



Electrical and
Electronic Drafting
Second Edition

RICHTER
RUBENSTEIN

Electrical and Electronic Drafting

Second Edition

Herbert W. Richter

**Charles F. Rubenstein,
B.E.E., M.E.E., P.E.**

Cuyahoga Community College
Cleveland Ohio

John Wiley & Sons

New York
Chichester
Brisbane
Toronto
Singapore

Cover photograph:
Jay Freis/The Image Bank

Copyright © 1985, by John Wiley & Sons, Inc.

All rights reserved. Published simultaneously in Canada.

Reproduction or translation of any part of this work beyond that permitted by Sections 107 and 108 of the 1976 United States Copyright Act without the permission of the copyright owner is unlawful. Requests for permission or further information should be addressed to the Permissions Department, John Wiley & Sons.

ISBN 0-471-05784-3

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

Electrical and Electronic Drafting

To my wife, Susan,
and to Fran, Glenda, Larry,
and my grandson Brian

Preface

This book was written expressly to introduce students to the various drafting techniques and types of drawings used in the design and construction of electronic and electrical equipment. It is appropriate for use in drafting technology programs at the associate degree level, as well as for courses offered in Bachelor of Engineering and Bachelor of Engineering Technology programs at colleges and universities.

It is assumed that the student who takes an Electrical and Electronic Drafting course has already completed a basic Technical Drawing or Engineering Drawing course and a first course in Electronic Devices.

The sequence of chapters presented in this edition of *Electrical and Electronic Drafting* is based on the successful course given at Cuyahoga Community College. Chapters 1, 2, and 3 provide a general overview of instruments, drawing techniques, lettering techniques, and standard approaches to preparing graphs and charts. Once students have learned this material, the instructor may wish to select subsequent chapters in an order tailored to the specific course requirements.

The use of the computer in the areas of engineering, drafting, and manufacturing has developed into a special application, CAD/CAM, for these areas. Chapter 14 reviews this new technology and describes a number of commercially available CAD/CAM systems.

The electrical and electronic components referred to in this edition are based on the MIL-STD requirements. Instructors may wish to obtain parts catalogues from local distributors for comparison with the MIL-STD components. If the class schedule permits, a tour of a local facility is suggested to enhance the students appreciation of subject matter by relating classroom assignments to industrial realities.

All electrical and electronic symbols conform to the current American National Standards Institute (ANSI) Y 32.2 series (as incorporated by the Institute of Electrical and Electronic Engineers (IEEE) standard 315. Graphical symbols for electrical wiring and layout diagrams used in architecture and building construction conform to the ANSI Y 32.9 series. Graphical symbols used in industrial motor control circuits conform to the latest Joint Industrial Council (JIC).

I gratefully acknowledge the assistance and support of the Wiley staff, in particular the guidance of Ms. Judith Joseph and Ms. Cindy Zigmund. Special thanks go to Mr. Bruce W. Owen, P.E., Vice President of Problem Solvers, Inc., for his detailed review of the preliminary manuscript. I also wish to express my appreciation to those organizations which provided data sheets, samples, photographs, and other related items. Helpful reviews of this text were provided by Dean Chowenhill (College of San Mateo), Jerry T. Baxter (Sabine Valley Vocational-Technical School), Thomas J. Bingham (St. Louis Community College), Steve Huycke (Lake Michigan College), Ron Ebben (North Central Technical Institute), Mark Kocher (Columbus Technical Institute), Thomas A. Singletary (Georgia Southern College), Lou Gross (Columbus Technical Institute), Larry D. Goss (Indiana State University at Evansville), Roman J. Ozarka (College of DuPage), and Robert S. McFarland (Columbus Technical Institute). I would also like to acknowledge the work of Herbert W. Richter, the author of the first edition of this text. It is my hope that the second edition will capture the concern for students and for new technology reflected in the first edition.

