

# ENGINEERING GRAPHICS

S I X T H E D I T I O N

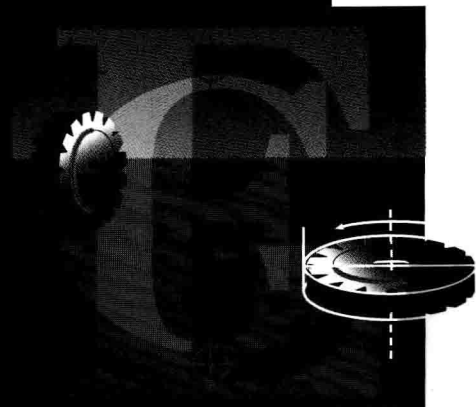


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Alva Mitchell / Henry Cecil Spencer / Ivan Leroy Hill

Robert Olin Loving / John Thomas Dygdon / James E. Novak

with Shawna Lockhart



*Sixth Edition*

# ENGINEERING GRAPHICS

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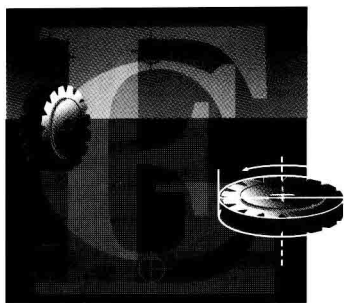
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# **ENGINEERING GRAPHICS**

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# P R E F A C E

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## ■ ABOUT THIS BOOK

This new edition of *Engineering Graphics* is intended to provide thorough coverage of technical drawing and design, descriptive geometry, and graphs and graphical computation, using both traditional methods and computer graphics. It can be used as a reference, as well as in courses where coverage of these subject areas is desired in one volume and especially where this material is covered in one semester. The book's extensive text material and problems make it equally adaptable to a two-semester course sequence.

The authors have introduced new industrial practices and developments focusing on the use of CAD and how engineers and designers work with computers. Extensive updates have been made to both text material and drawings to reflect current ANSI standards, while maintaining the high quality of drawing in the illustrations and problem material.

The importance of visualization is emphasized through the use of technical sketching, as well as the concept of drawing views and multiview drawing.

Many problems reflect the current ANSI standards which indicate a preference for the use of metric units. Other problems provide the student with an opportunity to convert dimensions to either the decimal-inch or the metric system.

The book is divided into three parts: "Technical Drawing and Design," "Descriptive Geometry," and "Graphs, Diagrams, and Graphical Computation." These comprehensive sections cover the principles and applications of engineering graphics. The first part, "Technical Drawing and Design," is the same as the first nineteen chapters of the recently issued tenth edition of *Technical Drawing* by Giesecke, Mitchell, Spencer, Hill, Dygdon and Novak, published by

Prentice Hall. The chapters on graphs, diagrams, and graphical computation are also identical to the corresponding chapters of that text. The "Descriptive Geometry" area includes seven exclusive chapters featuring material based upon an understanding of the elements of graphic communication, especially the fundamentals found in the chapters covering multiview projection, auxiliary views, and revolution, utilizing a simplified, time-saving notation system.

## ■ ABOUT THE COVER

The new cover of the Sixth edition helps illustrate an important goal of this text; integrating new technologies and techniques while retaining the principles that have made this text a classic. On the cover, we have taken one of the original, unaltered drawings, which has long been a favorite, the belt tightener, and "brought it to life" by modeling it with a modern CAE/CAD/CAM software tool, I-DEAS Master Series. In doing so, we hope to show learning, and practicing the fundamental principles of this course, long stressed by this series, gives the student a command and mastery of the discipline. Once learned, this knowledge affords him or her the ability and flexibility to handle this field's many challenges, in both present and future.

## ■ KEY IMPROVEMENTS TO THIS EDITION

*All Drawings reflect updated ANSI Standards*—we have identified notations that needed updating and carefully re-labeled them.

*All Drawings Reproduced for Clarity*—Enhanced clarity of drawings has been achieved by the use of all original master artwork rather than copies or repro-

ductions that did not have the sharp detail of the originals.

*New Design*—A new design and layout for the text provide better accessibility of information and a more visually interesting format for students.

*New Photo Program*—New, relevant images reflecting today's technologies have been included with the assistance of many industrial sources.

*New Pedagogical Aids for Students*—Each chapter now contains an Overview, Objectives, Key Terms, a Chapter Summary, and Review Questions. These aids are intended to help students organize their reading and make it easier to review what they have learned.

*Fully Updated Material on CAD*—CAD technology has changed rapidly since the last edition, and Ms. Shawna Lockhart, a popular AutoCAD author and head of the engineering graphics program at Montana State University, has contributed material addressing these changes in three ways:

*Consolidating the material on CAD in the previous edition's chapters 3 and 8 into one chapter.* The material has been streamlined, updated with new topics, and repositioned as chapter 2, emphasizing the importance this technology now plays in graphical communication.

*Updating all computer graphics sections and adding new material where appropriate.* These sections have been revised to explain how CAD techniques apply to each chapter.

*CAD at Work boxes.* This new feature discusses many of the new ways in which professionals use CAD. These boxes contain photos, artwork and innovative text.

Students will learn about what goes on in industry by reading about topics such as: *From Art to Part, CAD At the Movies, Object Snaps, Lettering with CAD, Virtual Reality on the World Wide Web, Sketching and Parametric Modeling, Multiview Projection from a 3D Model, Automatic Layout of Sheet Metal Parts, Rapid Prototyping, Semiautomatic Dimensioning, Geometric Tolerances, Fastener Libraries, Pro/JR, Technical Document Management Systems, Photorealistic Shading, From CAD to Napkin, Animation, Potatoes and Productivity, CAD Design, Electronic Symbol Libraries, Finite Element Analysis, Creating Digital Terrain Models, CAD Solutions for*

*Industrial Piping, CAD Welding Symbols and Much More, Easy Graphing Software, Spreadsheets as Electronic Alignment Charts.*

*Engineering News Boxes*—These boxes, in selected chapters, include real news items which highlight modern trends in graphical communication and engineering graphics. They encourage the student to look to the future by emphasizing the growing importance of the engineer's design function.

