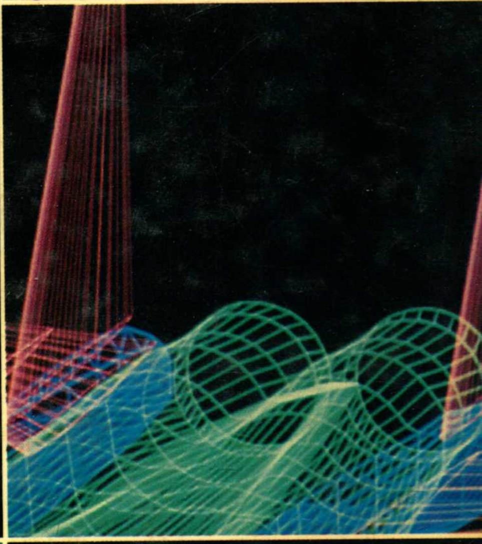
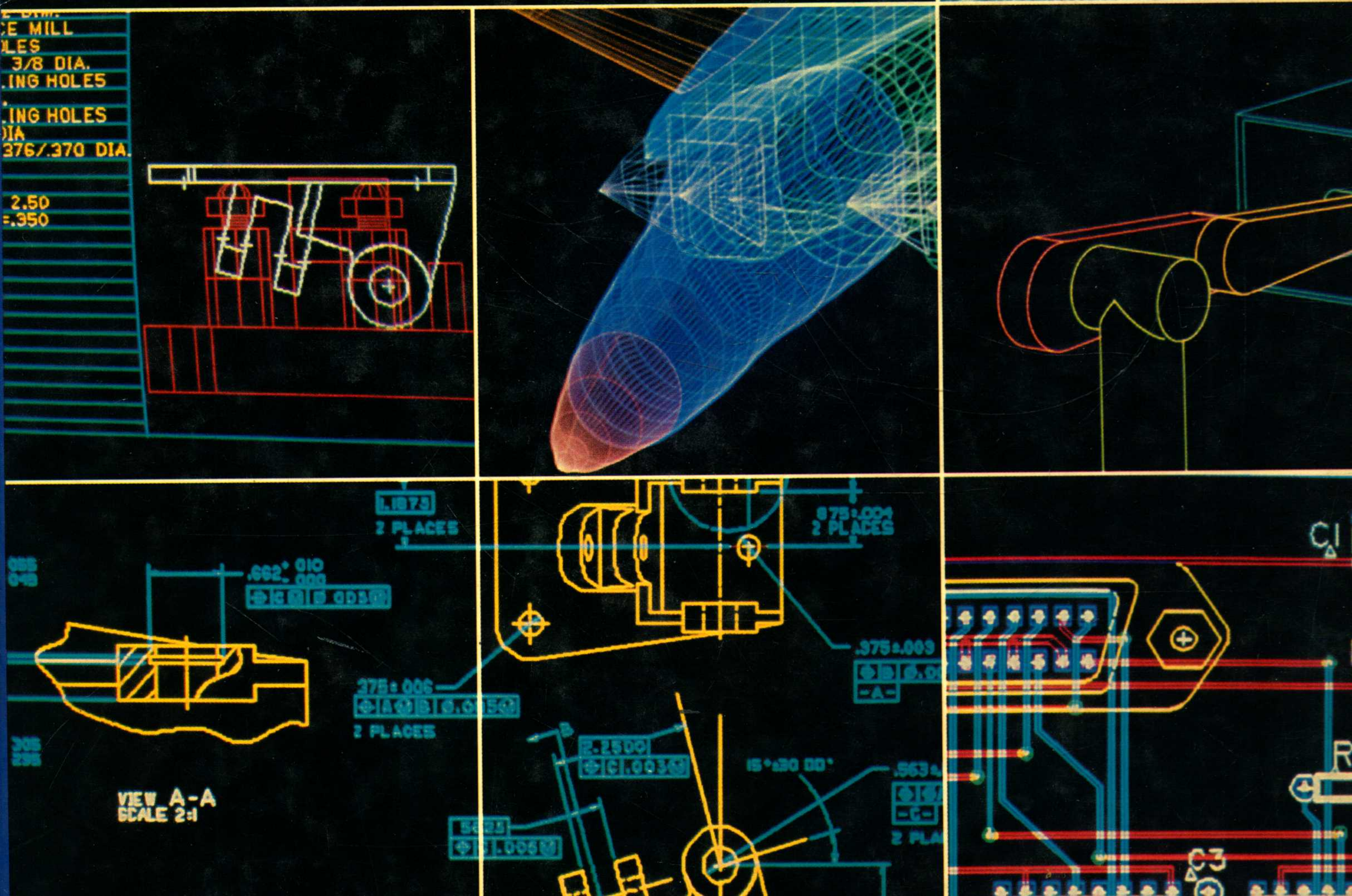
ENGINEERING DRAWING AND DESIGN

Jensen/Helsel

Third Edition





Engineering Drawing and Design

THIRD EDITION

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PREFACE

Engineering Drawing and Design, Third Edition, is prepared for a two-semester course in engineering drawing. The contents are consistent with the trends and practices currently used in the preparation of engineering drawings.

Technical drafting, like all technical areas, is constantly changing. The computer has revolutionized the way in which drawings are prepared. For this reason, three new topics have been introduced in the third edition of *Engineering Drawing and Design*—computer-aided drafting (CAD), computer-aided manufacturing (CAM), and electrical and electronics drafting. In this new edition, the authors have made every effort to translate the most current technical information available into the most usable form from the standpoint of both teacher and student. The latest developments and current practices in all areas of graphic communication, computer-aided drafting (CAD), electronics drafting, functional drafting, materials representation, shop processes, numerical control, true positioning, geometric tolerancing, and metrication have been incorporated into this text in a manner that synthesizes, simplifies, and converts complex drafting standards and procedures into understandable instructional units. Extensive author research and visits to drafting rooms throughout the country have resulted in a combination of current drafting practices and practical pedagogical techniques that produces the most efficient learning system yet designed for the instruction of engineering drawing.

A new Chapter 32, "Computer-Aided Design and Drafting," explains the basic concepts that a drafter or student drafter needs to know about CAD. It provides an excellent introduction to this topic.

Chapter 25, "Electrical and Electronics Drawings," introduces the student to the new state of the art—the use of computer chips and logic diagrams. The authors are indebted to Robert Chadwick, Technical Director at the McLaughlin C.V.I., Oshawa, Canada, for assisting in the selection of topics and projects for this chapter.

Additional problems and the clustering of existing problems provides greater choice of material. Every chapter in the text is divided into a number of single-concept units each with its own objectives, instruction, examples, review, and assignments. This organization provides the student with a logical sequence of experiences which can be adjusted to individual needs and also provides for maximum efficiency in learning essential concepts. Development of each unit is from the simple to the complex and from the familiar to the unfamiliar. Checkpoints are included to provide maximum reinforcement at each level.

Although the adoption of the metric system for drawings by smaller industries is not keeping pace with the large international companies, it is increasing in use. For that reason ANSI Y14.5M-1982 Dimensioning and Tolerancing, ANSI B4.2-1978 Preferred Metric Limits and Fits, and ANSI Y14.36-1978 Surface Texture Symbols have all been published in the metric units of size and measurement. In order to prepare our students for gainful employment upon graduation, it is recommended that both the International System of Units (SI) and the U.S. Customary System (USCS) units of measurement be included in all technical drawing programs.