Charles F. Rubenstein

Contents

1			
Instruments and Drawing Techniques	1		
INSTRUCTIONAL OBJECTIVES	1		
SELF-EVALUATION QUESTIONS	1		
1-1 Drawing Boards and Tables	2		
1-2 T-Squares and Triangles	4		
1-3 Drafting Machines	7		
1-4 Pencils and Line Widths	7		
1-5 Erasers and Erasing Shields	8		
1-6 Inks and Inking Pens	10		
1-7 Instrument Kit	11		
1-8 Drawing Papers and Materials	13		
1-9 Templates	14		
1-10 Drafting Aids	14		
1-11 Basics of Orthographic Drawing	15		
1-12 Work Habits	16		
SUMMARY	17		
PROBLEMS	17		
2			
Lettering	22		
INSTRUCTIONAL OBJECTIVES	22		
SELF-EVALUATION QUESTIONS	22		
2-1 The Importance of Lettering	22		
2-2 Letter Styles	24		
2-3 Guidelines and Guideline Devices	26		
2-4 Spacing of Letters	30		
2-5 Lettering Templates	30		
2-6 Title Box and Parts List	32		
2-7 Mechanical Lettering Machines and Appliqués	33		
SUMMARY	33		
PROBLEMS	34		
3			
Graphs and Charts		36	
INSTRUCTIONAL OBJECTIVES		36	
SELF-EVALUATION QUESTIONS		36	
3-1 Pie and Bar Graphs		37	
3-2 Rectilinear Graphs		37	
3-3 Graph Construction Standards		41	
3-4 Logarithmic Graphs		43	
3-5 Conversion Scales		43	
3-6 Nomographs		44	
3-7 Polar Graphs		47	
3-8 The Smith Chart		49	
SUMMARY		50	
PROBLEMS		52	
4			
Pictorial Assembly Drawings		55	
INSTRUCTIONAL OBJECTIVES		55	
SELF-EVALUATION QUESTIONS		55	
4-1 Purpose of Pictorial Drawings		56	
4-2 Isometric Drawing		57	
4-3 Oblique Drawing		60	
4-4 Dimetric Projection		60	
4-5 Perspective Drawing		61	
4-6 Photographic Pictorials		64	
4-7 Pictorial Assembly Design Factors		64	
4-8 Chassis Layout Design Factors		67	
SUMMARY		70	
PROBLEMS		71	
5			
Electronic Component Symbols		72	
INSTRUCTIONAL OBJECTIVES		72	
SELF-EVALUATION QUESTIONS		72	

X CONTENTS

5-1	The Development of Electronic Symbols	73	8-2	Grounds, Chassis, and Circuit Returns	126
5-2	Inductors	73	8-3	Layout of Schematic Diagrams	127
5-3	Capacitors	75	8-4	Rotary Switch Layout	129
5-4	Resistors	77	8-5	Identification of Components	131
5-5	Batteries and Cells	79		SUMMARY	132
5-6	Switches	79		PROBLEMS	132
5-7	Electron Tubes	81			
5-8	Two-Terminal Semiconductors	81	9		
5-9	Multiple-Terminal Semiconductors	85		Wire Assembly Diagrams	138
5-10	Accessory Devices	88		INSTRUCTIONAL OBJECTIVES	138
5-11	Size of Symbols	90		SELF-EVALUATION QUESTIONS	138
	SUMMARY	94	9-1	Wires and Cables	138
	PROBLEMS	95	9-2	Cable Drawings	140
6			9-3	Point-to-Point Connection Diagrams	140
	Basic Circuits	98	9-4	Baseline Connection Diagrams	143
	INSTRUCTIONAL OBJECTIVES	98	9-5	Highway Connection Diagrams	145
	SELF-EVALUATION QUESTIONS	98	9-6	Cable Harness Construction	
6-1	Power Supply Circuits	98		Drawings	147
6-2	Amplifier Circuits	100		SUMMARY	148
6-3	Interstage Coupling	101		PROBLEMS	149
6-4	Oscillator/Mixer Circuits	103			
6-5	Modulator/Demodulator Circuits	106	10		
6-6	Filter Circuits	106		Industrial Control	
6-7	Output Devices	109		Wiring Diagrams	153
6-8	Integrated Circuits	109		INSTRUCTIONAL OBJECTIVES	153
	SUMMARY	111		SELF-EVALUATION QUESTIONS	153
	PROBLEMS	112	10-1	Components and Symbols	154
7			10-2	Simple Control Systems	161
	Block and Logic Diagrams	115	10-3	Schematic Layout Conventions	163
	INSTRUCTIONAL OBJECTIVES	115	10-4	AC Motor Control Circuits	166
	SELF-EVALUATION QUESTIONS	115	10-5	Power Distribution Systems	170
7-1	Flow Diagrams	115		SUMMARY	173
7-2	Electronic System Diagrams	117		PROBLEMS	175
7-3	Digital Logic Diagrams	120			
	SUMMARY	122	11		
	PROBLEMS	123		Printed Circuit (PC) Drawings	177
8				INSTRUCTIONAL OBJECTIVES	177
	Drawing Schematic Diagrams	125		SELF-EVALUATION QUESTIONS	177
	INSTRUCTIONAL OBJECTIVES	125	11-1	Discrete Versus Printed Circuit Wiring	177
	SELF-EVALUATION QUESTIONS	125	11-2	Materials and Processes	178
8-1	Cables, Junctions, and Crossovers	126	11-3	Silk-Screen Printing	184
			11-4	Design Factors	186
			11-5	Circuit Board Layout	188

