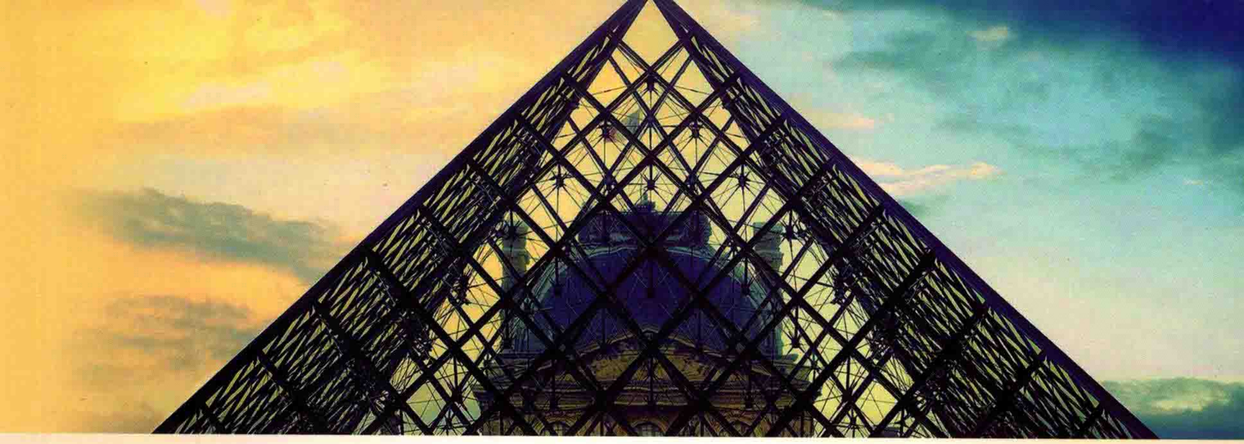
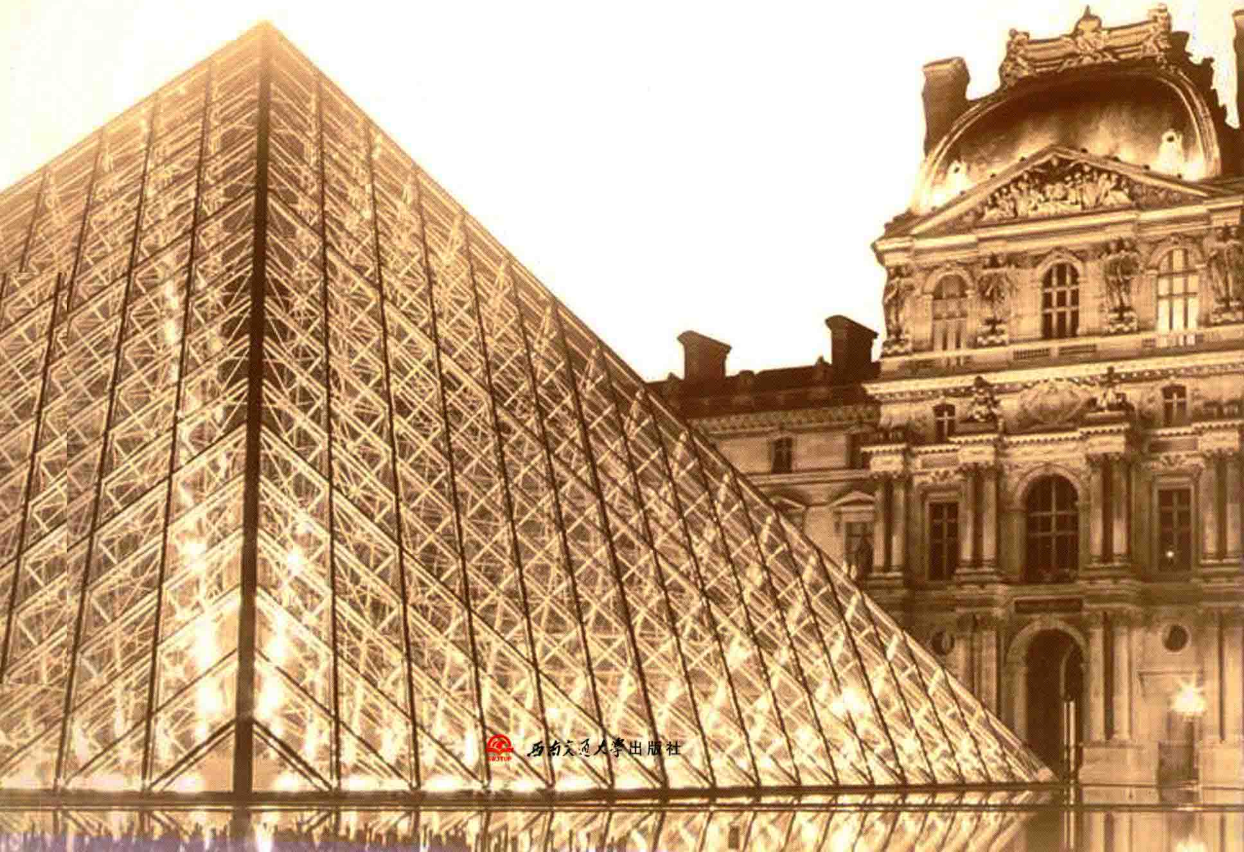


