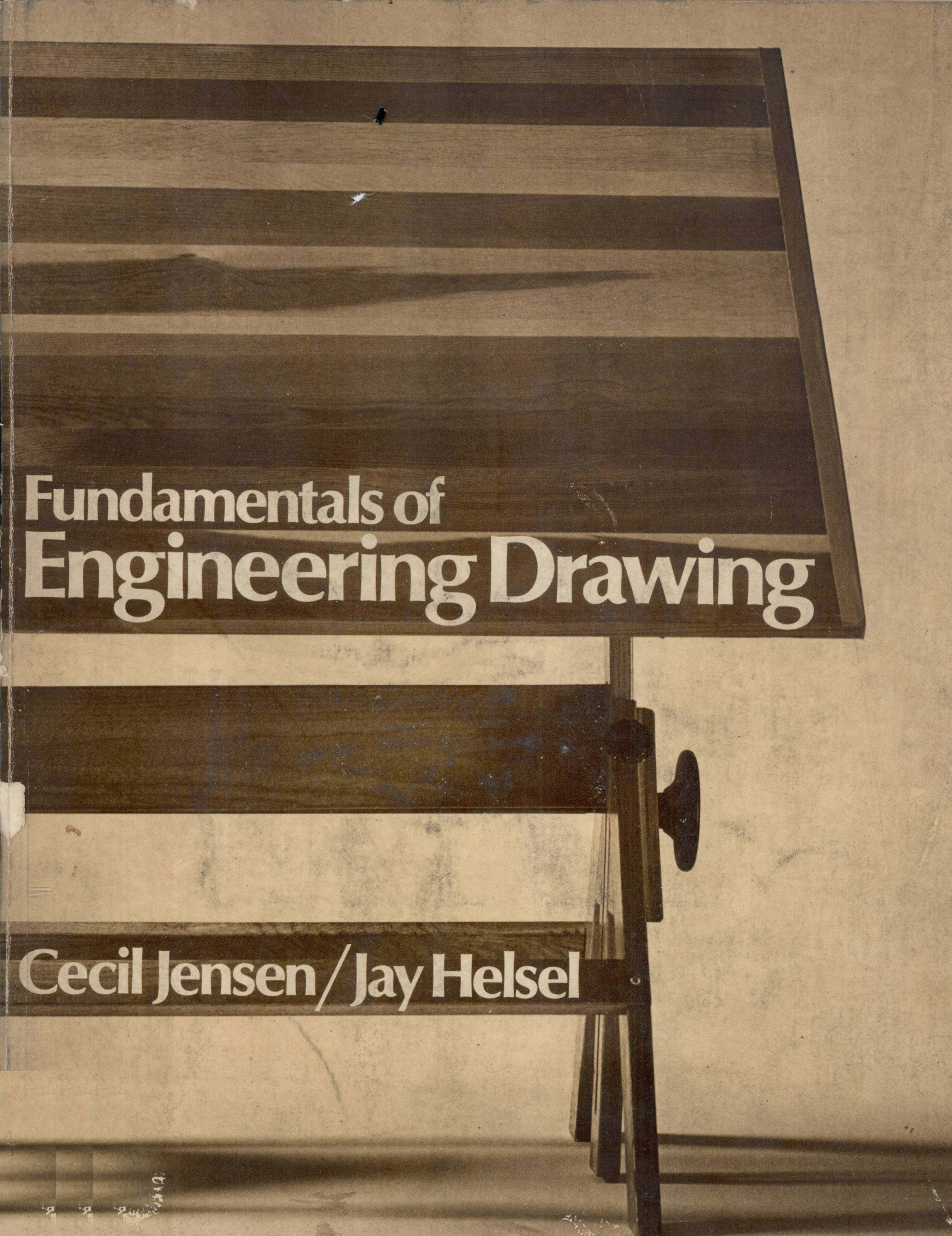

Fundamentals of Engineering Drawing

Cecil Jensen / Jay Helsel

Fundamentals of Engineering Drawing

CECIL JENSEN
Technical Director
R. S. McLaughlin Collegiate and
Vocational Institute
Oshawa, Ontario, Canada