11-6 Special Equipment for PCB Production	194
SUMMARY	198
PROBLEMS	198

12

Integrated Circuits (IC) Drawing 200

INSTRUCTIONAL OBJECTIVES	200
SELF-EVALUATION QUESTIONS	200
12-1 Microelectronics	200
12-2 The Planar Process	201
12-3 Integrated Circuit Resistors	203
12-4 Integrated Circuit Capacitors	204
12-5 Integrated Circuit Layout	205
12-6 Packing	210
12-7 Operational Amplifier	210
SUMMARY	210
PROBLEMS	211

13

Electrical Building Construction Wiring Diagrams 213

INSTRUCTIONAL OBJECTIVES	213
SELF-EVALUATION QUESTIONS	213
13-1 Symbols	214
13-2 Single Line Diagrams	216
13-3 Floor Plan Layouts	220
13-4 Convenience Outlet Details	221
13-5 Switching Circuit Details	221
13-6 Service Entrance Details	223
13-7 Branch Circuit Load Calculations	225
13-8 Service Load Calculations	225
SUMMARY	226
PROBLEMS	226

14

Introduction to CAD/CAM Systems 229

INSTRUCTIONAL OBJECTIVES	229
14-1 Introduction	229

14-2 Computer Programming	230
14-3 Equipment Requirements for a CAD/CAM System	230
14-4 Available Equipment	232
SUMMARY	243
PROBLEMS	243

Appendices 244

A Acronyms and Abbreviations for Electrical Terms	244
B Decimal Equivalents Table	248
C Resistor Color Code, Standard Stock Resistor Values, and MIL Standard Resistors	250
D Wiring Color Code	254
<i>D-1 Chassis Wiring</i>	254
<i>D-2 Power Transformer Leads</i>	254
<i>D-3 Audio Transformer Leads</i>	254
<i>D-4 Intermediate Frequency Transformer Leads</i>	255
<i>D-5 Industrial Control Circuit</i>	255
E Typical Mechanical Data of Semiconductors	256
F Engineering Standards and Specifications	263
<i>F-1 Military</i>	263
<i>F-2 Institute of Printed Circuits</i>	264
G Relay Operation Codes	265
H Circuit Board Eyelets	266
I Circuit Board Connectors	267
J Standard Drafting Paper and Film Sizes	269
K American Wire Gauge (AWG) Conductor Sizes	270
L MIL Standard Capacitors	271
M MIL Standard Toggle Switches	282
N Standard Screw Sizes and Clearance Hole Dimensions	284
O Drill Sizes, Decimal and Metric Equivalents	285
GLOSSARY	288
BIBLIOGRAPHY	307
INDEX	309

Chapter 1 Instruments and Drawing Techniques

Instructional Objectives

1. To learn the desirable characteristics and properties of a drawing board and T-square.
2. To understand the purposes and uses of a T-square and triangles.
3. To learn to draw parallel horizontal lines and lines at any angle.
4. To develop the correct techniques of using the instruments.
5. To become aware of the desirable characteristics and properties of drawing instruments and papers.
6. To become familiar with the applications of templates and other drafting aids.
7. To become aware of the proper care of drawing equipment.
8. To develop desirable work habits.

Self-Evaluation Questions

Test your prior knowledge of the information in this chapter by answering the following questions. Watch for the answers as you read the chapter. Your final evaluation of whether you understand the material is measured by your ability to answer these questions. When you have completed the chapter, return to this section and answer the questions again.

