ENGINEERING GRAPHICS

Second Edition

William P. Spence

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SECOND EDITION

ENGINEERING GRAPHICS

Prentice Hall, Englewood Cliffs, New Jersey 07632

Library of Congress Cataloging-in-Publication Data

SPENCE, WILLIAM PERKINS, 1925-
Engineering graphics.

Includes index.
1. Engineering graphics. I. Title.
T353.S573 1988 604.2 87-1276
ISBN 0-13-277865-3

This book is dedicated to
Bettye Margaret Spence
in acknowledgment of her
support, encouragement,
and productive assistance.

Editorial/Production Supervision: Mary Jo Stanley
Interior Design: Maureen Eide
Manufacturing Buyer: Lorraine Fumoso
Cover Photo: Pete Turner, The Image Bank
Cover Design: Suzanne Behnke

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

ISBN 0-13-277865-3 025

Prentice-Hall International (UK) Limited, *London*
Prentice-Hall of Australia Pty. Limited, *Sydney*
Prentice-Hall Canada Inc., *Toronto*
Prentice-Hall Hispanoamericana, S.A., *Mexico*
Prentice-Hall of India Private Limited, *New Delhi*
Prentice-Hall of Japan, Inc., *Tokyo*
Simon & Schuster Asia Pte. Ltd., *Singapore*
Editora Prentice-Hall do Brasil, Ltda., *Rio de Janeiro*

ENGINEERING GRAPHICS

PREFACE

The second edition of *Engineering Graphics* contains charts and illustrations updated to show the latest standards of the American National Standards Institute. Some changes are minor; others present major revisions. Most significant are those in dimensioning and tolerancing. The new standard issued by the American Welding Society, *Standard Symbols For Welding, Brazing and Nondestructive Examination,* is also included.

Considerable attention has been given to updating the study problems at the end of each chapter. They are now revised both to broaden the experience and to be more challenging.

As is common in revising first editions, a few corrections were necessary in some of the charts and illustrations. Every change suggested by those using the text has been considered, and alterations have been made in each illustration deemed to have an error or omission.

This text has been designed to provide basic and advanced instruction in engineering graphics. The basic content was developed from the results of an analysis of course outlines of introductory graphics courses being offered in accredited engineering schools. Additional material was included to reflect the rapidly changing techniques and procedures in engineering graphics and design.

The text is of sufficient breadth and depth to meet the needs of instructors of both one- and two-semester courses. Additional materials are included for those who wish to go beyond this level.

The coverage of engineering graphics is handled in such a way that a student with no prior experience can successfully comprehend the material and progress through the subject with a minimum of instruction. The basic principles have been explained as clearly as possible and have been carefully illustrated in order to increase student interest and encourage self-study. The instructor is therefore freed from teaching every minute detail and can devote teaching efforts to the major concepts in engineering graphics. A second color has been used to emphasize important parts of each illustration. Steps of procedure have been placed on the same page as the illustrations whenever possible. This makes it much easier for the student to follow the instructions. An extensive appendix provides additional technical data needed for design problems.

Some engineering graphics instructors emphasize the techniques of drafting and technical information; this type of material is extensively covered. Other instructors prefer to reduce emphasis on these and introduce the basic concepts of engineering design; *Engineering Graphics* permits this approach to be used while including extensive technical data. One chapter is devoted to the engineering design process, and references to it have been woven into various other chapters. A second chapter is devoted to student design projects and how they might be handled in an academic environment. Therefore, there is sufficient design information to offer a basic experience.

An extensive array of problems are available at the ends of chapters. They cover the areas discussed in the chapter and give the instructor a wide choice of types of problems as well as various levels of difficulty.

Metrics are thoroughly covered and in some cases expanded. The text includes a detailed explanation of the metric system, including symbols, pronunciation, and applications to engineering graphics. Metric standards are used when available.

The text begins by introducing the use of graphics in various engineering fields. The concepts of engineering design are then covered, followed by a study of the graphic language. The discussion of tools used in the production and reproduction of graphics are followed by the techniques of geometric construction. A considerable effort has been made to present the principles of orthographic projection in an easily understood form. Since engineering ideas often start with sketches, techniques for producing engineering sketches are presented.

The key to successful engineering design is an understanding of the principles and applications of descriptive geometry. Two chapters have been devoted to this important area. Related to these chapters are chapters on auxiliary views and revolutions.

Other means of presenting engineering ideas and designs, such as pictorial drawings and the use of sectional views, are given emphasis.

Considerable space is devoted to dimensioning, tolerancing, and surface finish. Careful attention has been given to standards and inch and metric requirements. Geometric tolerancing material includes the use of the various symbols, feature control principles, position, symmetry, form, runout cylindricity, straightness, flatness, profile angularity, parallelism tolerances, and the control of surface quality.