*Eight Page Color Insert*—To give students a feel for how color is often used in CAD software and other technological processes, but without overloading and obscuring the book's core content, we have included an eight page color insert.

## ■ SUPPLEMENTS

New materials are continually being prepared to enable instructors to make their classes more interesting and provide up-to-the-minute information to their students. The current package of supplements includes:

### INSTRUCTOR'S MANUAL WITH CD-ROM

This manual contains a presentation on CD-ROM including all figures from the text for instructional use. The CD-ROM will work with MAC or PC platforms.

### WORKBOOKS

Three workbooks with additional problems are available. These workbooks are fully class tested for effectiveness and relevance to the course. They range from having more traditional problems to more modern approaches.

- Series 1: Contains traditional workbook problems.
- Series 2: Contains traditional problems with an emphasis on engineering concepts.
- Series 3: A brand new workbook by **Paige Davis** and **Karen Juneau** of the **Louisiana State University**. This book contains modern problems, as well as an extensive, CAD based project.

### WORLDWIDE WEB SITE—

**HTTP://WWW.PRENHALL.COM/GIESECKE**

In order to provide instructors and their students with the most advanced, exciting information available, Prentice Hall has created the Giesecke Web Site. This



site features links to other graphics related areas, a selection of animations available for classroom instruction or student review, an exploration of VRML technology, case studies exploring how graphics communication is handled at several companies, and much more. The site will be a constantly updated resource available to help instructors and students remain as current as possible.

#### **PRENTICE HALL NEW YORK TIMES SUPPLEMENT**

The supplement is a biannual, free collection of articles excerpted from the *New York Times* which cover areas of interest to students and young engineers.

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# APPENDIX

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- 46 Cast-Iron Flanges, Drilling for Bolts and Their Lengths, 250 lb—American National Standard a78



# 1 Bibliography of American National Standards

American National Standards Institute, 11 West 42nd St., New York, NY. 10036. For complete listing of standards, see ANSI catalog of American National Standards.

## Abbreviations

Abbreviations for Use on Drawings and in Text, ANSI/ASME Y1.1–1989

## Bolts, Screws, and Nuts

Bolts, Metric Heavy Hex, ANSI B18.2.3.6M–1979 (R1995)  
 Bolts, Metric Heavy Hex Structural, ANSI B18.2.3.7M–1979 (R1995)  
 Bolts, Metric Hex, ANSI B18.2.3.5M–1979 (R1995)  
 Bolts, Metric Round Head Short Square Neck, ANSI/ASME B18.2.2.1M–1981 (R1995)  
 Bolts, Metric Round Head Square Neck, ANSI/ASME B18.5.2.2M–1982 (R1993)  
 Hex Jam Nuts, Metric, ANSI B18.2.4.5M–1979 (R1990)  
 Hex Nuts, Heavy, Metric, ANSI B18.2.4.6M–1979 (R1990)  
 Hex Nuts, Slotted, Metric, ANSI/ASME B18.2.4.3M–1979 (R1995)  
 Hex Nuts, Style 1, Metric, ANSI/ASME B18.2.4.1M–1979 (R1995)  
 Hex Nuts, Style 2, Metric, ANSI/ASME B18.2.4.2M–1979 (R1995)  
 Hexagon Socket Flat Countersunk Head Cap Screws (Metric Series), ANSI/ASME B18.3.5M–1986 (R1993)  
 Mechanical Fasteners, Glossary of Terms, ANSI B18.12–1962 (R1995)  
 Miniature Screws, ANSI B18.11–1961 (R1992)  
 Nuts, Metric Hex Flange, ANSI B18.2.4.4M–1982 (R1993)  
 Plow Bolts, ANSI/ASME B18.9–1958 (R1995)  
 Round Head Bolts, Metric Round Head Short Square Neck, ANSI/ASME B18.5.2.1M–1981 (R1995)  
 Screws, Hexagon Socket Button Head Cap, Metric Series, ANSI/ASME B18.3.4M–1986 (R1993)  
 Screws, Hexagon Socket Head Shoulder, Metric Series, ANSI/ASME B18.3.3M–1986 (R1993)  
 Screws, Hexagon Socket Set, Metric Series, ANSI/ASME B18.3.6M–1986 (R1993)  
 Screws, Metric Formed Hex, ANSI/ASME B18.2.3.2M–1979 (R1995)  
 Screws, Metric Heavy Hex, ANSI/ASME B18.2.3.3M–1979 (R1995)  
 Screws, Metric Hex Cap, ANSI/ASME B18.2.3.1M–1979 (R1995)  
 Screws, Metric Hex Flange, ANSI/ASME B18.2.3.4M–1984 (R1995)  
 Screws, Metric Hex Lag, ANSI B18.2.3.8M–1981 (R1991)  
 Screws, Metric Machine, ANSI/ASME B18.6.7M–1985 (R1993)

Screws, Socket Head Cap, Metric Series, ANSI/ASME B18.3.1M–1986 (R1993)  
 Screws, Tapping and Metallic Drive, Inch Series, Thread Forming and Cutting, ANSI B18.6.4–1981 (R1991)  
 Slotted and Recessed Head Machine Screws and Machine Screw Nuts, ANSI B18.6.3–1972 (R1991)  
 Slotted Head Cap Screws, Square Head Set Screws, and Slotted Headless Set Screws, ANSI/ASME B18.6.2–1995  
 Socket Cap, Shoulder, and Set Screws (Inch Series) ANSI/ASME B18.3–1986 (R1995)  
 Square and Hex Bolts and Screws, Inch Series, ANSI B18.2.1–1981 (R1992)  
 Square and Hex Nuts (Inch Series) ANSI/ASME B18.2.2–1987 (R1993)  
 Track Bolts and Nuts, ANSI/ASME B18.10–1982 (R1992)  
 Wood Screws, Inch Series, ANSI B18.6.1–1981 (R1991)