土木工程制图

Civil Engineering Drawing

王 宁　赵莉香　杨万理◎编著



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前言 | preface

Civil engineering drawing is a basic course of civil engineering, hydraulic engineering and traffic engineering. The key goal of the course is to help students establish the ability of spatial visualization.

This book is a textbook for whole-English teaching or bilingual teaching, as well as a reference book for civil engineering drawing. It is expected that this book will be useful to students familiarize with Chinese drawing standards and also understand international drawing standards. There are 9 chapters in the book, including introduction, use and care of drawing equipment, freehand sketches, constructional geometry, theory of drawing, orthographic drawing, point, line, plane and solid, section views and axonometric projection.

Most welcome and appreciated are comments and suggestions for the improvement of this book.

Wang Ning

2017.05

CONTENTS

Chapter 1 Introduction

Engineering designs start as images in the mind's eye of an engineer. Engineering graphics has evolved to communicate and record these ideas on paper both two- and three-dimensionally. In the past few decades, the computer has made it possible to automate the creation of engineering graphics. Today engineering design and engineering graphics are inextricably connected. Engineering design is communicated visually using engineering graphics.

1.1 The Importance of Engineering Drawings

"Visualizing" a picture or image in your mind is a familiar experience. The image can be visualized at many different levels of abstraction. Think about light and you might see the image of a light bulb in your "mind's eye". Alternatively, you might think about light versus dark. Or you might visualize a flashlight or table lamp. Such visual thinking is necessary in engineering and science. Albert Einstein said that he rarely thought in words. Instead, he laboriously translated his visual images into verbal and mathematical terms.

Visual thinking is the foundation of engineering. Walter P. Chrysler, founder of the automobile company, recounted his experience as an machinist apprentice where he built a model locomotive that existed "within my mind so real, so complete, that it seemed to have three dimensions there." Yet, the complexity of today's technology rarely permits a single person to build a device from his own visual image. The images must be conveyed to other engineers and designers. In addition, those images must be constructed in such a way that they are in a readily recognizable, consistent, and readable format. This assures that the visual ideas are clearly and unambiguously conveyed to others. Engineering graphics is a highly stylized way of presenting images of parts or assemblies.

A major portion of engineering information is recorded and transmitted using engineering graphics. In fact, 92 percent of the design process is graphically based. Written and verbal communications along with mathematics account for the remaining eight percent. To demonstrate the effectiveness of engineering graphics compared to a written description, we can try to visualize an object based on this word description:

An object is generally in the shape of a 140 mm × 80 mm × 10 mm rectangular prism. One end is beveled from zero thickness to the maximum thickness in a length of 40 mm to form a sharp edge. The opposite end is semicircular. A 20 mm-diameter hole is positioned so the center of the hole is 40 mm from the semicircular end and 40 mm from either side of the scraper.

It is evident immediately that the shape of the object is much more easily visualized from the graphical representation shown in Fig. 1.1 than from the word description. Humans grasp information much more quickly when that information is presented in a graphical or visual form rather than as a word description.