Both SI and USCS units are used throughout the text and in all problems. Thus, the text may be used in a completely metric-oriented course, or in a course which utilizes both metric and customary systems. The teacher may also customize the course by selecting appropriate problems or materials to emphasize or deemphasize any degree of metrication. The dual dimensions shown in this book, especially in the assignment sections, are neither hard nor soft conversions. Instead, the sizes are those that would be most commonly used in the particular dimensioning units and so are only approximately equal. Dual dimensioning in this way avoids awkward amounts and allows instructor and student to be confident that a drawing using either set of dimensions will be no more difficult to work than one dimensioned exclusively in either dimensioning system.

Two sets of A4- or B-size worksheets are available separately for the completion of the problems. The worksheets include the problem in metric form on one side and in customary form on the reverse side. They are preprinted with light lines to provide the student with a beginning to each problem. Using these worksheets eliminates some of the initial work such as preparing borders, legends, data lines, and so forth. The worksheets also provide the student with the positioning of the drawing on each sheet, thus enabling the student to concentrate on the solution to the problem rather than on the mechanics of beginning the drawing. This focuses attention specifically on the concept under consideration and eliminates time wasted in nonessential aspects of the lesson. In earlier units, a certain amount of the work is completed for the student; in later units, however, fewer lines are provided.

A complete solutions manual to most graphic problems found in the text is also available from the publisher.

The authors would like to thank the many users of the previous edition of the textbook for their thoughtful and useful comments. In addition, the help of Hal Lindquist, Donald Voisinet, and John Nee is appreciated and gratefully acknowledged.

Cecil Jensen
Jay D. Helsel

ABOUT THE AUTHORS

CECIL JENSEN is the author or coauthor of many successful technical books, including *Engineering Drawing and Design, Fundamentals of Engineering Drawing, Drafting Fundamentals, Interpreting Engineering Drawings, Architectural Drawing and Design for Residential Construction, Home Planning and Design,* and *Interior Design.* Some of these books are printed in three languages and are used in many countries.

He has twenty-seven years of teaching experience in mechanical and architectural drafting and was a technical director for a large vocational school in Canada.

Before entering the teaching profession, Mr. Jensen gained several years of design experience in the industry. He has also been responsible for the supervision of the teaching of technical courses for General Motors apprentices in Oshawa, Canada.

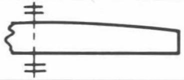
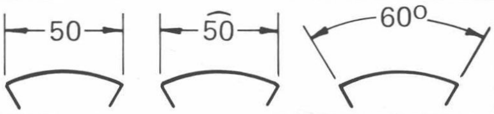
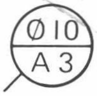
He is a member of the Canadian Standards Committee (CSA) on Technical Drawings (which includes both mechanical and architectural drawing) and is chairman of the Committee on Dimensioning and Tolerancing. Mr. Jensen is Canada's representative on the American (ANSI) Standards for Dimensioning and Tolerancing and has recently represented Canada at two world (ISO) conferences in Oslo (Norway) and Paris on the standardization of technical drawings.

He took an early retirement from the teaching profession in order to devote his full attention to writing.

JAY D. HELSEL is a professor of industrial arts and technology at California University of Pennsylvania. He completed his undergraduate work in industrial arts at California State College and was awarded a master's degree from Pennsylvania State University. He has done advanced graduate work at West Virginia and at the University of Pittsburgh, where he completed a doctoral degree in educational communications and technology. In addition, Dr. Helsel holds a certificate in airbrush techniques and technical illustration from the Pittsburgh Art Institute.

He has worked in industry and has taught drafting, metalworking, woodworking, and a variety of laboratory and professional courses at both the secondary and college levels. During the past twenty years, he has also worked as a free-lance artist and illustrator. His work appears in many technical publications.

Dr. Helsel is coauthor of *Engineering Drawing and Design, Fundamentals of Engineering Drawing, Programmed Blueprint Reading,* and *Mechanical Drawing.* He is also the author of a series of *Mechanical Drawing Film Loops.*

DRAFTING UPDATE (PRESENT DRAWING PRACTICES)			
FEATURE		**SYMBOL**	**ANSI PUBLICATION Y14.5M–1982 (EXCEPT WHERE NOTED, REFER TO CLAUSE NO.)**
LINES (THREE LINE WIDTHS NOW REPLACED BY TWO LINE WIDTHS.)		━━━ THICK ─── THIN	Y14.2M–1979
LETTERING (TWO APPROVED STYLES. HEIGHT OF LETTERING DEPENDENT ON DRAWING SIZE.)			Y14.2M–1979
MILLIMETER DIMENSIONING PRACTICES			CLAUSE 1.6.1
METRIC LIMITS AND FITS			B 4.2–1978
DIAMETER SYMBOL (NOW PRECEDES THE DIAMETER VALUE. THE SYMBOL REPLACES THE ABBREVIATION DIA)		Ø	CLAUSE 1.8.1
RADIUS SYMBOL (NOW PRECEDES THE RADIUS VALUE)		R	CLAUSE 1.8.2
REFERENCE DIMENSION		(8.6)	CLAUSE 1.7.6
SURFACE TEXTURE SYMBOL			Y14.36–1978
SPECIFYING REPETITIVE FEATURES		X	CLAUSE 1.9.5
COUNTERBORE OR SPOTFACE		⌴	CLAUSE 3.3.10
COUNTERSINK		⌵	CLAUSE 3.3.11
DEPTH		↧	CLAUSE 3.3.12
CONICAL TAPER		—▷— 0.2 : 1	CLAUSE 2.13
FLAT TAPER		—◺ 0.15 : 1	CLAUSE 2.14
SYMMETRICAL OUTLINES			CLAUSE 1.8.8
ALL AROUND		○	CLAUSE 3.4.2.3
DIMENSIONING CHORDS, ANGLES, AND ARCS			CLAUSE 1.8.3
NOT TO SCALE DIMENSION		←— <u>120</u> —→	CLAUSE 1.7.9
FEATURE CONTROL FRAME (FORMERLY CALLED FEATURE CONTROL SYMBOL. ORDER OF SEQUENCE CHANGED)		⌖ | Ø 0.1 | A	CLAUSE 3.4.2
DATUM TARGET SYMBOL			CLAUSE 3.3.3 AND 4.5.1
GEOMETRIC CHARACTERISTIC SYMBOLS	STRAIGHTNESS	—	CLAUSE 6.4.1
	FLATNESS	▱	CLAUSE 6.4.2
	PARALLELISM	//	CLAUSE 6.6.3
	SYMMETRY	⌖	CLAUSE 5.12
	CIRCULAR RUNOUT	↗	CLAUSE 6.7.2.1
	TOTAL RUNOUT	⌰	CLAUSE 6.7.2.2

