MANUAL OF INSTRUCTIONS

ENGINEERING DRAWING

PROPERTY IDENTIFICATION AND MAPPING PROJECT

TECHNICAL SERIES KY - 3

WAR SERVICE SECTION

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WORK PROJECTS ADMINISTRATION IN KENTUCKY

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PREFACE

This is the third in a series of technical manuals, issued by the War Service Section, Service Division of the Work Projects Administration in Kentucky. It is hoped that it will serve both as a guide to supervisors in instruction of workers and to workers themselves being trained for Engineering Drawing. It is not our intention to cover the field completely but rather to treat the fundamentals with a view to training workers in the drafting of property identification maps. A decimal page and chapter numbering system is used allowing for the insertion of revised pages.

Credit for the preparation of the manual should be extended to the staff of the Property Identification and Mapping Project. The greater part of the material was selected and prepared by Karl Boggs and Henry H. Lovett, Jr., Technicians. Walter M. Hoefelman, State Supervisor, arranged the material and reviewed the text. Thomas P. Lynch, Technician, reviewed the text and contributed useful ideas. Suggestions for improvement of the Manual are invited.

February 20, 1942

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Chapter 1

INTRODUCTION

ENGINEERING DRAFTING

Engineering Drafting is drawing as used in the industrial world by engineers and designers. It is the language in which they express and record the ideas and information necessary for the building of machines and structures, and for map making. Since engineering drawings depict only the outline of an object, the lines must give exact and positive information concerning every detail of the machine or the structure as it exists in the designer's mind, in order that the user of his drawing will understand its meaning and be able to construct the object from it. To the enginner it is a complete graphical language, by means of which he describes minutely every necessary construction operation and keeps a complete record of his work for duplication, repairs, or addition by others.

TYPES OF DRAWINGS

Architectural

Characteristics of Architectural Drawing. The general principles of drawing are the same for all types of technical work. Each branch of the engineering profession requires its own special application of the principles of mechanical drawing and the employment of particular methods, symbols, and conventions. In architectural drawing the necessary smallness of scale requires that the general drawings be made up largely of conventional symbols indicating the various parts of the project undertaken. Since so many notes of explanation and information concerning material and finish are required, it is impossible to include all of them on the drawings. They are therefore written separately in a document called "Specifications"

which is either attached to, or made a part of the drawing itself. These specifications are complementary to the drawings and have equal importance and weight.

In the makeup of an architect's drawings there is an evidence of artistic feeling, produced in part by the freehand work and lettering, and in part by the use of finer lines, which gives them an entirely different appearance from that of a set of machine drawings. One peculiarity found in many architectural drawings is the tendency to overrun corners. This in an experienced draftsman's work, gives a certain snap and freedom, however, it is often a license for carelessness and is therefore discouraged. The more clear cut the drawing, the more reason for the user to be careful in following the design.

Working Drawing

A working drawing is a drawing which gives all the information necessary for the complete manufacture or construction of the project represented. Further, it is a technical description of a machine, structure, or map designed for a definite purpose and must convey all the facts regarding the project in question so clearly and explicitly that further instruction concerning either manufacture, erection, or use will not be required. This type of drawing includes the following:

1. A full graphical representation to a definite scale of the shape and relationship of every part of the object (shape description).

2. The figured dimensions of all parts (size description).

3. Explanatory notes giving specifications in regard to materials, finish, heat treatment, etc.

4. A descriptive title.

Often, as in architectural and structural drawing, the notes of explanation and information concerning details of materials and workmanship are

too extensive to be included on the drawings, and are made up separately in typed or printed form and called the "specifications". These are considered a part of the drawing, the information in them having equal weight and importance with that shown on the drawing itself. Thus we have the term "drawings and specifications".

Although pictorial drawings are used to some extent in special cases, the basis of any working drawing is orthographic projection. To represent an object completely at least two views will be necessary, sometimes more. The general rule governing the number of views is to make as many views as are necessary to describe the object clearly and explicitly. Instances may occur in which the third dimension is so well understood as to make one view sufficient, i.e. the drawing of a shaft or bolt. In other cases perhaps a half dozen views might be required to describe the project completely.

Engineering

There are several different types of engineering drawings. We will discuss only those that are most commonly used by Engineers.

1. Profiles. The type of drawing more commonly used by civil engineers is the ordinary profile, a vertical section taken along a given line either straight or curved. Such drawings are necessary in problems of railroad construction, highway and street improvements, sewer construction, and other projects involving a study of the surface of the ground. Frequently draftsmen other than those in civil engineering are called upon to make these drawings. Profiles are drawn on special types of paper which are called profile and cross-section paper. In making a profile drawing the horizontal distances are plotted as abscissas and elevations as ordinates. The vertical distances representing

elevations are plotted to a larger scale; thus vertical exaggeration is obtained in relation to the horizontal scale, which is necessary in studying the profile for the establishment of grades. The vertical scale and horizontal scale is sometimes confusing to the layman or inexperienced draftsman, but ordinarily a profile would fail in its purpose if the horizontal and vertical scales were the same. Further, the profile unless so arranged would not only be too long and unweildy, but difficult to make.

2. Structural. Structural drawings differ from other drawings only in certain details and practices, which have developed because of peculiarities in the materials used, and their method of fabrication. These differences are so well established, that it is essential for the draftsman to know the methods of representation in structural drawing.