Two chapters are devoted to mechanical and permanent fasteners, including the details of inch and metric threads and fasteners.

Production drawings are the end product of the design effort. An entire chapter has been devoted to this topic and includes many problems for the students to solve.

Surface development and intersections occur on every product and are covered by two chapters. Since analysis is a function of the engineer, a chapter on vector analysis is included. Design involves the application of kinematic principles that are covered in a complete chapter that includes linkages, cams, and gears.

The presentation and graphic analysis of data are necessary parts of the engineering design process. Techniques for presenting data and making engineering analyses of experimental data and physical relationships are explained. Charts of various types and the use of graphical algebra and calculus are included.

Since computer-aided design and drafting (CADD) is assuming an increasingly important role in American industry, a detailed chapter on this subject is included. Chapter 24 begins with a discussion of the computer and how it functions. Computer languages are presented and examples of programs are shown. The key to any CADD operation is software, and this is described along with basic arithmetic operations. The CADD section is introduced with a general explanation followed by a detailed discussion of input and display devices. Plotters are discussed in a special section and considerable space is devoted to basic programming with a variety of programs shown. Included with these are illustrations showing how an object, as a square, is drawn.

Computer output microfilm is discussed and the equipment related to it is shown. Finally, a discussion of computer-aided manufacturing (CAM) explains how numerical control is used in manufacturing, and how to prepare drawings for CAM.

No publication of this size and depth can be completed without the help of many individuals and companies. These are acknowledged in the credits, and my thanks is again extended to each. Special acknowledgment is due to Dr. A. O. Brown, Dr. Joe Porter, and Professor Gene Chambers for their assistance with several of the chapters. And finally thanks is due to the reviewers who, while anonymous, read and commented on the chapters as they were developed.

WILLIAM P. SPENCE

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1

Graphics in Engineering

Many young people have an early interest in a career in engineering. Often they are not certain what an engineer does, but they want to be one. Young people do not generally have the opportunity to get into the plants and laboratories of industry and see what actually takes place. Even if their parents are engineers, they may not be certain what tasks they perform on the job. A study of the early chapters of this text plus a well-rounded experience in an engineering graphics course will give a brief look into some of the problems and opportunities of engineering.

WHAT ARE THE MAJOR AREAS OF WORK?

The work of an engineer covers a wide range of activities. Some work in areas—such as manufacturing management—where they draw upon a wide variety of experiences and knowledge. Others work in areas—such as nuclear research—where they draw upon a narrow but intensive area of specialization. Following are the broad areas in which engineers work and illustrations of how engineering graphics is used.

Engineers in Research

Engineers involved in research are attempting to apply known principles to solve existing problems or to discover new knowledge. This is usually a practical type of research that can involve many things, such as the use of materials or the development of a new process. This type of work is often slow to show results. While scientific knowledge is the basis for research, many attempts at solutions are by trial and error. Research engineers learn from failure as well as success. They add to the knowledge that can be used by others (Fig. 1–1).

Most of the time, research engineers work on research teams. The team can have a variety of people besides engineers. If the project involves chemical and biological factors, chemists and biologists may be on the team. Technologists and technicians also are a part of the team. They do much of the practical work, such as building prototypes or running routine tests.

Possible solutions and test procedures and equipment require the use of engineering drawings. The research engineer must be able to read engineering drawings and produce engineering sketches. Engineering drafters work from these sketches to produce the needed finished drawings (Fig. 1–2).

Research engineers must be thoroughly prepared in mathematics and the sciences. They must have a strong curiosity and a desire to question, try, reason, and speculate. Usually, advanced degrees are necessary for employment.

Engineers in Development

The area of development involves the actual use of discoveries. Development follows the research activity and sometimes occurs along with it. Because the two activities overlap, many companies combine them into a single research and development department.

Much of the work in engineering development involves improving and redesigning existing products. Engineers study other solutions. They find out why the product is not totally satisfactory and propose a new design. This could involve actual field testing of the product after the laboratory model has proven satisfactory. The final key to success is to have the solution perform satisfactorily under the actual conditions for which it was designed (Fig. 1–3).

Engineers in development must keep up to date on new discoveries and materials. This requires that they have a regular time for reading professional journals and attend seminars and other educational programs.

Development involves a great deal of drafting, including both sketches and finished engineering drawings. From these are developed the models or prototypes that are used in testing and manufacturing planning, which usually results in revisions, drawing changes, and more testing. If the project is successful, final drawings are used for production.