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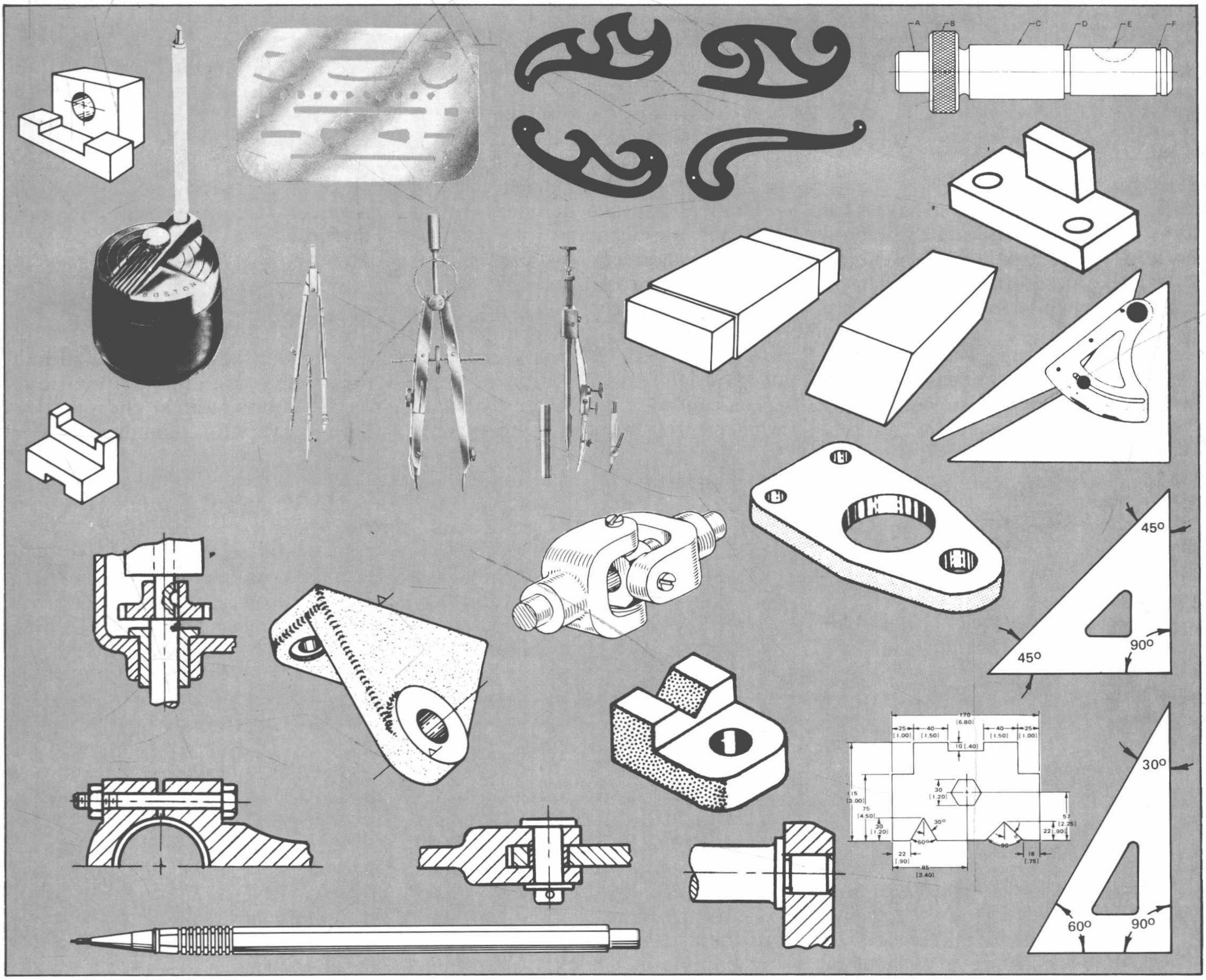
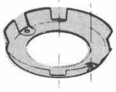
Basic Drawing Design



CHAPTER 1



The Language of Industry

UNIT 1-1

The Language of Industry

Since earliest times people have used drawings to communicate and record ideas so that they would not be forgotten. The earliest forms of writing, such as the Egyptian hieroglyphics, were picture forms.

The word *graphic* means dealing with the expression of ideas by lines or marks impressed on a surface. A drawing is a graphic representation of a real thing. Drafting, therefore, is a graphic language, because it uses pictures to communicate thoughts and ideas. Because these pictures are understood by people of different nations, drafting is referred to as a "universal language."

Drawing has developed along two distinct lines, with each form having a different purpose. On the one hand, artistic drawing is concerned mainly with the expression of real or imagined ideas of a cultural nature. Technical drawing, on the other hand, is concerned with the expression of technical ideas or ideas of a practical nature, and it is the method used in all branches of technical industry.

Even highly developed word languages are inadequate for describing the size, shape, and relationship of physical objects. For every manufactured object there are drawings that describe its physical shape completely and accurately, communicating engineering concepts to manufacturing. For this reason, drafting is referred to as the "language of industry."

Drafters translate the ideas, rough sketches, specifications, and calculations of engineers, architects, and designers into working plans which are used in making a product. See Figs. 1-1-1 through 1-1-7. Drafters may calculate the strength, reliability, and cost of materials. In their drawings and specifications, they describe exactly what materials workers are to use on a particular job. To prepare their drawings, drafters use instruments such as compasses, dividers, protractors, templates, and triangles, as well as drafting machines that combine the functions of several devices. They also may use engineering handbooks, tables, calculators, and computers to assist in solving technical problems.

Drafters are often classified according to their type of work or their level of responsibility. Senior drafters (designers) take the preliminary information provided by engineers and architects to prepare design "layouts" (drawings made to scale of the object to be built). Detailers (junior drafters) make drawings of each part shown on the layout, giving dimensions, material, and any other information necessary to make the detailed drawing clear and complete. Checkers carefully examine drawings for errors in computing or recording dimensions and specifications.

Drafters also may specialize in a particular field of work, such as mechanical, electrical, electronic, aeronautical, structural, or architectural drafting.

DRAWING STANDARDS

Throughout the long history of drafting, many drawing conventions, terms, abbreviations, and practices have come into common use. It is essential that different drafters use the same practices if drafting is to serve as a reliable means of communicating technical theories and ideas.

In the interest of efficient communication, the American National Standards Institute (ANSI) has adopted a set of drafting standards which are recommended for drawing practice in all fields of engineering and are used and explained throughout this text. These standards apply primarily to end product drawings, which usually consist of detail or part drawings and assembly or subassembly drawings, and are not intended to fully cover other supplementary drawings such as checklists, parts lists, schematic diagrams, electrical wiring diagrams, flowcharts, installation drawings, process drawings, architectural drafting, and pictorial drawing.

(Bond Ryder Associates)

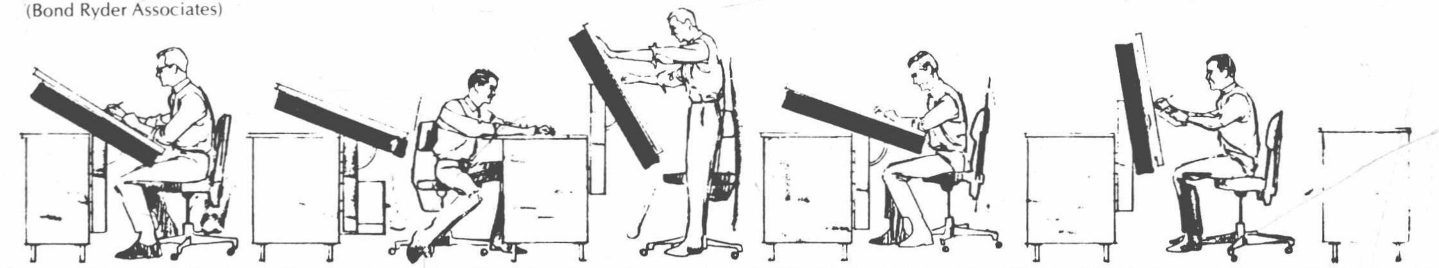


Fig. 1-1-1 Drafting—today and tomorrow. (Auto-Trol Corporation.)