Steel structures are made of steel beams and plates put together permanently by riveting or welding. The function of a structural drawing is to show the shapes and sizes used and the details of fastening. The structural draftsman must be familiar with the dimensions of the various sizes of standard steel beams, together with much other information before an accurate drawing can be made. The general drawings correspond in many respects to the design drawings and assembly drawings of the mechanical engineer, giving the sizes and weights of members and the number and spacing of all rivets, but in most cases the general dimensions, positions, and sizes of the members and the number of rivets are shown, leaving the details to be worked out in the shop or to be given on separate complete detail shop drawings. In order to show the details clearly the structural draftsman often uses two scales

draftsman often uses two scales in the same view, one for the center lines or skeleton of the structure showing the shape, and a larger one for the parts composing it.

3. Maps. In the treatment of various types of drawing the three dimensions of an object have been represented either pictorially or by drawing two or more views. In map drawing, the representation of features on parts of the earth's surface, there is the distinct difference in that the drawing is complete in one view. The third dimension is represented either by contour or hachure lines or omitted if it is not required for the particular purpose for which the map is made. The surveying and mapping of the site under consideration is the preliminary work in engineering projects. All engineers should be familiar with the methods and symbols used in this branch of drawing. It is not the purpose here to treat in detail the practice of surveying and plotting or the various methods used by cartographers in projecting the curved surface of the earth on a plane. Rather it is intended only to discuss the use and details of execution of plats and topographic maps. See (Raisz Erwin, "General Cartography," New York, 1938 p. 71 - 117).

The content or information on maps may be classified in general under three divisions:

1. The representation of imaginary lines, such as divisions between areas subject to different authority or ownership either public or private, and lines indicating geometric measurements on the ground. In this division may be included plats or land maps, farm surveys, city subdivisions and plats of mineral claims.
2. The representation of real or material features or objects within

the limits of the tract, showing their relative location or size depending upon the purpose of the map. When relative location only is required the scale may be small, and symbols may be employed to represent objects such as houses, bridges, or even towns. When the size of the object is an important consideration the scale must be large and the map becomes a real orthographic top view.

3. The representation of the relative elevation of the surface of the ground. Maps with this feature are called relief maps, or if contours are used with elevations marked on them, contour maps. Various combinations of these three divisions are required for different purposes.

Type of maps

Classified according to their purpose, maps may be geographic, topographic, cadastral, engineering, and planimetric.

Geographic maps include large areas and consequently must be to a small scale. They contain political boundaries, the more important towns and cities, streams, bodies of water, and symbols for mountain ranges.

Topographic maps are complete descriptions of specific areas to a larger scale. The content is the same as that depicted on geographic maps, with the exception that contour lines rather than symbols are used to indicate elevations.

Cadastral maps are control maps for cities and towns, drawn to a large scale with all features including boundary lines accurately scaled. They are used to control city development and operation, particularly taxation.

Engineering maps are working maps for engineering projects which

accurately delineate property lines, all objects on the site, and contour lines.

Planimetric maps represent graphically physical features such as streams, lakes, roads, railroads, property and other boundaries. Plats are maps plotted from a plane survey having the third dimension omitted. They are used in the description of a tract of land when it is not necessary to show relief, i.e. farm surveys or a city plat. The first principle to be observed in the execution of this kind of drawing is simplicity. The information should be clear, concise, and direct. The lettering should be done in a single stroke, and the north arrow and border be of the simplest character. It is impractical to prepare a map containing excess ornamentation which serves no useful purpose. The plat of a survey should give clearly all the information necessary for the legal description of the parcel of land. It should contain:

1. Lengths and bearings of all the sides.
2. Acreage.
3. Location and description of monuments found or set.
4. Location of highways, streams, etc.
5. Official division lines within the tract.
6. Names of owners of abutting property.
7. Title and north arrow.
8. Certification.

Sketches. The designer and inventor conceives his original idea in the form of a mental picture. Preliminary sketches made of the object as it was conceived preserve the idea. Later orthographic design sketches are made. Pictorial sketches of an object or of a detail of construction are more easily comprehended by a client or workman than the orthographic projections. A difficult working drawing is more easily understood if a pictorial sketch is first made. Further this type of sketch is more easily and quickly made. It, however, does not treat the object in the same detail as

the orthographic sketch. Neither, as used by the engineer, is intended to be a work of art but rather a record of information. The requirement common to both is good proportion.

Charts, Graphs, and Diagrams. The graphical chart provides one of the best methods for concise presentation of numerical data. It assists clear thinking by eliminating the mental effort required in keeping in mind an involved series of figures. When properly constructed and thoroughly understood, charts, graphs, and diagrams constitute an important aid for analysis of engineering data and the presentation of statistics for comparison or forecasting. When classified according to use, they may be divided roughly into two classes, those used for purely technical purposes, and those for popular appeal in the presentation of information or in advertising. The engineering draftsman is concerned chiefly with the first class, but he should have some acquaintance with the preparation and possibilities of the second. The aim here is to discuss briefly the types with which draftsmen should be familiar.

The construction of a graphical chart requires a fair degree of draftsmanship. In engineering and scientific work the important considerations are judgment as to the proper selection of coordinates, accuracy in plotting points and drawing the graph, and an understanding of the functions and limitations of the chart.

The title is very important. Its wording should be studied until it is clear and concise. In every case it should contain sufficient description to tell what the chart is, the source of authority, the name of the maker, and the date it was made.