## Dimensioning and Surface Finish

General Tolerances for Metric Dimensioned Products, ANSI B4.3–1978 (R1994)  
 Preferred Limits and Fits for Cylindrical Parts, ANSI B4.1–1967 (R1994)  
 Preferred Metric Limits and Fits, ANSI B4.2–1978 (R1994)  
 Surface Texture, ANSI/ASME B46.1–1995

## Drafting Manual (Y14)

Casting and Forgings, ANSI/ASME Y14.BM–1989  
 Decimal Inch, Drawing Sheet Size and Format, ANSI/ASME Y14.1–1995  
 Dimensioning and Tolerancing, ANSI/ASME Y14.5M–1994  
 Electrical and Electronics Diagrams, ANSI Y14.15–1966 (R1988)  
 Electrical and Electronics Diagrams—Supplement, ANSI Y14.15a–1971 (R1988)  
 Electrical and Electronics Diagrams—Supplement, ANSI Y14.15b–1973 (R1988)  
 Engineering Drawings, Types, and Applications, ANSI/ASME Y14.24M–1989. Revision of Engineering Drawings, ANSI/ASME Y14.35M–1992  
 Gear and Spline Drawing Standards—Part 2, Bevel and Hypoid Gears, ANSI Y14.7.2–1978 (R1994)  
 Gear Drawing Standards—Part 1, for Spur, Helical, Double Helical, and Rack, ANSI/ASME Y14.7.1–1971 (R1993)  
 Line Conventions and Lettering, ANSI/ASME Y14.2M–1992  
 Mechanical Spring Representation, ANSI/ASME Y14.13M–1981 (R1992)  
 Metric Drawing Sheet Size and Format, ANSI/ASME Y14.1M–1995  
 Multiview and Sectional View Drawings, ANSI/ASME Y14.3M–1994

Parts Lists, Data Lists, and Index Lists, ANSI/ASME Y14.34M–1990  
 Pictorial Drawing, ANSI/ASME Y14.4M–1989 (R1994)  
 Screw Thread Representation, ANSI/ASME Y14.6–1978 (R1993)  
 Screw Thread Representation, Metric, ANSI/ASME Y14.6aM–1981 (R1993)  
 Surface Texture Symbols, ANSI/ASME Y14.36M–1996

### ***Gears***

Basic Gear Geometry, ANSI/AGMA 115.01–1989  
 Gear Nomenclature—Terms, Definitions, Symbols, and Abbreviations, ANSI/AGMA 1012–F90  
 Nomenclature of Gear-Tooth Failure Modes, ANSI/AGMA 110.04–1980 (R1989)  
 Design Manual for Bevel Gearing, ANSI/AGMA 2005–B88  
 Tooth Proportions for Fine-Pitch Spur and Helical Gears, ANSI/AGMA 1003–G93

### ***Graphic Symbols***

Public Fire Safety Symbols, ANSI/NFPA 170–1994  
 Graphic Symbols for Electrical and Electronics Diagrams, ANSI/IEEE 315–1975 (R1994)  
 Graphic Symbols for Electrical Wiring and Layout Diagrams Used in Architecture and Building Construction, ANSI Y32.9–1972 (R1989)  
 Graphic Symbols for Fluid Power Diagrams, ANSI/ASME Y32.10–1967 (R1994)  
 Graphic Symbols for Grid and Mapping Used in Cable Television Systems, ANSI/IEEE 623–1976 (R1989)  
 Graphic Symbols for Heat-Power Apparatus, ANSI Y32.2.6M–1950 (R1993)  
 Graphic Symbols for Heating, Ventilating and Air Conditioning, ANSI Y32.2.4–1949 (R1993)  
 Graphic Symbols for Logic Functions, ANSI/IEEE 91–1984  
 Graphic Symbols for Pipe Fittings, Valves, and Piping, ANSI/ASME Y32.2.3–1949 (R1994)  
 Graphic Symbols for Plumbing Fixtures for Diagrams Used in Architecture and Building Construction, ANSI/ASME Y32.4–1977 (R1994)  
 Graphic Symbols for Process Flow Diagrams in the Petroleum and Chemical Industries, ANSI Y32.11–1961 (R1993)  
 Graphic Symbols for Railroad Maps and Profiles, ANSI/ASME Y32.7–1972 (R1994)  
 Instrumentation Symbols and Identification, ANSI/ISA S5.1–1984 (R1992)  
 Reference Designations for Electrical and Electronics Parts and Equipment, ANSI/IEEE 200–1975 (R1989)  
 Symbols for Mechanical and Acoustical Elements as Used in Schematic Diagrams, ANSI Y32.18–1972 (R1993)  
 Symbols for Welding, Brazing, and Nondestructive Examination, ANSI/AWS A2.4–93

### ***Keys and Pins***

Clevis Pins and Cotter Pins, ANSI/ASME B18.8.1–1994  
 Hexagon Keys and Bits (Metric Series), ANSI B18.3.2M–1979 (R1994)  
 Keys and Keyseats, ANSI B17.1–1967 (R1989)  
 Pins—Taper Pins, Dowel Pins, Straight Pins, Grooved Pins and Spring Pins (Inch Series), ANSI/ASME B18.8.2–1994  
 Woodruff Keys and Keyseats, ANSI B17.2–1967 (R1990)