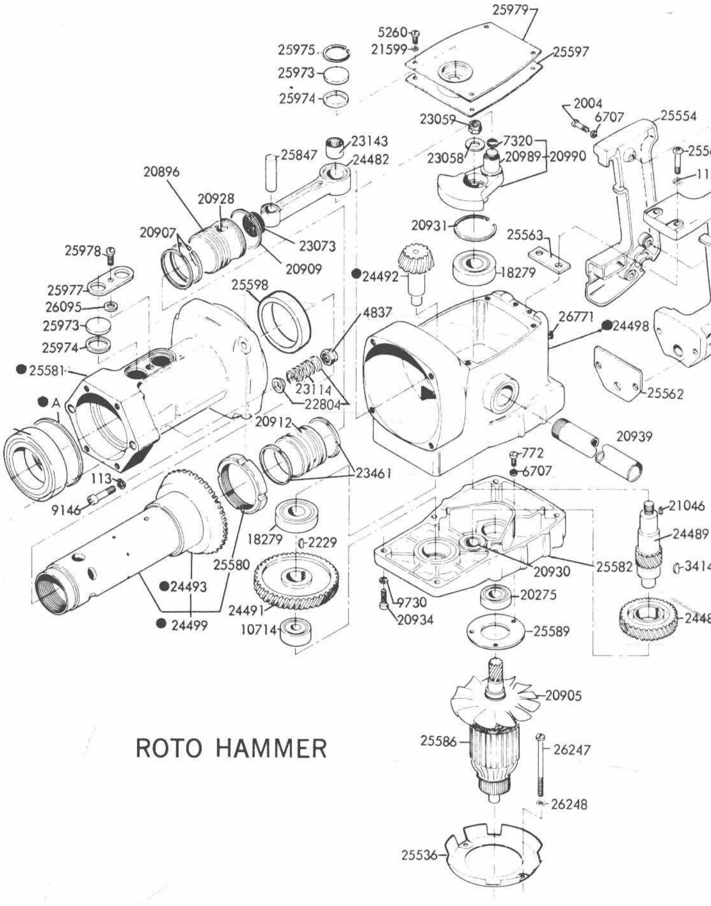


Fig. 1-1-2 Pictorial drawings. (Skil Corp.)

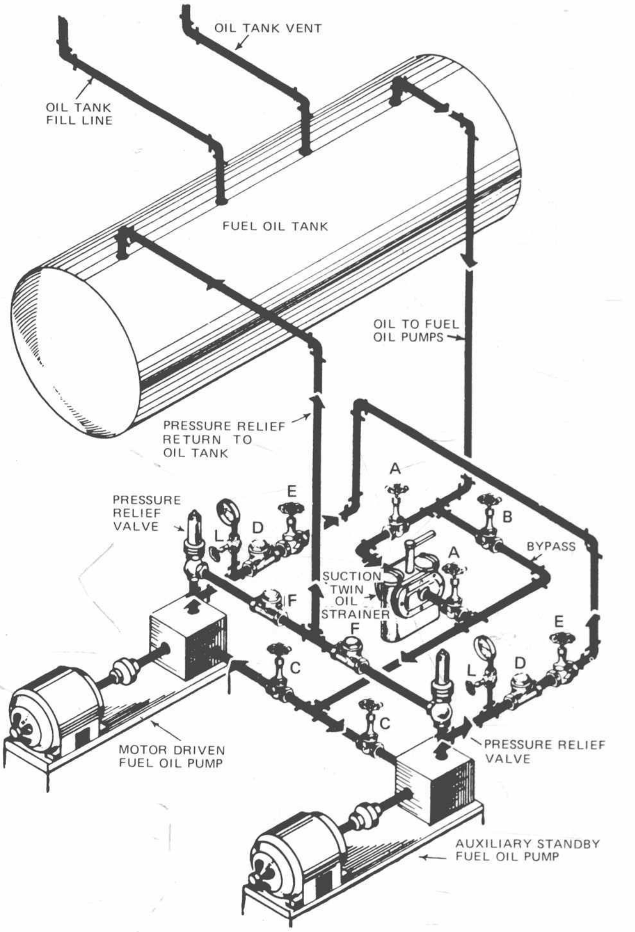


Fig. 1-1-4 Pipe drawings. (Jenkins Bros., Ltd.)

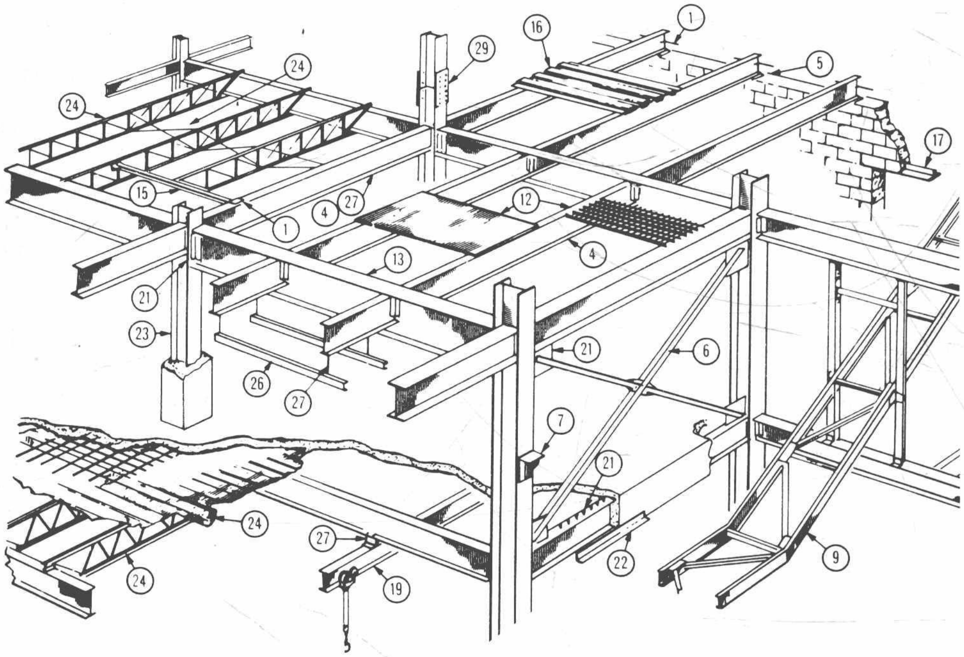


Fig. 1-1-3 Structural drawings. (American Institute of Steel Construction.)

