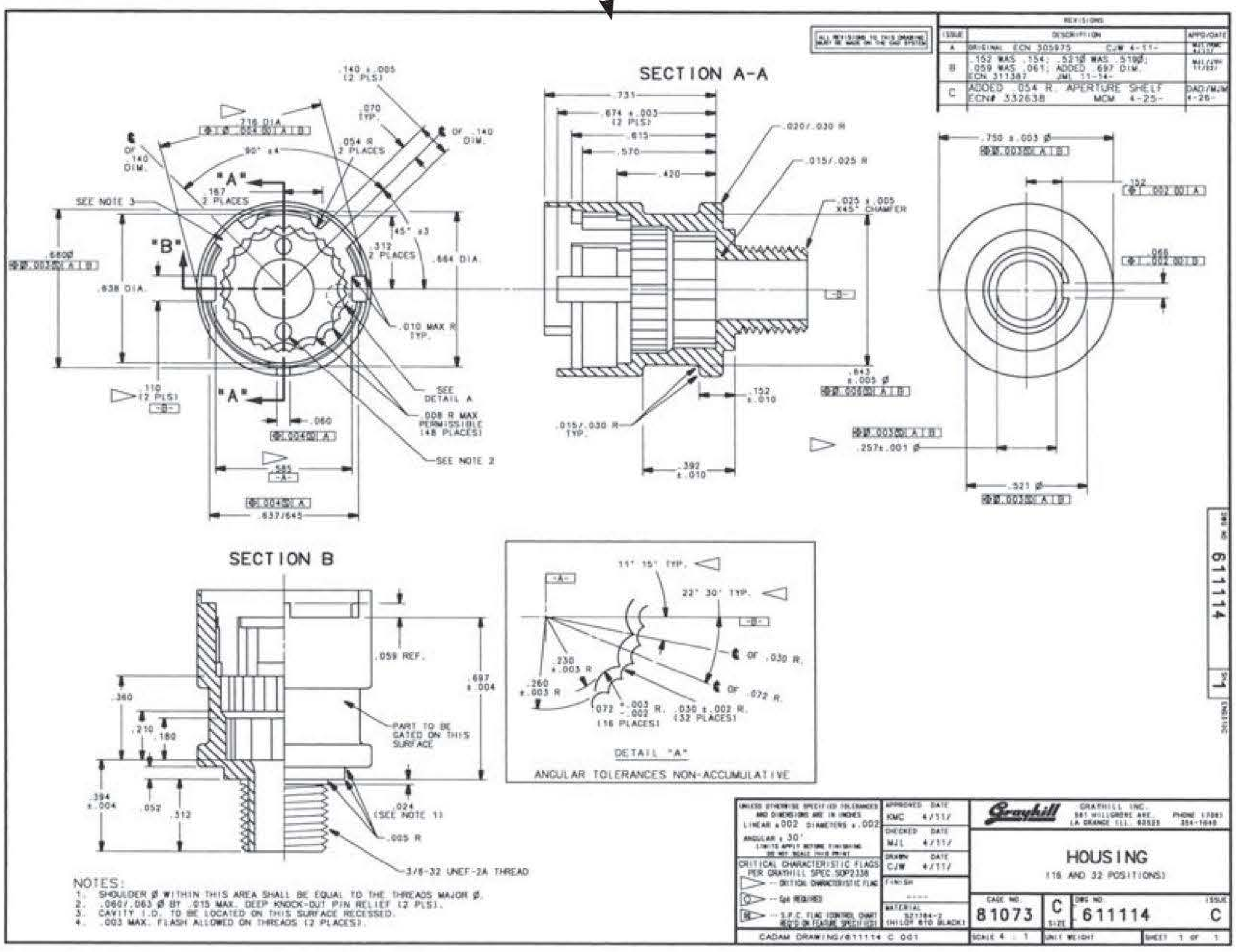


AP-003.
Print supplied by Grayhill, Inc.

Print supplied by Grayhill, Inc.

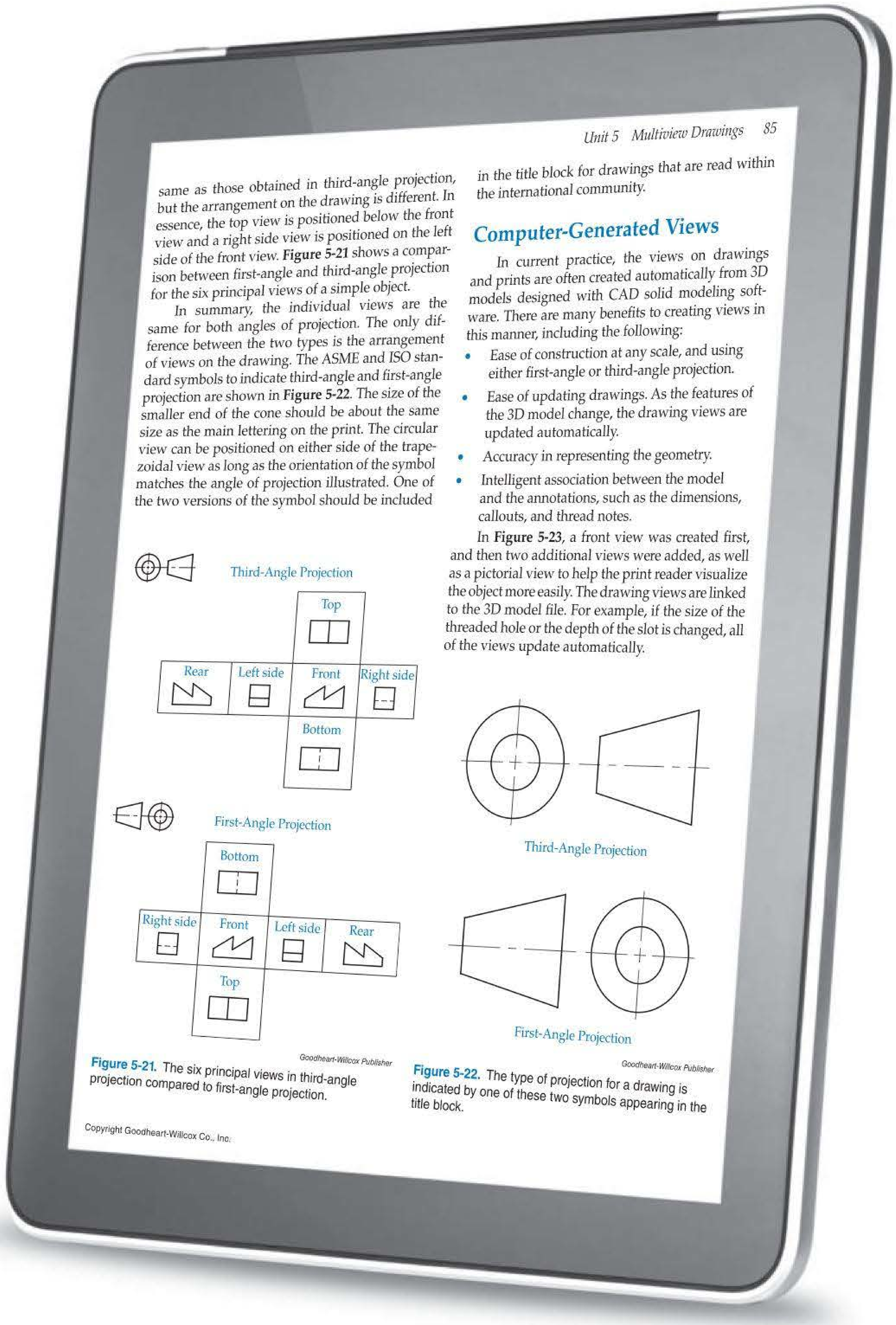
Student Materials

Large Prints Packet

Students can gain valuable hands-on print reading experience with the 28 bonus prints included in the Large Prints Packet that accompanies the textbook.

Online Textbook

This online version of the printed textbook gives students access anytime, anywhere, whether using an iPad, netbook, PC, or Mac computer. Using the Online Textbook, students can easily navigate from a linked table of contents, search specific topics, quickly jump to specific pages, zoom in to enlarge text, and print selected pages for offline reading. The Online Textbook is available at www.g-wonlinetextbooks.com.


Unit 5 Multiview Drawings 85

same as those obtained in third-angle projection, but the arrangement on the drawing is different. In essence, the top view is positioned below the front view and a right side view is positioned on the left side of the front view. **Figure 5-21** shows a comparison between first-angle and third-angle projection for the six principal views of a simple object.

In summary, the individual views are the same for both angles of projection. The only difference between the two types is the arrangement of views on the drawing. The ASME and ISO standard symbols to indicate third-angle and first-angle projection are shown in **Figure 5-22**. The size of the smaller end of the cone should be about the same size as the main lettering on the print. The circular view can be positioned on either side of the trapezoidal view as long as the orientation of the symbol matches the angle of projection illustrated. One of the two versions of the symbol should be included in the title block for drawings that are read within the international community.

Computer-Generated Views

In current practice, the views on drawings and prints are often created automatically from 3D models designed with CAD solid modeling software. There are many benefits to creating views in this manner, including the following:

- Ease of construction at any scale, and using either first-angle or third-angle projection.
- Ease of updating drawings. As the features of the 3D model change, the drawing views are updated automatically.
- Accuracy in representing the geometry.
- Intelligent association between the model and the annotations, such as the dimensions, callouts, and thread notes.

In **Figure 5-23**, a front view was created first, and then two additional views were added, as well as a pictorial view to help the print reader visualize the object more easily. The drawing views are linked to the 3D model file. For example, if the size of the threaded hole or the depth of the slot is changed, all of the views update automatically.

Figure 5-21. The six principal views in third-angle projection compared to first-angle projection.

Figure 5-22. The type of projection for a drawing is indicated by one of these two symbols appearing in the title block.

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Instructor Materials

ExamView® Assessment Suite

Quickly and easily prepare, print, and administer tests with the ExamView® Assessment Suite. With hundreds of questions in the test bank corresponding to each chapter, you can choose which questions to include in each test, create multiple versions of a single test, and automatically generate answer keys. Existing questions may be modified and new questions may be added.

Instructor's Presentations for PowerPoint®

These presentations are designed to allow for customization to meet daily teaching needs. They include objectives and images from the textbook.

Instructor's Resource CD

One resource provides instructors with time-saving preparation tools such as answer keys, lesson plans, correlation charts, and other teaching aids. Electronic versions of the 28 prints found in the Large Prints Packet and the 43 prints found in the textbook are included.

Online Instructor Resources

Online Instructor Resources are time-saving teaching materials organized in a convenient, easy-to-use online bookshelf. Lesson plans, answer keys, PowerPoint® presentations, ExamView® Assessment Suite software with test questions, and other teaching aids are available on demand, 24/7. Accessible from home or school, Online Instructor Resources provide convenient access for instructors with busy schedules.

G-W Online

G-W Online provides robust instructional resources in an easily customizable course management system. This online solution contains an Online Textbook, workbook questions, e-flash cards, activities, and assessments for a deeply engaging, interactive learning experience. G-W Online enhances your course with powerful course management and assessment tools that accurately monitor and track student learning. The ultimate in convenient and quick grading, G-W Online allows you to spend more time teaching and less time administering.

Brief Contents

Expanded Table of Contents

Unit 1

Prints: The Language of Industry

Learning Objectives

After completing this unit, you will be able to:

- ❑ **Identify** the importance of prints.
- ❑ **Discuss** historical processes and technologies related to prints.
- ❑ **Explain** the historical and current role of prints in the design process.
- ❑ **Identify** and **define** terms related to prints.
- ❑ **Explain** how prints are produced.
- ❑ **Identify** two important elements of print reading.
- ❑ **Identify** ways in which to care for prints.
- ❑ **Identify** and **discuss** options for using prints in an electronic (digital) format.
- ❑ **Discuss** the role of various organizations in the standardization of drawings.
- ❑ **Discuss** trends in engineering documentation that may reduce the need for paper prints.

Technical Terms

additive manufacturing
American Society of Mechanical Engineers (ASME)
blueprint
computer-aided engineering (CAE)
design process
design web format (DWF)
diazo
drafting
International Organization for Standardization (ISO)
model and drawing method
model only method
plotter
portable document format (PDF)
print
print reading
product definition data set
rapid manufacturing
rapid prototyping
raster image
sinter
standard
three-dimensional (3D) printing
vellum
viewer program
visualization

You have probably heard the saying, "a picture is worth a thousand words." This is certainly true when referring to a drawing of a product. It would be next to impossible for an engineer or designer to describe in words the shape, size, and relationship of the various parts of a machine in sufficient detail for skilled workers to produce the object. Drawings are the universal language used by engineers, designers, technicians, and skilled workers to quickly and accurately communicate the necessary information to fabricate, assemble, or service industrial products, **Figure 1-1**.

The Importance of Prints

Within the context of this book, the word ***print*** will simply be defined as a copy of a drawing, but can generally be used the same as the word *drawing*. In many situations, drawings may not be printed, but nevertheless are still a primary means of communication within the manufacturing industry. Many industrial products, such as automobiles, aircraft, and computers, consist of thousands of component parts. These parts may be manufactured in a variety of settings around the globe. The "moment of truth" in the manufacture of these products comes during final assembly or when a spare part is installed in the field. These parts must always fit. Therefore, to meet manufacturing requirements, all industries need workers who can read and understand prints.

A drawing describes what an object should look like when it is completed. Prints provide workers with the details of size, shape, tolerances (allowable variation), materials used, finish, and other special treatments. In many cases, the print is also an important part of the contractual agreement within the industrial setting. The supplier of parts must meet the specifications dictated by the print. Often, purchasing agents have to ensure the print is contractually sufficient to ensure vendors supply quality parts without cutting corners. Quality-control inspectors have to verify that all parts, both those made by suppliers and those made in-house, match the print and continually review the print's role in controlling the precision and quality of the parts needed.

Monkey Business Images/Shutterstock.com

Figure 1-1. Drawings are the universal language used by engineers, designers, technicians, and skilled workers to quickly and accurately communicate the necessary information to fabricate, assemble, or service industrial products.

History of Prints

The study of print reading is closely related to the study of ***drafting***, the general term for creating drawings of objects in technical fields. Of course, those who have studied drafting not only know how to create prints, but also read prints. Courses, curricular programs, and textbooks for drafting have used a multitude of terms throughout the years. Engineering graphics is a common term used within engineering programs, while technical drawing is a common term in drafting programs that train technicians and technologists. In addition, terms such as mechanical drafting or instrumental drafting were used in the past to describe the process of creating industrial drawings. While the focus of this textbook is on reading the drawings, information about creating drawings will also be examined to provide insight into the standards the drafter should be following.

One of the earliest printmaking processes began in the middle of the nineteenth century. It involved exposing treated, photosensitive paper under an original drawing on translucent paper. This early method and the copy paper it used required submersion in a liquid to process the copy. The resulting print had a blue background and white lines. Thus, this type of print was called a ***blueprint***, **Figure 1-2**. Even though the process that created "blue" prints has not been used for decades, the term blueprint has become a part of our common vocabulary to mean "any plan of action or detailed procedure to accomplish a task."

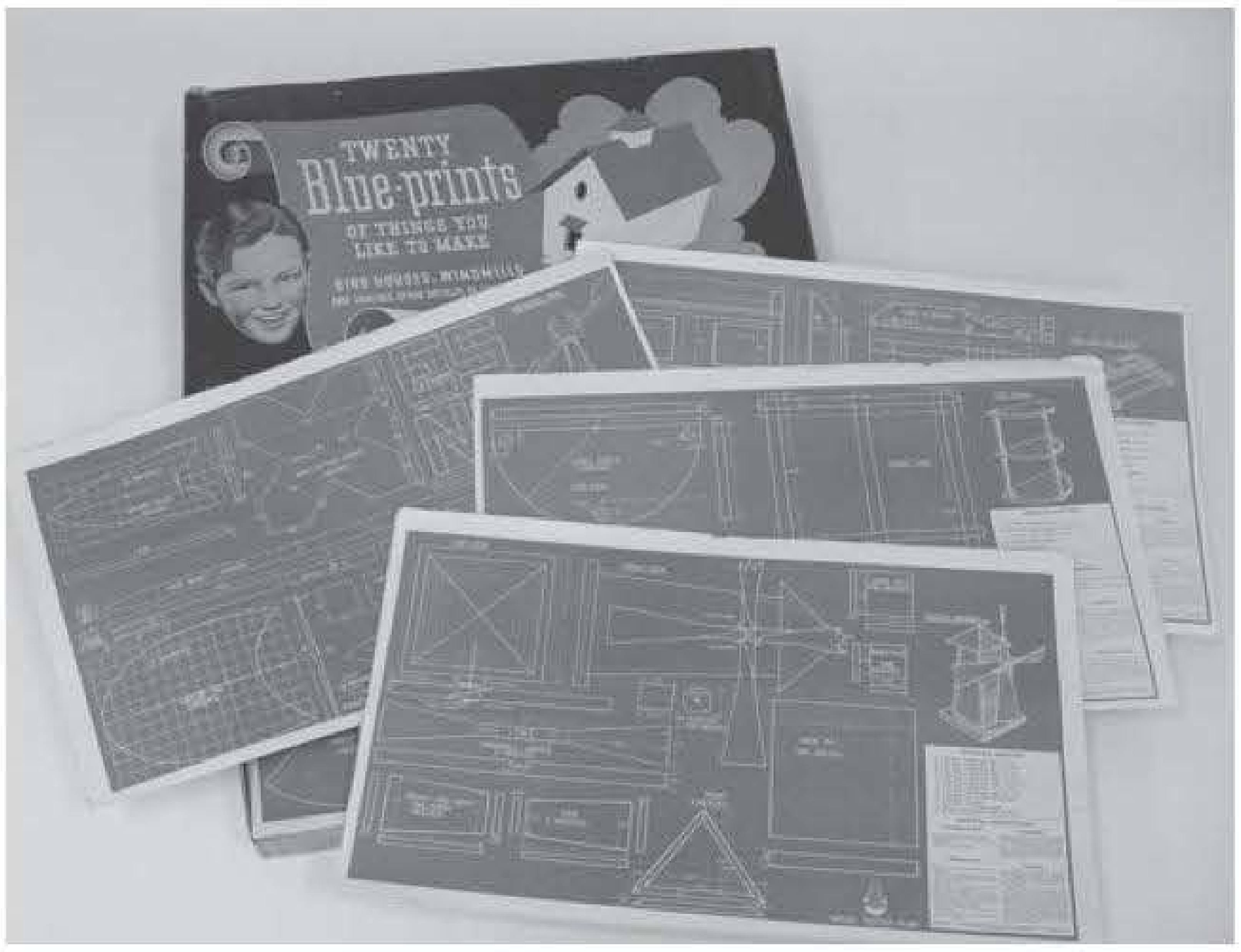

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Figure 1-2. Years ago, copies of drawings (prints) were made that featured a blue background and white lines. This is the origin of the term blueprint, which is still in our vocabulary today.

During the 1940s, a dry process evolved that used a paper coated with a type of organic compound referred to as a ***diazo*** compound. Exposure to light evaporated the background area while leaving the coating where lines blocked the light. Ammonia vapor then converted the remaining coating to a permanent blue. This type of print was sometimes called a whiteprint or a blue-line print, but often the term blueprint continued to be used. While the diazo process may still be found in use in a few settings today, most companies have replaced that technology with engineering photocopiers or plotters used to make paper prints.

Original drawings were produced on ***vellum*** (transparent, resin impregnated paper) or plastic film because the copying process required an original that would be durable but also allow light to pass through. Copies of the drawings, or prints, were made and distributed to those who needed them.

Throughout most of the twentieth century, companies produced paper copies of drawings of parts and assemblies, either drawn with traditional drafting equipment or plotted from computer-aided drafting (CAD) systems. These original drawings—created by the drafter or plotted by the CAD operator—were then stored in a file-drawer system supervised by the engineering or quality control department. Original drawings were seldom used in the plant or field. Instead, prints were made for distribution.

While some companies may still use these traditional systems, for many companies original drawings no longer exist in paper format. Prints can be created directly from the computer as needed. It is also possible for those who need prints to view the drawings in electronic (digital) format using viewing software. There are many software utility programs that allow 2D drawings and 3D models to be viewed without CAD software. At the end of this unit, future trends will be discussed. In some industries today, digital design models already serve as the primary description of parts.

How Prints Are Made

Today, most drawings are produced using a CAD system, **Figure 1-3**. If needed, a hardcopy of the drawing is plotted with a laser or inkjet printer or a pen- or cartridge-based ***plotter***. See **Figure 1-4**. Originally, the term *plotter* indicated a vector-based

Chuck Rausin/Shutterstock.com

Figure 1-3. Most original drawings are now produced using a computer-aided drafting (CAD) system.

DesignJet Division, Hewlett-Packard

Figure 1-4. Hard copies are generated from a CAD system using an output device, such as this cartridge-based plotter.

output device that physically drew lines with pens, but today most plotters use an ink-cartridge system. The images are actually transferred to the paper as a raster image. The paper is roll-fed into the machine. A ***raster image*** is composed of tiny pixels or dots. Under high magnification you can see the dots, but the quality is more than adequate for industrial prints.