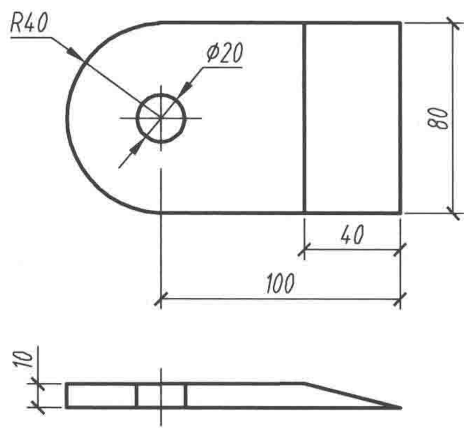

Fig. 1.1 The shape of the object

Engineering drawings, whether done using a pencil and paper or a computer, start with a blank page or as creen. The image of an engineer's mind's eye must be transferred to the paper or a computer screen. The creative nature of this activity is similar to that of an artist. Perhaps the greatest example of this is Leonardo da Vinci, who had exceptional engineering creativity devising items such as parachutes and ball bearings, shown in Fig. 1.2, hundreds of years before which were re-invented. He also had exceptional artistic talent, creating some of the most famous pictures ever painted such as *Mona Lisa* and *The last supper*.

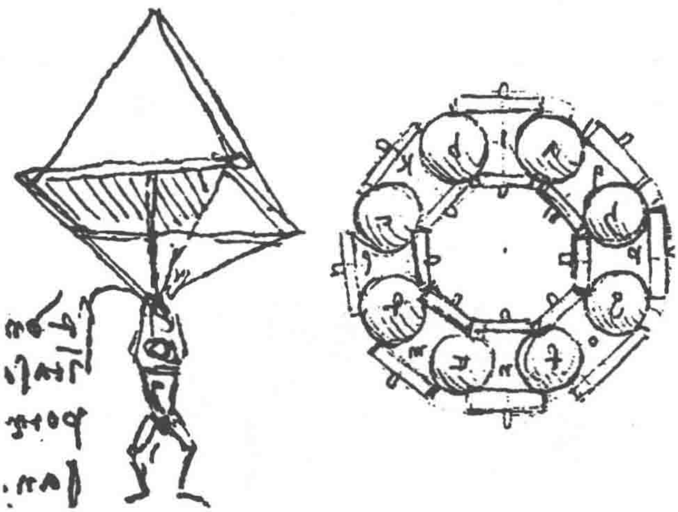

Fig. 1.2 Sketches by Leonardo da Vinci

1.2 Engineering Graphics

The first authentic record of engineering graphics dates back to 2130 B. C., based on a statue now in the Museum of the Louvre, Paris. The statue depicts an engineer and governor of a small city-state in an area later known as Babylon. At the base of the statue are measuring scales and scribing instruments along with a plan of a fortress engraved on a stone tablet.

Except for the use of pen and paper rather than stone tablets, it was not until printed books appeared around 1450 that techniques of graphics advanced.

Around the same time, pictorial perspective drawing was invented by artist Paolo Uccello. This type of drawing presents an object much like it would look into the human's eyes or a photograph, as shown in Fig. 1.3. The essential characteristic of a perspective drawing is that parallel lines converge at a point in the distance like parallel railroad tracks seem to converge in the distance. Copper-plate engravings permitted the production of finely detailed technical drawing using pictorial perspective in large numbers. The pictorial perspective drawings were crucial to the advancement of technology through the Renaissance and the beginning of the Industrial Revolution. But these drawings could not convey adequate details of the construction of an object. One solution to this problem was the use of the exploded view developed in the 15^{th} century and perfected by Leonardo da Vinci. The exploded view of an assembly of individual parts shows the parts spread out along a common axis. The exploded view reveals details of the individual parts along with showing the order in which they are assembled.

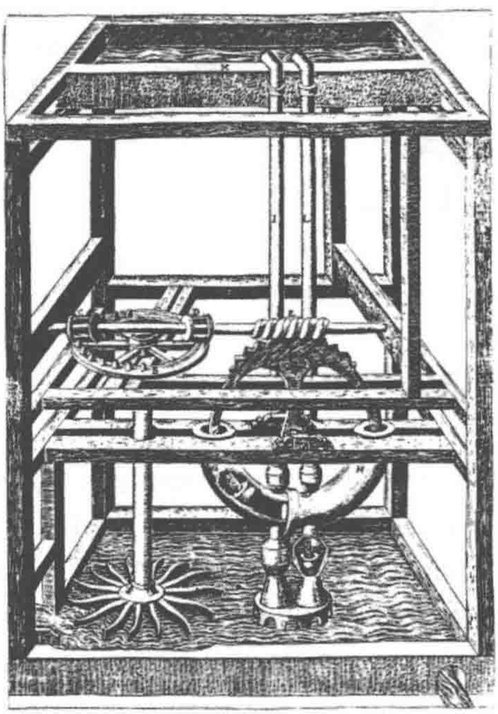

Fig. 1.3 An example of pictorial perspective by Agostino Ramelli in 1588.