Approved practice places the title at the top of the sheet arranged symmetrically about a center line. If placed within the ruled space a border line or box will set it out from the sheet. Each sheet of curves should have a title. When more than one curve is shown on a sheet they should be drawn so as to be easily distinguishable. This may be done by varying the character of the lines, using full, dotted, and dot-and-dash lines with a tabular key for identification, or by lettering the names of the curves directly along them. When not intended for reproduction different colored inks may be used.

CHAPTER 2

INSTRUMENTS AND MATERIAL

Instruments.-The draftsman is dependent for his success, to a certain extent, upon the quality of the instruments and materials which he uses. As a beginner, he will find that an inexpensive set of instruments will suffice for his needs, but after he has become skilled it will be necessary for him to secure instruments of better construction and finish so as to enable him to do more accurate work.

In learning the use of drawing instruments particular attention should be paid to the correct methods of handling them. Read carefully the instructions given and observe strictly all the details of the technique. Bad form in drawing is distressingly common and may be traced in almost every instance to lack of care or knowledge at the beginning. This is the start of bad habits, which when formed are most difficult to overcome. Learn to hold the tools properly; take an easy, comfortable position at the drawing board; practice in a smooth uncramped style, trying to improve with each lesson. It will be a revelation to the student when he realizes how easy it is to draw. The secret is continued practice of the correct technique in manipulation of tools. The two requirements are accuracy and speed, and in commercial work neither is worth much without the other. Accurate pencil work is the first consideration. The beginner should learn that a good drawing can be made just as quickly as a poor one. Erasing is expensive and generally avoidable. The draftsman, of course erases an occasional mistake and therefore should know methods of making erasures.

Drawing Board.-The drawing board is usually made of well-seasoned and straight-grained soft pine, the grain running lengthwise of the board. Each end of the board is protected by a side strip, 1-3/4 to 2 inches in width,

whose edge is made perfectly straight for accuracy in use of the T-square. Frequently the end pieces are fastened by a glued, matched joint, nails, or screws. Two cleats on the bottom, extending the entire width of the board, will reduce the tendency to warp. Drawing boards are made in such sizes as to accomodate the sizes of paper in general use. Large drawing boards are usually mounted on specially designed horses or tables. Provision is made for adjustment of the height of the board and for tilt to the size of the drawing being prepared. Drawers may be included for storage of instruments and supplies. Adjustable stools and foot rests may be used with this type board. To clean a drawing board art gum or wall paper cleaner is used. Water is never used, because it may cause the board to warp. Remove the thumb tacks or scotch tape when through with the drawing board.

The drawing table should be set so that the light comes from the left and adjusted to a convenient height for standing, that is, from 36 to 40 inches. (One may draw with more freedom standing than sitting). The board should be inclined at a slope of about 1 to 8 inches. Table and instruments should be dusted off before drawing begins.

T-Square.- The T-square is always used with the head on the left side of the drawing board. An exception may be made in the case of a lefthanded person, whose table should be arranged with the light coming from the right and the T-square used on the right edge.

Since the T-square blade is more rigid near the head than toward the outer end, the paper, if much smaller than the board, should be placed close to the left edge of the board (within about two inches or so) with its lower edge several inches from the bottom. With the T-square against the left edge of the board, square the top of the paper approximately. Hold in this position, slipping the T-square down from the edge, and put a thumb tack or scotch drafting tape in each upper corner. Move the T-square down over the

paper to smooth out possible wrinkles and put thumb tacks or scotch drafting tape in the other two corners. Scotch drafting tape is preferable because it does not interfere with the use of the T-square.

The primary use of the T-square is the drawing of parallel horizontal lines. They should always be drawn from left to right. Consequently, points for their location should be marked on the left side. Vertical lines are drawn with the triangle set against the T-square, always with the perpendicular edge nearest the head of the square and toward the light. These lines are always drawn from bottom to top. Therefore their location points should be made at the bottom. In drawing lines great care should be exercised in keeping them accurately parallel to the T-square or triangle, holding the pencil point lightly but close against the edge, and not varying the angle of the pencil during the progress of the line.

The T-square is manipulated by sliding the head along the left edge of the board with the fingers against the end of the head. Adjustments are made with the thumb above and the fingers touching the board, or oftener with the fingers on the blade and the thumb on the board. In drawing vertical lines, the T-square is held in position against the left edge of the board, the thumb on the blade, while the fingers of the left hand adjust the triangle. One may be sure the T-aquare is in contact with the board by hearing the little double click as they meet.

Triangles.- Triangles are made of various substances, such as wood, rubber, celluloid, and steel. Wooden triangles are cheap but are likely to warp out of shape. Those of rubber are frequently used and are in general satisfactory. Celluloid triangles are extenseively used because of their transparency, which enables the draftsman to see the work completed even when it is covered by the triangle. In using rubber or celluloid triangles take care that it lies perfectly flat, or is hung up when not in use. When

allowed to lie on the drawing board with a pencil or an eraser under one corner it will have a tendency to warp, especially if the room is hot or the sun happens to strike the triangle. Triangles from 6 to 8 inches on a side will be found convenient for most work, although there are many cases where a small triangle measuring about 4 inches on a side will be found useful. Every draftsman should have at least two triangles, one having two angles of 45 degrees and one right angle, and the other having angles of 30, 60, and 90 degrees respectively.

We have stated that vertical lines are drawn with the triangle set against the T-square. Generally the 60-degree triangle is used because it has the longer perpendicular. In both penciling and inking it is best to use a triangle in contact with a guiding straight-edge. To insure accuracy never work to the extreme corner of a triangle. The T-square should be kept at least a half inch below the base line when in use with triangles. Practice-exercises 1 through 4, Plate No. 3, by the use of the T-square and triangle, using the dividers for measuring the spaces, also see page 3.4.7 for instruction exercises, 1 and 2.