### ***Piping***

Cast Bronze Threaded Fittings, Class 125 and 250, ANSI/ASME B16.15–1985 (R1994)  
 Cast Copper Alloy Pipe Flanges and Flanged Fittings, ANSI/ASME B16.24–1991  
 Cast Iron Pipe Flanges and Flanged Fittings, Class 25, 125, 250 and 800, ANSI/ASME B16.1–1989  
 Gray Iron Threaded Fittings, ANSI/ASME B16.4–1992  
 Ductile Iron Pipe, Centrifugally Cast, ANSI/AWWA C151/A21.51–91  
 Factory-Made Wrought Steel Buttwelding Fittings, ANSI/ASME B16.9–1993  
 Ferrous Pipe Plugs, Bushings, and Locknuts with Pipe Threads, ANSI/ASME B16.14–1991  
 Flanged Ductile-Iron Pipe with Threaded Flanges, ANSI/AWWA C115/A21.15–94  
 Malleable-Iron Threaded Fittings, ANSI/ASME B16.3–1992  
 Pipe Flanges and Flanged Fittings, ANSI/ASME B16.5–1988  
 Stainless Steel Pipe, ANSI/ASME B36.19M–1985 (R1994)  
 Welded and Seamless Wrought Steel Pipe, ANSI/ASME B36.10M–1995

### ***Rivets***

Large Rivets ( $\frac{1}{2}$  Inch Nominal Diameter and Larger), ANSI/ASME B18.1.2–1972 (R1995)  
 Small Solid Rivets ( $\frac{7}{16}$  Inch Nominal Diameter and Smaller), ANSI/ASME B18.1.1–1972 (R1995)  
 Small Solid Rivets, Metric, ANSI/ASME B18.1.3M–1983 (R1995)

### ***Small Tools and Machine Tool Elements***

Jig Bushings, ANSI B94.33–1974 (R1994)  
 Machine Tapers, ANSI/ASME B5.10–1994  
 Milling Cutters and End Mills, ANSI/ASME B94.19–1985  
 Reamers, ANSI/ASME B94.2–1995  
 T-Slots—Their Bolts, Nuts and Tongues, ANSI/ASME B5.1M–1985 (R1992)  
 Twist Drills, ANSI/ASME B94.11M–1993

### ***Threads***

Acme Screw Threads, ANSI/ASME B1.5–1988 (R1994)  
 Buttress Inch Screw Threads, ANSI B1.9–1973 (R1992)  
 Class 5 Interference-Fit Thread, ANSI/ASME B1.12–1987 (R1992)

Dryseal Pipe Threads (Inch), ANSI B1.20.3-1976 (R1991)  
 Hose Coupling Screw Threads, ANSI/ASME B1.20.7-1991  
 Metric Screw Threads—M Profile, ANSI/ASME B1.13M-1995  
 Metric Screw Threads—MJ Profile, ANSI/ASME B1.21M-1978  
 Nomenclature, Definitions and Letter Symbols for Screw Threads, ANSI/ASME B1.7M-1984 (R1992)  
 Pipe Threads, General Purpose (Inch), ANSI/ASME B1.20.1-1983 (R1992)  
 Stub Acme Threads, ANSI/ASME B1.8-1988 (R1994)  
 Unified Screw Threads (UN and UNR Thread Form), ANSI/ASME B1.1-1989  
 Unified Miniature Screw Threads, ANSI B1.10-1958 (R1988)

### Washers

Lock Washers, Inch, ANSI/ASME B18.21.1-1994  
 Lock Washers, Metric, ANSI/ASME B18.21.2M-1994

Plain Washers, ANSI B18.22.1-1965 (R1981)  
 Plain Washers, Metric, ANSI B18.22M-1981

### Miscellaneous

Knurling, ANSI/ASME B94.6-1984 (R1995)  
 Preferred Metric Sizes for Flat Metal Products, ANSI/ASME B32.3M-1984 (R1994)  
 Preferred Metric Equivalents of Inch Sizes for Tubular Metal Products Other Than Pipe, ANSI/ASME B32.6M-1984 (R1994)  
 Preferred Metric Sizes for Round, Square, Rectangle and Hexagon Metal Products, ANSI B32.4M-1980 (R1994)  
 Preferred Metric Sizes for Tubular Metal Products Other Than Pipe, ANSI B32.5-1977 (R1994)  
 Preferred Thickness for Uncoated Thin Flat Metals (Under 0.250 in.), ANSI B32.1-1952 (R1994)  
 Surface Texture (Surface Roughness, Waviness and Lay), ANSI/ASME B46.1-1995  
 Technical Drawings, ISO Handbook, 12-1991

## 2 Technical Terms

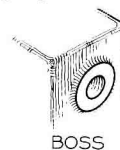
“The beginning of wisdom is to call things by their right names.”

—CHINESE PROVERB

*n means a noun; v means a verb*

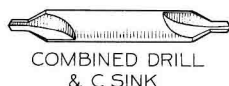
**acme** (*n*) Screw thread form, §§14.3 and 14.13  
**addendum** (*n*) Radial distance from pitch circle to top of gear tooth.  
**allen screw** (*n*) Special set screw or cap screw with hexagon socket in head, §14.31.  
**allowance** (*n*) Minimum clearance between mating parts, §13.12.  
**alloy** (*n*) Two or more metals in combination, usually a fine metal with a baser metal.  
**aluminum** (*n*) A lightweight but relatively strong metal. Often alloyed with copper to increase hardness and strength.  
**angle iron** (*n*) A structural shape whose section is a right angle, §11.20.  
**anneal** (*v*) To heat and cool gradually, to reduce brittleness and increase ductility, §11.22.  
**arc-weld** (*v*) To weld by electric arc. The work is usually the positive terminal.  
**babbitt** (*n*) A soft alloy for bearings, mostly of tin with small amounts of copper and antimony.  
**bearing** (*n*) A supporting member for a rotating shaft.  
**bevel** (*n*) An inclined edge, not at right angle to joining surface.

**bolt circle** (*n*) A circular center line on a drawing, containing the centers of holes about a common center, §12.25.  
**bore** (*v*) To enlarge a hole with a boring mill, Figs. 11.15b and 11.18b.  
**boss** (*n*) A cylindrical projection on a casting or a forging.