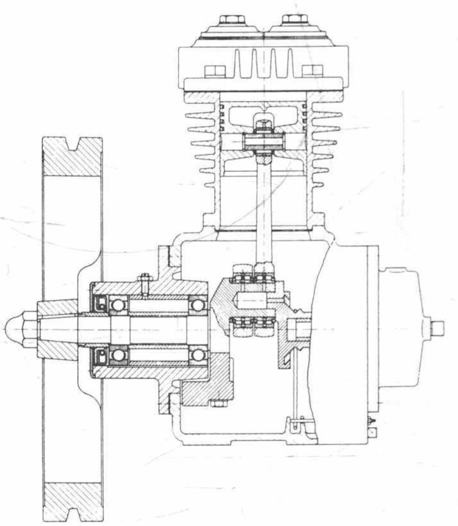


Fig. 1-1-5 Machine drawings.

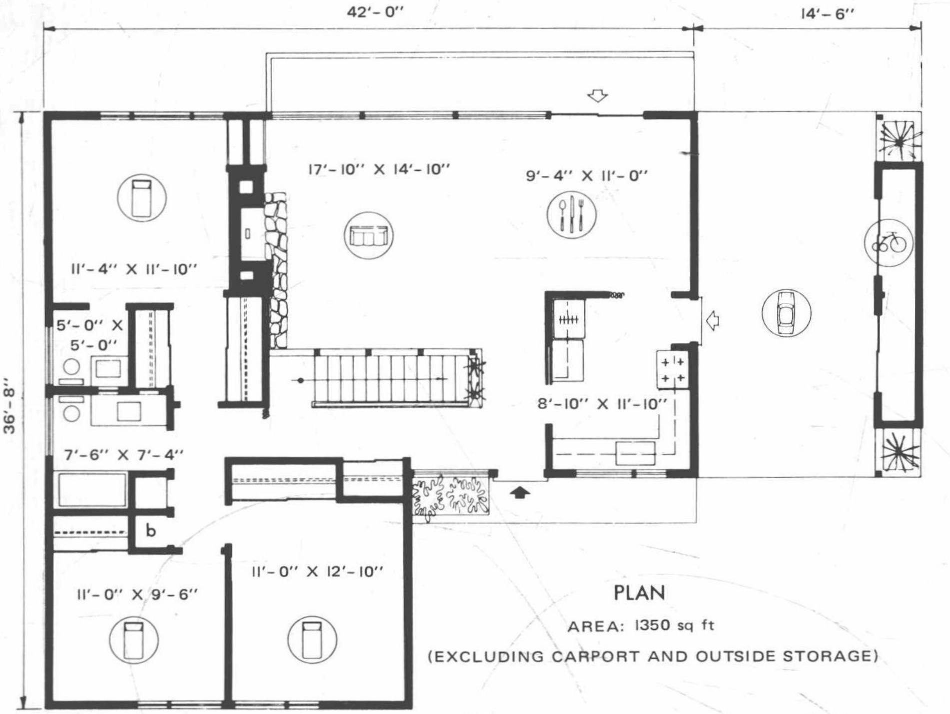


Fig. 1-1-6 Architectural drawings.

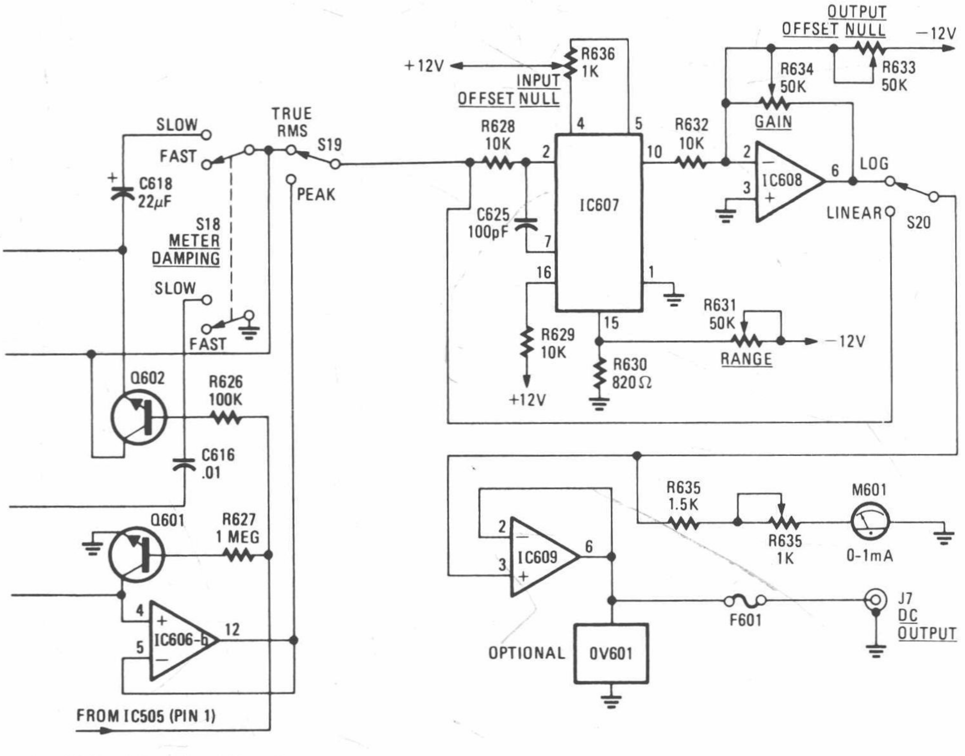


Fig. 1-1-7 Electrical drawings.

The information and illustrations shown have been revised to reflect current industrial practices in the preparation and handling of engineering documents. The increased use of reduced-size copies of engineering drawings made from microfilm and the reading of microfilm require the proper preparation of the original engineering document. All future drawings should be prepared for eventual photographic reduction or reproduction. The observance of the drafting practices described in this text will contribute substantially to the improved quality of photographically reproduced engineering drawings.

CHANGING TIMES[1]

Fifty years have brought great changes to the drafting room. Its physical appearance, furnishings, even its drafters and engineers have moved quickly from their battered domain of old into the Space Age.

These changes were brought about largely by the recognition of many factors that affect the performances of working people. Because designing and drafting are specialized technical fields today that require a high level of precision, personnel efficiency in these areas has been closely linked to the working atmosphere.

A constant reappraisal of this atmosphere should be a prime responsibility of all chief engineers and chief drafters. With an eye to improving working conditions, thereby increasing efficiency and bettering performance, they should reevaluate periodically the tables, boards, seating arrangements, drafting machines and tools, lighting, reference materials, and file units assigned to their department.

Drafting room technology has progressed at the same rapid pace as the economy of our country. Many changes have taken place in the modern drafting room as compared to a typical drafting room scene before the turn of the century, shown in Fig. 1-1-8. Not only are there far more tools, but they are of much higher quality. From automated drafting machines to computer-aided drafting systems and from combination reference tables with adjustable drawing boards to drawing media that contain all the desired qualities for reproduction. Noteworthy progress has been made and continues to be made as our expanding technology takes giant steps forward in this modern age.