1. Give the name of the type of drawing in which all lines lie at right angles to the plane of projection.
2. Give the advantages in fastening drawing paper to a drawing board using adhesive tape rather than thumbtacks.
3. How should the drafting pencil be held and inclined when drawing a line using a straightedge?
4. What is the minimum drafting equipment needed to produce an orthographic drawing?
5. Describe the proper method of drawing a perpendicular to a given nonhorizontal line.
6. What are the important characteristics of vellum drawing paper?
7. What method would you use to draw a line accurately connecting two points?
8. What effect does conversion to the metric system have on drawing techniques?
9. How could an angle of 75° be drawn using two drafting triangles (45° and $30^\circ/60^\circ$) and a T-square?
10. Describe your method to draw an angle of 22.5° using T-square, triangles, and compass.

**1-1
Drawing
Boards and
Tables**

The *drawing board* must be large enough to accommodate the largest drawing that may be contemplated. Its surface must be smooth, flat, and constructed of a warp-free material. If a *T-square* rather than a drafting machine is used, one edge of the board must be a *straight* or reference edge for perfect alignment with the *head* of the T-square. Often to protect the board surface, a sheet of paper slightly smaller in size than the board dimensions is fastened to the surface with tape. This provides a clean, nonslip, and only slightly resilient surface that protects the board from nicks, cuts, or dents.

Many different board materials may meet these specifications: smooth pine, plywood, particle board, linoleum, or sheet metal. Boards 38 × 48 in. (97 × 122 cm) and larger may be provided with either permanent or folding legs. Such *drafting tables* are also provided with an adjustment so that the drawing surface may be made to slope at a convenient angle as shown in Figure 1-1. The overall height of most pedestal-type tables may be adjusted at the legs for a less tiring posture; desk-type drafting tables may not have this advantage but often contain storage space. The table shown in Figure 1-1 is actually a specialized drafting table in that it has a *translucent* glass or plastic working surface illuminated from below the tabletop; this construction is extremely useful for tracing work and printed circuit board layout.



Figure 1-1 Light table. (Courtesy of Hamilton Industries.)



Figure 1-2 Drafting attache Case. (Courtesy of The Uteley Co., Inc.) (a) T-square; (b) erasing shield; (c) instrument case; (d) triangular scale; (e) dust brush; (f) sandpaper block; (g) drafting tape; (h) Ames Lettering Guide; (i) French curve; (j) protractor; (k) circle template.

1-2 T-Squares and Triangles

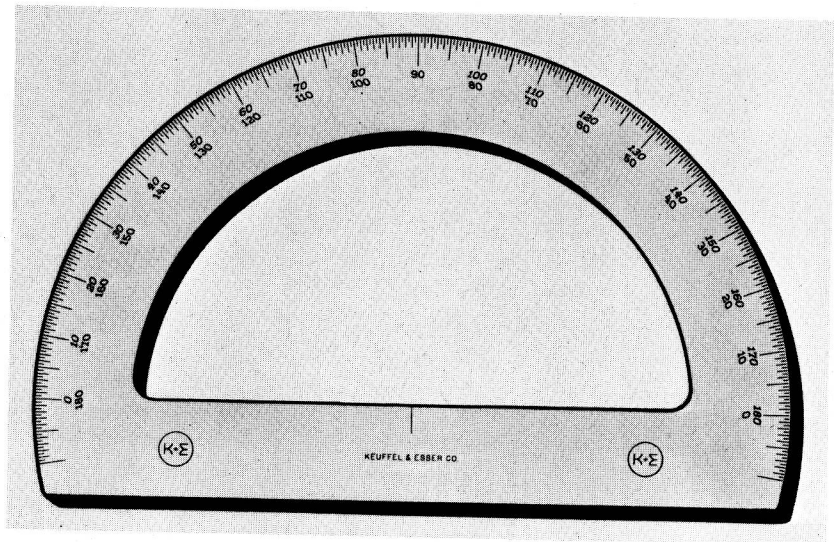
The purpose of a *T-square* is to draw *horizontal* and *parallel* lines. The T-square, in conjunction with drafting *triangles*, is used to draw *vertical* lines in a fundamental drafting procedure called *orthographic* or multiview projections (Fig. 1-11). A clear plastic straightedge may be bonded to the blade providing a convenient “see-through” edge (Fig. 1-2).

The T-square is possibly the most easily damaged drafting tool. If it is dropped, the head may no longer be rigidly attached at right angles to the blade. Lines drawn when the head is loose are no longer parallel to each other. Obviously, a nicked straightedge results in drawing a discontinuous line.