In some companies, approved originals may still be produced and filed. Prints can be made by authorized personnel using a photocopier. In other companies, approved originals may only exist in a protected directory of the computer network. Prints can be sent to output devices by authorized personnel.

Print Reading

Print reading is the process of analyzing a print to obtain information. This task involves two principal elements—visualization and interpretation. ***Visualization*** is the ability to envision or "see" the shape of the object from the various views shown on a print. See **Figure 1-5**. Every view created by the drafter or designer is based on a projection of the object onto a two-dimensional plane, such as a sheet of paper or a computer screen. Learning the principles of projection will help the reader gain the ability to visualize objects from the views shown on a print. The interpretation of lines, symbols, dimensions, notes, and other information on a print is also an important factor in print reading. These factors are presented in this text. Actual industrial prints are provided in this text so you can learn print reading on "real-life" drawings.

Care of Prints

Prints are valuable records of information. When working with prints, you should observe the following rules:

- Never write on a print unless you have been authorized to make changes.
- Keep prints clean, especially free of oil and dirt. Soiled prints are difficult to read and contribute to errors.
- If working with prints that are stored in filing cabinets, very carefully fold and unfold prints to avoid tearing.
- Do not lay sharp tools, machine parts, or similar objects on top of prints.

If the drawing border and title block conform to industry standards, the prints can be folded with the title block showing. A second print number is usually visible when stored in a drawer folder, **Figure 1-6**. In many companies, prints are easily accessed from a print control area or engineering department. In most organizations, tight control is maintained over all prints. This helps ensure the most-recent revision is always used. With CAD

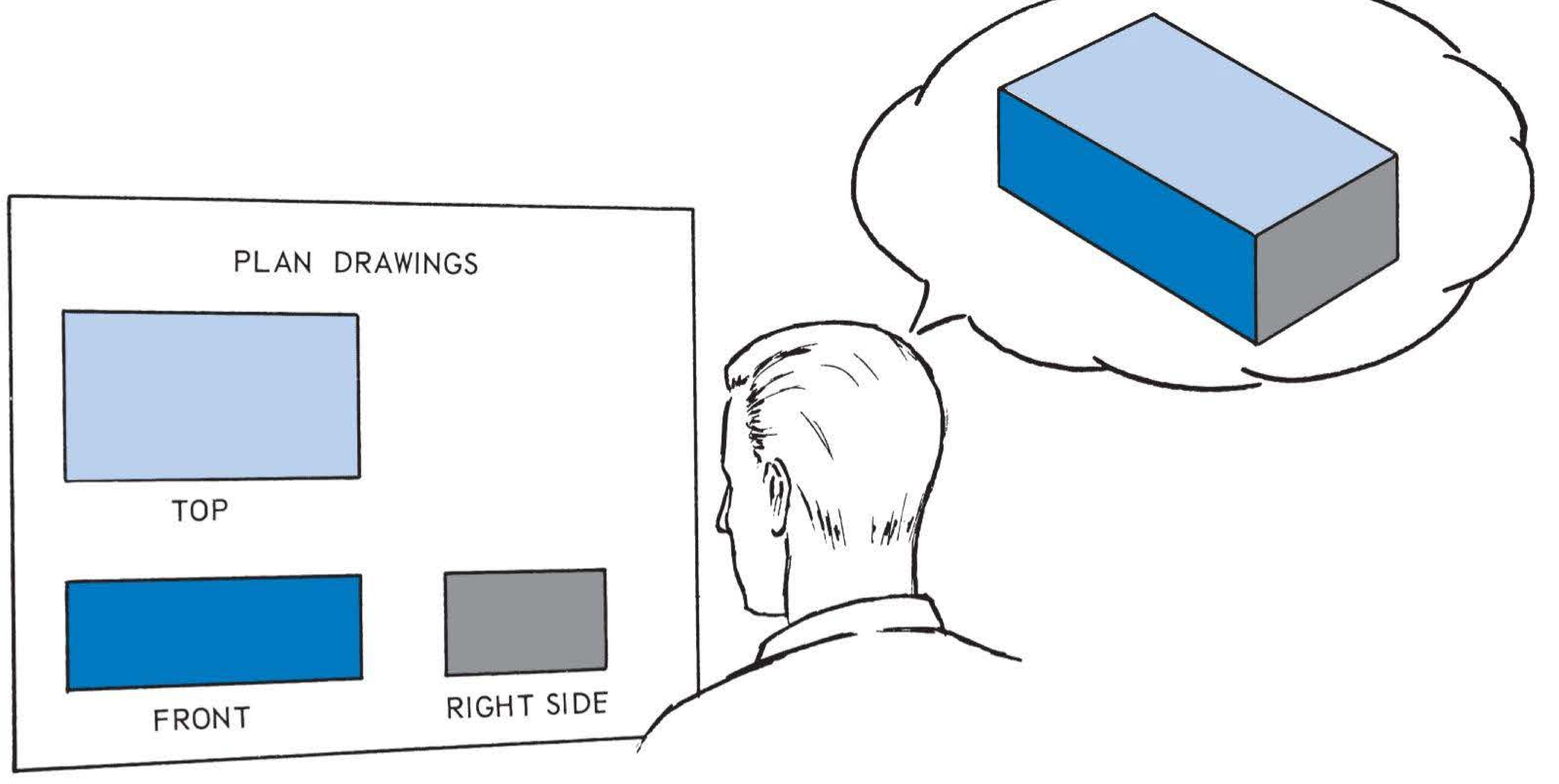

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Figure 1-5. Visualization is the ability to "see" the shape of an object from the various views shown on a print.

drawings, protected or "read-only" drawing files may be available through a company computer network. This allows the design and manufacturing teams to make their own prints as needed or to view the design on a computer screen.

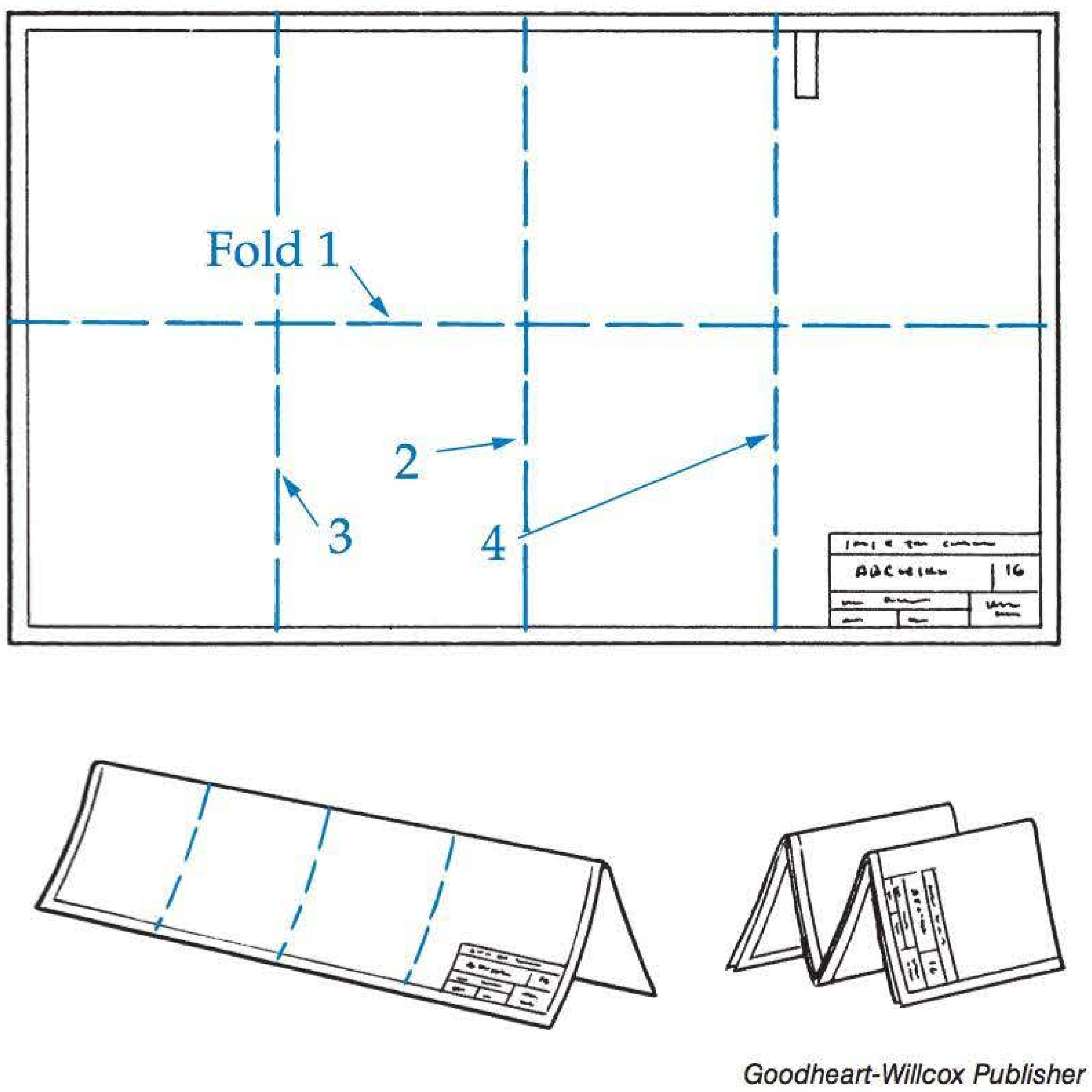

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Figure 1-6. If paper prints are filed in a file folder, larger prints should be folded in such a way as to keep the title block showing.

Electronic Formats for Drawings

In recent years, digital file formats have become available that enhance the ability to electronically share prints without jeopardizing or supplying the actual CAD data. The most common electronic format is the ***portable document format (PDF)***, developed by Adobe Systems, the parent company of Adobe Acrobat® and Adobe Reader® software. Most CAD software programs provide tools for exporting files to PDF format.

The PDF format was originally designed to allow users to easily share printable documents regardless of computer platform (Windows®, Macintosh®, etc.). The PDF format includes many useful features, such as the ability to combine multiple sheets into one file, mark up and review documents, preserve CAD layer structures, and add password and duplication protection. Depending on the type of CAD software used, PDF files can be generated in 2D or 3D format. A 3D PDF created from a 3D model includes zooming, panning, shading, and rendering functions, as well as "orbiting" functions for dynamically rotating the model, **Figure 1-7**.

In 2008, Adobe opened the door for the PDF standard to be published and controlled by the ***International Organization for Standardization (ISO)*** as ISO 32000-1. The ISO is responsible for

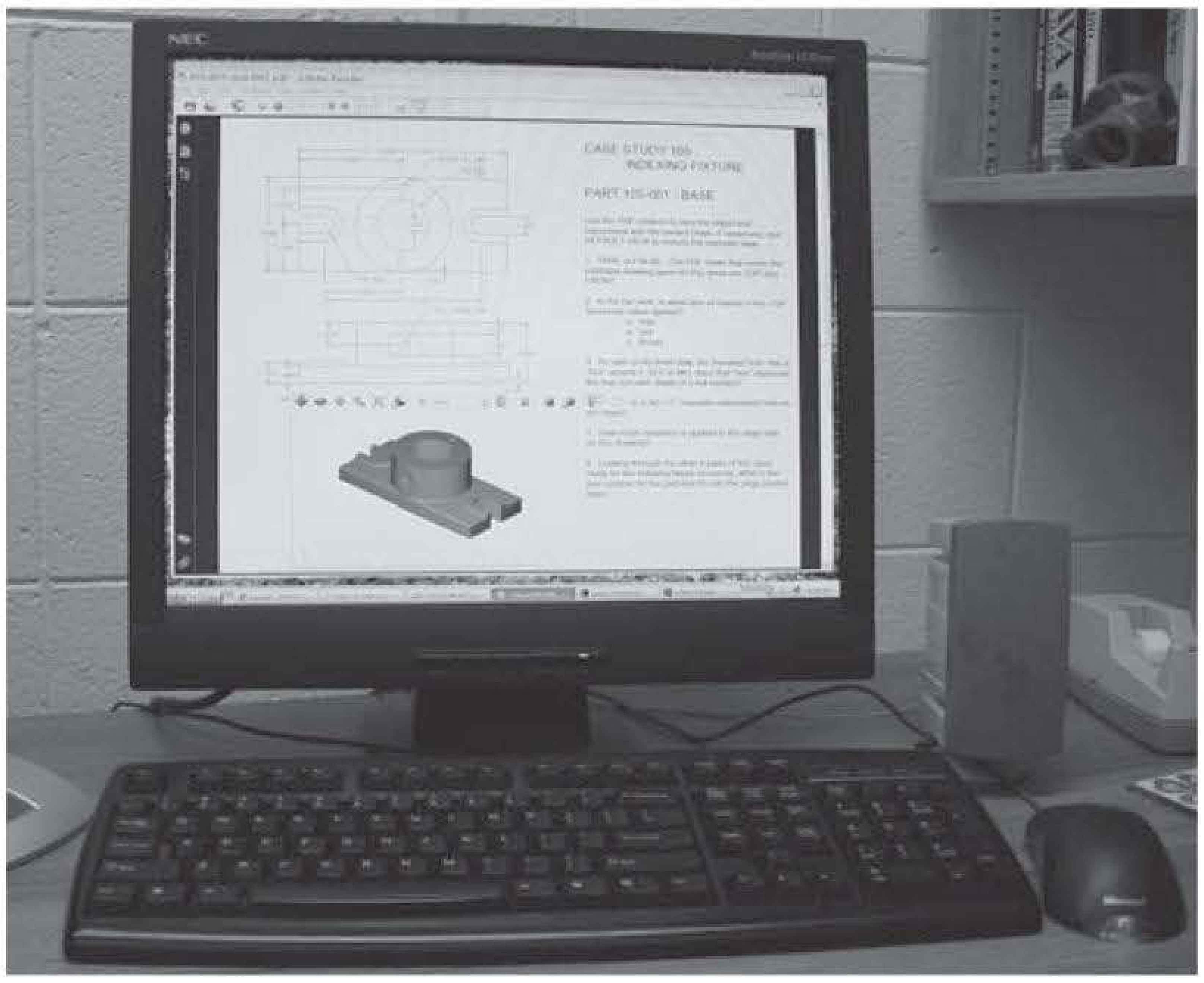

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Figure 1-7. This PDF file can be viewed on a computer screen with zoom, pan, and turn-and-tilt (3D orbit) capabilities.

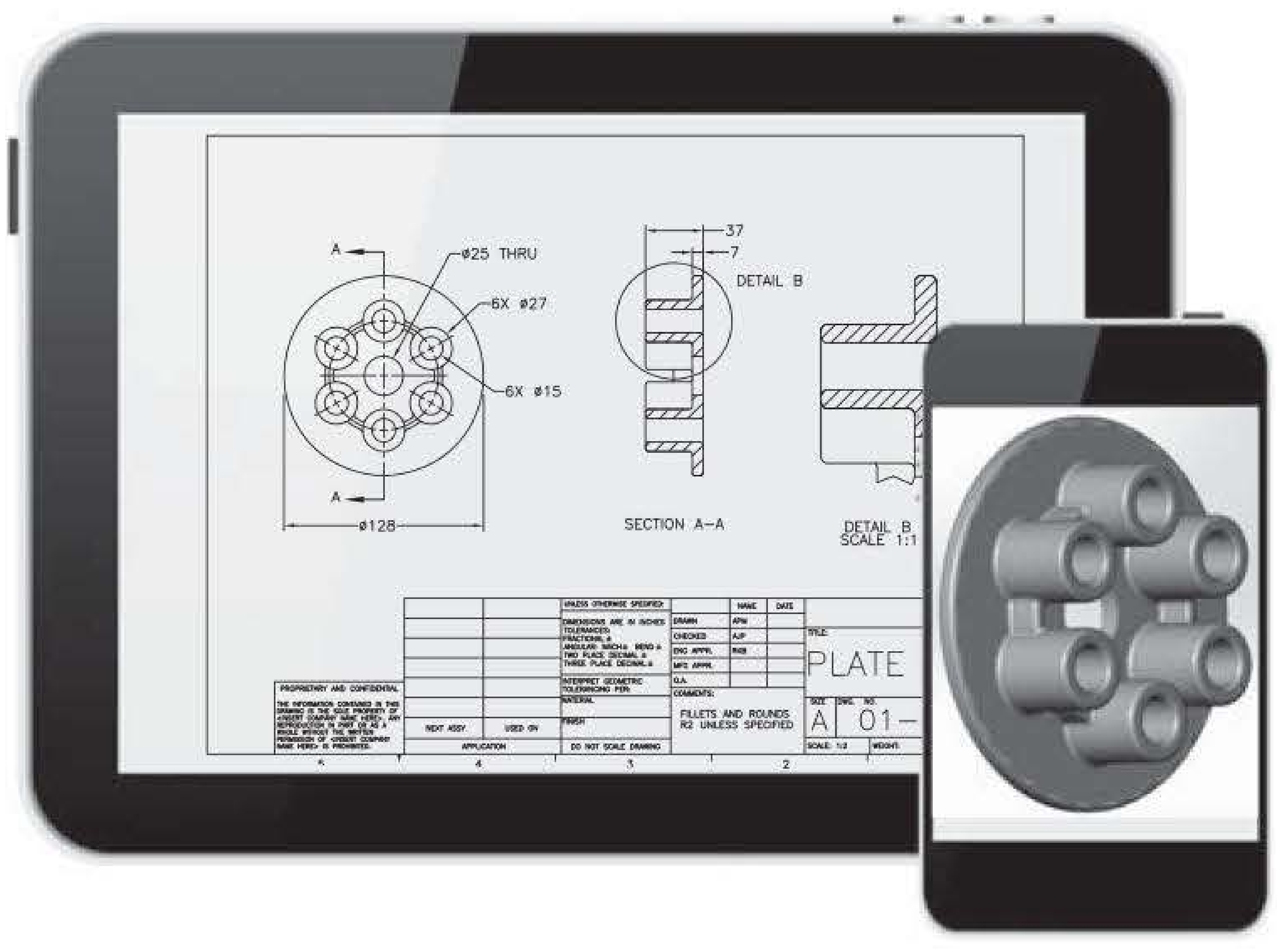
establishing and publishing manufacturing standards worldwide. In short, the PDF format is now the predominant method of creating and sharing electronic documents.

Another common electronic format is the ***design web format (DWF)*** developed by Autodesk, parent company of several CAD programs, including AutoCAD® and Inventor®. The format was originally designed to allow AutoCAD® drawings to be published in a web-based format, but has evolved into a primary means, within the Autodesk product line, of creating documents that are similar to PDFs in purpose. The DWF format is not intended to replace the drawing (DWG) file format, but allows team members such as designers, project managers, and engineers to share design data without every user having to own the CAD software.

Viewer programs enable users to open, view, and print files in different formats. Most viewer programs are available as free downloads. Viewer programs typically provide tools for mark up, review, and comment tracking. Viewer programs allow drawings and "prints" to be viewed on personal devices such as smartphones and tablets, **Figure 1-8**.

Standards for Engineering Drawings

Almost every aspect of an engineering drawing can be conformed to an established standard. By definition, a ***standard*** is a voluntary guideline. Companies can elect to have their own supplemental



Chukcha/Shutterstock.com; Goodheart-Willcox Publisher

Figure 1-8. Smartphones and tablets can view 2D drawings and 3D models in electronic formats using a variety of apps.

standards. While voluntary, standards are often incorporated into regulations and business contracts between manufacturers and their subcontractors and suppliers.

In the United States, the standardization of engineering drawings, including most aspects of prints covered within this text, has long been established through the ***American Society of Mechanical Engineers (ASME)***, **Figure 1-9**. This is an independent, not-for-profit organization that, for decades, has defined standards for engineering drawings. On the cover of an ASME booklet, it states it is "An American National Standard."