The Industrial Revolution brought with it the need to tie more closely the concept of a design with the final manufactured product using technical drawing. The perspective drawing of a simple object in Fig. 1.4(a) shows pictorially what the object looks like. However, it is difficult to represent accurately dimensions and other details in a perspective drawing. Orthographic projections, developed in 1528 by German artist Albrecht Durer, who accomplish this quite well. An orthographic projection typically shows three views of an object. Each view shows a different side of the object (say the front, top, and side). An example of an orthographic projection is shown in Fig. 1.4(b). Orthographic projections are typically easy to draw, and the lengths and angles in orthographic projections have little distortion. As a result, orthographic drawings can convey more information than a perspective drawing. But their interpretation takes more effort than a pictorial perspective, as is evident from Fig. 1.4. French philosopher and mathematician Rene Descartes laid the foundation for the mathematical principles of projection by connecting geometry to algebra in the 17^{th}century. Much later Gaspard Monge, a French mathematician, "invented" the mathematical principles of projection known as descriptive geometry. These principles form the basis of engineering graphics today. However, because these principles were thought to be of such strategic importance, they remained military secrets until 1795. By the 19^{th} century, William Farish, and the English mathematician, formalized the isometric view and introduced it to engineers. The isometric view simplifies the pictorial perspective. In an isometric view, parallel lines remain parallel rather than converging to a point in the distance, as shown in Fig. 1.4c. Keeping parallel lines parallel distorts the appearance of the object slightly. But the distortion in an isometric view is negligible for objects of limited depth. For situations in which the depth of the object is large, such as an architectural view down a long hallway, the pictorial perspective is preferable. The advantage of the isometric view, though, is that it is much easier to draw than a pictorial perspective view.

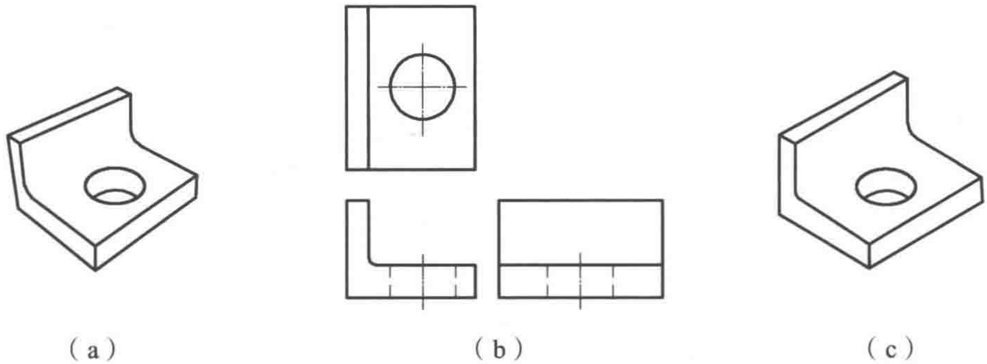

Fig. 1.4 Technical drawings

1.3 CAD

The introduction of the computer revolutionized engineering graphics. Pioneers in computer-aided engineering graphics envisioned the computer as a tool to replace paper and pencil drafting with a system that is more automated, efficient, and accurate. The first demonstration of a computer-based drafting tool was a system called SKETCHPAD developed at the Massachusetts Institute of Technology in 1963 by Ivan Sutherland. The system used a monochrome monitor with a light pen for input from the user. The following year IBM commercialized computer-aided drafting.

During the 1970s, computer-aided drafting blossomed as the technology changed from scientific endeavor to an economically indispensable industrial tool for design. Commands for geometry generators to create commonly occurring shapes were added. Functions were added to control the viewing of the drawing geometry. Modifiers such as rotate, delete, and mirror were implemented. Commands could be accessed by typing on the keyboard or by using a mouse. Perhaps most importantly, three-dimensional modeling techniques became a key part of engineering graphics software.

By the 1980s, computer-aided drafting became fully developed in the market place as a standard tool in industry. In addition, the current technology of solids modeling came about. Solids models represent objects in the virtual environment of the computer just as they exist in reality, having a volume as well as surfaces and edges. The introduction of Pro/ENGINEER@ in 1988 and Solid Works@ in the 1990s revolutionized computer-aided design and drafting. Today solids modeling remains the state-of-the-art technology.