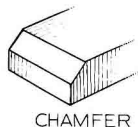


**brass** (*n*) An alloy of copper and zinc.  
**braz** (*v*) To join with hard solder of brass or zinc.  
**Brinell** (*n*) A method of testing hardness of metal.  
**broach** (*n*) A long cutting tool with a series of teeth that gradually increase in size which is forced through a hole or over a surface to produce a desired shape, §11.15.  
**bronze** (*n*) An alloy of eight or nine parts of copper and one part of tin.  
**buff** (*v*) To finish or polish on a buffing wheel composed of fabric with abrasive powders.  
**burnish** (*v*) To finish or polish by pressure upon a smooth rolling or sliding tool.  
**burr** (*n*) A jagged edge on metal resulting from punching or cutting.

- bushing** (*n*) A replaceable lining or sleeve for a bearing.
- calipers** (*n*) Instrument (of several types) for measuring diameters, §11.17.
- cam** (*n*) A rotating member for changing circular motion to reciprocating motion.
- carburize** (*v*) To heat a low-carbon steel to approximately 2000°F in contact with material which adds carbon to the surface of the steel, and to cool slowly in preparation for heat treatment, §11.22.
- caseharden** (*v*) To harden the outer surface of a carburized steel by heating and then quenching.
- castellate** (*v*) To form like a castle, as a castellated shaft or nut.
- casting** (*n*) A metal object produced by pouring molten metal into a mold, §11.3.
- cast iron** (*n*) Iron melted and poured into molds, §11.3.
- center drill** (*n*) A special drill to produce bearing holes in the ends of a workpiece to be mounted between centers. Also called a “combined drill and countersink,” §12.35.



- chamfer** (*n*) A narrow inclined surface along the intersection of two surfaces.



- chase** (*v*) To cut threads with an external cutting tool.
- cheek** (*n*) The middle portion of a three-piece flask used in molding, §11.3.
- chill** (*v*) To harden the outer surface of cast iron by quick cooling, as in a metal mold.
- chip** (*v*) To cut away metal with a cold chisel.
- chuck** (*n*) A mechanism for holding a rotating tool or workpiece.
- coin** (*v*) To form a part in one stamping operation.
- cold-rolled steel** (CRS) (*n*) Open hearth or Bessemer steel containing 0.12–0.20% carbon that has been rolled while cold to produce a smooth, quite accurate stock.
- collar** (*n*) A round flange or ring fitted on a shaft to prevent sliding.



- colorharden** (*v*) Same as *caseharden*, except that it is done to a shallower depth, usually for appearance only.
- cope** (*n*) The upper portion of a flask used in molding, §11.3.

- core** (*v*) To form a hollow portion in a casting by using a dry-sand core or a green-sand core in a mold, §11.3.
- coreprint** (*n*) A projection on a pattern which forms an opening in the sand to hold the end of a core, §11.3.
- cotter pin** (*n*) A split pin used as a fastener, usually to prevent a nut from unscrewing, Figs. 14.31g and 14.31h and Appendix 30.
- counterbore** (*v*) To enlarge an end of a hole cylindrically with a *counterbore*, § 11.16.



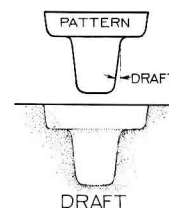
- countersink** (*v*) To enlarge an end of a hole conically, usually with a *countersink*, §11.16.



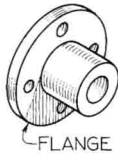
- crown** (*n*) A raised contour, as on the surface of a pulley.
- cyanide** (*v*) To surface-harden steel by heating in contact with a cyanide salt, followed by quenching.
- dedendum** (*n*) Distance from pitch circle to bottom of tooth space.
- development** (*n*) Drawing of the surface of an object unfolded or rolled out on a plane.
- diametral pitch** (*n*) Number of gear teeth per inch of pitch diameter.
- die** (*n*) (1) Hardened metal piece shaped to cut or form a required shape in a sheet of metal by pressing it against a mating die. (2) Also used for cutting small male threads. In a sense is opposite to a tap.
- die casting** (*n*) Process of forcing molten metal under pressure into metal dies or molds, producing a very accurate and smooth casting.
- die stamping** (*n*) Process of cutting or forming a piece of sheet metal with a die.
- dog** (*n*) A small auxiliary clamp for preventing work from rotating in relation to the face plate of a lathe.
- dowel** (*n*) A cylindrical pin, commonly used to prevent sliding between two contacting flat surfaces.



- draft** (*n*) The tapered shape of the parts of a pattern to permit it to be easily withdrawn from the sand or, on a forging, to permit it to be easily withdrawn from the dies, §§11.3 and 11.21.



- drag** (n) Lower portion of a flask used in molding, §11.3.
- draw** (v) To stretch or otherwise to deform metal. Also to temper steel.
- drill** (v) To cut a cylindrical hole with a drill. A *blind hole* does not go through the piece, §11.16.
- drill press** (n) A machine for drilling and other hole-forming operations, §11.8.
- drop forge** (v) To form a piece while hot between dies in a drop hammer or with great pressure, §11.21.
- face** (v) To finish a surface at right angles, or nearly so, to the center line of rotation on a lathe.
- FAO** Finish all over, §12.17.
- feather key** (n) A flat key, which is partly sunk in a shaft and partly in a hub, permitting the hub to slide lengthwise of the shaft, §14.34.
- file** (v) To finish or smooth with a file.
- fillet** (n) An interior rounded intersection between two surfaces, §§7.34 and 11.5.
- fin** (n) A thin extrusion of metal at the intersection of dies or sand molds.
- fit** (n) Degree of tightness or looseness between two mating parts, as a *loose fit*, a *snug fit*, or a *tight fit*. §§12.9 and 13.1–13.3.
- fixture** (n) A special device for holding the work in a machine tool, *but not for guiding the cutting tool*.
- flange** (n) A relatively thin rim around a piece.