Prior to 1994, however, the standards were identified by the American National Standards Institute (ANSI) document numbers, even though

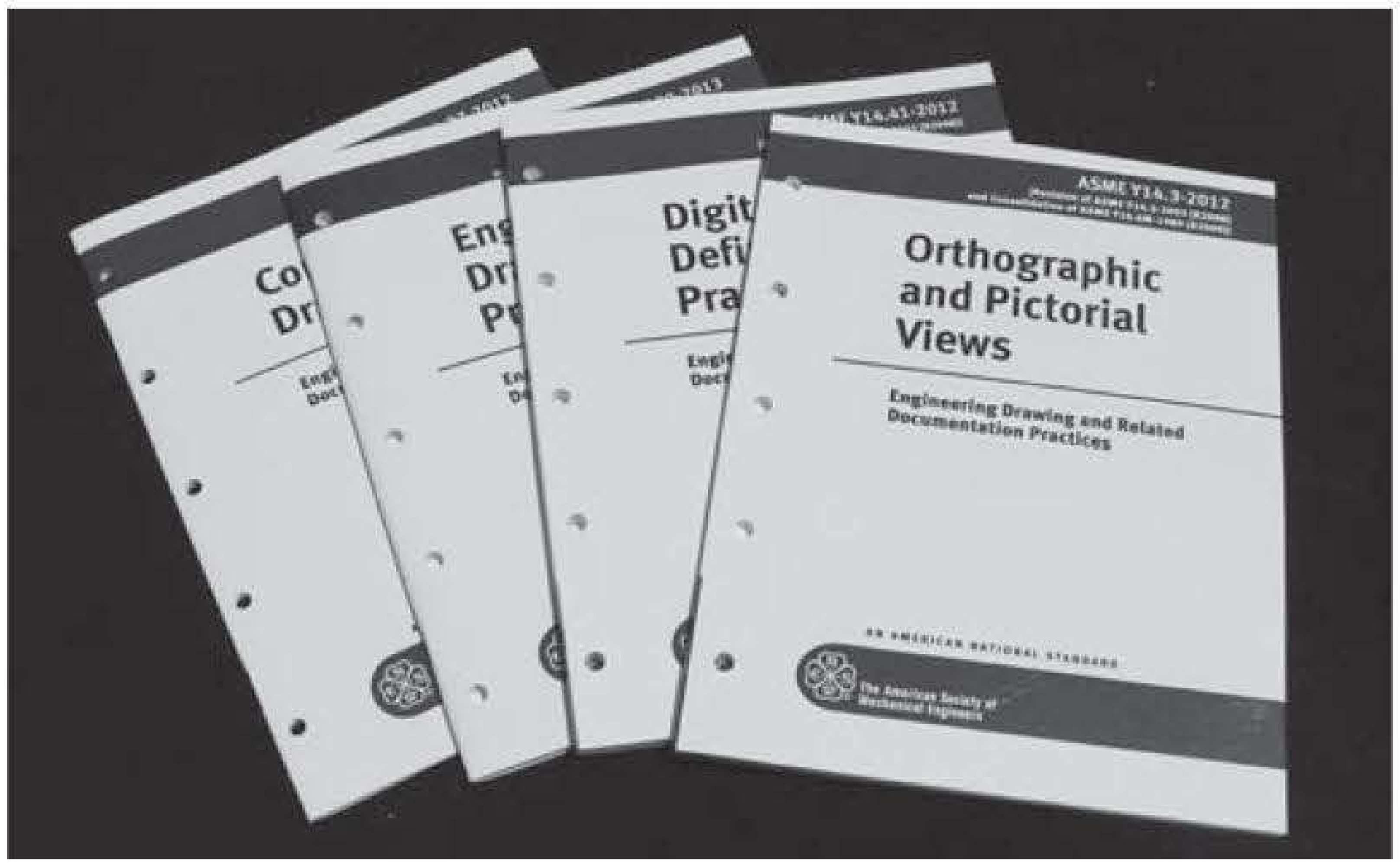


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Figure 1-9. The American Society of Mechanical Engineers (ASME) oversees and publishes standards for engineering drawings.

they were published by ASME. For example, the document entitled *Multi and Sectional View Drawings* was identified as ANSI Y14.3-1975. Currently, that document is identified as ASME Y14.3-2012 and is entitled *Orthographic and Pictorial Views*.

ANSI is the umbrella organization that serves as an overseeing body and is still relevant, but publications are now purchased through ASME, either in paper or protected PDF format. Throughout this text, you will become familiar with some of the ASME standard publications that impact various aspects of print reading. **Figure 1-10** lists a few of the standards most relevant to this text.

For companies with an international presence and product line, the ISO standards may be the more appropriate set of practices. For example, ISO 128-1:2003 is entitled *Technical drawings—General principles of presentation—Part 1: Introduction and index* and ISO 5456-2:1996 is entitled *Technical drawings—Projection methods—Part 2: Orthographic representations*. These standards are a major investment for engineering departments, but necessary for success in the twenty-first century.

The general purpose and scope of this text is focused on industrial prints that follow ASME standard practices, both current and recent. It is important to reiterate that not all companies follow all ASME guidelines, sometimes intentionally and sometimes unintentionally. As feasible, this text will identify situations on the "real" exercise prints in the text with respect to their deviation from current ASME standard practice.

ASME Standards	
Y14.1	Decimal Inch Drawing Sheet Size and Format
Y14.1M	Metric Drawing Sheet Size and Format
Y14.2	Line Conventions and Lettering
Y14.3	Orthographic and Pictorial Views
Y14.5	Dimensioning and Tolerancing
Y14.6	Screw Thread Representation
Y14.8	Castings, Forgings, and Molded Parts
Y14.13	Mechanical Spring Representation
Y14.24	Types and Applications of Engineering Drawings
Y14.31	Undimensioned Drawings
Y14.34	Associated Lists
Y14.35	Revision of Engineering Drawings and Associated Documents
Y14.36	Surface Texture Symbols
Y14.37	Composite Part Drawings
Y14.38	Abbreviations and Acronyms for Use on Drawings and Related Documents
Y14.41	Digital Product Definition Data Practices
Y14.100	Engineering Drawing Practices

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Figure 1-10. ASME standards related to *Print Reading for Industry*.

Engineering Drawings and the Design Process

While twenty-first century design processes have been complemented by a new set of computer-based tools, the actual steps of the ***design process*** are not that different from a century ago. In general, to bring an idea to market or to improve a current product, the design process, as illustrated in **Figure 1-11**, happens in the following five steps, with a cycling or looping between the steps:

1. Statement of the problem.
2. Generate possible solutions.
3. Refine promising solutions.
4. Testing and analysis.
5. Implementation.

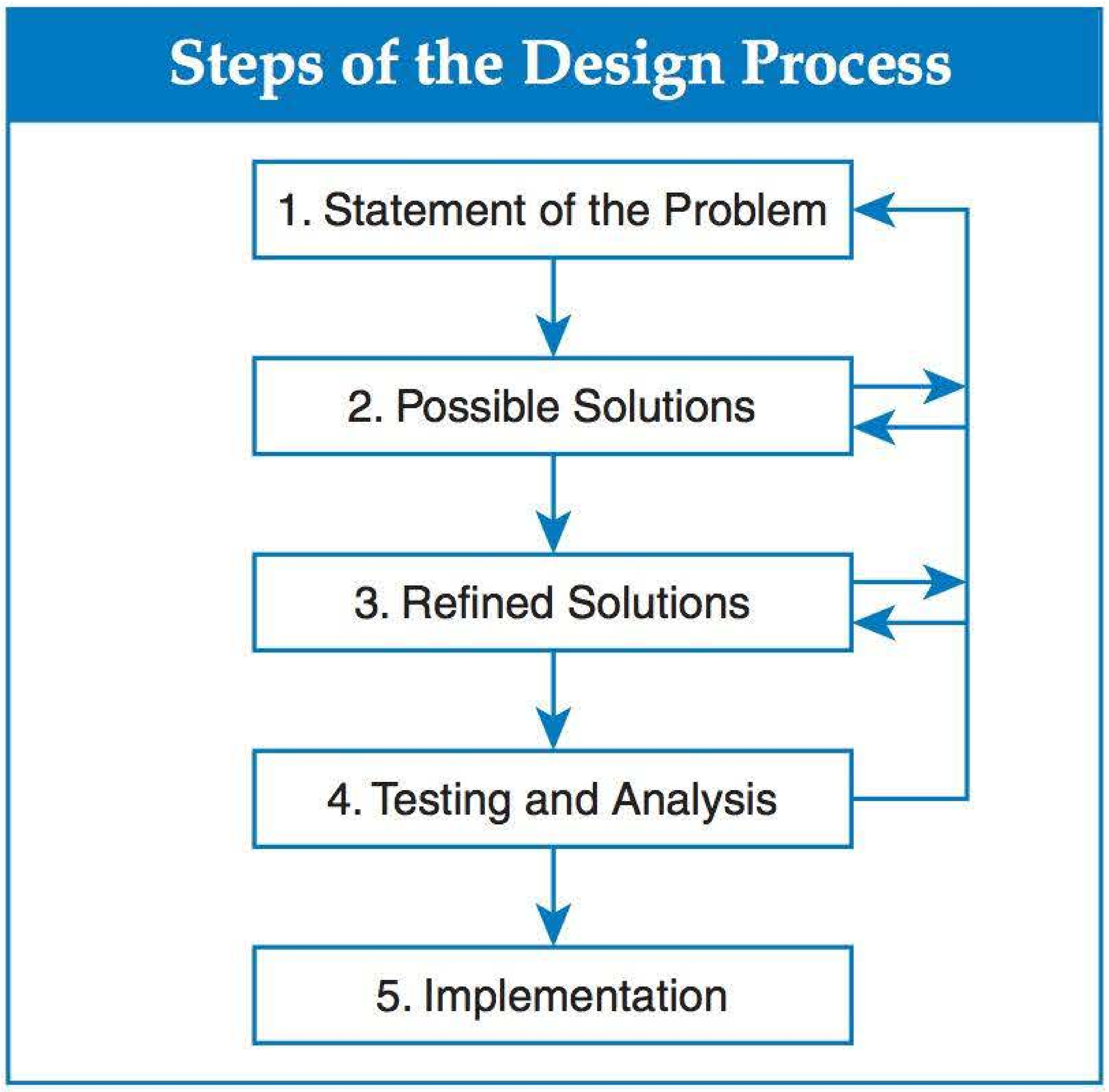

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Figure 1-11. The design process involves a number of steps, and includes a looping strategy until a successful solution is reached.

Step 1 is to define the problem. This usually involves identifying a problem statement. This statement could be very general, such as identifying a need for "a better scooter," or more specific, such as the desire to "profitably market a low-cost, plastic, one-piece scooter stand for small-wheel scooters."

After the problem statement is established, Step 2 is to generate possible solutions. Step 2 may incorporate brainstorming sessions, researching current products, and creating sketches to help communicate possible solutions. These sketches and drawings also help document the dates and creative thoughts for future patents. Even at this stage, an understanding of many topics covered by this text can aid in the design process. Understanding spatial dimensions, geometric constructions, and how to use a combination of front, top, and pictorial views can all aid the design team in discovering solutions.

Step 3 involves refining promising solutions. At this stage, sketches may be recreated in a CAD program as precise geometric drawings, either as 2D views or 3D models. An analysis of the strengths and weaknesses of all the possible ideas, as well as visual and aesthetic opinions, may lead to necessary compromises. The results of Step 3 may suggest a return back to Step 2 or even Step 1.

Step 4 involves testing and analysis. The design team will build prototypes or create a virtual model in a 3D CAD program. ***Rapid prototyping*** technologies have made it possible to generate prototypes of parts directly from a 3D CAD model without the need for preliminary drawings, **Figure 1-12**. Current 3D modeling software enables the design team to test more ideas, try more variations of shapes and proportions, check for fits and interferences, and conduct strength tests of the component parts. Drawings and prints may or may not be needed at this stage, but can help communicate design intent to the modelmakers and machinists. As with each previous step, depending on the test results, a decision may be made to loop back to a previous step.

The final step, Step 5, can be broadly described as the implementation step. This involves communicating the results to those who will get the product to market. In many cases, this is the step that includes the production of drawings or prints—contract documents that specify much of the information required to manufacture the part. In addition to production drawings, other materials need to be developed, including assembly and operating instructions, specifications, maintenance diagrams, and marketing materials.

Additive Manufacturing and Prints

As discussed in the previous section, rapid prototyping has impacted the role of drawings in the design process, especially the middle stages.

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Figure 1-12. The original product on the left was redesigned and the plastic prototype in the center was generated directly from a CAD file. Although prints were not given to a modelmaker, drawings and sketches were useful in the design process. The prototype facilitated assembly, function, and comfort factor testing. The new molded plastic part is on the right.

In almost all cases, rapid prototyping technologies build parts by adding material in a series of layers, giving rise to the term ***additive manufacturing***. While many processes create a part by subtracting materials, such as drilling a hole or milling a surface, additive manufacturing technologies are based on adding material to the model layer by layer. The resemblance of some additive manufacturing technologies to inkjet printing led to the coining of the term ***3D printing***, **Figure 1-13**.

While rapid prototyping technologies originally created parts from plastic or thin layers of paper that could only function as prototypes, new and different technologies have evolved. Some additive manufacturing technologies can melt, or ***sinter***, metal powder into solid parts. As the processes improved, parts made of plastic and metal proved to be quite functional, and not merely prototypes. Small quantities of parts, as well as special-ordered parts, could be built directly from a CAD model. ***Rapid manufacturing*** is the application of additive manufacturing technologies to the full-scale production of parts and products.

Future developments in additive manufacturing may bring further changes in how prints are used. There are some applications wherein official "prints" or "drawings" will not be needed, at least not in the same role of describing a part to a modelmaker or machinist. Even the final step of creating a set of working drawings before the product is mass-produced and brought to market is changing. As technologies continue to develop, the role of prints and drawings will continue to be impacted in a variety of ways.

Monkey Business Images/Shutterstock.com

Figure 1-13. Desktop 3D printers can create plastic prototypes directly from a CAD file. The same technology can also create functioning parts for certain applications.

Trends in Engineering Drawing

Newer forms of model documentation and data management are emerging to meet the requirements of modern manufacturing processes. In addition to providing the data included in sophisticated 3D CAD models, ***computer-aided engineering (CAE)*** programs are generating data about manufacturing processes and the properties of parts. Examples of CAE processes include finite element analysis (FEA) for strength analysis, tool path generation software for creating CNC machine tool procedures, and mold flow simulation software, which simulates how well liquid materials fill a mold. This data also assists with managing and sharing a more complete description of a part and its history. Product data management (PDM) software helps manage all of this electronic data, and facilitates processing review, revision, and inventory management tasks electronically.

In response to industry demands to incorporate electronic data into the manufacturing process, the ASME Y14.41 *Digital Product Definition Data Practices* standard was developed. This standard establishes practices for communicating design intent and other pertinent information with digital data. A ***product definition data set*** is the total collection of information required to completely define a component part or an assembly of parts, **Figure 1-14**. These data sets can completely define a product for the purpose of design function and analysis, as well as functional test results, manufacturing procedures or tool paths, and inspection data.

The ASME Y14.41 standard addresses two methods of preparing a product definition data set. In the ***model only method***, annotations (such as dimensions, tolerances, and notes) are directly attached to an individual model file. The model in this context is a combination of the design model, annotations, and attributes that describe a product. When using this method, a drawing graphic sheet is not required. The ***model and drawing method*** allows for a hybrid approach to describing a part or assembly. The drawing graphic sheet requires and incorporates the ASME Y14.1 standard specifications for a border line and title block, and allows for 2D geometric views in accordance with other ASME standards. Annotations such as notes and dimensions can still be attached to the model or the graphic sheet, and must still conform to other ASME standards, in line with current practices. As conceived, the ASME Y14.41 standard will enable model geometry, associated lists, materials, finishes, processes, notes, and analytical data to join a drawing graphic sheet as a means of communication within the manufacturing industry, serving the same role as a print.

This is not to suggest that drawings or print reading will no longer be needed. The concepts discussed in the units to follow will continue to be important to the overall design process and the role of prints as a key communication tool of industry will continue to evolve. Blueprints and whiteprints may no longer be used today, but the principles associated with those prints remain relevant. As John W. Gardner, former US Secretary of Health, Education, and Welfare, once said, "History never looks like history when you are living through it."

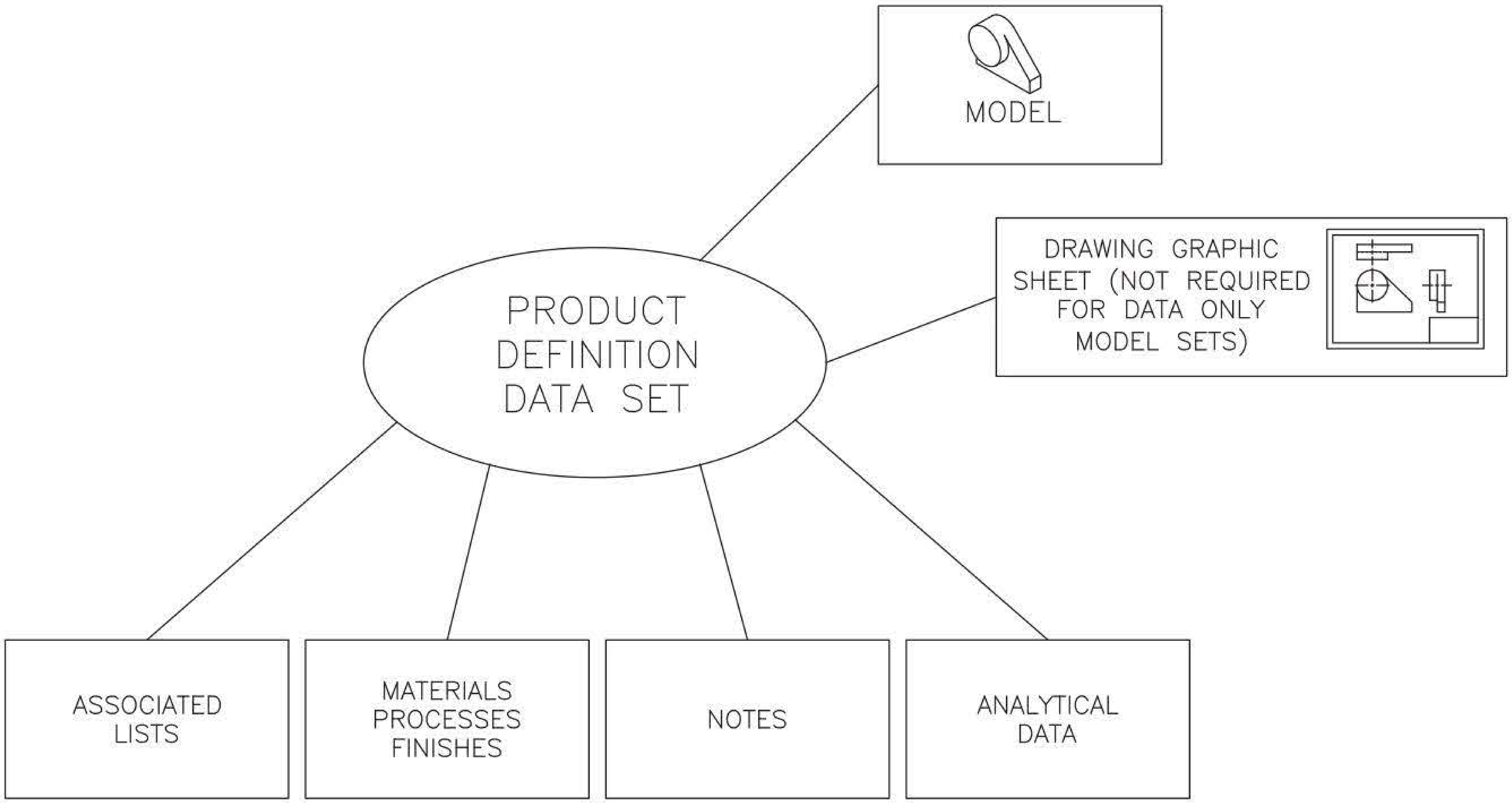

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Figure 1-14. Potential contents of a product definition data set.

Name ______________________ Date ____________ Class ______________

Review Questions

Answer the following questions using the information provided in this unit.

__________ 1. A print can simply be defined as a(n) _____ of a drawing.

__________ 2. *True or False?* Prints are often an important part of a contractual agreement.

__________ 3. The study of print reading is closely related to the study of _____.

A. measurements
B. drafting
C. machining
D. art

4. Briefly explain why *prints* are sometimes called *blueprints*.

____

____

5. List two sheet materials that have been primary media for original drawings.

____

____

6. What name is often applied to a large, roll-fed output device for a CAD system?

____

7. List the two principal elements of print reading.

____

____

__________ 8. *True or False?* Every view created by the drafter or designer is based on a projection.

__________ 9. What does PDF stand for?

A. Printable Document Format.
B. Plotted Drawing File.
C. Portable Document Format.
D. Print Detail Freehand.

10. Expand the acronym and briefly describe the DWF file format.

____

11. Expand the acronym and briefly describe the DWG file format.

____

Name ______________________________ Date _____________ Class ________________

12. What does ASME stand for, and what is its purpose?

____

____

____

_______________ 13. Which of the following is *not* a recognized engineering drawing standard?
   A. ANSI.
   B. ADSN.
   C. ISO.
   D. ASME.

14. List the five steps of the design process.

Step 1: ____

Step 2: ____

Step 3: ____

Step 4: ____

Step 5: ____

_______________ 15. Rapid prototyping technologies are also known as _____ manufacturing processes.

_______________ 16. Machining operations, such as milling and drilling, are _____ processes.

_______________ 17. *True or False?* Even with product definition data sets, print reading skills will still be important.

Unit 2

Line Conventions and Lettering

Learning Objectives

After completing this unit, you will be able to:

- ❑ **Identify** the standard alphabet of lines.
- ❑ **Describe** the types of lines by appearance and purpose.
- ❑ **Identify** the style of lettering recommended for standard industrial drawings.