JAY HELSEL
Vice President for Administrative Affairs
California State College
California, Pennsylvania

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FUNDAMENTALS OF ENGINEERING DRAWING

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Fundamentals of Engineering Drawing

ABOUT THE AUTHORS

CECIL JENSEN, a technical director in the education system of the Province of Ontario, has had over twenty-five years teaching experience in mechanical drafting. He is the author of many successful technical books, including *Engineering Drawing and Design, Interpreting Engineering Drawings, Drafting Fundamentals,* and *Home Planning and Design.* Before entering the teaching profession, Mr. Jensen gained several years of design experience in industry. He has also been responsible for the supervision of adult education in Durham County in Ontario, Canada, and the supervision of the teaching of technical courses for General Motors apprentices in Oshawa, Canada. He is a member of the Canadian (CSA) Committee on Engineering Drawings and has represented Canada at several world conferences on the standardization of engineering drawings.

JAY HELSEL is a professor of industrial arts and vice president for administrative affairs at California State College in 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 fifteen years, he has worked as a freelance artist and illustrator. His work appears in a great variety of technical publications.

Dr. Helsel is coauthor of *Engineering Drawing and Design, Programmed Blueprint Reading, Mechanical Drawing, Reading Engineering Drawings Through Conceptual Sketching, Drawing and Blueprint Reading Transparencies, Architectural Drafting Transparencies, Woodworking Transparencies,* and *Automotive Transparencies.* He is also the author of a series of *Mechanical Drawing Film Loops.*

Preface

Fundamentals of Engineering Drawing is prepared for a one-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. In *Fundamentals of Engineering Drawing,* 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, functional drafting, materials representation, shop processes, numerical control, 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.

Every chapter in *Fundamentals of Engineering Drawing* is divided into a number of single-concept units each with its own objective, 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.

Metric conventions as utilized on a practical level by American industry

have been incorporated into this text.* Dual dimensioning, presenting both metric and customary units, is used throughout the text and in all problems. Each problem is stated in both conventional and metric form. Thus, the text may be used in a completely conventional (customary) course, in a complete metric-oriented course, or in a course which utilizes both metric and conventional systems. The teacher may also customize the course by selecting appropriate problems or materials to emphasize or deemphasize any degree of metrication.