PLACES OF EMPLOYMENT[2]

There are over 400 000 people working in drafting positions in the United States. Approximately 4 percent are women. About 9 out of 10 drafters are employed in private industry. Manufacturing industries that employ large

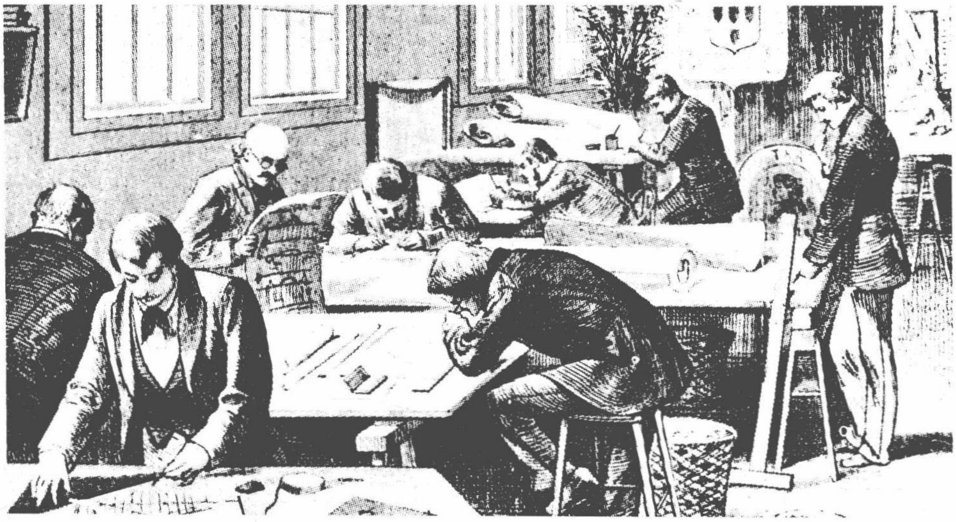


Fig. 1-1-8 The drafting office at the turn of the century. (Bettman Archive, Inc.)

numbers are those making machinery, electrical equipment, transportation equipment, and fabricated metal products. Nonmanufacturing industries employing large numbers are engineering and architectural consulting firms, construction companies, and public utilities.

Over 25 000 drafters work for the government; the majority work for the armed services. Drafters employed by state and local governments work chiefly for highway and public works departments. Several thousand drafters are employed by colleges and universities and by nonprofit organizations.

TRAINING, QUALIFICATIONS, ADVANCEMENT

Young people interested in becoming drafters can acquire the necessary training from a number of sources, including technical institutes, junior and community colleges, extension divisions of universities, vocational and technical high schools, and correspondence schools. Others may qualify for drafting positions through on-the-job training programs combined with part-time schooling or through 3- or 4-year apprenticeship programs.

The prospective drafter's training, whether obtained in high school or post-high school drafting programs, should include courses in mathematics and physical sciences, as well as in mechanical drawing and drafting. Studying shop practices and learning some shop skills also are helpful, since many higher-level drafting jobs require knowledge of manufacturing or construction methods. Many technical schools offer courses in structural design, strength of materials, and physical metallurgy.

Young people having only high school drafting training usually start out as tracers, or detailers. Those having some formal post-high school technical training can often qualify as junior drafters. As drafters gain skill and experience, they may advance to higher-level positions as checkers, detailers, senior drafters, designers, or supervisors of other drafters. See Fig. 1-1-9. Drafters who take courses in engineering and mathematics are sometimes able to transfer to engineering positions.

Qualifications for success as a drafter may include the ability both to visualize objects in three dimensions and to do freehand drawing. Although artistic ability is not generally required, it may be helpful in some specialized fields.

Drafting work also requires good eyesight (corrected or uncorrected), eye-hand coordination, and manual dexterity.

EMPLOYMENT OUTLOOK

Employment opportunities for drafters are expected to be favorable in the future. Prospects will be best for those having post-high school drafting training as many industries now regard the 2-year post-high school program as a prerequisite for their drafters. Well-qualified high school graduates who have had only high school drafting, however, also will be in demand.

Employment of drafters is expected to rise rapidly as a result of the increasingly complex design problems of modern products and processes. In addition, as engineering and scientific occupations continue to grow, more drafters will be needed as support personnel. On the other hand, photoreproduction of drawings and expanding use of electronic drafting equipment and computers are eliminating some routine tasks done by drafters. This development will probably reduce the need for some less skilled drafters.

References

1. Charles Bruning Co.
2. *Occupational Outlook Handbook.*

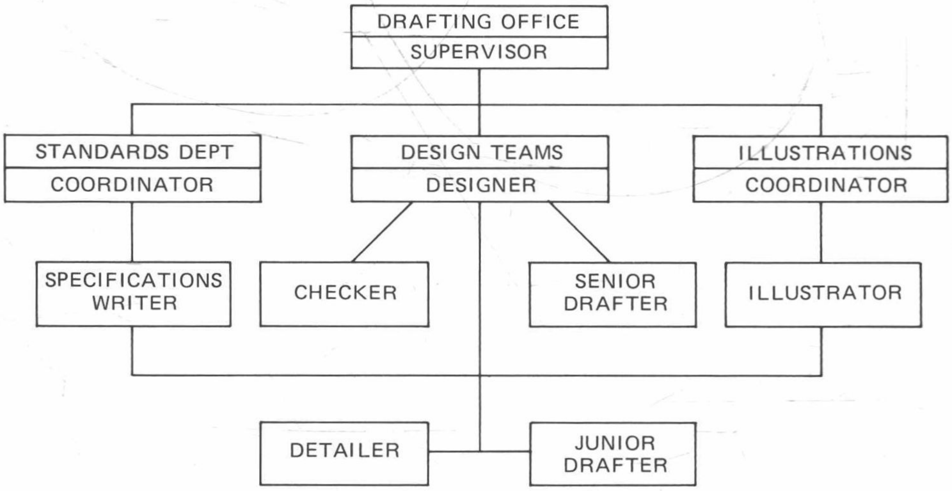


Fig. 1-1-9 Positions within the drafting office.

CHAPTER 2

Drafting Skills and Drawing Office Practices

UNIT 2-1
The Drafting Office

The drafting office is the starting point for all engineering work. Its product, the *engineering drawing*, is the main method of communication between all people concerned with the design and manufacture of parts. Therefore the drafting office must provide accommodations and equipment for the drafters, from designer and checker to detailer or tracer; for the personnel who make copies of the drawings and file the originals; and for the secretarial staff who assist in the preparation of the drawings (Fig. 2-1-1).

Most engineering departments still rely on manual drafting needs. In the majority of cases, this is all that is necessary. Equipment for manual drafting is varied and is steadily being improved. Where a high volume of finished or repetitive work is not necessary, this equipment does the job adequately and inexpensively, and most designers are accustomed to working with it.

A growing number of companies have turned to automated drafting. The reason is not simply to speed the drafting process. Automated drafting can serve as a full partner in the design process, enabling the designer to do jobs that are simply not possible or feasible with manual equipment.

Computer-aided-drafting, normally referred to as CAD, and drawings for numerical control are covered in detail in Chaps. 32 and 16, respectively.