To test the accuracy of the 45-degree angles of a triangle, place the triangle with the lower edge resting on the working edge of the T-square, and draw a line. Now without moving the T-square place the triangle so that the other 45-degree angle is in position occupied by the first. If the two 45-degree angles coincide they are accurate. For various uses of triangles see Plate No.1. For testing a triangle see Plate No. 1, illustration 3.

Lettering triangle.- The lettering triangle is an instrument used to space guide lines for freehand letters. It is similar in appearance to other triangles with the exception that it has evenly spaced holes inserted in the celluloid. In using the lettering triangle the edge is place against the

T-aquare and the pencil point is inserted in the holes. By sliding the triangle, a guide line is made. The lines are always drawn from left to right without applying much pressure on the pencil. Too much pressure will cause the point to break and spoil the line.

Scale: a rule graduated to a definite number of units to the inch and used to measure lines of a drawing in a predetermined ratio to the exact measurements of the object or area represented.

To represent objects, the full size of which are larger than can be conveniently drawn, it is necessary to reduce the dimensions of the drawing proportionately. For this purpose either the engineer's or architect's scale is used. These are made in several forms, the most convenient being the flat with beveled edges, and the triangular. They are of various lengths, but that more commonly used is the 12 inch. The triangular scale has six surfaces on which are different graduations and the scales are arranged so that the drawing may be made in any proportion to the actual size. For mechanical work, the common divisions are multiples of 2; thus, drawings are made full size, $\frac{1}{2}$ size, $\frac{1}{4}$, 1/8, 1/16, 1/32, 1/64, etc. If a drawing is $\frac{1}{4}$ size, 3 inches is divided into 12 equal parts and each division represents 1 inch. For architectural work the common division is a multiple of 2. If a smaller division on a scale represents, for example, 1/16 inch, the scale is said to read 1/16 inch. Scales are often divided into 1/10, 1/20, 1/30, 1/40, 1/50, 1/60, etc., for use by civil engineers and for measuring indicator cards. As far as possible successive measurements on the same line should be made without shifting the scale. For plotting and map drawing the civil engineer's scale of decimal parts, 10, 20, 30, 40, 50, 60, 80, 100 to the inch is used. This scale should never be used for machine or structural work. The most important consideration in drawing to scale is the thinking and speaking of each dimension in its

full size and not in the reduced size as it appears on the drawing.

The scale should never be used as a substitute for the triangle or T-square in drawing lines.

Dividers

The dividers are instruments similar in appearance to the compass. Both legs are pointed and are straight and rigid. They have two primary uses, dividing a line into parts and transferring dimensions from the scale. Since they are basic instruments, ease in their use should be developed.

Adjustment

Dividers should be opened with one hand by pinching the chamfer with the thumb and second finger. This will throw them into correct position with the thumb and forefinger on the outside of the legs, the second and third finger on the inside and the head resting just above the second joint of the forefinger. It is thus under perfect control, with the thumb and forefinger to close it and the other two to open it. This motion should be practiced until an adjustment to the smallest fraction can be made. In coming down to small divisions, the second and third fingers must be gradually slipped out from between the legs while they are being closed.

Example in its Use

In bisecting a line the dividers are opened to an estimated one-half of the length of the line. This distance is marked off on the line, while holding the instrument by the handle with the thumb and forefinger. If the division is short, the leg should be moved out to one-half the remainder, estimating by sight, but not removing the other leg from its position on the paper. Then the line is spaced again with this setting. If this does not divide the line, the operation is repeated, until the correct adjustment has been arrived at. In like manner a line can be divided into any number of equal parts.

The proportional divider is a special instrument used in making reproductions of drawings, at a different scale than the original. The needle points on one end of the instrument are set on the extreme ends of the line to be reproduced. The distance between the needle points of the other end is the correct proportion of the new scale, that is, the exact distance.

Compass

The compass has the same general shape as the divider and is manipulated in a similar way. It has several detachable parts, a pen part, pencil part, and lengthening bar. First of all the needle peg of the compass should be adjusted so that the needle extends a trifle beyond the pen point or pencil point. Insert the pen in place of the pencil leg. Turn the needle adjustment nut and set it a trifle longer than the pen. If the pencil leg is used, replace the pen leg. Sharpen the lead to a long bevel and adjust it to the needle point.

Use

To draw a circle, measure and mark the radius on the paper. Place the needle point at the center guiding it with the left hand, and adjust the pencil to the radius setting the compasses with one hand. When the lead is adjusted to pass exactly through the mark, raise the right land to the handle and draw the circle clockwise in one swoop, rolling the handle with the thumb and forefinger,at the same time inclining the compasses slightly in the direction of the line.

Circles up to about three inches in diameter can be drawn with the legs straight, but for the larger sizes both the needle point leg and the pencil or pen leg should be turned at the knuckle joints so as to be perpendicular to the paper. The 6-inch compasses may be used

in this way for circles up to perhaps ten inches in diameter. Larger circles are made by using the lengthening bar or beam compasses. In drawing concentric circles the smallest should always be drawn first, before the center hole has become worn.

The bow instruments are used for small circles, particularly when a number of circles are to be made of the same diameter. In changing the setting, to avoid wear and final stripping of the thread, the pressure of the spring against the nut should be relieved by holding the points in the left hand and spinning the nut in or out with the finger. Small adjustments should be made with one hand, holding the needle point in position on the paper.