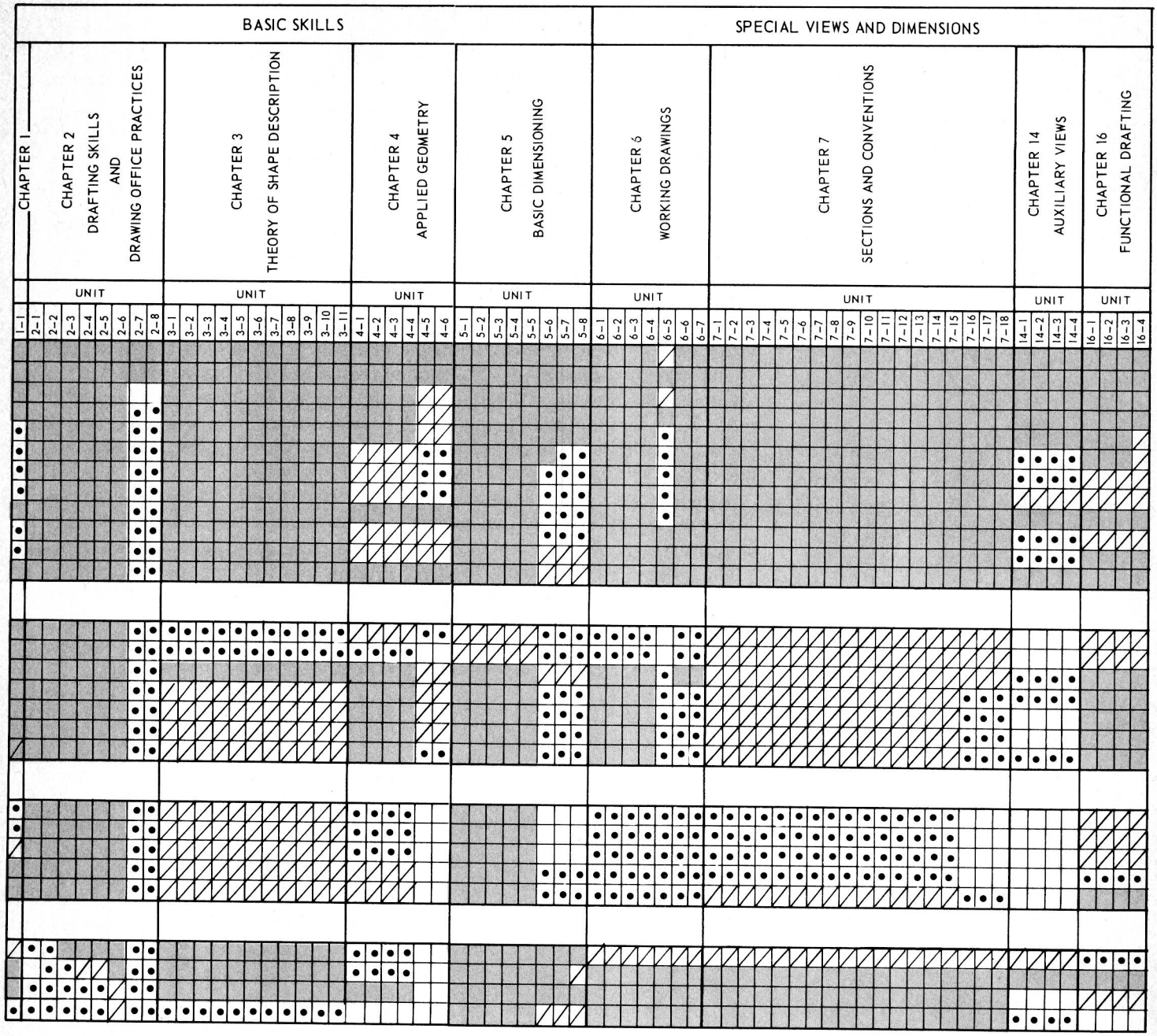
A set of 11 x 17 inch worksheets is available for the completion of the problems. The worksheets include the problem in metric form on one side and in customary form on the reverse side. They are preprinted with light lines to provide the student with a beginning to each problem. Using these worksheets 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 teacher's manual which provides complete solutions to all graphic problems, both metric and conventional, found in the text is also available from the publisher.

The authors wish to thank Fred Newman who has spent countless hours preparing the worksheets and solutions which accompany this text. Mr. Newman is the head of the drafting department in a secondary school. He has had many years of experience in education and in industry, and he has brought these combined experiences to the preparation of the student assignments.

Cecil Jensen
Jay Helsel

* Since many major American corporations such as Caterpillar Tractor Company, Clark Equipment Company, Deere and Company, Ford Motor Company, General Motors, Honeywell, Inc., International Business Machines, and International Harvester Company now use the *re* spelling for metre and litre, this spelling has been adopted. If and when the official spelling is changed to meter, future printings of this text will reflect the latest standards.