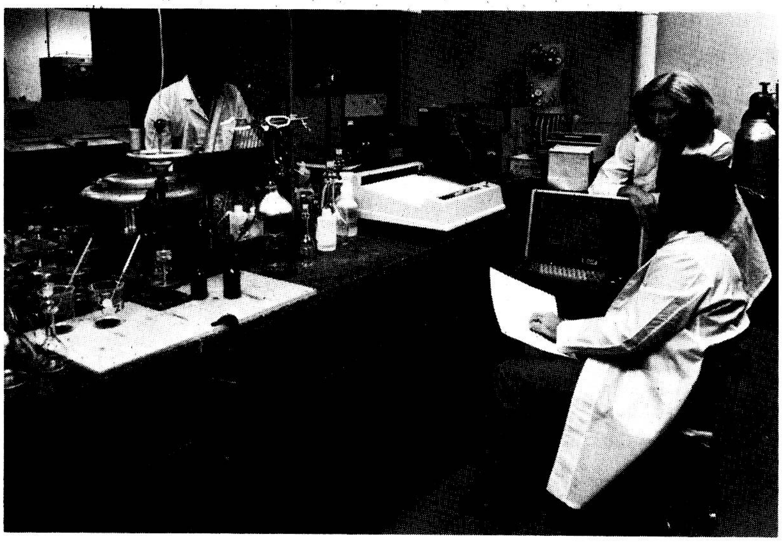

FIGURE 1–1 Engineering research involves the use of computer graphics for engineering testing and data analysis. (Courtesy of Tektronix, Inc.)

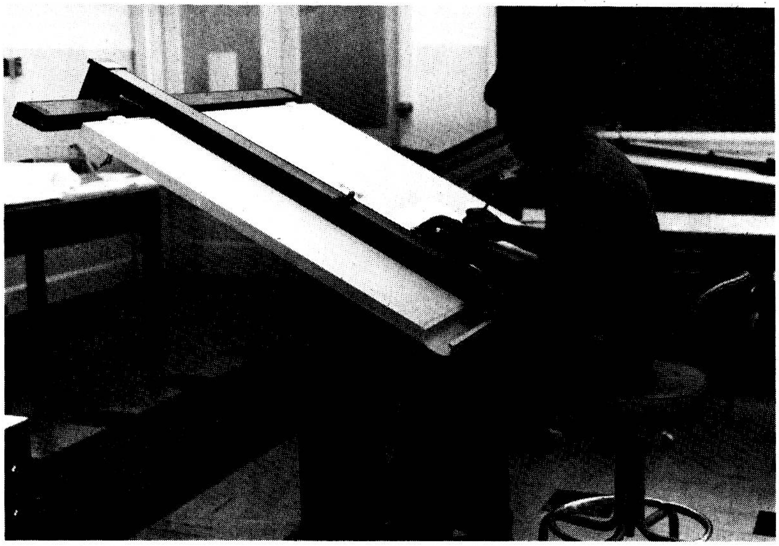

FIGURE 1–2 Research engineers must be able to produce engineering sketches and drawings.

Engineers in Design

The design engineer works on both mass-produced and single-item products. For example, a typical *mass-produced product* is the radio. Its various components provide a variety of possible design solutions. These include AM and FM reception, a variety of electronic circuits and components, the inclusion of cassette recording and playing capabilities, shortwave bands, a clock, and other possibilities. The components are housed in a variety of packages, from a basic rectangle to a square to a sphere. They can be designed for use in a home, car, or boat or as portable units. The design engineer is involved with designing a salable product that will function in the described environment and will meet the needs of the purchaser at a price people will pay.

An example of a *single-item design* project would be a multistory office building or a satellite. These are designed for a specific situation and are not likely to be built again (Fig. 1–4).

The design engineer works with many materials and must be thoroughly prepared in the basic

FIGURE 1–3 Development engineers evaluate designs using laboratory and field tests. (Courtesy of Cessna Aircraft Company.)