The pen should be kept with both nibs on the paper by using the knuckle joint, and the instrument inclined slightly in the direction of the line. In adjusting the compasses for an arc which is to connect other lines, the pen point should be brought down very close to the paper without touching it in order to be sure that the setting is exactly right.

It is a fixed rule in inking that circles and circle arcs are drawn first. It is easier to connect a straight line to a curve than to connect a curve to a straight line.

When it is required to measure or transfer considerable distances on a drawing or to describe arcs having long radii, a Beam Compass is necessary. It serves both as a compass and divider. The Beam Compasses consist, generally, of three distinct parts: (1) a box or sleeve of nickel silver, provided with a means for clamping it to a bar or tube, which part in turn carries the pen or pencil and a micrometer for making the fine adjustment of the drawing point to the desired length or radius. (2) a box or sleeve of nickel silver provided with a clamp, which carries the fixed or center point and slides freely along a bar or tube; and (3) a tube of nickel silver or a

bar of the same, or of wood, to which the boxes or sleeves are attached.

Ruling Pens

The ruling pen is for inking straight lines and non-circular curves. The important feature is the shape of the blades, which should have a well-designed ink space between and the point which should be rounded (elliptical form) equally.

Care. If the ruling pen is pointed, the ink will arch up and flow of ink will be difficult to start. If rounded to a blunt point the ink will flow too freely, resulting in bulbs and over-runs at the ends of the lines. Pens in constant use become dull and worn. To tell whether or not a pen is dull, look for the reflection of light that travels from the side and over the end of the point when the pen is turned in the hand. If the reflection is visible all the way the pen is dull and should be sharpened.

How to Sharpen a Pen

In sharpening a pen the nibs must be restored to the correct shape. This is done by screwing them together until they touch,while holding the pen in the same manner as when drawing lines. The pen is drawn in pendulum fashion back and forth on an oil stone. An Arkansas oil stone is considered desirable. This operation restores equal shape and length to the nibs, but leaves them at this point very dull. The point is then opened slightly and each blade is sharpened. In doing this the pen is held at an acute angle with the oil stone and moved back and forth with a rocking motion conforming to the shape of the blade. The points should not be sharp enough to cut paper but sufficiently sharp to draw the finest lines clearly and sharply. An inexperienced person should not sharpen a pen until he has had proper supervision by a person trained in this work.

Use. The ruling pen is never used freehand. It is always used in connection with a guiding edge, T-square, triangle, straight-edge, or curve. The T-square and triangle should be held in the same position as for penciling. It is faulty practice to ink by using the triangle alone. Use it in unison with a straight-edge or T-square.

To fill a pen take it to the bottle and touch the quill filler between the blades of the pen. Be careful that there is no ink on the outside of the blades. Not more than three-sixteenths to one-fourth of an inch should be put in the pen because the weight of the ink will cause it to drop out and blot the tracing. The pen should be held in the finger tips with the thumb and second finger in such position that they may be used in turning the adjusting screw and the handle resting on the forefinger, so that the proper width of line will be drawn. The tendency will be to bend the second finger to the position in which a pencil or writing pen is held. This is not necessary with a ruling pen, because the stroke is left to right, if right-handed, (right to left, if left-handed) and bottom to top. A fine drawing means a drawing made with uniform lines, accurate joints and tangents, not fine or narrow lines.

The pen should be held against the straight-edge with the blades parallel to it, the screw on the outside, the handle inclined slightly to the right (if left-handed, to the left) and in a plane through the line perpendicular to the paper. The pen is guided by the upper edge of the ruler, whose distance from the pencil line will vary with the thickness of the line and with the thickness of the under blade of the pen. If the pen point is thrown out from the perpendicular it will run on one blade and form a line ragged on one side. If the pen is turned in from perpendicular, the ink will have a tendency to run under the edge and to cause a blot.

A line is drawn with a free movement of the entire arm, the hand resting on the tips of the third and fourth fingers and the angle of inclination kept constant. Just before the end of the line is reached the two guiding fingers on the straight-edge should be stopped, and, without halting the motion of the pen, the line finished with a finger movement. Short lines are drawn with a finger movement. When the end of the line is reached the pen is lifted quickly and the straight-edge is moved away from the line. The pressure on the paper should be light, just enough to give a clean-cut line. The amount of pressure necessary will vary with the kind of paper and the sharpness of the pen. There should be no more pressure against the T-square than is necessary to guide the pen's direction. If the ink does not flow, it is because it has dried and clogged in the extreme point of the pen. If pinching the blades slightly or touching the pen on the finger nail does not start it, the pen should be wiped out and fresh ink used. Pens must be wiped clean after using because the ink will corrode the steel and injure the pen.

In inking on either paper or cloth the full lines are much wider than the pencil lines and the beginner must be very careful to have the center of the ink line cover the pencil line.

French Curves

Curved rulers, called irregular curves or French curves, are used for curved lines other than circle arcs. The patterns for these curves are laid out in parts of ellipses and spirals or other mathematical curves in various combinations. For the student one ellipse curve and one spiral will be sufficient.