Drafting equipment made of wood has a tendency to warp if care is not taken in its storage. A quick condition check of both the board and T-square is made by placing the T-square blade on edge upon the board surface. If light is seen between the T-square edge and the board surface, it is obvious that either or both the T-square and board are warped.

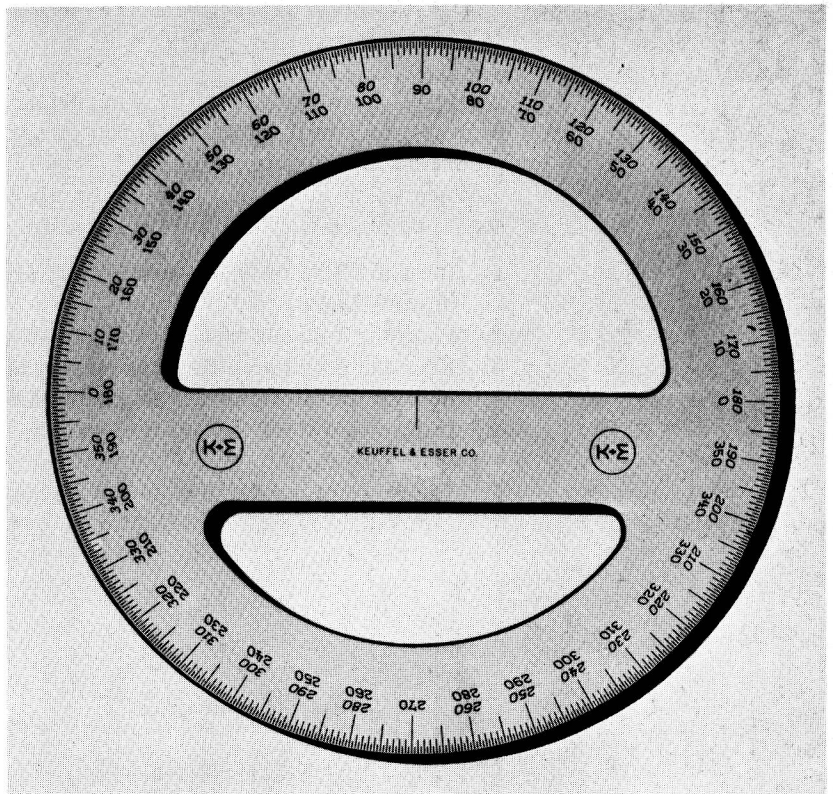
A 30 to 60° and a 45° *right-angled triangle* are needed if the drafter does not use a drafting machine (Fig. 1-5). Conventional triangles permit the accurate drafting of 30°, 45°, and 60° angles with respect to the horizontal or T-square blade. Using both the 45° and 30 to 60° triangles permits the drafter to construct angles in multiples of 15°. For example, if the long side or *hypotenuse* of a 45° triangle is placed in contact with the short side of a 30 to 60° triangle, the total *included angle* is 105°.

A *protractor* is also useful when angles other than 15° multiples are drawn. These instruments are now made of clear plastic for “see-through” conve-

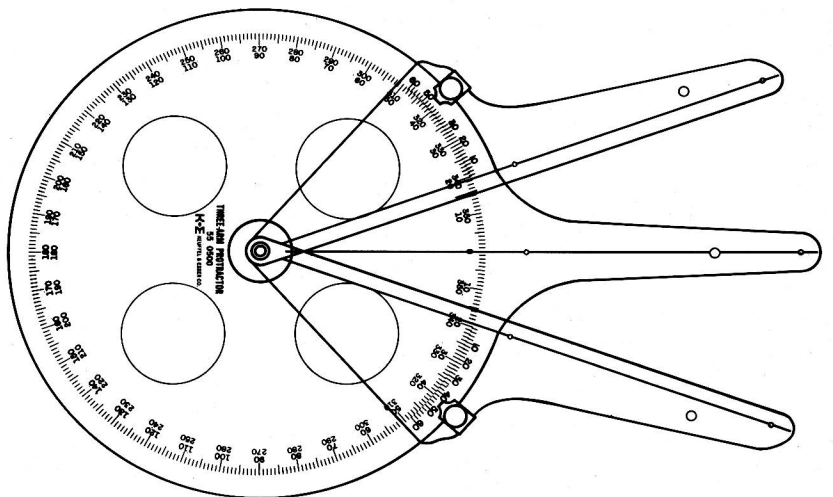


(a) 180° protractor

Figure 1-3 Protractors. [Courtesy of Keuffel & Esser (a KRATOS Company), Morristown, New Jersey.]