FLANGE

- flash** (n) Same as *fin*.
- flask** (n) A box made of two or more parts for holding the sand in sand molding, §11.3.
- flute** (n) Groove, as on twist drills, reamers, and taps.
- forge** (v) To force metal while it is hot to take on a desired shape by hammering or pressing, §11.21.
- galvanize** (v) To cover a surface with a thin layer of molten alloy, composed mainly of zinc, to prevent rusting.
- gasket** (n) A thin piece of rubber, metal, or some other material, placed between surfaces to make a tight joint.
- gate** (n) The opening in a sand mold at the bottom of the *sprue* through which the molten metal passes to enter the cavity or mold, §11.3.
- graduate** (v) To set off accurate divisions on a scale or dial.
- grind** (v) To remove metal by means of an abrasive wheel, often made of carborundum. Use chiefly where accuracy is required, §11.14.
- harden** (v) To heat steel above a critical temperature and then quench in water or oil, §11.22.

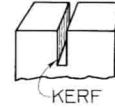
**heat-treat** (v) To change the properties of metals by heating and then cooling, §11.22.

**interchangeable** (adj.) Refers to a part made to limit dimensions so that it will fit any mating part similarly manufactured, §13.1.

**jig** (n) A device for guiding a tool in cutting a piece. Usually it holds the work in position.

**journal** (n) Portion of a rotating shaft supported by a bearing.

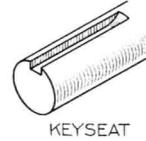
**kerf** (n) Groove or cut made by a saw.



KERF

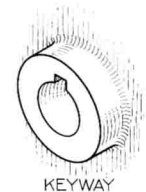
**key** (n) A small piece of metal sunk partly into both shaft and hub to prevent rotation, §14.34.

**keyseat** (n) A slot or recess in a shaft to hold a key, §14.34.



KEYSEAT

**keyway** (n) A slot in a hub or portion surrounding a shaft to receive a key, §14.34.



KEYWAY

**knurl** (v) To impress a pattern of dents in a turned surface with a knurling tool to produce a better hand grip, §12.37.

**lap** (v) To produce a very accurate finish by sliding contact with a *lap*, or piece of wood, leather, or soft metal impregnated with abrasive powder.

**lathe** (n) A machine used to shape metal or other materials by rotating against a tool, §11.7.

**lug** (n) An irregular projection of metal, but not round as in the case of a *boss*, usually with a hole in it for a bolt or screw.

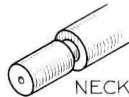
**malleable casting** (n) A casting that has been made less brittle and tougher by annealing.

**mill** (v) To remove material by means of a rotating cutter on a milling machine, §11.9.

**mold** (n) The mass of sand or other material that forms the cavity into which molten metal is poured, §11.3.

**MS** (n) Machinery steel, sometimes called *mild steel* with a small percentage of carbon. Cannot be hardened.

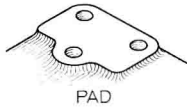
**neck** (v) To cut a groove called a *neck* around a cylindrical piece.



**normalize** (v) To heat steel above its critical temperature and then to cool it in air, §11.22.

**pack-harden** (v) To *carburize*, then to *caseharden*, §11.22.

**pad** (n) A slight projection, usually to provide a bearing surface around one or more holes.



**pattern** (n) A model, usually of wood, used in forming a mold for a casting. In sheet metal work a pattern is called a *development*.

**peen** (v) To hammer into shape with a ballpeen hammer.

**pickle** (v) To clean forgings or castings in dilute sulphuric acid.

**pinion** (n) The smaller of two mating gears.

**pitch circle** (n) An imaginary circle corresponding to the circumference of the friction gear from which the spur gear was derived.

**plane** (v) To remove material by means of the *planer*, §11.11.

**planish** (v) To impart a planished surface to sheet metal by hammering with a smooth-surfaced hammer.

**plate** (v) To coat a metal piece with another metal, such as chrome or nickel, by electrochemical methods.

**polish** (v) To produce a highly finished or polished surface by friction, using a very fine abrasive.

**profile** (v) To cut any desired outline by moving a small rotating cutter, usually with a master template as a guide.

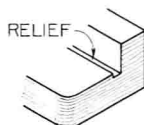
**punch** (v) To cut an opening of a desired shape with a rigid tool having the same shape, by pressing the tool through the work.

**quench** (v) To immerse a heated piece of metal in water or oil to harden it.

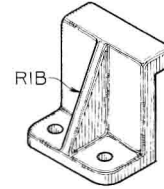
**rack** (n) A flat bar with gear teeth in a straight line to engage with teeth in a gear.

**ream** (v) To enlarge a finished hole slightly to give it greater accuracy, with a *reamer*, §11.16.

**relief** (n) An offset of surfaces to provide clearance for machining.



**rib** (n) A relatively thin flat member acting as a brace or support.



**rivet** (v) To connect with rivets or to clench over the end of a pin by hammering, §14.36.

**round** (n) An exterior rounded intersection of two surfaces, §§7.34 and 11.5.

**SAE** Society of Automotive Engineers.

**sandblast** (v) To blow sand at high velocity with compressed air against castings or forgings to clean them.

**scleroscope** (n) An instrument for measuring hardness of metals.

**scrape** (v) To remove metal by scraping with a hand scraper, usually to fit a bearing.

**shape** (v) To remove metal from a piece with a *shaper*, §11.10.

**shear** (v) To cut metal by means of shearing with two blades in sliding contact.

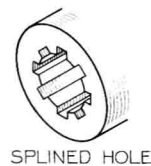
**sherardize** (v) To galvanize a piece with a coating of zinc by heating it in a drum with zinc powder, to a temperature of 575–850°F.

**shim** (n) A thin piece of metal or other material used as a spacer in adjusting two parts.

**solder** (v) To join with solder, usually composed of lead and tin.

**spin** (v) To form a rotating piece of sheet metal into a desired shape by pressing it with a smooth tool against a rotating form.

**spline** (n) A keyway, usually one of a series cut around a shaft or hole.



**spotface** (v) To produce a round *spot* or bearing surface around a hole, usually with a *spotfacer*. The spotface may be on top of a boss or it may be sunk into the surface, §§7.33 and 11.16.