Technical Terms

alphabet of lines
break line
center line
chain line
convention
cutting-plane line
dimension
dimension line
extension line
hidden line
leader line
lettering
phantom line
section line
stitch line
symmetry line
viewing-plane line
visible line

By definition, a ***convention*** is a generally accepted way of doing something. Before computers, prints were created by drafters with pencils and pens, and lettering was primarily a freehand craft. Lines were made with lead pencils and the ability to create a line of an exact width was a skill that took time to develop. The ASME Y14.2 *Line Conventions and Lettering* standard sets forth the recommended appearance of lines, although in our current age of computers the guidelines no longer specify dash length and line width as precisely as in years past. Because drawings can easily be printed at a variety of scales and sizes, there is more flexibility today.

Alphabet of Lines

There are several types of lines commonly used in engineering drawings, depending on the field of study. The current ASME standard illustrates these and identifies each by name. On some occasions, more than one option for the appearance of the line is given. Each line has a particular meaning to an engineer, designer, or drafter. A skilled technician must recognize and understand the meanings of these lines in order to correctly interpret an industrial print used in the manufacturing environment.

The list of line types, defined in many references as the ***alphabet of lines***, is used throughout industry. See **Figure 2-1**. Each line has a definite form or dash pattern and a standard line weight (width). In older standards, three line weights were recommended—thin, medium, and thick. Current standards recommend two line weights—thick and thin. The standard thick line is recommended to be 0.6 mm in width. The standard thin line is recommended to be 0.3 mm in width. Of course, these lines may vary depending on the size of the drawing and whether or not the drawing is photographically reduced or enlarged. In all cases, however, the thin-to-thick ratio should remain 1:2. In most cases, CAD programs can be configured to print drawings at any size or scale while maintaining any desired line thickness. It is important to note that thinner lines should not be lighter. All linework should be black.

Be aware, many drawings throughout the years have been produced without attention to standard line weight. Many of the early CAD systems could not easily print variations in line weight. This often created a drawing that was harder to read

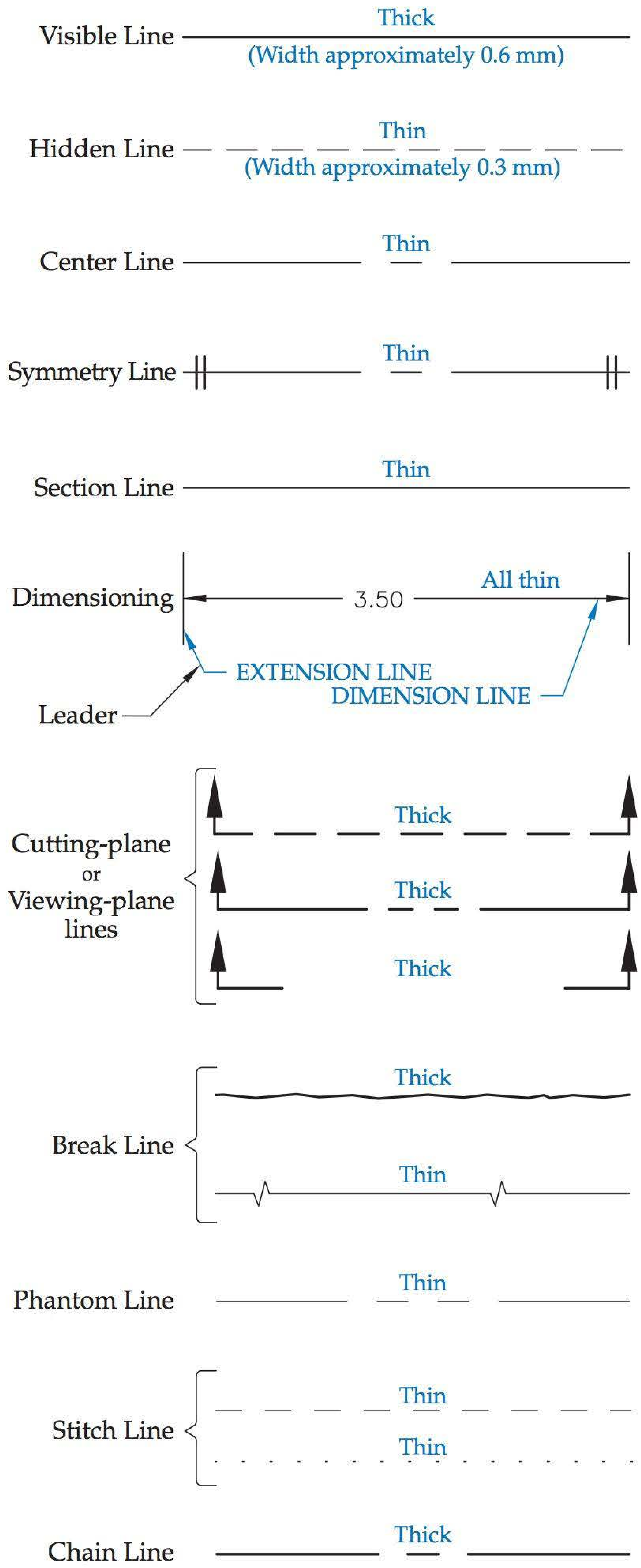

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Figure 2-1. The alphabet of lines is a standardized list of lines from which the drafter can choose. Each line has a definite form or pattern, and an intended purpose and meaning.

and interpret. Within your company, you have the opportunity to be the champion for conformance to industry standards, thus promoting drawings that "speak with the proper language."

Lines in a drawing convey information essential to understanding the print. Therefore, to understand the print, you must know and understand the alphabet of lines. Refer to **Figures 2-1** and **2-2** as you read the remainder of this unit.

Primary View Lines

Of primary importance to the print reader are the three lines in the alphabet that are used in multiview drawings. Discussed in Unit 5, multiview drawings are characterized by a set of views. Within each view, many features may be hidden, while other features may be curved or symmetrical.

Of utmost importance is the ***visible line***. This is a thick, continuous line representing all of the edges and surfaces of an object that are visible in the view, **Figure 2-3**. These lines should be twice as thick as the thin lines of the view. Visible lines give the print reader the shape description of the object. Many books and drafting teachers have also referred to visible lines as object lines.

Another line that is especially important in the multiview drawing is the ***hidden line***. This is a line that features thin, short dashes spaced closely together. Earlier standards recommended the dashes be about 1/8" long and spaced approximately 1/32" apart. Hidden lines are used to show

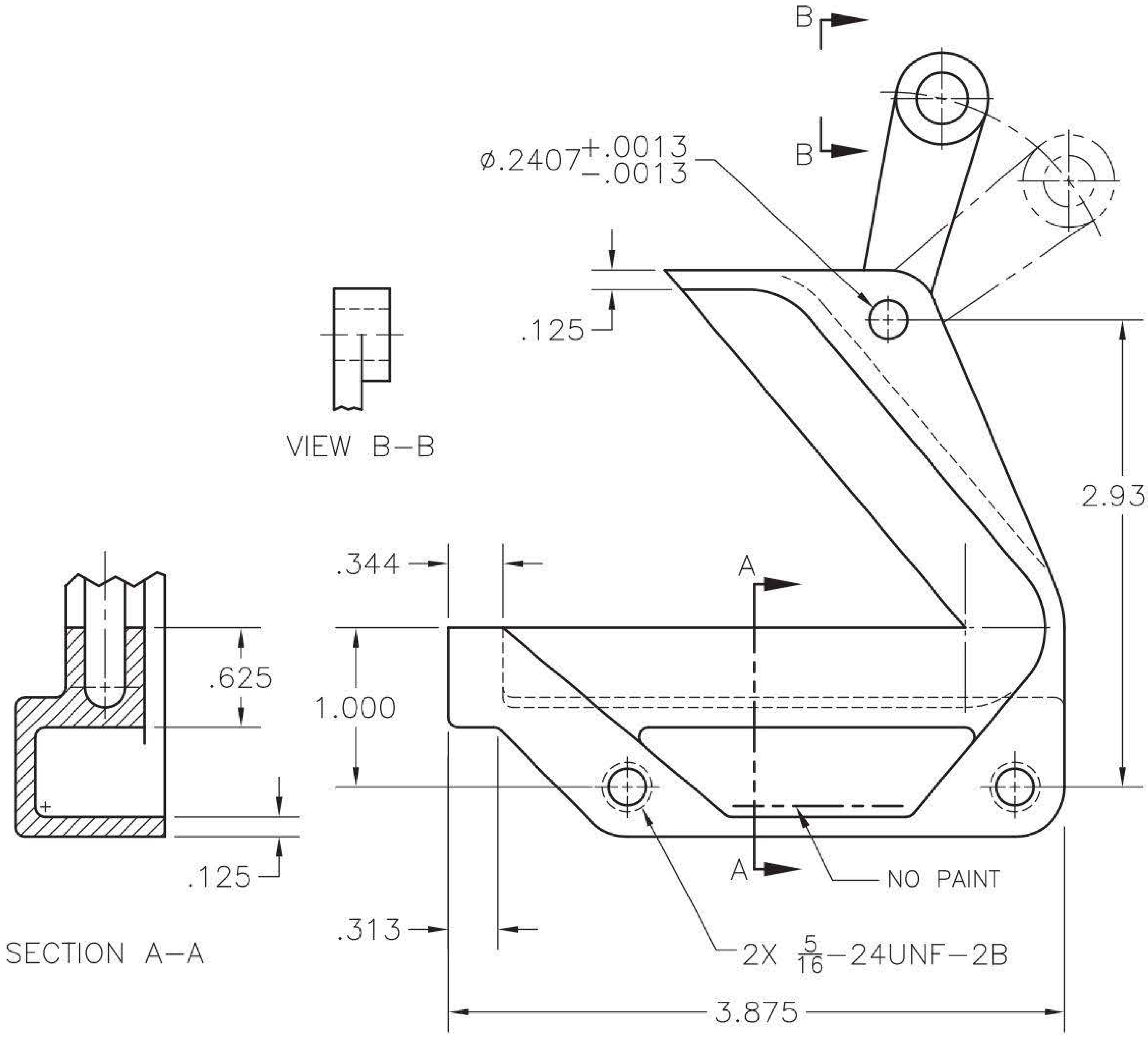

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Figure 2-2. This drawing features visible lines, hidden lines, center lines, phantom lines, section lines, a cutting-plane line, a viewing-plane line, dimension lines, extension lines, leader lines, and a chain line. Can you find all of them?

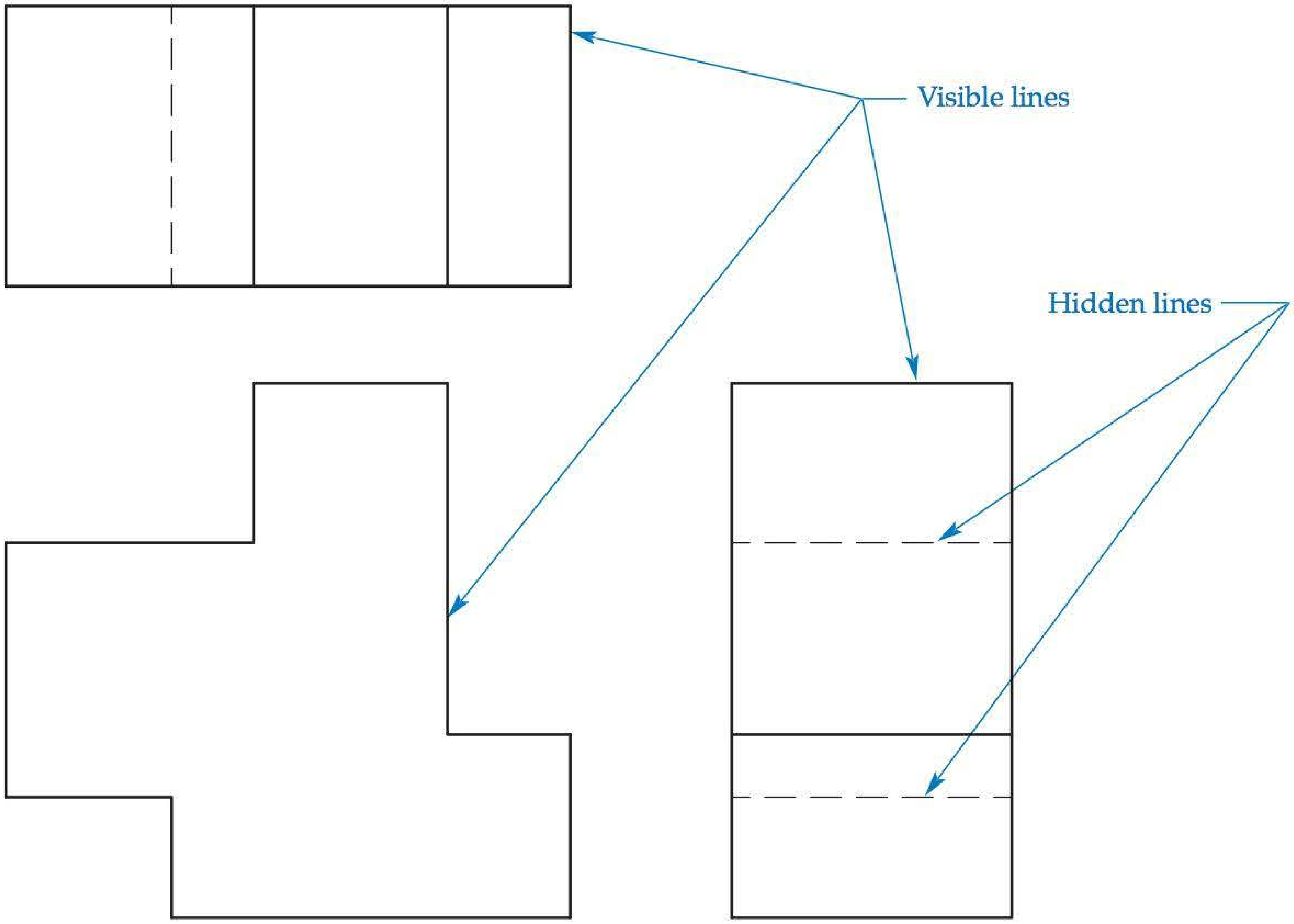

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Figure 2-3. A visible line is a thick, continuous line representing all edges and surfaces on an object visible in the view, while hidden lines represent hidden features.

edges, surfaces, and features not visible in a particular view, **Figure 2-3**. Hidden lines are used to clarify a drawing. Sometimes, hidden lines are omitted on complex views when the drawing is clear without them. On older drawings, these lines may have been created with a medium weight.

The third type of line especially important in the multiview drawing is the ***center line***. This is a thin line with alternating long and short dashes used to designate centers of holes, arcs, and other symmetrical features, **Figure 2-4**. In a circular view, two center lines are used and should form a "plus" in the center of the circle. Some CAD programs do not, by default, show center lines crossing in the center of a circle quite as well as drawings drawn by hand. In these cases, the drafter should adjust the scale of the center line so the short dashes make a plus. Center lines are also used to indicate paths of motion, as shown in **Figure 2-2**. In addition, on some drawings, only one side of a part is drawn and a symbol is placed on each end of the center line to indicate the other side is symmetrical (identical in dimension and shape). When these symbols are added to the center line, the line can be called a ***symmetry line***.

Section View Lines

Some lines are used primarily in section view drawings, which are discussed in Unit 6. Section views are views that show the object as if it has been cut through. Additional conventions are needed to express these views on a drawing.

For surfaces that are assumed to be cut, ***section lines*** are used. These are thin, continuous lines usually drawn at an angle, most commonly 45°. Section lines indicate the surface of an object in a section view that was "cut" by a "cutting plane." Sometimes, section lines have dashes to indicate a particular material. General purpose section lining is the same as the cast iron pattern shown in **Figure 2-5**. This type of section lining is commonly used for other materials in section unless the drafter or designer wants to indicate the specific material. Some CAD programs refer to a section-lined area as hatching or cross-hatching.

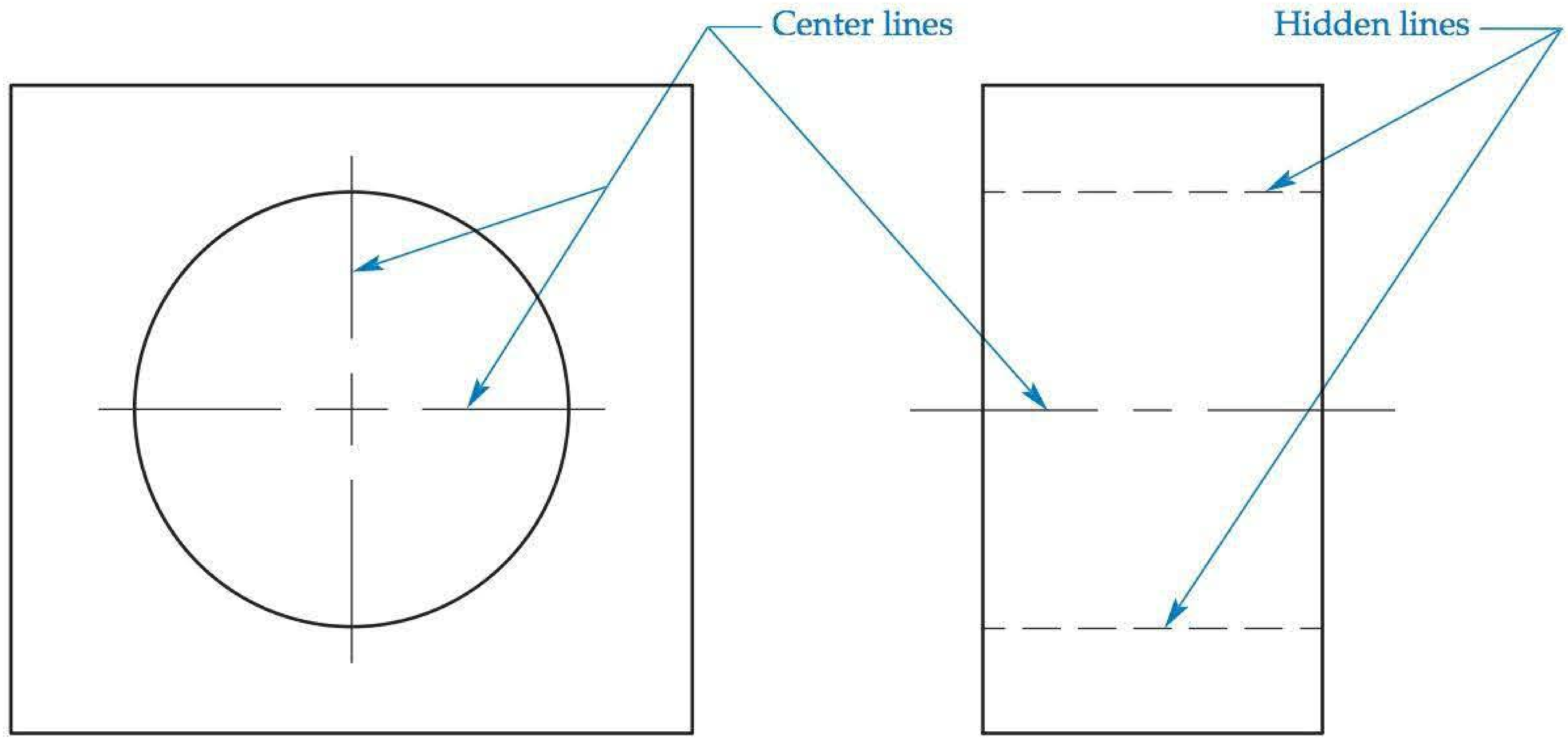

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Figure 2-4. Center lines are thin lines with alternating long and short dashes. They designate centers of holes, arcs, and other symmetrical objects.