The French curve, as has been stated, is a ruler for non-circular curves. When sufficient points have been determined, it is best to sketch in the line lightly in pencil freehand, without losing the points,

until it is a clean smooth continuous line, satisfactory to the eye. The curve should then be applied to it, selecting a part that will fit most nearly a portion of the line, noting particularly that the curve is so laid that the direction of its increase in curvature is in the direction of increasing curvature of the line. In drawing the part of the line matched by the curve, always stop short of the distance that seems to coincide. After drawing this portion, the curve is shifted to find another part that will coincide with the continuation of the line. In shifting the curve, care should be taken to preserve the smoothness and continuity and to avoid breaks or cusps. This may be done if in its successive positions the curve is always adjusted so that it coincides for a short distance with the part already drawn. At each joint the tangent must coincide. For use of the French curve see plate No.1, Problem 4.

If the curved line is symmetrical about an axis after it has been matched accurately on one side, marks locating the axis may be made in pencil on the curve and the curve reversed. In such a case exceptional care must be taken to avoid a "hump" at the joint. It is often better to stop a line short of the axis on each side and to close a gap afterwards with another getting of the curve.

When inking with the curve, the pen should be held perpendicularly and the blades kept parallel to the edge. Inking curves will be found to be practical exercises which will teach control of the pen. Sometimes, particularly at sharp turns, a combination of circle arcs and a curve may be used as, for example, in inking a long narrow ellipse. The sharp curves may be inked by selecting a center on the major axis by trial, and drawing as much of an arc as will practically coincide with the ends of the ellipse, then finishing the ellipse with the curve. This trial method should only be attempted with a pencil of considerable hardness.

Chapter 3

Selection of Material

Paper, Detail.- In selecting a drawing paper, the first thing to be considered is the kind of paper most suitable for the proposed work. For shop drawings, a manila paper is frequently used because it is tough and strong. These drawings are likely to be subjected to hard usage. If a finished drawing is to be made the best white drawing paper should be obtained in order that the drawing will not fade or become discolored with age. A good drawing paper should be strong; should have uniform thickness and surface; should stretch evenly and lie smoothly when stretched or when ink or colors are used; should neither repel nor absorb liquids; and should allow considerable erasing without spoiling the surface. It is, of course, impossible to find all these qualities in any one paper, as great strength cannot be combined with fine surface. A type should be chosen which combines the greatest number-of these qualities for the usage to which the drawing will be subjected.

Tracing.- In Engineering Offices drawings are frequently traced requiring a paper through which the lines of the underlying drawing are clearly visible. This paper is correctly termed "Tracing Paper". In architectural work little tracing is done, since the original drawings and sketches are made directly on paper sufficiently transparent to produce blueprints. This paper however is also known as "Tracing Paper". Consequently, while the term "Tracing Paper" is used for all transparent drawing papers, many of these papers are not used for tracing.

In the first case, where the paper is really used for tracing, the visibility of the lines of the original drawing through the tracing paper is of great importance. The special characteristics of a paper conforming to this requirement we shall call "Tracing Transparency". In the second

case, since the transparency of the paper is required only for making blueprints, we shall call it "Blueprinting Transparency", which represents the amount of actinic light passing through the paper. While the latter generally goes hand in hand with tracing transparency, in some papers a considerable difference does exist between the Tracing Transparency and the Blueprinting Transparency. This is especially true with prepared (oiled) papers, in which the Tracing Transparency is greater than the Blueprinting Transparency. In other words, some prepared tracing papers may appear very transparent in tracing lines, but will not produce as good blueprints as their apparent transparency would seem to indicate. Matural tracing papers also vary considerable in this respect due to the difference in surface and material.

Tracing Cloth is a fine-thread fabric, sized and transparentized with a starch preparation. The smooth side is considered by the makers to be the right side, but most draftsmen prefer to work on the dull side which will take pencil marks. The cloth should be tacked down smoothly over the pen drawing and its selvedge torn off. It should then be dusted with chalk or prepared pounce. Talcum powder and a powder puff work very well, or a blackboard eraser may be used and rubbed off with a cloth. This removes traces of grease which sometimes prevents the flow of ink.

Pencils

Lead pencils are graded according to their hardness. The degree of hardness is indicated by the letters and numbers, which vary from 7B to 9H. For general line drawings a 5H or 6H pencil should be used. A softer 4H pencil is better for making letters, figures, and points. The hard lead pencil should be sharpened so that in penciling a drawing, the lines will be very fine and light. In sharpening a pencil the wood is cut away

to allow $\frac{1}{4}$ or $\frac{1}{5}$ inch of lead to project. The lead can then be sharpened to a fine point by rubbing it against a bit of sandpaper or a fine file. In drawing lines the draftsman places the lead against the T-square or triangle, and by rotating the pencil is able to draw a fine line of even width through a given point. If the pencil is not rotated a wedge shaped line will result. If the drawing is not to be inked but is made for tracing or for rough usage in the shop, a softer pencil, Grade B or softer, may be used. This gives a somewhat thicker and heavier line. The lead for compasses can be sharpened to a point. Most draftsman prefer to use a bevel edge.

In using a very hard pencil a light pressure should be used so that the point will not make a deep impression which cannot be erased from the paper.

Ink

India ink is always used for drawing because it makes a permanent black line. It is obtainable in solid stick or liquid form. The liquid form is more convenient but contains an acid which corrodes steel and makes it necessary to keep the pen perfectly clean.

Erasers and Shields

What little erasing is necessary in making drawings, should be done with a soft rubber. To avoid erasing the surrounding work some draftsmen use a card in which a slit is cut about 3 inches long and 1/8 to 1/4 inch wide. An erasing shield of thin metal is also very convenient especially in erasing letters. For cleaning drawings when they are completed a sponge rubber or a preparation called "art gum" may be used, but in either case care should be taken not to make the lines dull by too hard rubbing.