**sprue** (n) A hole in the sand leading to the *gate* which leads to the mold, through which the metal enters, §11.3.

**steel casting** (n) Like cast-iron casting except that in the furnace scrap steel has been added to the casting.



**swage** (v) To hammer metal into shape while it is held over a *swage*, or die, which fits in a hole in the *swage block*, or anvil.

**sweat** (v) To fasten metal together by the use of solder between the pieces and by the application of heat and pressure.

**tap** (v) To cut relatively small internal threads with a *tap*. §11.16.

**tape** (n) Conical form given to a shaft or a hole. Also refers to the slope of a plane surface, §12.33.

**taper pin** (n) A small tapered pin for fastening, usually to prevent a collar or hub from rotating on a shaft.



**taper reamer** (n) A tapered reamer for producing accurate tapered holes, as for a taper pin, §§12.33 and 14.35.

**temper** (v) To reheat hardened steel to bring it to a desired degree of hardness, §11.22.

**template** or **templet** (n) A guide or pattern used to mark out the work, guide the tool in cutting it, or check the finished product.

**tin** (n) A silvery metal used in alloys and for coating other metals, such as tin plate.

**tolerance** (n) Total amount of variation permitted in limit dimension of a part, §13.2.

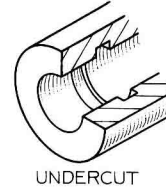
**trepan** (v) To cut a circular groove in the flat surface at one end of a hole.

**tumble** (v) To clean rough castings or forgings in a revolving drum filled with scrap metal.

**turn** (v) To produce, on a lathe, a cylindrical surface parallel to the center line, §11.7.

**twist drill** (n) A drill for use in a drill press, §11.16.

**undercut** (n) A recessed cut or a cut with inwardly sloping sides.

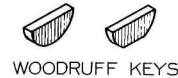


**upset** (v) To form a head or enlarged end on a bar or rod by pressure or by hammering between dies.

**web** (n) A thin flat part joining larger parts. Also known as a *rib*.

**weld** (v) Uniting metal pieces by pressure or fusion welding processes, §11.19.

**Woodruff key** (n) A semicircular flat key, §14.34.



**wrought iron** (n) Iron of low carbon content useful because of its toughness, ductility, and malleability.

### 3 CAD/CAM Glossary\*

**access time** (or disk access time) One measure of system response. The time interval between the instant that data is called for from storage and the instant that delivery is completed—i.e., read time. See also *response time*.

**alphanumeric** (or alphameric) A term that encompasses letters, digits, and special characters that are machine-processable.

**alphanumeric display** (or alphameric display) A work-station device consisting of a CRT on which text can be viewed. An alphanumeric display is capable of showing a fixed set of letters, digits, and special characters. It allows the designer to observe entered commands and to receive messages from the system.

**alphanumeric keyboard** (or alphameric keyboard) A work-station device consisting of a typewriter-like keyboard that allows the designer to communicate with the system using an English-like command language.

**American Standard Code for Information Interchange** (ASCII) An industry-standard character code widely used for information interchange among data processing systems, communications systems, and associated equipment.

**analog** Applied to an electrical or computer system, this denotes the capability to represent data in continuously varying physical quantities.

**annotation** Process of inserting text or a special note or identification (such as a flag) on a drawing, map, or diagram constructed on a CAD/CAM system. The text can be generated and positioned on the drawing using the system.

**application program** (or package) A computer program or collection of programs to perform a task or tasks specific to a particular user's need or class of needs.

**archival storage** Refers to memory (on magnetic tape,

\* Extracted from *The CAD/CAM Glossary*, 1983 edition, published by the Computervision Corporation, Bedford, MA 01730; reproduced with permission of the publisher.

disks, printouts, or drums) used to store data on completed designs or elements outside of main memory.

**array** (*v*) To create automatically on a CAD system an arrangement of identical elements or components. The designer defines the element once, then indicates the starting location and spacing for automatic generation of the array. (*n*) An arrangement created in the above manner. A series of elements or sets of elements arranged in a pattern—i.e., matrix.

**ASCII** See *American National Standard Code for Information Exchange*.

**assembler** A computer program that converts (i.e., translates) programmer-written symbolic instructions, usually in mnemonic form, into machine-executable (computer or binary-coded) instructions. This conversion is typically one-to-one (one symbolic instruction converts to one machine-executable instruction). A software programming aid.

**associative dimensioning** A CAD capability that links dimension entities to geometric entities being dimensioned. This allows the value of a dimension to be automatically updated as the geometry changes.

**attribute** A nongraphic characteristic of a part, component, or entity under design on a CAD system. Examples include: dimension entities associated with geometry, text with text nodes, and nodal lines with connect nodes. Changing one entity in an association can produce automatic changes by the system in the associated entity; e.g., moving one entity can cause moving or stretching of the other entity.

**automatic dimensioning** A CAD capability that computes the dimensions in a displayed design, or in a designated section, and automatically places dimensions, dimensional lines, and arrowheads where required. In the case of mapping, this capability labels the linear feature with length and azimuth.

**auxiliary storage** Storage that supplements main memory devices such as disk or drum storage. Contrast with *archival storage*.

**benchmark** The program(s) used to test, compare, and evaluate in real time the performance of various CAD/CAM systems prior to selection and purchase. A *synthetic* benchmark has preestablished parameters designed to exercise a set of system features and resources. A *live* benchmark is drawn from the prospective user's workload as a model of the entire workload.

**bit** The smallest unit of information that can be stored and processed by a digital computer. A bit may assume only one of two values: 0 or 1 (i.e., ON/OFF or YES/NO). Bits are organized into larger units called *words* for access by computer instructions.

Computers are often categorized by word size in bits, i.e., the maximum word size that can be processed as a

unit during an instruction cycle (e.g., 16-bit computers or 32-bit computers). The number of bits in a word is an indication of the processing power of the system, especially for calculations or for high-precision data.

**bit rate** The speed at which bits are transmitted, usually expressed in bits per second.

**bits per inch** (bpi) The number of bits that can be stored per inch of a magnetic tape. A measure of the data storage capacity of a magnetic tape.