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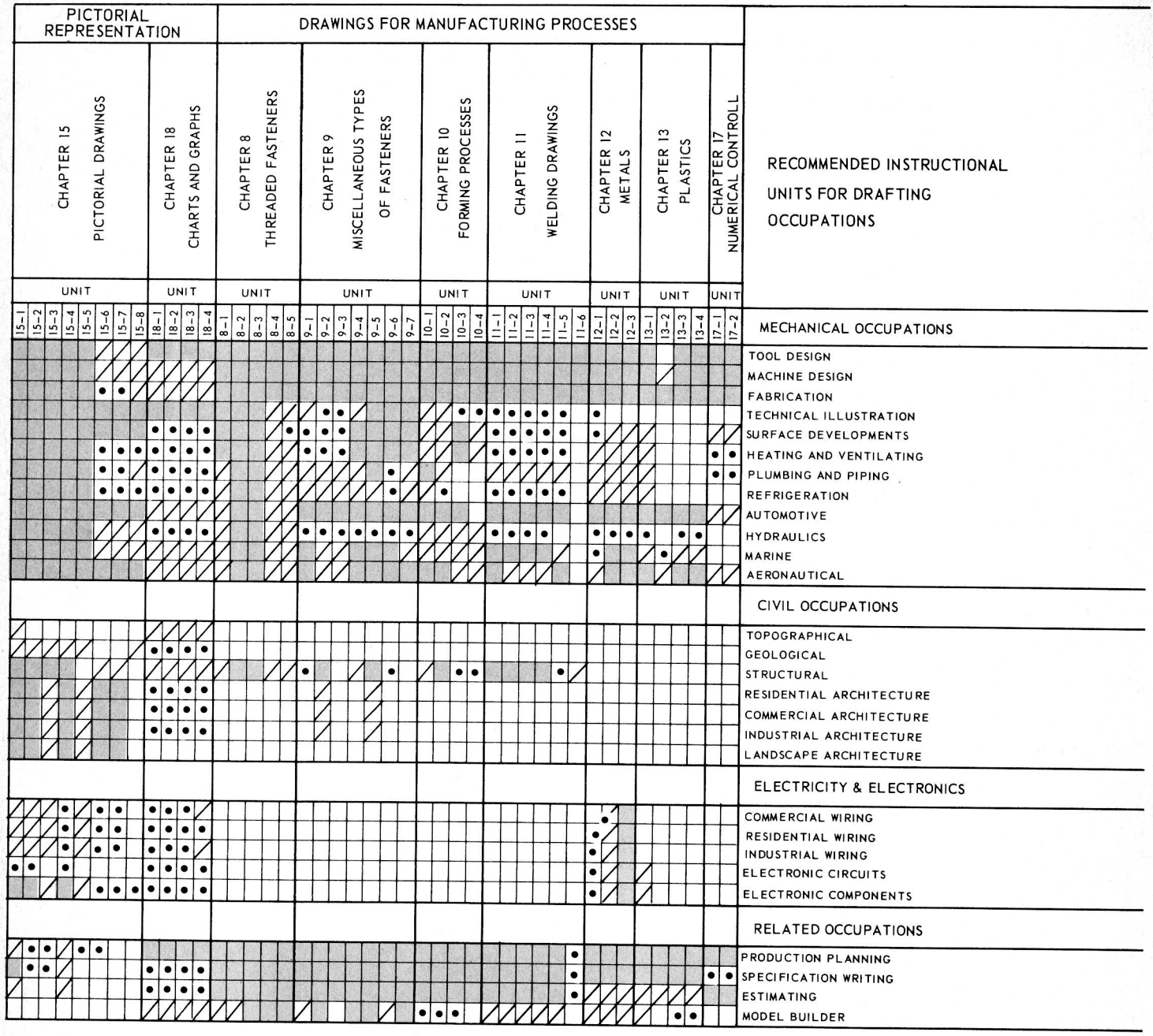
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Chapter 1
The Language of Industry

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 the drafter's ideas to the worker. 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. 1-1-3 through 1-1-8. 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 set squares, as well as machines that combine the functions of several devices. They also may use engineering handbooks, tables, and calculators to assist in solving technical problems.

Drafters are often classified according to their type of work or their level of responsibility. Senior drafters take the preliminary information provided by engineers and architects to prepare design "layouts" (drawings made to scale of the object to be built). Detailers make drawings of each part shown on the layout, giving dimensions, material, and any other information necessary to make the

Fig. 1-1-1 Drafting—today and tomorrow.

detailed drawing clear and complete. Checkers carefully examine drawings for errors in computing or recording dimensions and specifications. Under the supervision of drafters, tracers make minor corrections and prepare drawings for reproductions by tracing them on transparent cloth, paper, or plastic film.