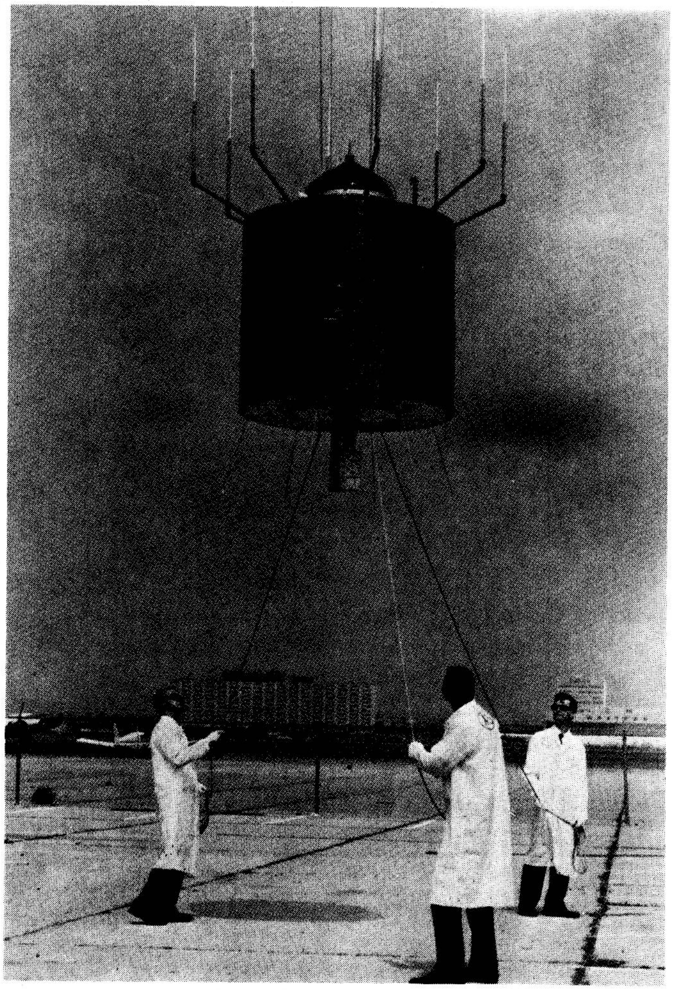

FIGURE 1–4 Design engineers working with a satellite. (Courtesy of National Aeronautics and Space Administration.)

principles of engineering. Often, the engineer will call on specialists in other disciplines for advice and assistance. The design engineer must know the thousands of stock parts available and have access to catalogs listing them. These are used because they are cheaper, and final cost is a primary aspect of the design solution. A product made with stock 6-mm bolts will be cheaper than if special bolts of an unusual size have to be made especially for that product. The engineer in construction will certainly consider the use of stock 4 × 8-ft sheets of plywood rather than requiring special sizes such as 4 ft 6 in. × 8 ft 6 in. be manufactured.

As a product is developed, several acceptable solutions might be reached. In making decisions, the engineer will consider the cost of manufacture and the ease of acquiring materials. Marketing staff are often consulted to see which solution might be best for sales promotion. In the end the design engineer must consider all factors and select the final solution.

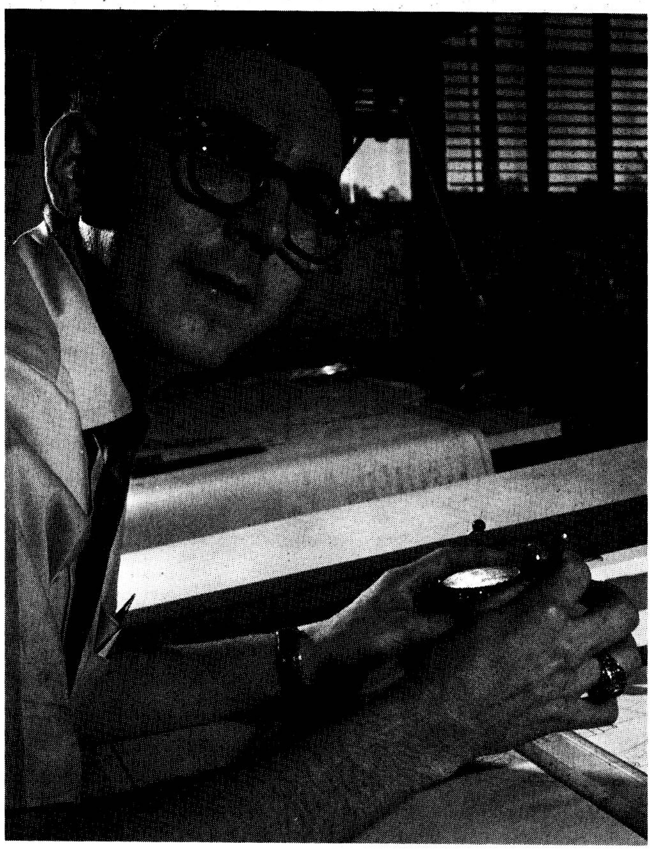

FIGURE 1–5 Engineers in design use drawings to record ideas and check possible solutions. (Courtesy of Bendix.)

An important part of the design process is the production of engineering drawings (Fig. 1–5). Possible solutions can be first tested by making appropriate drawings. The location and sizing of parts can be checked with a drawing. Various solutions can be analyzed and revised before expensive models or prototypes are built. Changes developing from the construction of models or prototypes are recorded on drawings (Fig. 1–6). The engineer must be able to read and produce design drawings and supervise the engineering drafting staff.

The design engineer must have a good general engineering background. Interest in the practical and a concern for cost are essential. Since design engineers often direct the work of others, preparation in management is helpful.

Engineers in Manufacturing

The engineer in manufacturing is closely involved with the production of the product. This includes aspects such as fabrication and assembly of parts, establishing the work flow in the plant, quality control, safety, equipment selection, standards of workmanship, and production schedules (Fig. 1–7). A knowledge of how materials of all kinds are pro-