Thumb Tacks and Scotch Tape

Thumb tacks are used to fasten the paper to the drawing board. They are usually made of steel, pressed into shape - as in the cheaper grades- or with heads of German silver, the points being screwed and riveted to them. For most work draftsmen use small one-ounce copper or iron tacks, because they are cheap and can be forced flush with the drawing paper, thus offering no obstruction to the T-square.

Scotch Drafting Tape is the most efficient means of holding paper or tracing cloth to the drawing board. It permits the sliding of T-squares and triangles over the drawing board without interference and holds down all edges securely, preventing torn paper and curled edges. No moistening is required and it is easily and quickly applied and removed. Because of its unusual adhesive qualities it can be used over and over again, without leaving any stain or residue. This tape is especially made for drafting purposes and consists of a one-inch strip of prepared paper, with a special adhesive, packed in cartons of 10 and 72 yard rolls.

Chapter 4

Practice Exercises

Freehand.- In doing drafting work the draftsman must be able to coordinate his sight with the finger muscles. It is necessary that the heights and spacings of the work are uniform.

On Plate No. 2 there are four exercises which the beginner should practice, beginning with Number 1 and continuing through Number 4, until uniformity is obtained. These exercises are designed to provide training in coordination of vision or sight with muscle. Through these exercises skill is developed in evenness and uniform spacing of lines. Faithful practice by the student will prove very helpful in developing skill in other stages of mechanical drawing.

Since the T-square and triangle are the most frequently used instruments in drafting work the beginner should become familiar with their use.

The figures on Plate No. 2 should be drawn using the eye for spacing. In making these drawings, begin with Number 1 and continue through Number 4, doing each figure until some degree of uniformity has been developed.

Scaling

Almost all drafting work is done to a scale, and for this reason the beginner should have some actual experience in its use.

Draw the following distances to a scale given in the following problems:

(1)	100 ft.	at a scale of	1 in.	=	20 ft.
(2)	400 ft.	" "	1 in.	=	100 ft.
(3)	900 ft.	" "	1 in.	=	300 ft.
(4)	160 ft.	" "	1 in.	=	40 ft.
(5)	300 ft.	" "	1 in.	=	50 ft.
(6)	240 ft.	" "	1 in.	=	60 ft.
(7)	125 ft.	" "	1 in.	=	20 ft.
(8)	51 ft.	" "	1 in.	=	10 ft.
(9)	400 ft.	" "	1 in.	=	150 ft.
(10)	145 ft.	" "	1 in.	=	25 ft.

Measure the following lines in feet using the scale given:

10 _____

30 _____

50 _____

60 _____

600 _____

Lettering

To give all the information necessary for the complete construction of a machine or structure there must be added to the lines describing its shape, the figured dimensions, notes on materials and finish, and a descriptive title, all of which must be lettered freehand in a style that is perfectly legible, uniform, and capable of rapid understanding. So far as the over-all appearance is concerned there is no part of a drawing as important as the lettering. A good drawing may be ruined not only in appearance but in usefulness by careless or poor lettering, because illegible figures are very apt to cause mistakes in use of the drawing.

Single-stroke Lettering

By far the greatest amount of lettering on drawings is done in a rapid "single-stroke" letter either vertical or inclined, and every draftsman must be skillful in the use of these styles. The ability to letter well can be acquired by anyone having normal muscular control of the fingers who will take the trouble to observe carefully the shapes of the letters, the sequences of strokes composing them and the rules of composition. Keeping these factors in mind, constant practice is necessary. It is not a matter of artistic talent or even of dexterity in handwriting.

The terms "single-stroke" or "One-stroke" do not mean that the entire letter is made without lifting the pen, but that the width of the stroke of the pen is the width of the stem of the letter. For the desired height therefore, a pen must be selected which will give the necessary width of stroke without spreading the nibs, and one that will make a uniform stroke in all directions. In making single stroke letters the vertical strokes are all made downward and the horizontal strokes are all made from left to right, as shown on Plate No. 4.

There are two types of letters, upper case and lower case. The upper case letter is known to the average individual as the "capital letter" and may be made in either the vertical or inclined style. The lower case letter is commonly called the small or little letter. It may also be made in both styles.

Lettering

1. Letter the alphabet and numerals, 0 through 9, using inclined upper case letters. This should be done several times to learn the strokes of the letters;

2. Letter the alphabet and numerals, 0 through 9, using inclined lower case letters. This also should be done several times.

3. Letter the alphabet and numerals, 0 through 9, two or more times, using vertical upper case letters.

4. Letter the alphabet and numerals, 0 through 9, two or more times, using vertical lower case letters.

5. Letter the following, two or more times, using inclined upper case letters.

A quick movement of the enemy would jeopardize our six gunboats.

6. Letter the above sentence, two or more times, using inclined lower case letters.

Dividers

To become familiar with the use of the dividers, the exercises on Plate 5 should be repeated several times. Exercises 1, 2, and 3 should not be practiced on the page, but similar lines and figures should be drawn on practice sheets and divided as shown.

Exercise 1 - Plate 5

To divide a line into two or more parts. Set dividers by eye as closely as possible to the number of divisions of the line desired. Start at point "A" on the exact left end of the line with one point of the dividers. Without moving the first point of the dividers set at "A", rotate the dividers to the right until the free point is exactly on the line, then with that point as a pivot lift the first point, rotating it to the right until it is again exactly on the line. Continue this stepping of the dividers until the desired numbers of steps have been taken. If the point at the right end is missed, adjust the free point by eye so that the length missed is divided by the number of divisions desired. Move dividers back to point "A" and repeat this process until point "B" on the right end of the line is hit exactly. Then each point located by each step of the dividers on the last trial becomes an accurate division point of the line.