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

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 every chief engineer and chief drafter. 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, shown in Fig. 1-1-2, as compared to a typical drafting room scene before the turn of the century. Not only are there far more tools, but they are of much higher quality. From electric erasers to automated drafting machines 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.

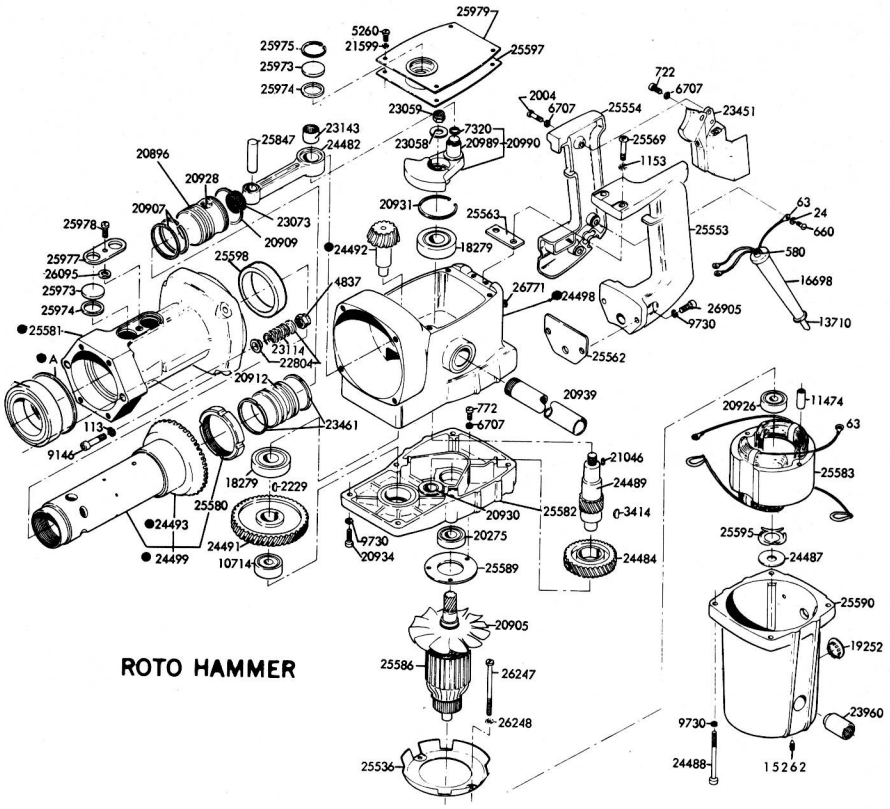
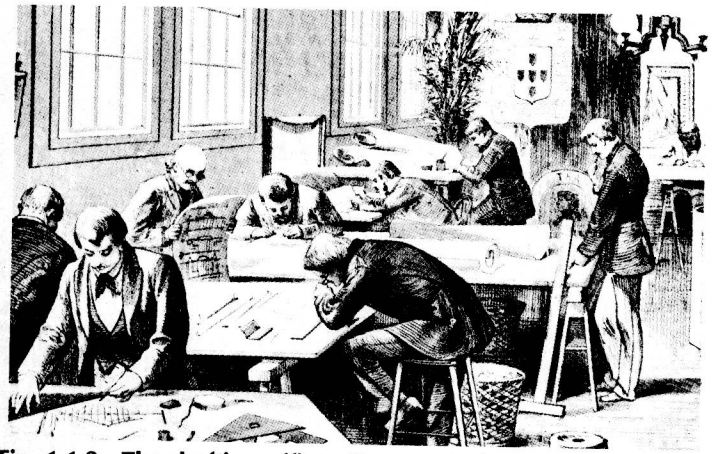


Fig. 1-1-3 Pictorial drawings. (Skill Corp. [Canada] Ltd.)