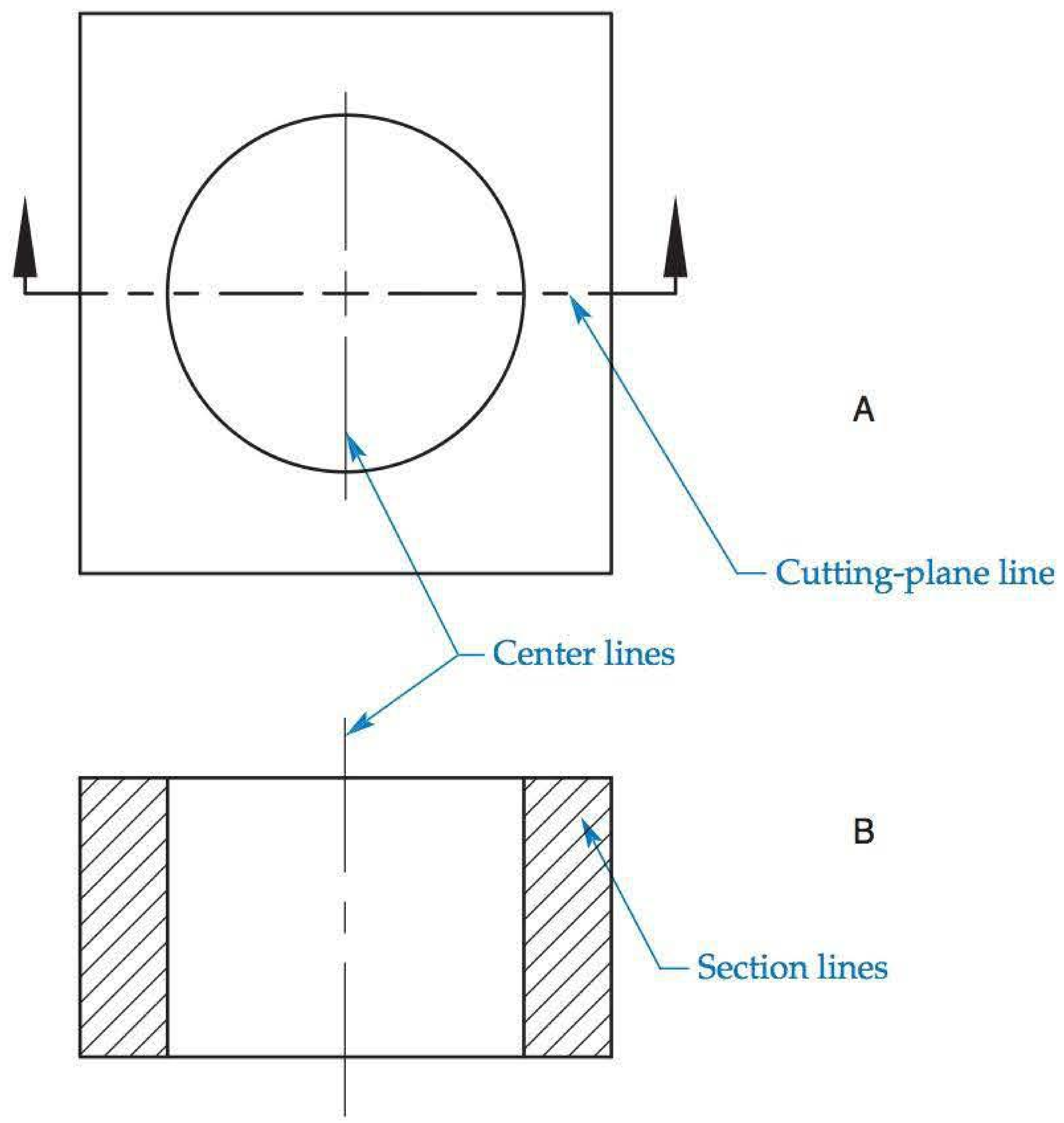

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Figure 2-5. Cutting-plane lines can be made in different ways, but the method indicated in A is common. Section lines, shown in B, are thin, continuous lines usually drawn at 45° and about 1/8″ apart.

For section view drawings, a ***cutting-plane line*** can be shown on the view adjacent to the section view to help the print reader know where the "cut" is made. The cutting-plane line should be a thick, dashed line. It usually terminates in a short line at 90° to the cutting plane with arrowheads in the direction of sight for viewing the section. Letters may be used to indicate the section.

There are currently three different choices for the drafter when creating a cutting-plane line. Refer to **Figure 2-1**. The most common cutting-plane line features a long dash and then two short dashes. Another version represented in the standard is a series of medium-size dashes, about twice as long as hidden line dashes. The current standard also allows for two "elbows" with identifying labels and arrows. In any case, the lines should be the same thickness as visible lines.

Dimensioning Lines

While the visible, hidden, and center lines are used to create the shape description of an object, the size description of an object is indicated in annotations known as ***dimensions***. Dimensions are composed of a variety of lines, all drawn without dashes and all with a thin line weight. Dimensioning is discussed in Unit 9.

The lines that extend the edges of the object out away from the view are called ***extension lines***, **Figure 2-6**. Some books, references, and CAD systems refer to these as witness lines. The purpose of the extension lines is to keep the dimensional annotation away from the shape description. Extension lines begin about 1/16" away from the object's visible corners and extend about 1/8" beyond the arrows of the dimension line.

Between the extension lines are ***dimension lines***, which indicate the extent and direction of part dimensions, **Figure 2-6**. In most engineering drawings, the dimension line is broken in the middle for the dimensional value. Dimension lines are usually terminated by arrowheads against extension lines. Dimensioning methods are becoming more diverse in industrial applications, including arrowless coordinate dimensioning and geometric dimensioning and tolerancing. These topics are discussed in later units.

In dimensioning, ***leader lines***, commonly known as leaders, are used to point to a feature or drawing area to which a local note applies, **Figure 2-6**. Leaders are also used in conjunction with dimension lines if there is insufficient room for dimensional values within the dimension line. Leaders are thin, continuous lines characterized by an arrow on one end and a shoulder on the other. The shoulder end of the line is vertically centered on the beginning or end of the note.

Miscellaneous Lines

A few other lines should be discussed in this unit. As you progress through the textbook, you will encounter applications for these lines. These examples will help to reinforce your ability to discuss the purpose and function of each line.

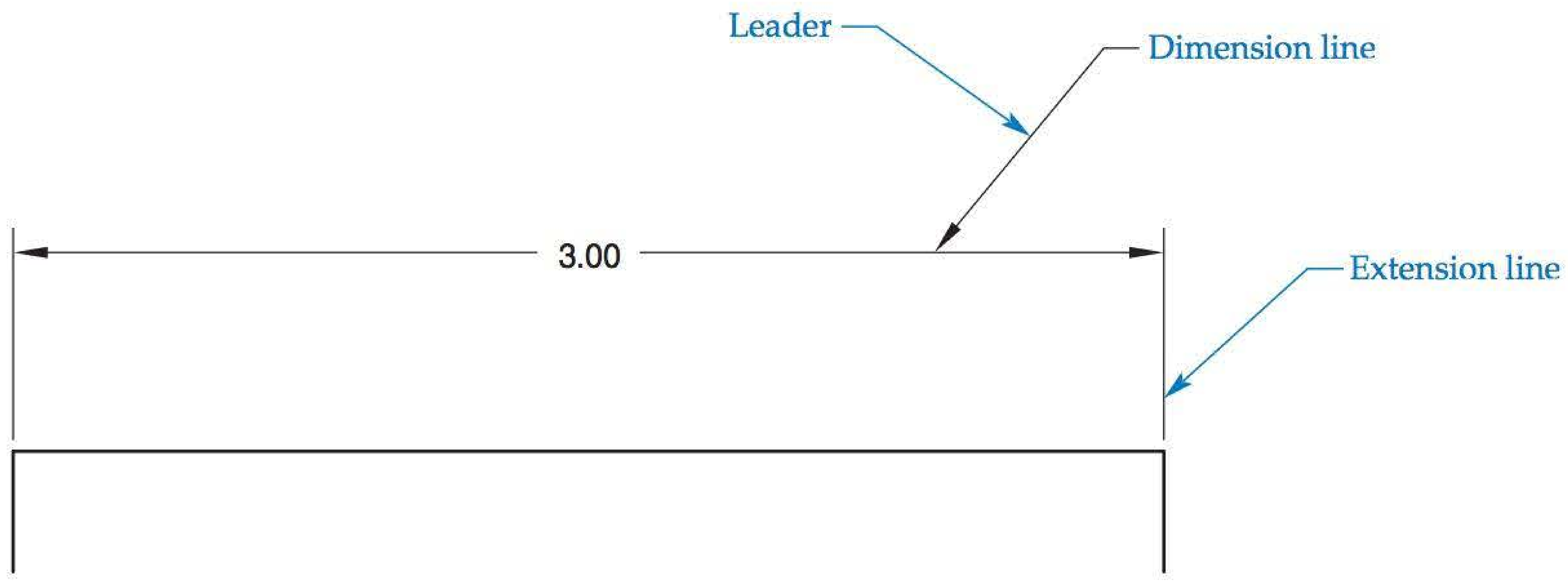

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Figure 2-6. Dimension lines are thin lines used to indicate the extent and direction of part dimensions, while the extension lines extend the object. Leaders are characterized by an arrow on one end and a shoulder on the other end, which is vertically centered with the beginning or end of the note.

Sometimes it is not practical to view a particular feature from the normal viewing arrangement. A different viewing direction can be established with a ***viewing-plane line***, **Figure 2-7**. The viewing-plane line is equivalent in appearance to the cutting-plane line, but simply "floats" outside of the object instead of being placed at a hypothetical cutting position.

The two types of ***break lines*** are used in drawings to "break out" or "break off" a portion of a view. Long break lines are used to shorten objects that are constant in detail, yet too long to fit on the drawing, such as a shovel handle or a long bar, **Figure 2-8**. Long break lines are thin, straight lines with zigzags.

The short break line is used in section view drawings if it is desirable for the cutting plane not to go all the way through an object, **Figure 2-8**. The short break line, if drawn by hand, should be freehand and thick. This line should not be an exaggerated zigzag like lightning or splintered wood, but should look more like torn paper. Short break lines are also used to break an edge or surface to help clarify a feature such as a hidden surface.

In some cases, round stock, such as shafts (solid) or pipe (tubular), may need to be broken. In these cases, a conventional "S" break is used, **Figure 2-9**. When the part to be broken is not round, a short break line is used.

Phantom lines are thin lines composed of long dashes alternating with pairs of short dashes. The dash pattern is similar to a cutting-plane line, but the line weight should be thin, not thick. Phantom lines are primarily used to indicate alternate

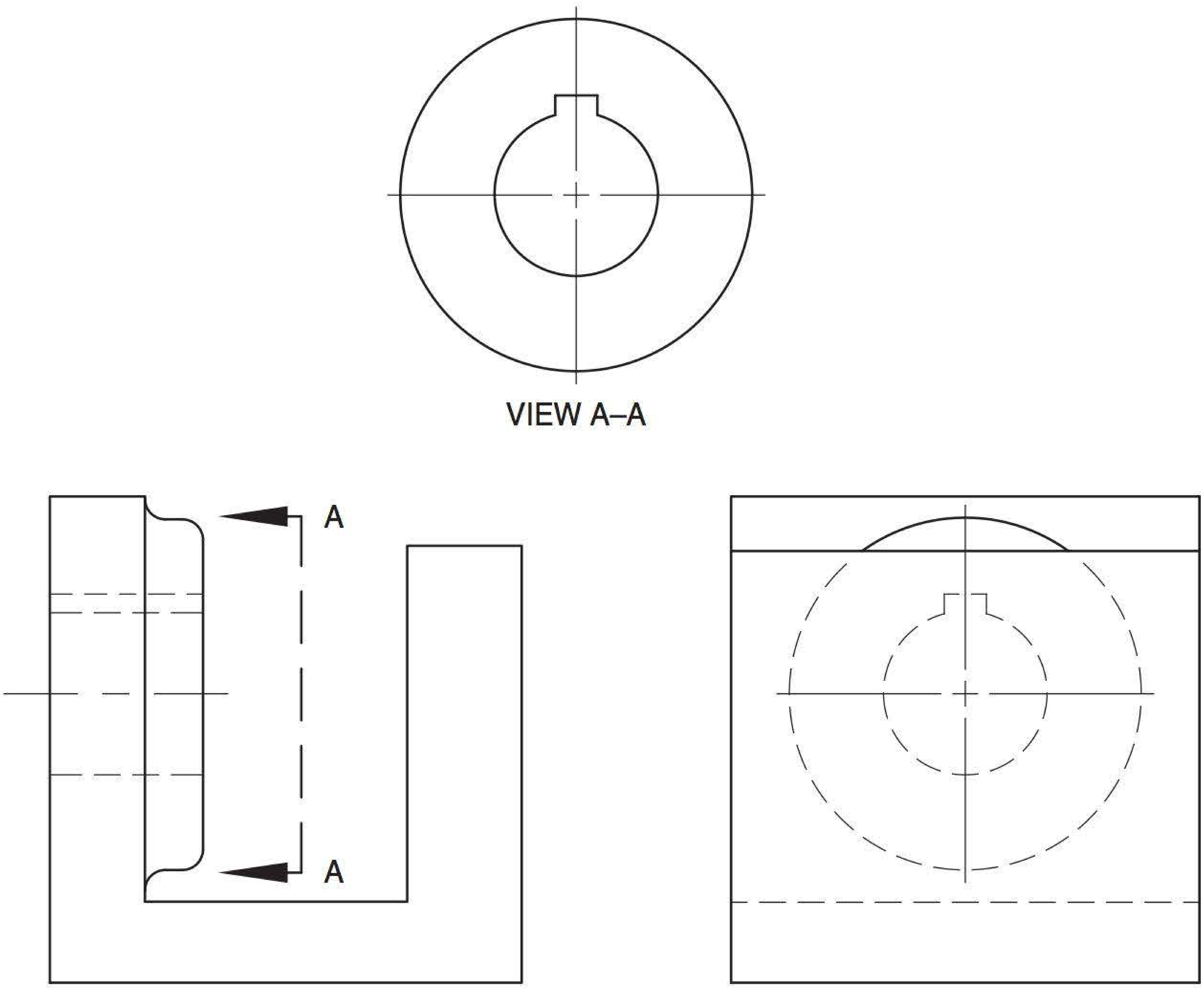

Figure 2-7. A viewing-plane line for a partial view is drawn the same as a cutting-plane line, although there are three standard options. This viewing-plane line indicates the direction for viewing VIEW A-A.

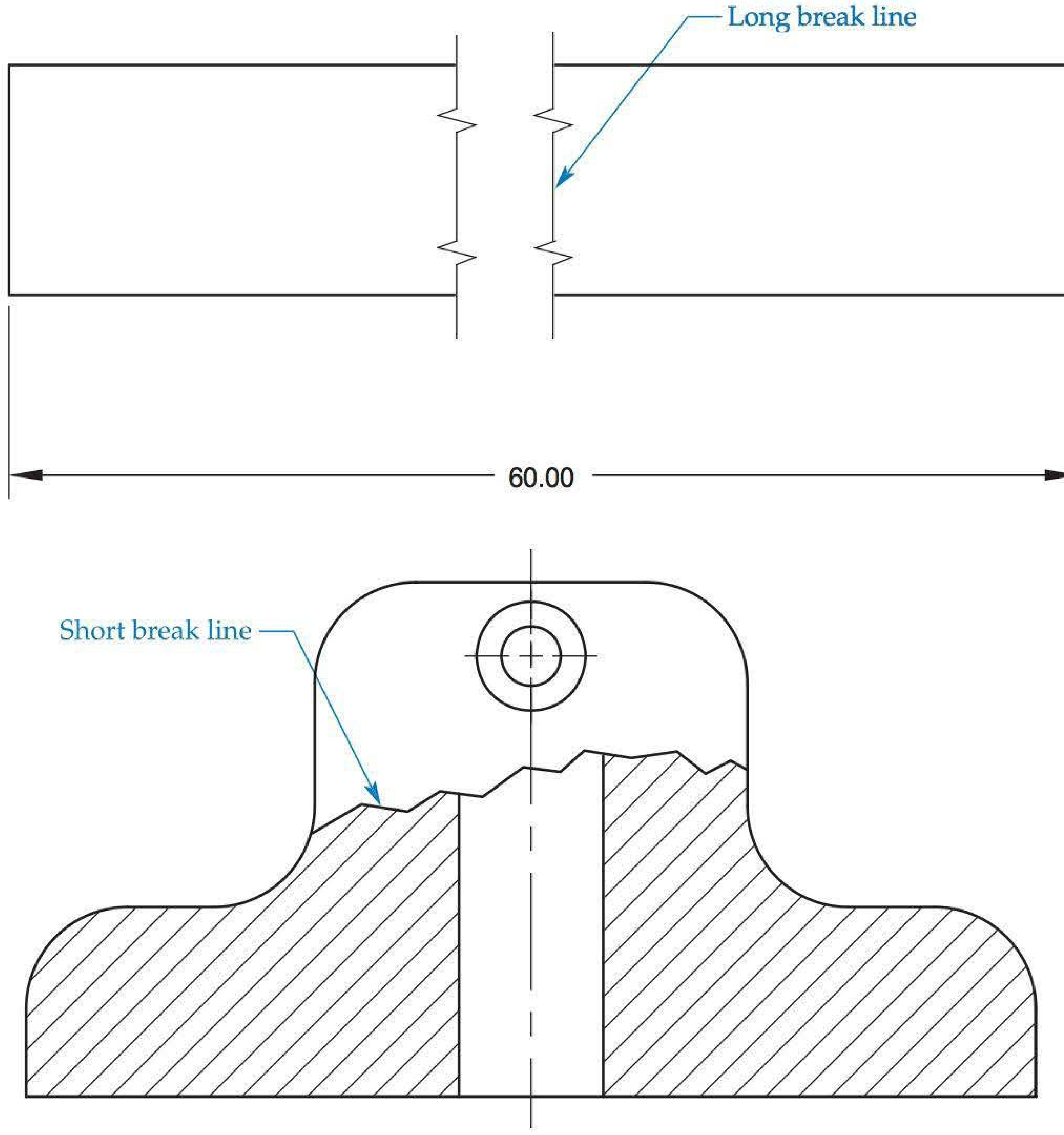

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Figure 2-8. Break lines can be used within views to "break out" sections for clarity or for shortening a view featuring a long and redundant part, such as a handle or tube.

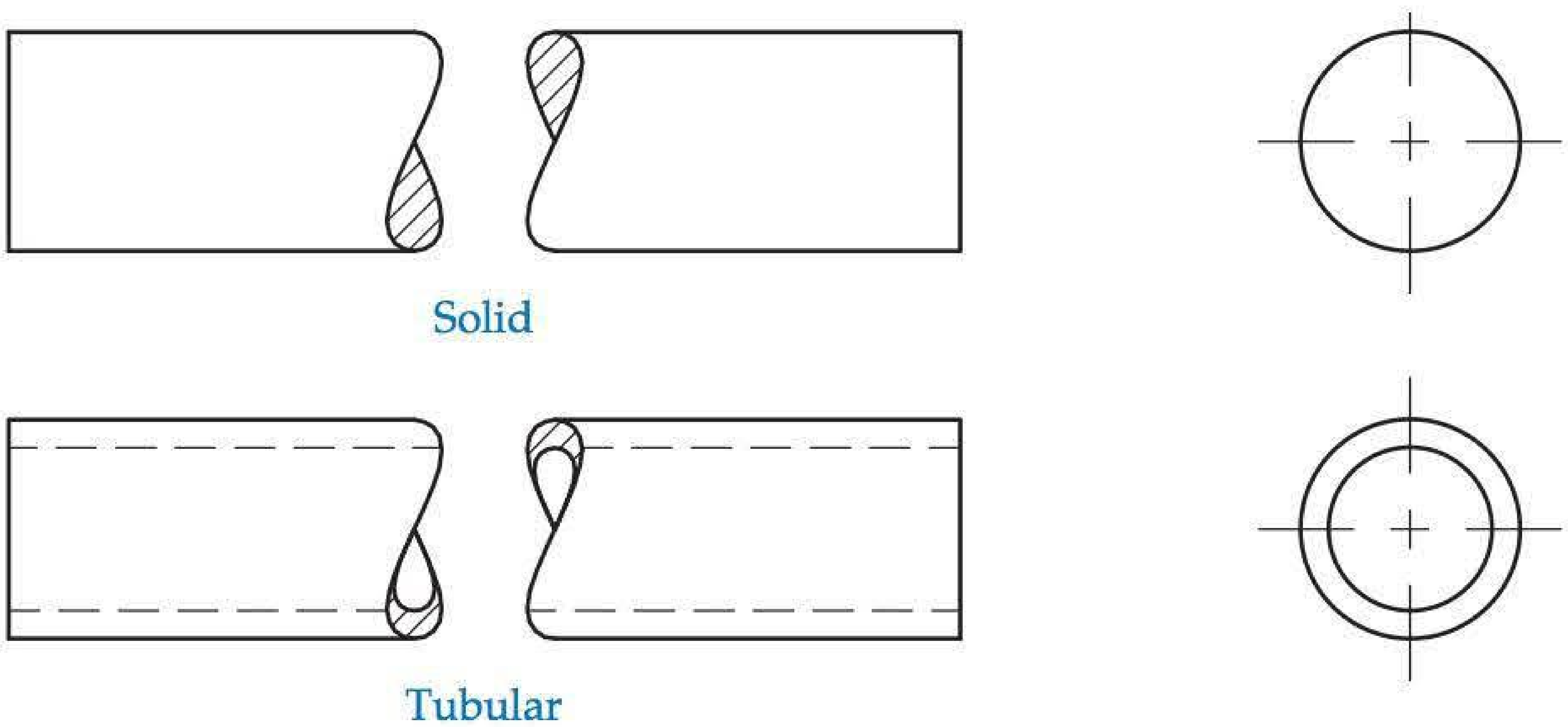

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Figure 2-9. Conventional breaks for solid cylindrical and tubular objects use "S" shaped break lines.