What we have been referring to as computer-aided drafting is usually termed CAD, an acronym for Computer Aided Design, Computer Aided Drafting, or Computer Aided Design and Drafting. Originally the term Computer Aided Design included any technique that uses computers in the design process such as drafting, stress analysis, and motion analysis. But over the last 35 years CAD has come to refer more specifically to Computer Aided Design and Drafting. Computer Aided Engineering(CAE) is used to refer to the broader range of computer-related design tools.

Chapter 2 Use and Care of Drawing Equipment

It is necessary for an engineer to know drafting methods and practice, whether he is in the design, drafting, construction, or operation and maintenance department. His work is constantly placing himself in contact with the drafting room. He also uses the drawings and specifications turning out at the drafting offices. The way to become proficient in reading and handling drawings is to study the fundamental principles of making them. A study of these principles can best be accomplished by application in making the drawings.

To become proficient in the art of drawing, the student must first know the technique of handling his instruments and other drawing equipment. There is a technique in drawing as in other lines of work which requires skillful operations or dexterous manipulations. Good form, that is, the proper technique of handling drawing equipment, which should be insisted upon throughout this course and subsequent drawing courses. It may seem awkward enough to the beginner, but an experienced draftsman can appreciate the application of drawing technique. It enables one to speed up his work and at the same time to turn out better drawings. The beginner, therefore, should ever bear in mind the following instructions in the use and care of drawing equipment.

This chapter will describe the most common drafting instruments in use today and discuss how they are used. As one becomes more comfortable in the use of instruments over an extended period of practice, drawings will be made with greater speed, neatness, and accuracy. While only a minority of students become professional drafters, it is very satisfying to be able to draw at least well enough to convey sound information.

2.1 Drawing Boards

The true edges of a drawing board are the two strips which are dovetailed or tongue and-grooved into the body of the board. These strips should normally come to the right and left of the draftsman. The top and bottom of the board are not true and should never be used as a guide for the T-square. A right-handed person should draw with the head of the T-square to the left. A left-handed person should use the reverse form. The T-square head should not be switched from one edge of the board to the other. In the course time, either the T-square or board, or both, is almost sure to become slightly out of true. If the head is always kept on the same edge of the board, the error will be compensating.

For a right-handed draftsman the board should preferably be placed so that the light will come from the left and front.

2.2 T-Square

As previously stated, the head of the T-square should be placed on the left edge of the drawing board and kept there. Obviously, the T-square is used primarily for drawing horizontal lines. These lines should be drawn from left to right. Vertical and inclined lines should be drawn with the T-square and triangles, shown in Fig. 2.1. A check should be applied often to see that the T-square blade has not slipped, especially when working out near the end of the blade. This is done by releasing the T-square, pressing the head lightly against the board, and then running the fingers along the blade in order to hold it in the proper position. Weights should not be placed on the T-square to hold it in place. The paper, if much smaller than the board, should be placed at the lower left-hand corner, but up several inches from the bottom. A true edge of the paper, in case the sheet has been cut, should be placed at the top and lined up even with the top edge of the T-square. The paper can then be held in place, the T-square slipped down, and a piece of tape or a thumbtack put in each upper corner and pressed firmly into position. If the sheet is not too large, the two tacks in the upper corners will be sufficient. A draftsman should always avoid running the T-square over thumbtacks. When a drawing is put back on a board, the same thumbtack holes should not be used again.