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 communica-



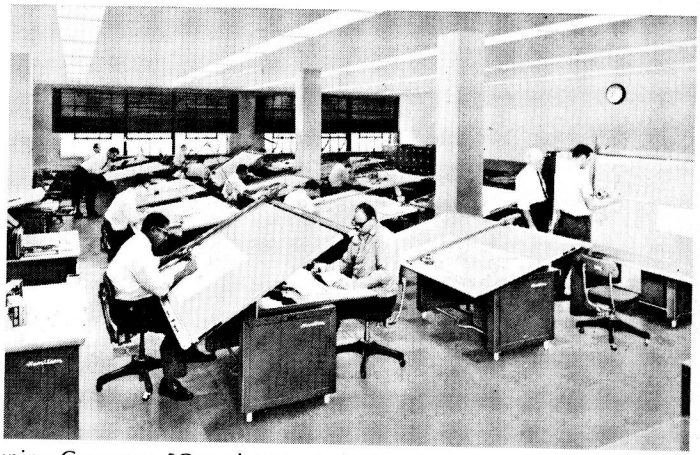


Fig. 1-1-2 The drafting office. (Bettman Archive, Inc. and Charles Bruning Company [Canada] Limited.)

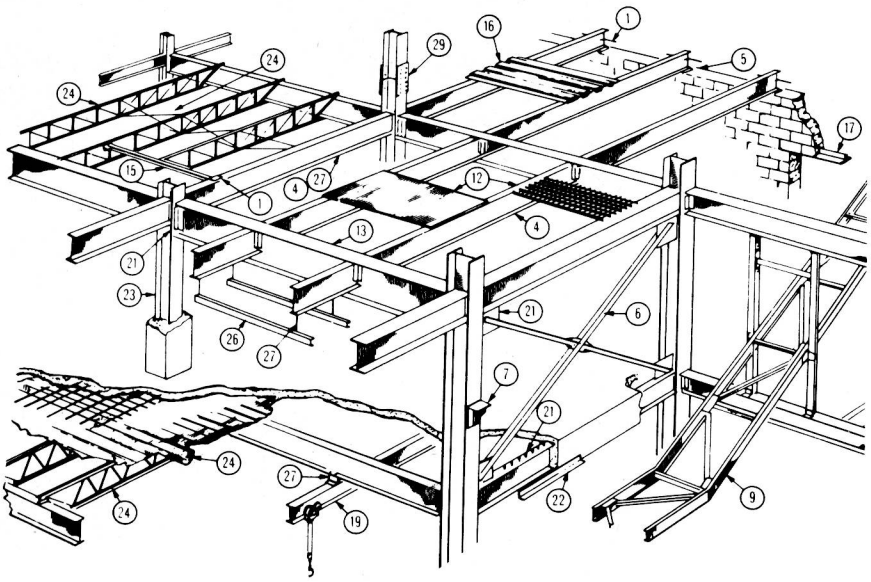


Fig. 1-1-4 Structural drawings. (Canadian Institute of Steel Construction.)

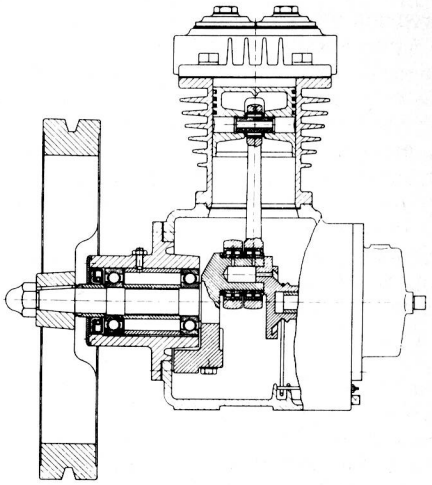


Fig. 1-1-6 Mechanical drawings.

tion, the American National Standards Institute (ANSI) and the Canadian Standards Association (CSA) have 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, but 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.

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 suitable 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.