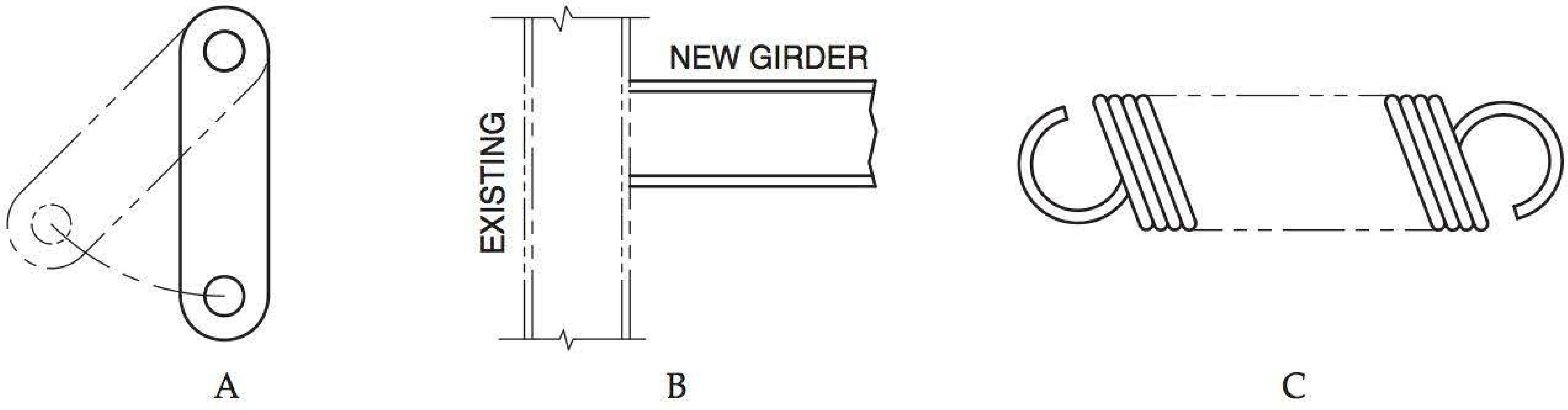

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Figure 2-10. Phantom lines are used to show: A—Alternate positions of moving parts. B—Adjacent positions of related parts. C—Repeated detail.

positions of moving parts, such as a machine arm, **Figure 2-10A**; adjacent positions of related parts, such as an existing column, **Figure 2-10B**; or for repeated detail, **Figure 2-10C**.

Stitch lines are included in the ASME standard. These lines simply represent the path of a sewing or stitching process. They are comprised of either short dashes with spaces that are the same length or a series of dots approximately 1/8″ apart.

The ***chain line*** is used to indicate an area on the drawing wherein something special applies, as illustrated by the NO PAINT note in **Figure 2-2**. For example, if the last inch of a rod is to be heat treated, a 1″ chain line is drawn next to that area of the part. A local note can point to the chain line. A chain line appears somewhat similar to a center line, with short and long dashes alternating, but is thick instead of thin.

Standardized Lettering

In engineering drawings, the text and numeric information is referred to as ***lettering***. Within the context of drafting, "lettering" is not only the letters and numerals themselves, but also the process of creating those characters. In the past, when drawing and lettering were both done by hand, it was of the utmost importance that the lettering be legible, uniform, and standard. Even today, for any documents created by hand, such as preliminary sketches, legible lettering helps avoid potentially costly mistakes. Additional information about freehand lettering can be found in the appendices of this book.

Within the context of print reading, lettering is covered in this unit to establish the definition and standard expression recommended by the ASME standard. Lettering on an industrial print is to be uppercase lettering, unless lowercase lettering is specifically required. The recommended minimum height for lettering is 3 mm (1/8″), with exceptions for drawing block headings, zone letters and numerals, section and view letters, and other information in the title block, such as part name and number. For additional discussion on title block information, see Unit 3.

By definition, engineering drawings created by hand use a "font" referred to in most drafting resources as "single-stroke Gothic lettering," **Figure 2-11**. "Single-stroke" does not imply each letter is created with a single stroke, but rather refers to the freehand technique of forming each letter from a series of single strokes. Gothic means simple, "sans serif" (without serifs) lettering, as opposed to a Roman font, which contains serifs. Serifs are the small tails that make letters appear fancier. As CAD technologies and computer fonts were developed, not everyone used the same terminology. For example, one popular CAD system has a font called GOTHIC, but it appears like a traditional "old English" font. The same system has a font called ROMAN SIMPLEX that matches the engineering Gothic style rather well, but also a ROMAN DUPLEX font that is a truly Roman-style lettering, complete with serifs. This can be confusing when establishing CAD template drawings and standard CAD management protocols. However, CAD lettering is consistent and accurate, and there are many fonts and styles from which to choose. It is critical that industrial prints have clear and concise lettering, and computer applications have helped to meet that goal.

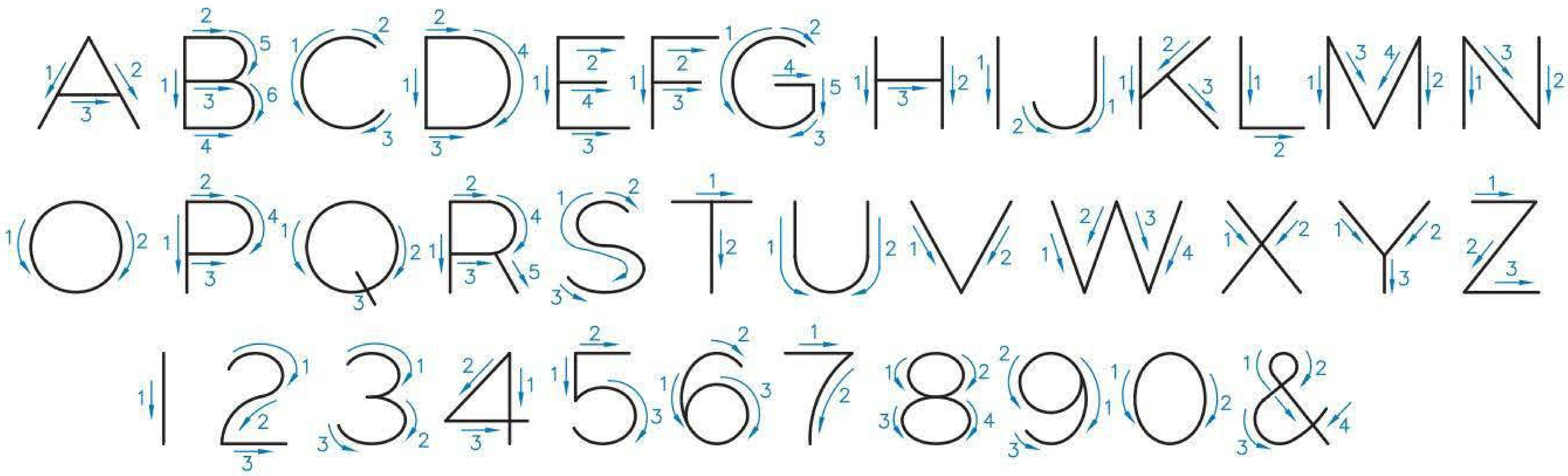

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Figure 2-11. Single-stroke Gothic lettering, usually set in uppercase letters, is the established standard for engineering drawings.

Name ______________________ Date ______________ Class ______________

Review Questions

Answer the following questions using the information provided in this unit.

__________ 1. The term for a "generally accepted way of doing things" is a(n) _____.

__________ 2. *True or False?* In the current standards, only two standard line weights (widths) are recommended in the alphabet of lines.

__________ 3. Which of the following lines does *not* feature any dashes?

A. Extension line.
B. Hidden line.
C. Phantom line.
D. Center line.

4. How many options are there for the style of a cutting-plane line?

____

5. List two different lines that feature a repeating pattern of a short dash followed by a long dash.

____

____

__________ 6. Of the following lines, which is *not* drawn thick?

A. Visible line.
B. Short break line.
C. Chain line.
D. Long break line.

__________ 7. A(n) _____ line is used to point to a feature or drawing area and usually has an arrowhead on only one end.

__________ 8. *True or False?* If drawn by hand, the short break line should be drawn with a straightedge.

__________ 9. The _____ line is used to show an alternate position, adjacent related parts, or repeated detail.

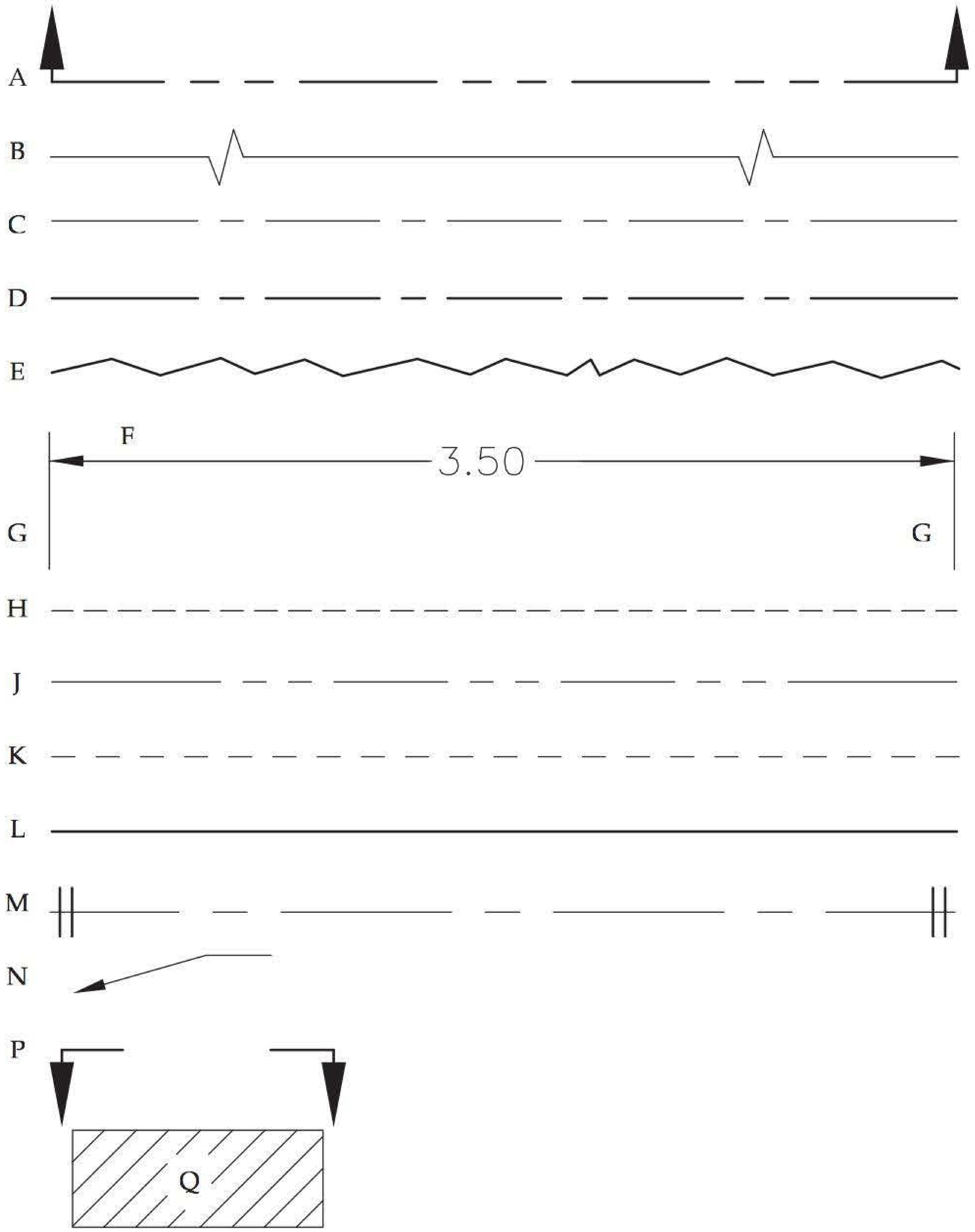
__________ 10. Which statement listed below regarding characteristics of lettering is *false*?

A. Lettering, if done by hand, is composed of a series of single strokes.
B. Lettering on an engineering drawing should be a Gothic style or font.
C. Lettering on an engineering drawing has serifs and is very fancy.
D. Lettering is uppercase, not lowercase.

Name ______________________ Date ______________ Class ________________

Review Activity 2-1

Match the letter of each illustrated line with the correct name. Items are matched only once.

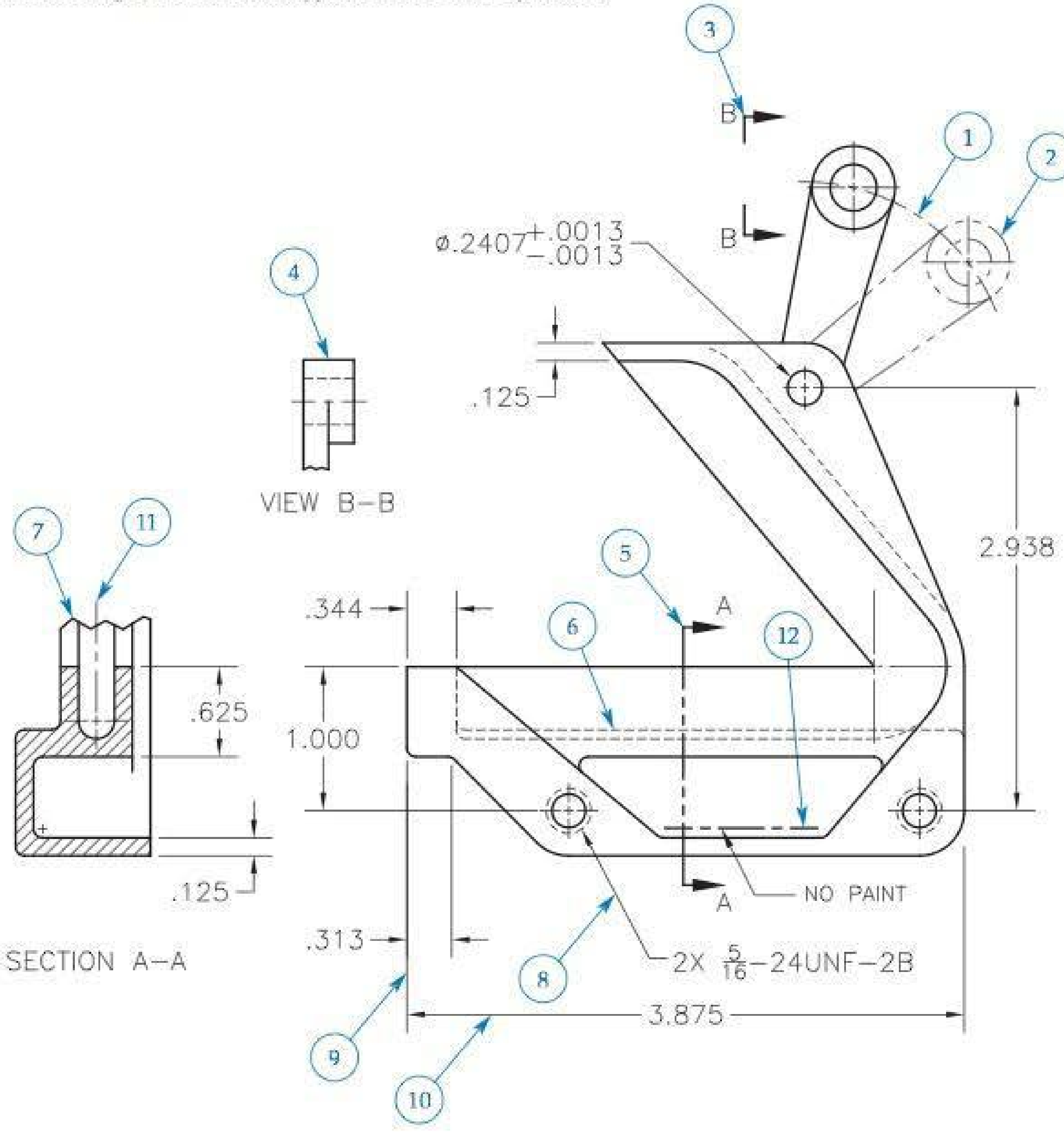


_____	1. Short break line	_____	6. Leader line	_____	11. Viewing-plane line
_____	2. Hidden line	_____	7. Dimension line	_____	12. Chain line
_____	3. Center line	_____	8. Extension line	_____	13. Long break line
_____	4. Phantom line	_____	9. Cutting-plane line	_____	14. Stitch line
_____	5. Section line	_____	10. Visible line	_____	15. Symmetry line

Name ____________________ Date ____________ Class ______________

Review Activity 2-2

Study the drawing below and identify the twelve lines by name.



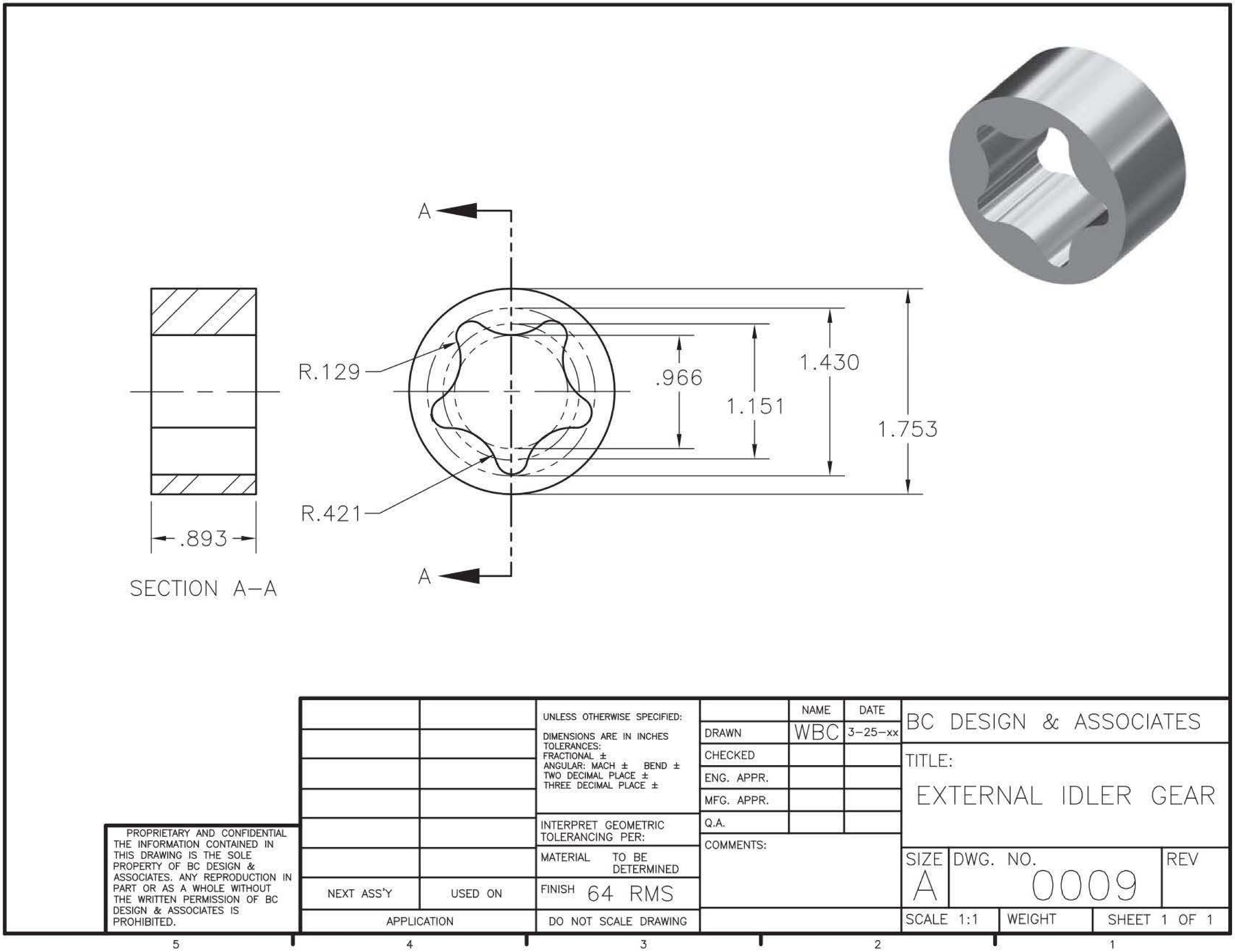
1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6. ______________________
7. ______________________
8. ______________________
9. ______________________
10. ______________________
11. ______________________
12. ______________________

Name ______________________________ Date _______________ Class __________________

Industry Print Exercise 2-1

Refer to print PR 2-1. Closely examine the print to see which lines from the alphabet of lines are present or absent. For each question, answer P *for present or* A *for absent.*

_____ 1. Cutting-plane line
_____ 2. Dimension line
_____ 3. Stitch line
_____ 4. Section line
_____ 5. Short break line
_____ 6. Extension line
_____ 7. Leader line
_____ 8. Hidden line
_____ 9. Chain line
_____ 10. Center line
_____ 11. Long break line
_____ 12. Visible line



PR 2-1. External Idler Gear.

Print supplied by BC Design and Associates.