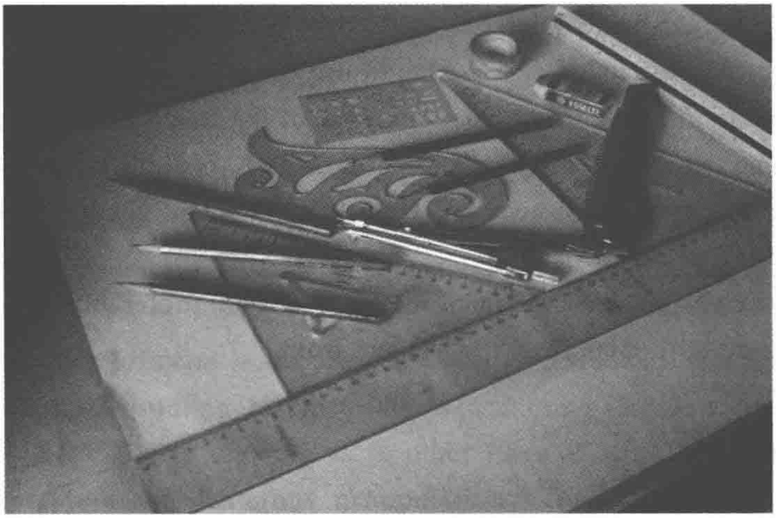

Fig. 2.1 Drawing instruments

2.3 Pencils

All work on a drawing, except the lettering, should be done with a hard pencil. A soft pencil leaves an excess of pencil dust on the drawing which will result in a smear when the T-square and other implements are running across the lines so drawn. To avoid this damage, a hard pencil should be used for drafting, the degree of hardness depending upon the kind of paper used. Usually a 4H or a 6H pencil will do. The lettering should be put on a drawing last to prevent smears. A soft pencil should be used for lettering or sketching. An HB or H is recommended. In all cases the pencil should be kept sharpened and well pointed. Penciling should always be done light. A heavy hand will put creases in the paper which will result in kinky or wavy lines when the penciling is inked.

The pencil should be sharpened to a long, slim, conical point, leaving about 10 mm of the blunt lead exposed. The pencil is then pointed on a sandpaper pad, as shown in Fig. 2.1. The wedge and chisel points, in addition to the conical, are often used to advantage by an experienced draftsman, but they are not recommended for beginners. The pencil should be held nearly vertical, leaning slightly in the direction that the line is to be drawn. The wood of the pencil should not touch the straightedge. That is, the top of the pencil should be held firmly against the straightedge. The pencil should be turned constantly in the fingers while penciling is being done. This will insure an even, conical point until the pencil needs sharpening again.

2.4 Triangles

A draftsman's outfit should have at least one 45° triangle, one 30°-60° triangle, and a lettering triangle, shown in Fig. 2.2. As previously pointed out, vertical lines are drawn by means of the triangle placed against the T-square. A triangle, when being used, should be placed against another straightedge, usually the T-square, but another triangle is sometimes used. A line should never be continued until a corner of the triangle is reached. An inaccuracy in the line is likely to occur.

The common angles used so much in drafting can be laid out by combinations of the triangles and straightedge. They are the multiples of 15°, that is, 15°, 30°, 45°, 60°, 75°, 90°, 105°, etc. These angles can be laid out much faster by the use of the triangles, and the construction is much more accurate than by the protractor. For this reason the protractor should not be used when constructing the common angles.

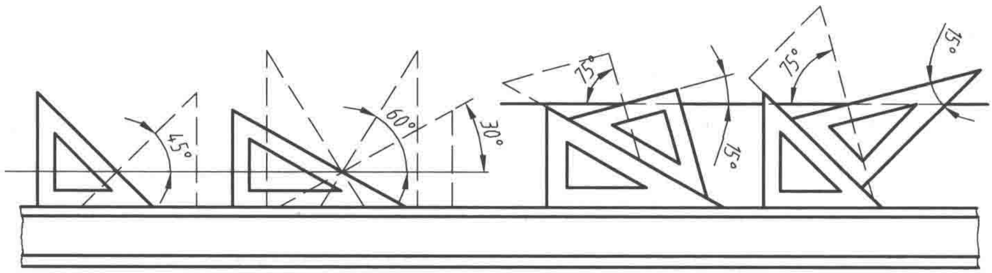

Fig. 2.2 Triangles

Guide lines should always be drawn only one when an experienced draftsman is making letters of the height which he is accustomed to making. A beginner, however, should draw the base and cap lines when he is making capitals and numerals and should draw all three guide lines when making lower-case letters. This will apply even though a single letter or numeral is being made.

To draw parallel lines—Place a triangle against the T-square or another triangle, move the two along until one edge of the triangle comes in contact and coincides with the given line. Hold the straightedge firmly, and slide the triangle along until the place is reached where the required line is to be drawn. Hold the triangle and straightedge with one hand and draw the parallel line with the other.

To draw perpendicular lines—One line given: Place the hypotenuse of a triangle against a straightedge. Move the two until a leg of the triangle coincides with the given line. Slide the triangle along until the other leg reaches the point on the given line where the required perpendicular line is to be drawn. The perpendicular line can now be drawn.

2.5 Scale

A scale is defined as a piece of metal, wood, or other material graduated with lines of use in making measurements. In some instances the scale refers solely to the graduations on the article. Scales are usually made