(b) 360° protractor



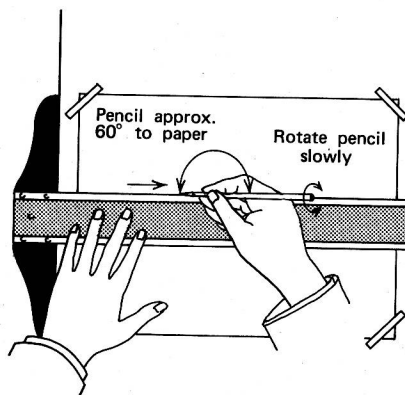
(c) three-arm protractor

Figure 1-3 (continued)

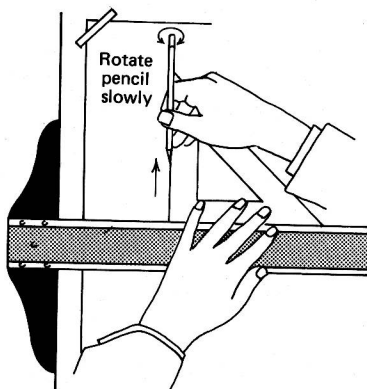
nience. The protractor is a flat semicircular or circular device engraved in degrees from zero through 180° or 360° , respectively. Three different types of protractors are shown in Figure 1-3.

When using either the T-square or triangles, several basic precautions should be observed. To draw a horizontal line (Fig. 1-4a):

1. Press the head of the T-square firmly against the referenced edge of the drawing board.
2. Press the T-square blade tightly against the paper.
3. Keep the pencil vertical to the board while drawing the line. The pencil may be leaned slightly in the direction of motion.
4. If the pencil is rotated slowly as the line is drawn, the pencil point wears more uniformly.
5. The pencil point should not touch the bottom edge of the T-square blade,



(a) Drawing a horizontal line



(b) Drawing a vertical line

Figure 1-4 Pencil techniques.

since the blade and drawing may become soiled. This is particularly important when drawing inked lines.

To draw either vertical or inclined lines (Fig. 1-4b):

1. The base of a triangle should rest evenly and firmly against the T-square blade.
2. The pencil is maintained vertical to the board but the line is drawn *upward*, or away from, the drafter; the pencil may be leaned slightly in the direction of motion.
3. When a line is to be drawn between two points, the pencil is placed vertically at one of the points. A straightedge is then moved to touch the pencil point and aligned with the second point before drawing the line.

The T-square and a triangle, or a pair of triangles, may also be used to draw a line parallel to a given nonhorizontal line:

1. Move the triangle and T-square as a unit until the hypotenuse of the triangle lines up with the given line.
2. Hold the T-square firmly in position.
3. Slide the triangle away from the given line.
4. Draw the required line along the hypotenuse.

1-3 Drafting Machines

Drafting machines may be purchased apart from or with a drawing board. The *parallel-rule mechanism*, known as a drafting machine, is shown in Figure 1-5. An L-shaped straightedge replaces the T-square, and its position is maintained parallel to the top edge of the board by an arrangement of cords, pulleys, gears, or levers. Triangles and protractor are not needed since the left end of the straightedge may be pivoted and locked at any angle as measured by the protractor on the machine. This function is of special value when making pictorial drawings.

The drafting machine is a precision instrument; the protractor degree dial at the lower left may be adjusted to a fraction of a degree. The vertical straight edge is maintained at 90° to the horizontal straightedge.

1-4 Pencils and Line Widths

Pencil leads are made of *graphite*. A special clay is added in different amounts to make 18 *grades of hardness* from 7B to 9H. The *soft* grades, 2B through 7B, are used for preliminary sketches since the lines produced are easier to erase. The *medium* grades, B through 3H, are used for general-purpose work and lettering. The *hard* grades, 4H through 9H, are only used when extreme accuracy is required because the lines produced are apt to be too light. The final choice of pencil hardness also depends on the brand of pencil and the texture of the drawing paper.

The drafting pencil is usually sharpened to about 1.5 in. (4cm) from the end, with about $\frac{3}{8}$ in. (10 mm) of uncut lead exposed. The lead may be shaped