Places of Employment[2]

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

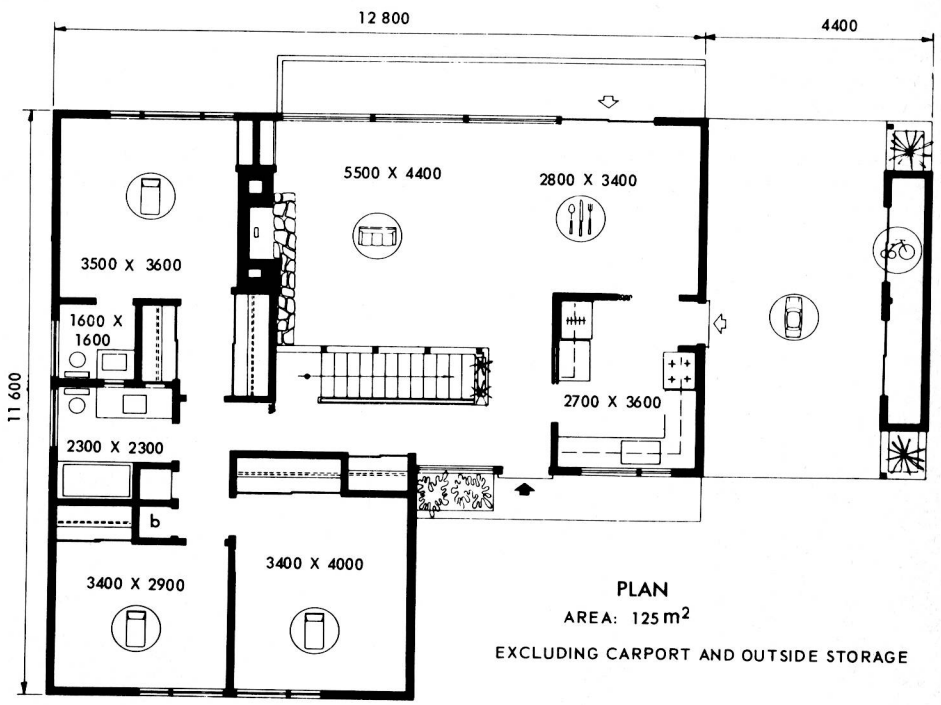


Fig. 1-1-5 Architectural drawings.

through on-the-job training programs combined with part-time schooling or through three- or four-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, or supervisors of other drafters. 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 such 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.

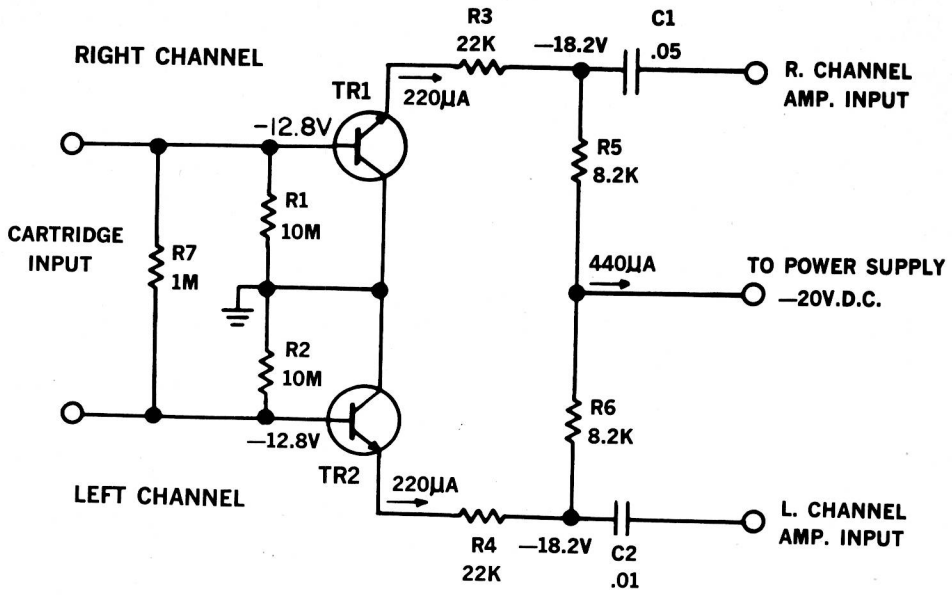
Employment Outlook

Employment opportunities for drafters are expected to be favorable in the future. Prospects will be best for those having post-high school drafting training. Well-qualified high school graduates who have had only high school drafting, however, also will be in demand for some types of jobs.