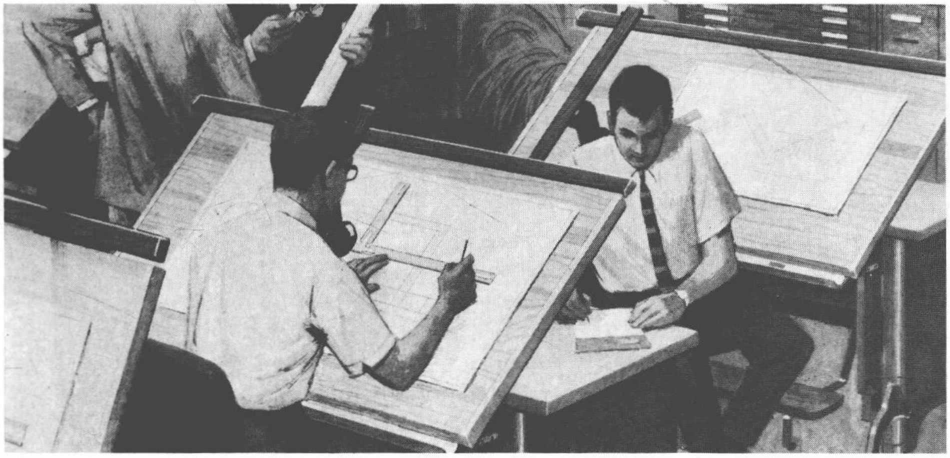


Fig. 2-1-1 Drafting Office. (Vemco Corp.)

UNIT 2-2
Manual Drafting Equipment and Supplies

Over the years, the designer's chair and drafting table have evolved into a drafting station which provides a comfortable, integrated work area. Yet much of the equipment and supplies employed years ago are still in use today, although they have been vastly improved.

DRAFTING FURNITURE

Special tables and desks are manufactured for use in single-station or multistation design offices. Typical are desks with attached drafting boards (Fig. 2-2-1). The boards may be used by the occupant of the desk to which it is attached, in which case it may swing out of the way when not in use, or may be reversed for use by the person in the adjoining station.

In addition to such special work stations, a variety of individual desks, chairs, tracing tables, filing cabinets, and special storage devices for drawings are available (Fig. 2-2-2).

The simplest manually adjustable tables typically consist of a hinged surface riding on a vertical rod secured by a setscrew. The setscrew is loosened,

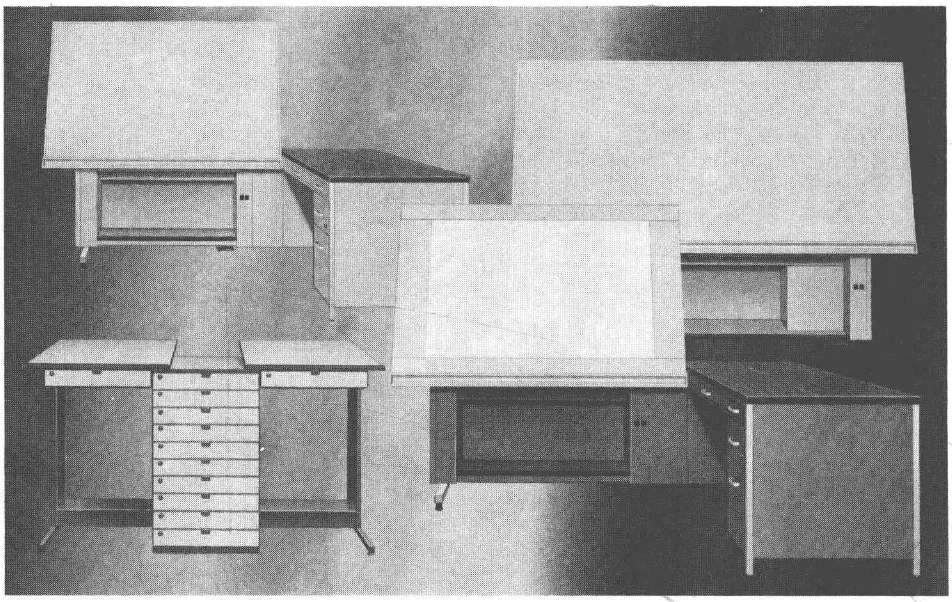


Fig. 2-2-1 Drafting tables are available in a variety of sizes and styles. (Bruning Division, Addressograph Multigraph Corp.)

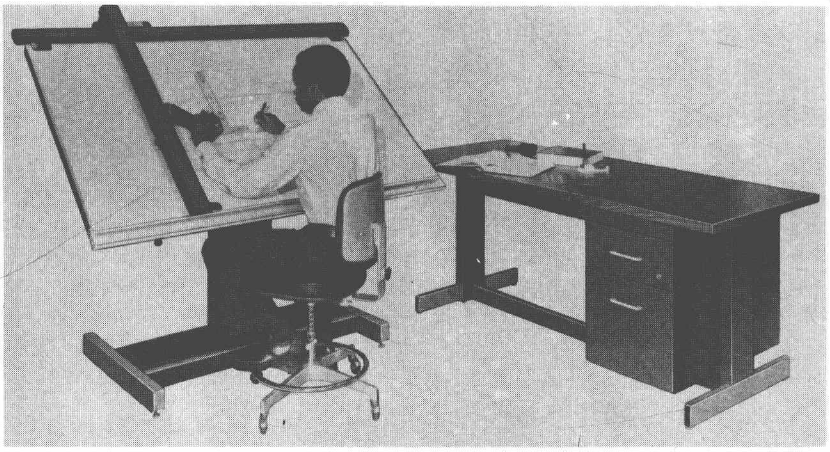
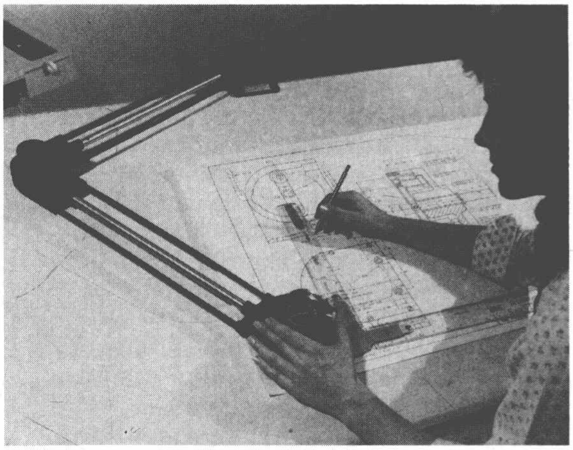


Fig. 2-2-2 Drafting work stations. (Teledyne Post.)



(*Bruning.*)

the top is set at the desired angle, and the setscrew is retightened.

DRAFTING EQUIPMENT

See Fig. 2-2-3 for a variety of drafting equipment.

Drawing Boards

The drawing sheet is attached directly to the surface of a drafting table or a portable drawing board (Fig. 2-2-4). Drafting boards are used in schools and for home use and generally have a smaller work surface than what is found on drafting tables. They are designed to stay flat and have straight guiding edges.