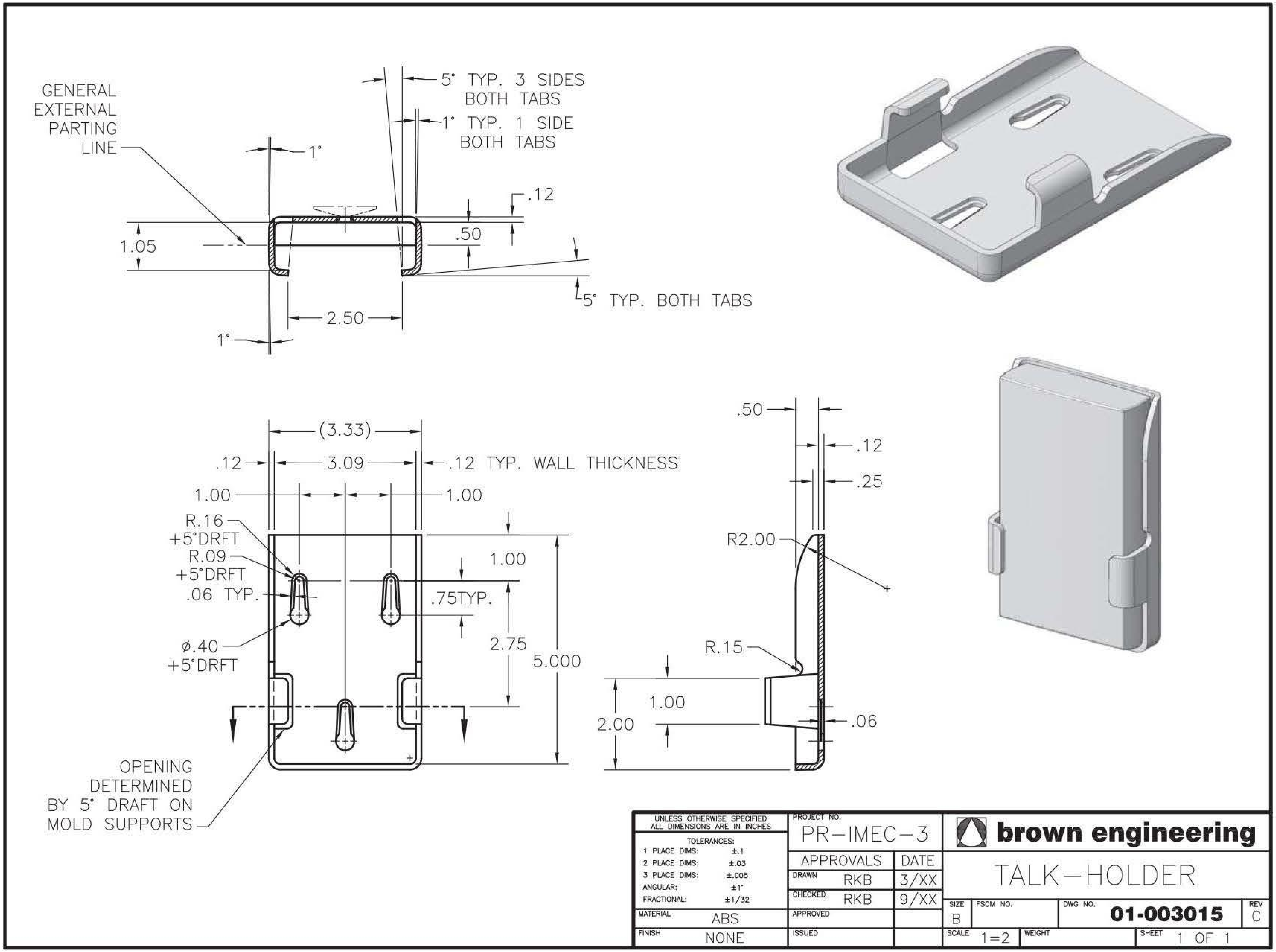
Name ______________________________ Date ______________ Class __________________

Industry Print Exercise 2-2

Refer to the print PR 2-2. Closely examine the print to see which lines from the alphabet of lines are present or absent. For each question, answer P *for present or* A *for absent.*

______ 1. Extension line
______ 2. Phantom line
______ 3. Stitch line
______ 4. Visible line
______ 5. Short break line
______ 6. Cutting-plane line
______ 7. Long break line
______ 8. Hidden line
______ 9. Dimension line
______ 10. Center line
______ 11. Leader line
______ 12. Section line

PR 2-2. Talk-Holder.



Print supplied by Brown Engineering.

Name ______________________ Date ______________ Class ________________

Bonus Print Reading Exercises

The following questions are based on the various bonus prints located in the folder that accompanies this textbook. Refer to the print indicated, evaluate the print, and answer the question.

Print AP-001

1. Do the visible lines of the object appear to be thicker than the center lines and section lines?

   ____

2. What type of line is used to indicate the circular area being enlarged for View A?

   ____

Print AP-003

3. In how many of the four main views are section lines used?

   ____

4. List the types of lines that appear in Section A-A, including the different types of lines used in dimensioning, if any.

   ____

   ____

Print AP-007

5. In the view with one dimension, 8X R.015, what two types of lines are featured besides the leader line?

   ____

Print AP-008

6. What type of line is used to indicate the cylindrical surfaces that are to be heat treated?

   ____

7. What type of line is used to indicate the involute splines that are specified on each end of this shaft?

   ____

Print AP-012

8. What line name is given to the thicker dashed lines with arrows that are labeled A, B, C, D, etc.?

   ____

Print AP-015

9. Describe the manner (pattern) in which the cutting-plane line is drawn. Remember, there are other options in the ASME standards.

____

____

10. What type of line is used to show the partial view break off?

____

11. Name the lines that appear in Section A-A.

____

____

Print AP-019

12. Name the lines that appear in the enlarged detail A.

____

____

13. Not counting leader line callouts and arc radius dimensions, how many dimension lines were used without using extension lines?

____

Print AP-020

14. What type of line is used in the upper-left round view to indicate the remaining gear teeth without drawing all of them?

____

Print AP-021

15. Not counting the lines used for dimensioning, list the types of lines that appear on this print:

____

____

Notes

Unit 3

Title Blocks and Parts Lists

Learning Objectives

After completing this unit, you will be able to:

- ❑ **Describe** drawing sheet sizes and formats.
- ❑ **Identify** marginal information and zoning methods for drawing sheets.
- ❑ **Identify** the elements of the title block as defined by industry standards.
- ❑ **Explain** the techniques for identifying parts of an assembly drawing as represented in a basic parts list.

Technical Terms

angle of projection block
application block
balloon
CAGE code
drawing number
drawing title
parts list
revision
revision history block
revision status of sheets block
scale
title block
tolerance
tolerance block
zone

Industrial drawings are placed on a variety of sheet sizes, depending on the complexity or size of the part. The drafter uses both of these factors to determine the physical size of the views that will be needed to clearly show detail and describe the part. Several factors are used together to determine the final sheet size and main scale for the majority of the views. More complex parts may even require more than one sheet.

ASME Y14.1, entitled *Decimal Inch Drawing Sheet Size and Format*, and ASME Y14.1M, entitled *Metric Drawing Sheet Size and Format*, cover the basics of sheet layout and format, title blocks, and revision blocks. ASME Y14.34, entitled *Associated Lists*, sets forth recommendations for parts lists and data lists.

The primary focus for this unit is on the title block and parts lists. Every print reader needs to begin with the title block to get his or her bearings regarding the task at hand. Within the title block resides information about the part name and number, drawing creation date, revision dates, and from what material the part is to be made. With assembly drawings, the parts list is usually critical to identifying the components that need to be assembled.

Sheet Size and Format

Drawings are prepared on standard-size sheets, but there are two systems for inch-based paper sizes: engineering and architectural. **Figure 3-1** illustrates

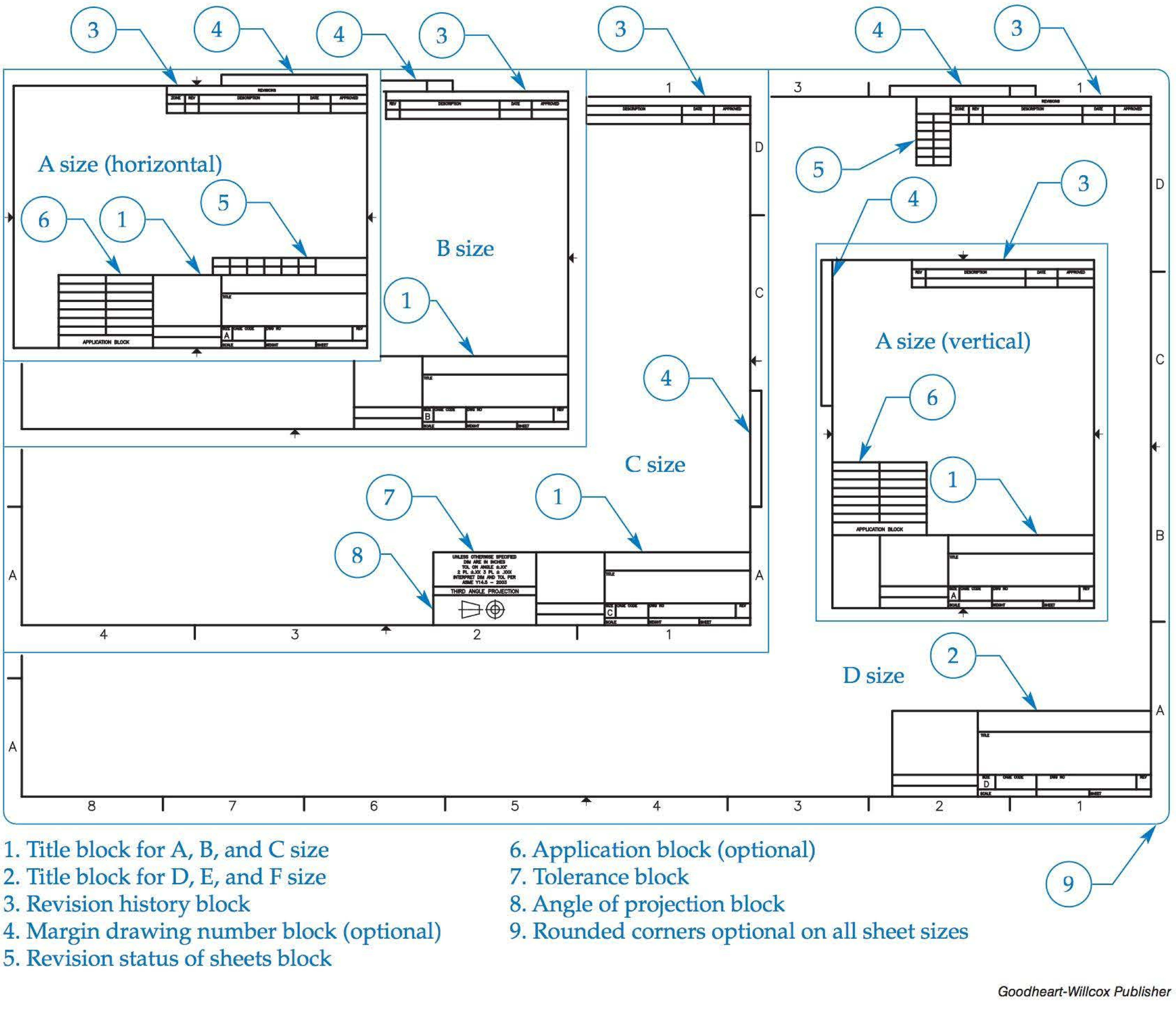


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Figure 3-1. Flat-sheet formats are standardized by ASME. Sheet formats A through D in landscape mode and A in portrait mode are shown here.

four of the paper sizes, identified as sizes A through D. As illustrated, engineering sheet sizes are in multiples of 8 1/2″ × 11″, which is commonly referred to as A-size. If D-size paper, 22″ × 34″, is cut in half, the result is two C-size sheets, each 17″ × 22″. Likewise, C-size paper cut in half results in two B-size sheets, each 11″ × 17″. Roll-size format G, H, J, and K are also available for large parts and assemblies.

Architectural drawings are usually larger than engineering drawings, and are based on rolls of paper manufactured in widths of 24″, 36″, or 48″. The drawing sheet sizes are therefore larger as well. The A-size sheet for architectural applications is 9″ × 12″, B-size sheets are 12″ × 18″, C-size sheets are 18″ × 24″, and D-size sheets are 24″ × 36″. Most professional output devices can accommodate both systems of paper. See **Figure 3-2** for a size comparison.

In the United States, the decimal-inch system is still predominant, especially with respect to paper sheet sizes. Even if drawings are created with metric units, most office supplies are still specified to decimal-inch paper sizes. The ISO 216 standard sets metric paper size standards for an "A series" set of paper sizes. Metric paper sizes have the additional benefit that each size, if halved or doubled, maintains the same aspect ratio (length versus height).

Metric sheet sizes commonly used for industrial prints are identified as A0, A1, A2, A3, and A4. See **Figure 3-2** for a size comparison chart. **Figure 3-3** illustrates metric sheet sizes for the ISO 216 "A" series. This unit will not attempt to cover both decimal inch and metric systems, as the content is virtually the same, simply with different units.

Letter Size	Engineering Standard	Architectural Standard	Similar to ISO standard
A	8.5 × 11	9 × 12	A4
B	11 × 17	12 × 18	A3
C	17 × 22	18 × 24	A2
D	22 × 34	24 × 36	A1
E	34 × 44	36 × 48	A0
E1		30 × 42	
F	28 × 40		

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Figure 3-2. The engineering standard for paper is different than the architectural standard. Similar metric paper sizes are also available.

Borders and Zoning

As illustrated in **Figure 3-1**, the margins for a drawing vary depending on sheet size and available space. The recommended minimum space varies from .25″ to 1.00″. Roll-feed sheets for plotters may require more space along one edge. A border line is usually included around the edge of the paper. Border lines are technically not in the alphabet of lines. They are usually drawn thick, perhaps even thicker than visible lines.

ASME standards recommend zoning for sheet sizes larger than B-size, although zoning is permissible even for smaller sheets. Outside of the border, ***zones*** are used to aid in locating details of parts or revision notes, **Figure 3-4**. The zoning system is similar to that used on highway maps. Numbers are used at intervals from right to left. Letters are used at intervals from bottom to top. Zones are noted with the letter first and the number second, for example, zone D3.

ISO 216 "A" Series	Size in Millimeters	Size in Inches
A4	210 × 297	8.3 × 11.7
A3	297 × 420	11.7 × 16.5
A2	420 × 594	16.5 × 23.4
A1	594 × 841	23.4 × 33.1
A0	841 × 1189	33.1 × 46.8

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Figure 3-3. The ISO 216 standard specifies the dimensions of the A series of metric sheet sizes.

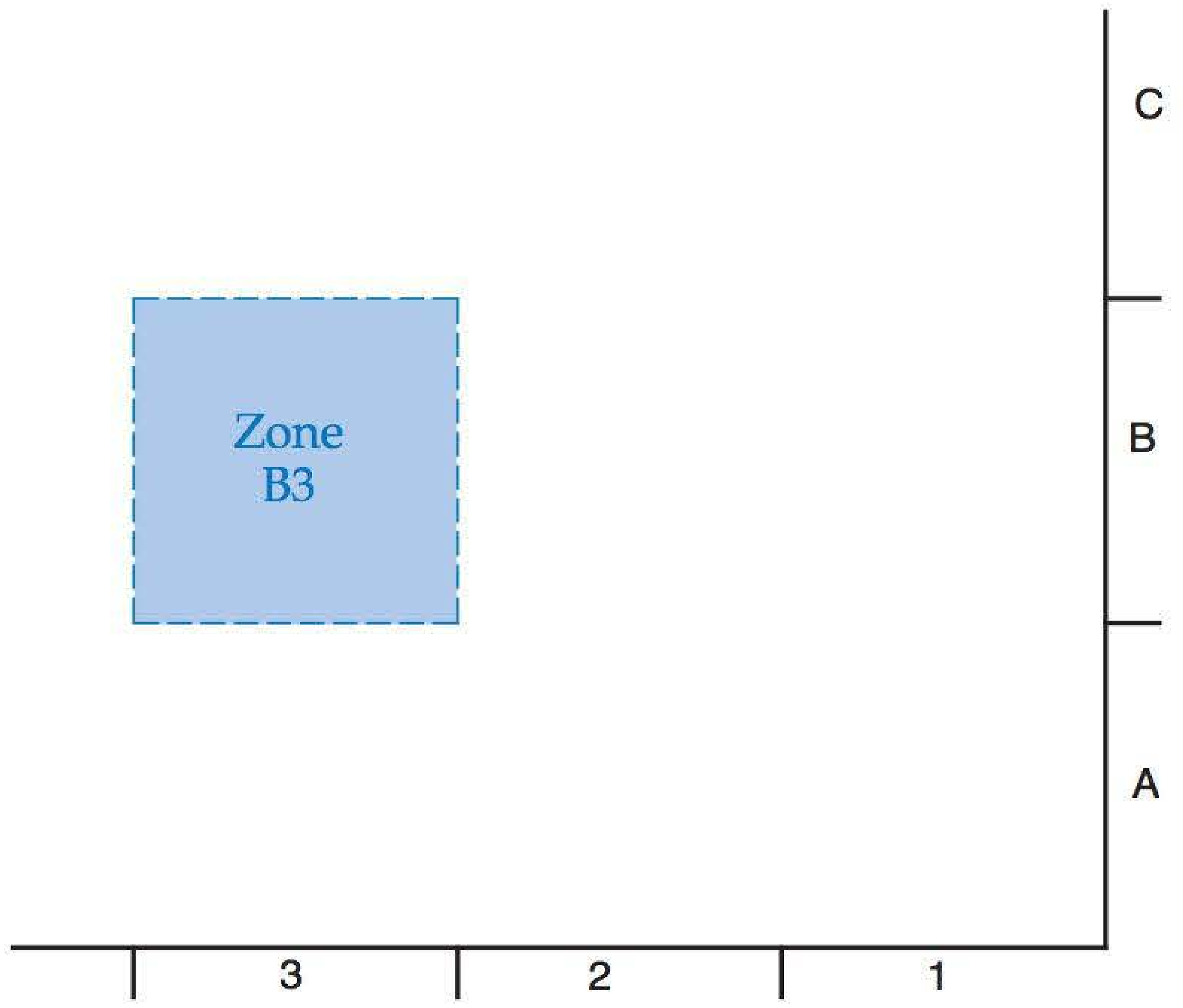

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Figure 3-4. Zoning is used to specify an area of a large print, similar to what is used on highway maps.

Basic Title Block Elements

The ***title block*** provides information that aids in identification and filing of the print. The title block also provides supplementary information about the part or assembly. The title block is usually located in the lower, right-hand corner of the print so that it can be seen when the print is correctly folded. This allows for easy reference and filing.

While many companies have their own variations of the standard title block, the information found in a title block is similar between companies. Title block information included on plans by most industries is explained in this unit. Understanding the information typically found in a title block will help you properly interpret all title blocks.

The name and address of the company is usually placed in the upper part of the title block, **Figure 3-5A**. Often, the company logo also appears in this space. With CAD systems, it is easy to insert a standard logo into a drawing.

The ***drawing number*** is used to identify and control the print. It is also used to designate the part or assembly shown on the print, **Figure 3-5B**. The number is usually coded to indicate department, model, group, serial number, and dash numbers. The drawing number may also be shown in the margin of the drawing, usually in a rectangular box. This is designed so the drawing number shows along the top edge when the drawing is folded to A-size, **Figure 3-6**.

The ***drawing title*** indicates the name of the part. The title should be descriptive, brief, and clearly state an identification of the part or assembly. See **Figure 3-5C**. The title starts with the name of the part or assembly, followed by descriptive modifiers. When the title is read out loud, the descriptive modifier is read first. For example, the title in **Figure 3-7** is read "pressure regulating valve assembly."