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 supporting 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. (Canada) Ltd.
2. *Occupational Outlook Handbook.*



ELEMENTARY DIAGRAM OF A PREAMPLIFIER

Fig. 1-1-7 Electrical drawings.

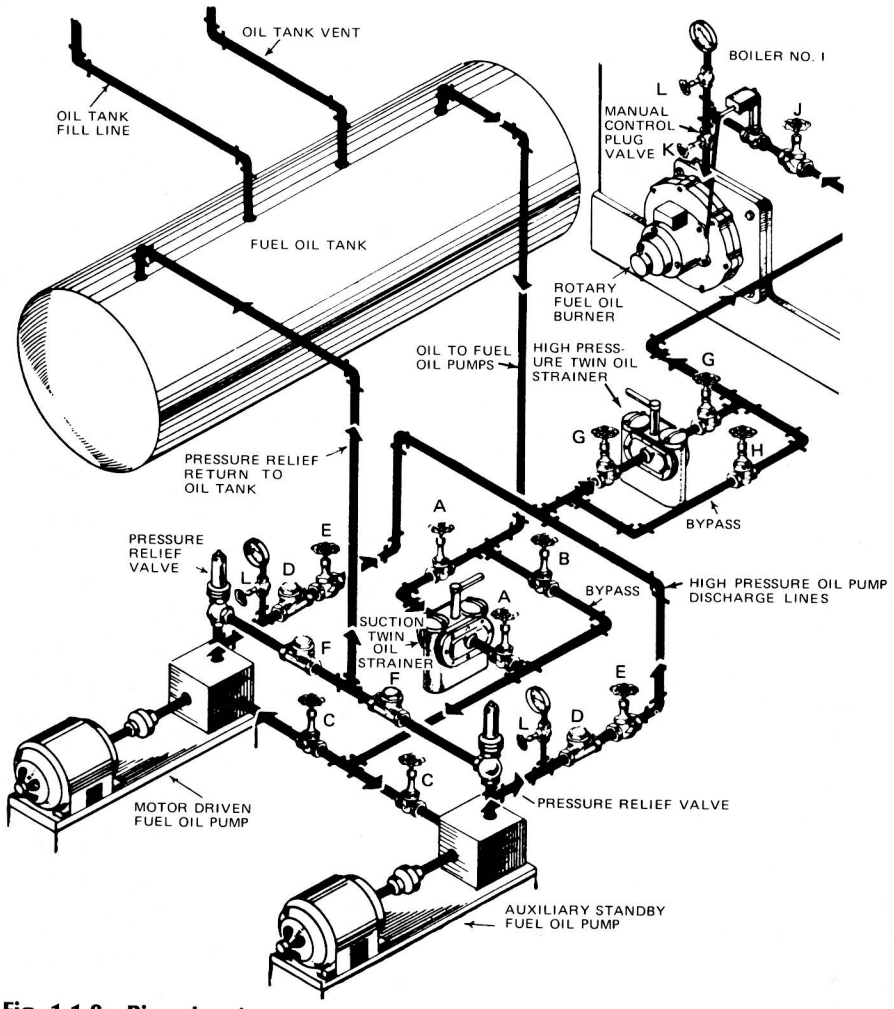


Fig. 1-1-8 Pipe drawings. (Jenkins Bros. Ltd.)

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 persons 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).

Fig. 2-1-1 Drafting office. (Charles Bruning Co. [Canada] Limited.)

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. Automatic 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.

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 is still in use today, although it has been vastly improved.