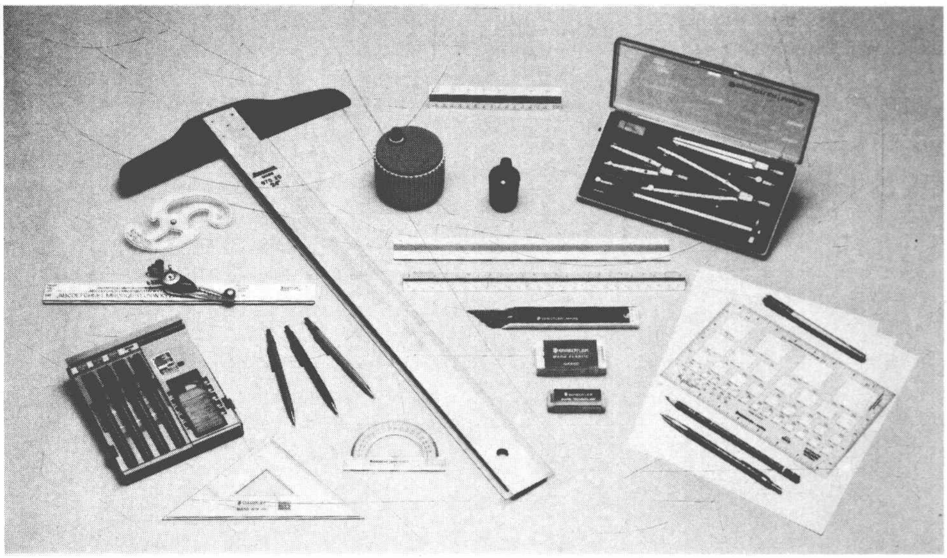


Fig. 2-2-3 Drafting equipment. (Staedtler-Mars.)

Drafting Machines

In the well-equipped engineering department, where the designer is expected to do accurate drafting, the T square has been replaced largely by the drafting machine. This device, which combines the functions of T square, triangles, scale, and protractor, is estimated to save up to 50 percent of the user's time. All positioning is done with one hand, while the other hand is free to draw.

Drafting machines may be attached to any drafting board or table. Two types are currently available. In the track type, a vertical beam carrying the drafting instruments rides along a horizontal beam fastened to the top of the table. In the arm, or elbow type (Fig. 2-2-5), two arms pivot from the top of the machine and are relative to each other.

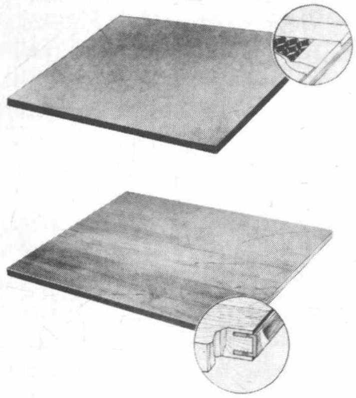


Fig. 2-2-4 Drawing boards. (Teledyne Post.)

Fig. 2-2-6 Drafting table with parallel slide. (Addressograph Multigraph Corp.)

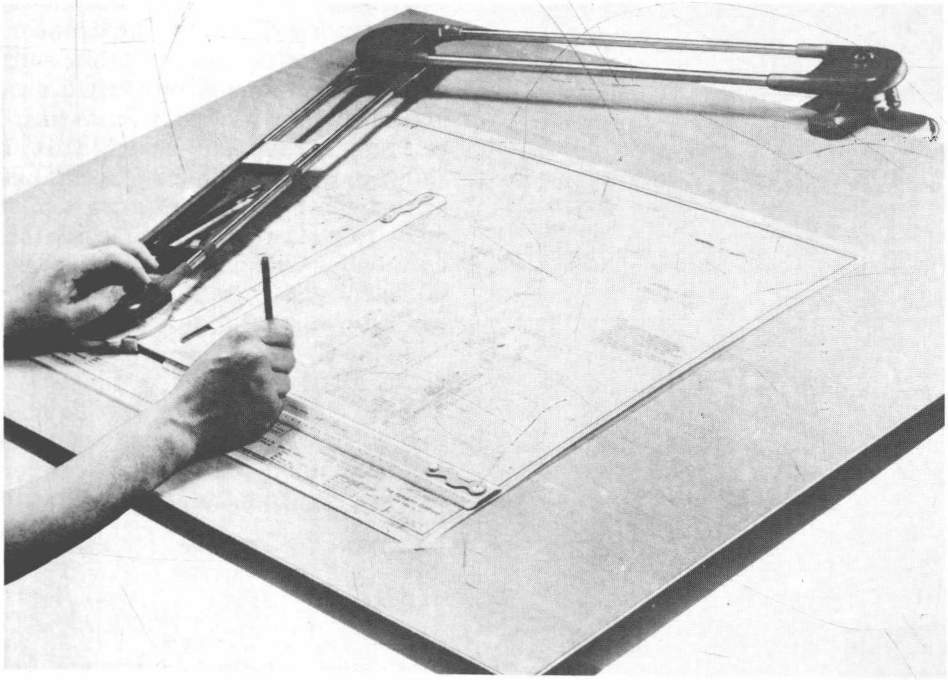
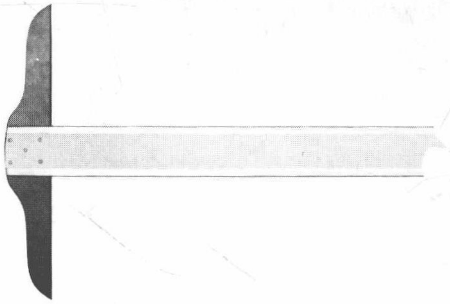
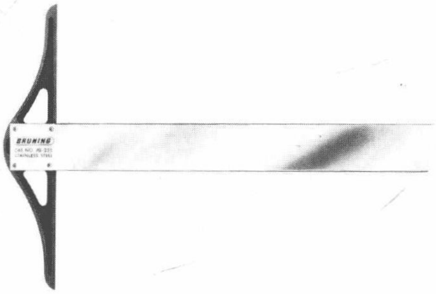


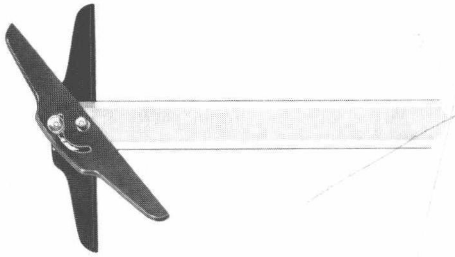
Fig. 2-2-5 Arm type drafting machine. (Keuffel and Esser Co.)



(A) WOOD OR PLASTIC HEAD WITH PLASTIC EDGE BLADE



(B) STEEL BLADE



(C) ADJUSTABLE HEAD WITH PLASTIC EDGE BLADE

Fig. 2-2-7 T squares are available in various styles and materials. (AM Bruning International.)

Track-type drafting machines are especially suitable for long-line work and large drawings.

Parallel Slide

The parallel slide is used in drawing horizontal lines and for supporting triangles, when vertical and sloping lines are being drawn. (See Fig. 2-2-6.) It is fastened on each end to cords, which pass over pulleys. This arrangement permits movement up and down the board while maintaining the parallel slide in a horizontal position.

T Squares

The T square (Fig. 2-2-7) performs the same function as the parallel slide. T squares are made of various materials, the more popular being plastic-edged wood blades with heads made from wood or plastic.

To check the accuracy of a T square draw a sharp line along the drawing edge of the T square on a sheet of paper. Turn the T square upside down and using the same drawing edge check the line for error. If the drawing edge and the pencil line do not match, the T square is not accurate.

The head of the T square is placed on the left side of a drawing board for use by right-handed people and on the right side of the drawing board for use by left-handed people.

Triangles

Triangles are used together with the parallel straightedge or T square when you are drawing vertical and sloping lines (Fig. 2-2-8). The triangles most commonly used are the 30/60° and the 45° triangles. Singly or in combination, these triangles can be used to form angles in multiples of 15°. For other