**blank** A CAD command that causes a predefined entity to go temporarily blank on the CRT. The reversing command is *unblank*.

**blinking** A CAD design aid that makes a predefined graphic entity blink on the CRT to attract the attention of the designer.

**boot up** Start up (a system).

**B-spline** A sequence of parametric polynomial curves (typically quadratic or cubic polynomials) forming a smooth fit between a sequence of points in 3D space. The piece-wise defined curve maintains a level of mathematical continuity dependent upon the polynomial degree chosen. It is used extensively in mechanical design applications in the automotive and aerospace industries.

**bug** A flaw in the design or implementation of a software program or hardware design that causes erroneous results or malfunctions.

**bulk memory** A memory device for storing a large amount of data, e.g., disk, drum, or magnetic tape. It is not randomly accessible as main memory is.

**byte** A sequence of adjacent bits, usually eight, representing a character that is operated on as a unit. Usually shorter than a word. A measure of the memory capacity of a system, or of an individual storage unit (as a 300-million-byte disk).

**CAD** See *computer-aided design*.

**CAD/CAM** See *computer-aided design/computer-aided manufacturing*.

**CADDS®** Computervision Corporation's registered trademark for its prerecorded software programs.

**CAE** See *computer-aided engineering*.

**CAM** See *computer-aided manufacturing*.

**CAMACS™** (CAM Asynchronous Communications Software) Computervision's communications link, which enables users to exchange machine control data with other automation systems and devices, or to interact directly with local or remote manufacturing systems and machines. CAMACS tailors CAD/CAM data automatically for a wide range of machine tools, robots, coordinate measurement systems, and off-line storage devices.

**cathode ray tube** (CRT) The principal component in a CAD display device. A CRT displays graphic representations of geometric entities and designs and can be of vari-

ous types: storage tube, raster scan, or refresh. These tubes create images by means of a controllable beam of electrons striking a screen. The term *CRT* is often used to denote the entire display device.

**central processing unit (CPU)** The computer brain of a CAD/CAM system that controls the retrieval, decoding, and processing of information, as well as the interpretation and execution of operating instructions—the building blocks of application and other computer programs. A CPU comprises arithmetic, control, and logic elements.

**character** An alphabetical, numerical, or special graphic symbol used as part of the organization, control, or representation of CAD/CAM data.

**characters per second (cps)** A measure of the speed with which an alphanumeric terminal can process data.

**chip** See *integrated circuit*.

**code** A set of specific symbols and rules for representing data (usually instructions) so that the data can be understood and executed by a computer. A code can be in binary (machine) language, assembly language, or a high-level language. Frequently refers to an industry-standard code such as ANSI, ASCII, IPC, or Standard Code for Information Exchange. Many application codes for CAD/CAM are written in FORTRAN.

**color display** A CAD/CAM display device. Color raster-scan displays offer a variety of user-selectable, contrasting colors to make it easier to discriminate among various groups of design elements on different layers of a large, complex design. Color speeds up the recognition of specific areas and subassemblies, helps the designer interpret complex surfaces, and highlights interference problems. Color displays can be of the penetration type, in which various phosphor layers give off different colors (refresh display) or the TV-type with red, blue, and green electron guns (raster-scan display).

**command** A control signal or instruction to a CPU or graphics processor, commonly initiated by means of a menu/tablet and electronic pen or by an alphanumeric keyboard.

**command language** A language for communicating with a CAD/CAM system in order to perform specific functions or tasks.

**communication link** The physical means, such as a telephone line, for connecting one system module or peripheral to another in a different location in order to transmit and receive data. See also *data link*.

**compatibility** The ability of a particular hardware module or software program, code, or language to be used in a CAD/CAM system without prior modification or special interfaces. *Upward compatible* denotes the ability of a system to interface with new hardware or software modules or enhancements (i.e., the system vendor provides with each new module a reasonable means of transferring data,

programs, and operator skills from the user's present system to the new enhancements).

**compiler** A computer program that converts or translates a high-level, user-written language (e.g., PASCAL, COBOL, VARPRO, or FORTRAN) or source, into a language that a computer can understand. The conversion is typically one to many (i.e., one user instruction to many machine-executable instructions). A software programming aid, the compiler allows the designer to write programs in an English-like language with relatively few statements, thus saving program development time.

**component** A physical entity, or a symbol used in CAD to denote such an entity. Depending on the application, a component might refer to an IC or part of a wiring circuit (e.g., a resistor), or a valve, elbow, or vee in a plant layout, or a substation or cable in a utility map. Also applies to a subassembly or part that goes into higher level assemblies.

**computer-aided design (CAD)** A process that uses a computer system to assist in the creation, modification, and display of a design.

**computer-aided design/computer-aided manufacturing (CAD/CAM)** Refers to the integration of computers into the entire design-to-fabrication cycle of a product or plant.

**computer-aided engineering (CAE)** Analysis of a design for basic error checking, or to optimize manufacturability, performance, and economy (for example, by comparing various possible materials or designs). Information drawn from the CAD/CAM design data base is used to analyze the functional characteristics of a part, product, or system under design and to simulate its performance under various conditions. In electronic design, CAE enables users of the Computervision Designer system to detect and correct potentially costly design flaws. CAE permits the execution of complex circuit loading analyses and simulation during the circuit definition stage. CAE can be used to determine section properties, moments of inertia, shear and bending moments, weight, volume, surface area, and center of gravity. CAE can precisely determine loads, vibration, noise, and service life early in the design cycle so that components can be optimized to meet those criteria. Perhaps the most powerful CAE technique is finite element modeling. See also *kinematics*.

**computer-aided manufacturing (CAM)** The use of computer and digital technology to generate manufacturing-oriented data. Data drawn from a CAD/CAM data base can assist in or control a portion or all of a manufacturing process, including numerically controlled machines, computer-assisted parts programming, computer-assisted process planning, robotics, and programmable logic controllers. CAM can involve production programming, manufacturing engineering, industrial engineering, facilities engineering, and reliability engineering (quality control).