The sheet area of the title block is used for sheet numbering. Sheet numbering is used on multi-sheet prints to indicate the consecutive order and

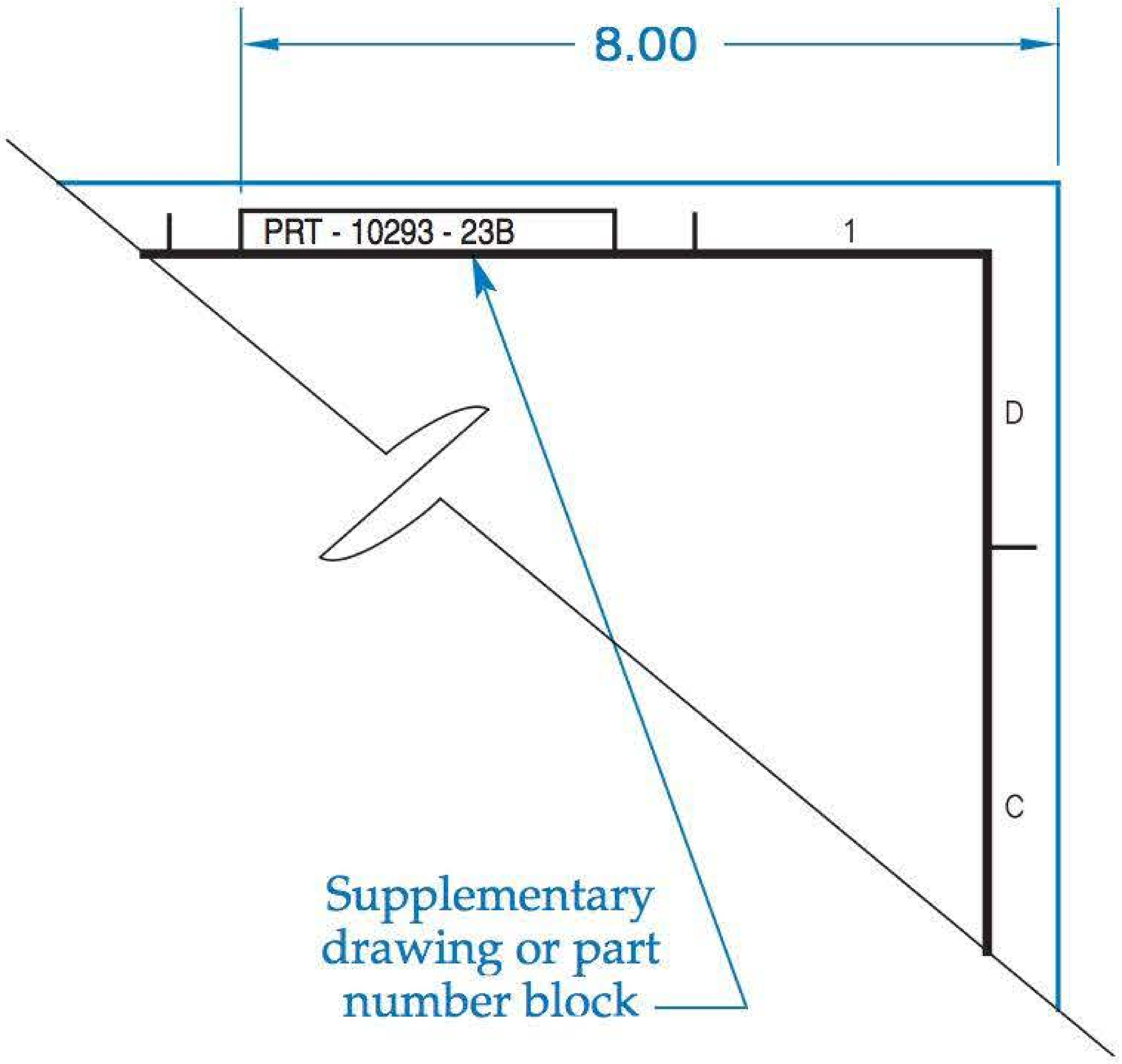

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Figure 3-6. Standards allow for the drawing number to be shown in the margin to aid in finding a drawing in the filing drawer.

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Figure 3-7. A part name often contains descriptive modifiers. When read out loud, the modifiers are read first and then the part name.

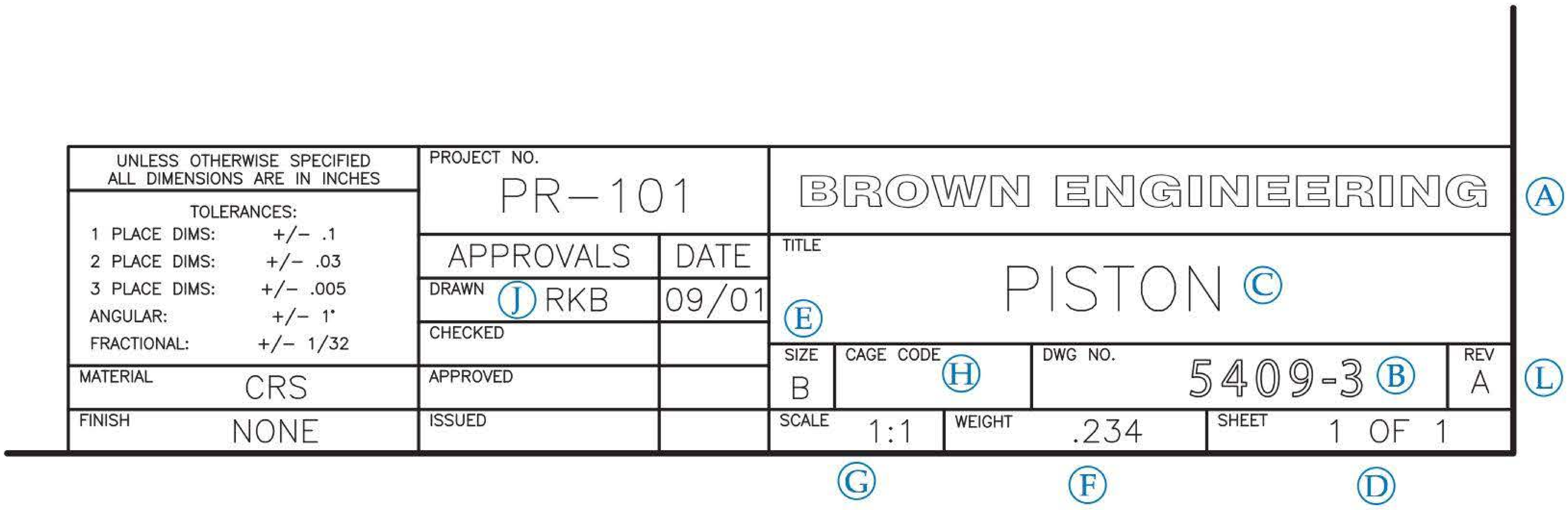

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Figure 3-5. Most title blocks contain similar information. Standard formats are recommended, but not required.

total number of prints. Sheet numbering is often written as SHEET *x* OF *n*, where *x* is the number of the sheet, and *n* is the total number of sheets for that set. See **Figure 3-5D**.

The size area of the title block is used to indicate which sheet size is used for the print. A letter designation such as B, C, or D indicates the standard size paper. Refer to **Figure 3-2** or **3-3** for standard paper sizes.

The weight area of the title block provides the weight of the part, **Figure 3-5F**. The weight can be either the actual or calculated weight, as indicated. Calculated weight is used during design stages to control the weight of the finished part or assembly. Actual weight is obtained after the part or assembly is actually manufactured.

The scale area indicates the scale of the drawing. The ***scale*** is the ratio between the part as drawn and the actual part. It is usually expressed as *paper = real* or *paper:real*, where the first number (*paper*) indicates the size measured on the paper and the second value represents the size measured on the actual part. See **Figure 3-5G**. Typical scale notations are: 1/2″ = 1″ (half size), 1:2 (half size), FULL (actual size), 1:1 (actual size), and 2:1 (twice size). Sometimes 2X or 3X is used to indicate 2:1 or 3:1, respectively. When several scales are used in the drawing, the scale is shown AS NOTED, and each scale is indicated below the particular view to which it pertains. Some drawings, especially diagrams, have no scale. Pictorial drawings representing a part or assembly in 3D are often not shown to scale, as the object is "turned and tilted" and the object lines are foreshortened. The designation NONE is an appropriate entry in the title block for a drawing with no scale.

It is important to note that even though drawings are usually printed to scale and the scale is indicated in the title block, measurements should *never* be made directly on a print. This is because the print may be reduced in size or stretched. Work from the dimension values given on the print. If you believe these to be in error, report it to the appropriate person in the company.

Some title blocks have an area labeled ***CAGE code***, which is a unique identifier given to vendors for the government, **Figure 3-5H**. CAGE is an acronym for Commercial and Government Entity. On older drawings, this block may be identified as FSCM (Federal Supply Code for Manufacturers) or NSCM (National Supply Code for Manufacturer). In summary, this area is used to identify part suppliers on drawings. For parts not requiring a CAGE code, this area is left blank or it may be omitted from the title block layout.

On the left side of a title block is an area for the signatures and date of release notation. These areas are not specified in current standards, but may appear as shown in **Figure 3-5J**. Entries in this area are made by those responsible for making or approving certain facets of the drawing or manufacture of the part. There may be many signatures on a given drawing. The following are some areas of responsibility:

- **Drawn**. This area is for the drafter who made the drawing and the date completed.
- **Checked**. This area is for the engineer or checker who checked the drawing for completeness, accuracy, and clarity.
- **Approved**. This area is to record any other required approvals.
- **Issued**. This area indicates the person who finally issues the drawing as available for general use, making it an "official" drawing.

Intermediate Title Block Elements

There are many other areas of information that will be more clearly understood after some additional units are covered. Within your progression of study, it is important to understand the importance of studying the title block early and often in the process of interpreting the full scope of the product or part. Additional title block information is discussed in future units, but this section is a brief overview of additional information found in some title blocks.

In manufacturing, part dimensions are often within a range. The total amount of the range is the ***tolerance*** for that value. Most title blocks include a ***tolerance block***, which indicates the general tolerance limits for one-, two-, and three-place decimal values and a certain number of degrees for angular dimensions. These limits are to be applied unless the tolerance is otherwise indicated on the drawing. Refer to Unit 13 for a discussion on tolerancing.

The ***angle of projection block*** is usually located below the tolerance block and identifies whether the drawing is a first-angle or third-angle projection. Refer to Unit 5 for a discussion on angles of projection.

The finish area in a title block indicates general finish requirements, such as paint, chemical, or other. Any specific finish requirements are called out in a local note with the word NOTED in the finish area. Refer to Units 11 and 12 for a discussion on machining specifications and surface texture symbols.

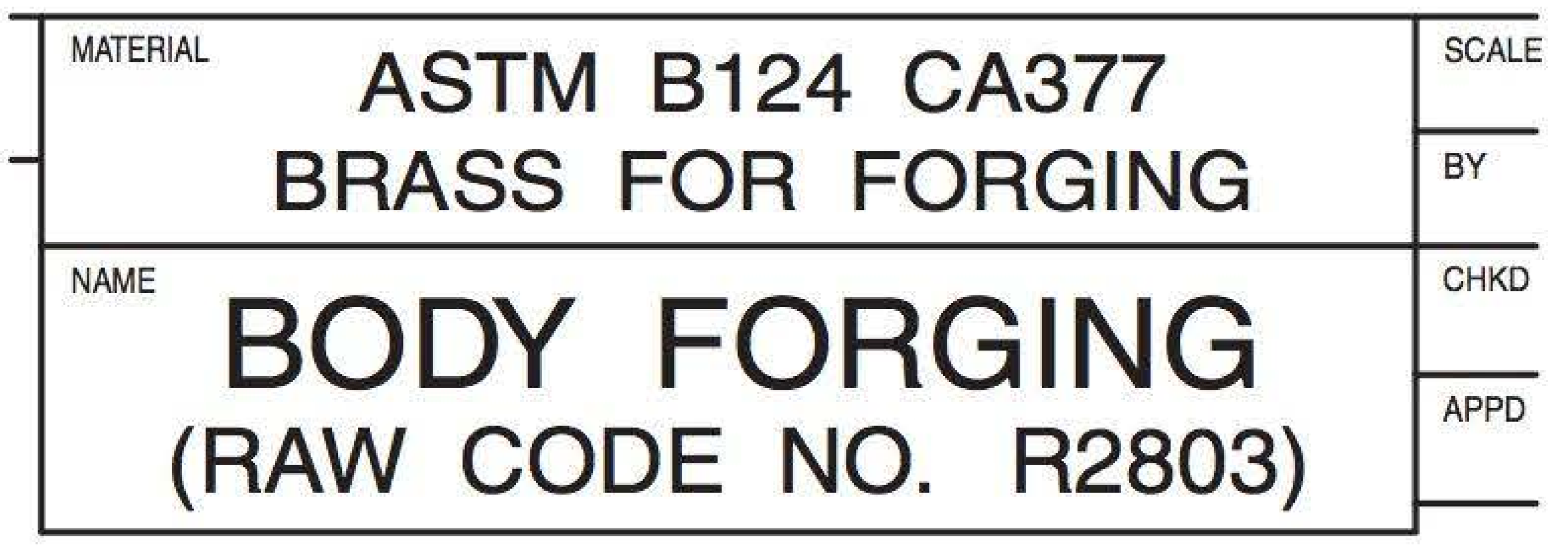
The materials area in a title block indicates the material used to make the part. Some companies have material numbers assigned to all raw materials. The number of the material is then indicated in the title block. See **Figure 3-8**.

The heat treatment area in a title block indicates heat treatment and hardness requirements. See **Figure 3-9**. The entry may be AS REQUIRED or NOTED, which means the part must conform to the specification block notation or to the callout on the drawing detail. If heat treatment is not required, the word NONE or a diagonal line is entered in the block.

An ***application block*** can be added to the title block. The application block lists the assembly or subassembly in which the part or subassembly is used. See **Figure 3-10**. Indicating where the part or assembly is used can help determine the effects of a change in the part or assembly. Refer to Unit 16 for a discussion on assembly drawings.

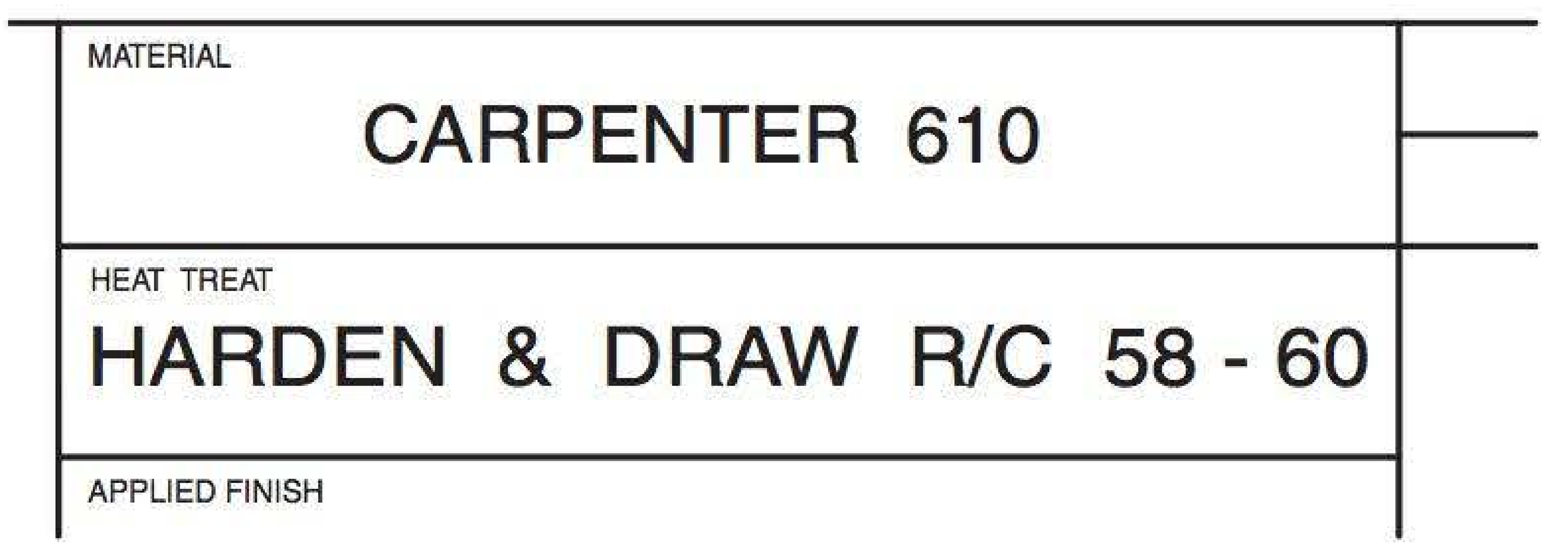
A few companies include information in the title block indicating DRAWING SUPERSEDED BY or DRAWING SUPERSEDES. For example, if PART 111 supersedes PART 110, then PART 111 is the new part that replaced PART 110 in the system. This enables a drawing to report the previous part number or drawing number as a historical record, which helps the print reader locate information connected to the history of the part. This information can also be applied to a drawing that is being discontinued and archived so individuals can find the new drawing and part that superseded the old part.

Other information may appear in a title block. The customer for whom the product is being produced is sometimes listed, as is the contact number. Standards used for inspection may be used to refer to specific sets of inspection standards used by the company. A diagonal line or X appearing in any part of the title block means the item is not required.



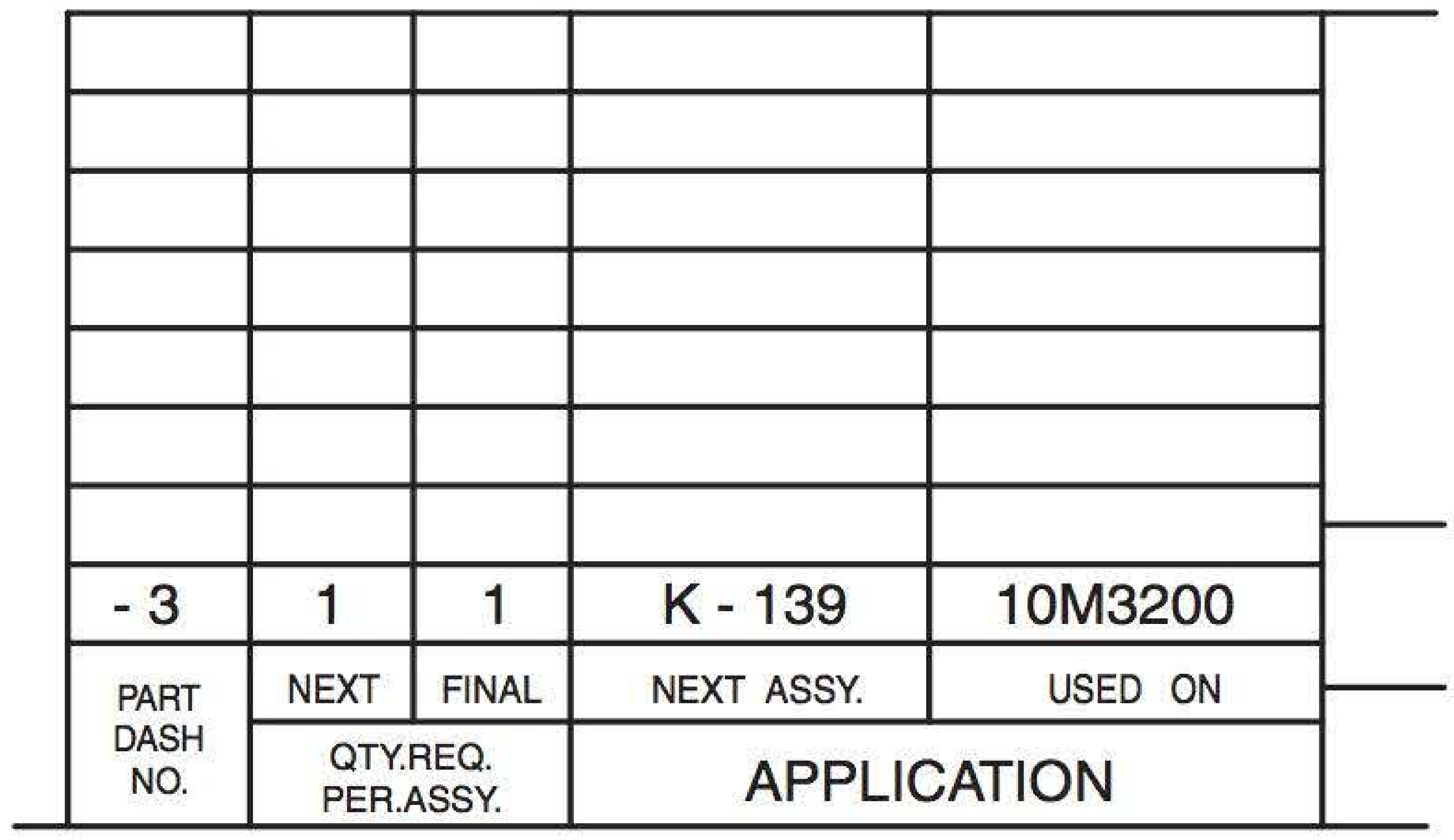
Goodheart-Willcox Publisher

Figure 3-8. The material area of the title block indicates the material used to make the part.



Goodheart-Willcox Publisher

Figure 3-9. The heat treatment area in the title block indicates heat treatment and hardness requirements.



Goodheart-Willcox Publisher

Figure 3-10. The application block, if present, is attached to the title block and lists the assembly or subassembly in which the part is used.

Revision History Block

A ***revision*** is any change made to the original drawing. A system for reporting the history of changes to a part and its drawing is also included on the sheet. Unit 14 discusses revision systems in more detail, but locating the current revision status for a drawing is often a necessary initial step in the print reading process. As a part is revised, the differences are usually recorded on the drawing with alphabetical notations. It is important that the print reader establish the current revision status of the drawing and if the drawing is up-to-date. There are times when a revision is pending, which should be indicated somewhere on the print, perhaps as a bold or brightly colored stamp.

The ***revision history block*** should be located in the upper-right corner for most sheet layouts, **Figure 3-11**. This block may include information such as the letter assigned to a change, what change order number was assigned, the date, and other