Exercise 2 - Plate 5

To divide a circle into 5 segments. With an arbitrary point "O" as a center and the compass set at an arbitrary radius, draw a circle. Adjust the dividers by eye to one-fifth of the length of the circumference. Place one leg of the dividers exactly at point "A" selected any place on the circumference. Rotate dividers to the right, making each divider point fall exactly on the circumference until five steps have been taken. If point "A" has been

missed, adjust the dividers by eye one-fifth of that distance and repeat until point "A" is hit exactly. Then each point located on the final trial becomes an accurate subdivision of the circumference. Now draw lines from each of the five points on the circumference to center point "O" to divide the circle into five equal segments. Any circle can be divided into any number of parts by this method.

Exercise 3 - Plate 5

To divide two equal semi-circles adjacent and falling on a straight line into 8 equal segments.- Divide line "AB" at "O" into two equal parts. Divide "AO" and "OB" each into two equal parts at "C" and "D". With "C" as the center and radius "CO", strike arc "AO" and with the same radius and "D" as the center, strike arc "BO". Adjust the dividers by eye to one-fourth of arc "AO". Start at point "A" and rotate the dividers to the right, making each trial point fall exactly on arc "AO". If point "O" is missed adjust the dividers to one-fourth of that distance and repeat until point "O" is hit exactly. The last trial points "E", "F", and "G" divide arc "AO" into four equal parts. Without changing the adjustment of the dividers step them along arc "OB" dividing it into four equal parts. Draw radii from "C" to "E", "F" and "G", and from "D" to "H", "I", and "J".

Exercise 4 - Plate 5

This is the reverse method of using the dividers as in the previous exercises. The dividers' points are set by scale or rule at a given distance apart and as many spaces as are desired are located.

On two lines bisecting each other at right angles, points are stepped off from the center of intersection with the dividers' points set exactly $\frac{1}{2}$-inch apart. Then by using the T-square and triangle a line is drawn from each determined point parallel with its axis.

Compass

In order to obtain actual practice in the use of the compass, the figures on Plate 6 should be repeated until the handling of the compass does not feel awkward. Begin practicing with Number 1 and continue through Number 4.

Exercise 1 - Plate 6

To draw concentric circles with equal distances between circumferences.- Divide any line "AB" to "O" into two equal parts. Divide "AO" into the desired number of equal parts. With "O" as a center and through each point in turn to "A", draw a complete circle.

Exercise 2 - Plate 6

Divide line "AB" into 12 equal parts. With point "O" as a center draw a circle through "A" and "B". With "C" as a center draw arc "AJ" and without changing compass adjustment at "D" as a center draw arc "BI".

With "E" as acenter readjust compass and draw arc "AF" and without changing compass adjustment at "F" as a center draw arc "BE".

With "C" as a center readjust compass and draw arc "AO" and without changing compass adjustment at "H" as a center draw arc "BO".

With "K" as a center readjust compass and draw arc "AI" and without changing compass adjustment at "L" as a center draw arc "BJ".

With "I" as a center readjust compass and draw arc "AE" and without changing compass adjustment at "J" as a center draw arc "BF".

Exercise 3 - Plate 6

Divide line "AB" at "O" into two equal parts.- Through "O" draw line "CD" perpendicular and equal in length to "AB". Divide line "AO" into four equal parts. With radii equal to "AE", "AF", "AG", and "AO", draw concentric semicircles opposite point "O" from points "A", "B", "C", and "D".

With tangents from opposite semicircles as guides draw straight line from the tangent of the opposite semicircles to its perpendicular in alternate quarters.

Exercise 4 - Plate 6

Divide "AB" at "O" into two equal parts.- With "O" as acenter draw circle through "AB". From point "A" divide circle into four equal parts at "BC" and "D". Draw line "CD" through "O".

Divide "AO" into three equal parts at "E" and "F". With distance "OF" as a radius draw circle around "O". Without changing compass adjustment draw four circles using as each center the points on inner circle cut by lines "AB" and "CD".

With points where outer circumference of these four circles are cut by "AB" and "CD" draw four more equal circles.

French Curves and Irregular Curves

Exercises 1, 2, 3, and 4 - Plate 7

Starting at "A" find by trial a section of the French Curve which cuts through points A,A', and A". Move curve so that another section cuts through A" fitting back into the line between A' and A" and forward through at least two more dots. Continue until all points through B are connected smoothly.

In cases where the curve reverses, the guide curve must be fitted so that the straighter part is pointing toward the point at which the curve reverses.

Sometimes parts of a reverse curve should be connected with a straight line.

Exercises for T-square and Triangle

Exercise 1 - Plate 1, illustration No. 1

Given line AB, to draw a line parallel to it.- Place the T-square or a triangle below the line. Adjust to the line a triangle resting on,

the T-square or other triangle. Holding the guiding edge in position, and with one edge of the triangle on the line, slide it to the desired position.

Exercise 2 - Plate 1 - illustration No. 2

Given line AB, draw a perpendicular to it.- Fit the hypotenuse of a triangle to the line with one edge resting against the T-square or another triangle. Holding the T-square in position, turn the triangle until its other edge is against the edge of the T-square. The hypotenuse will then be perpendicular to the line and the triangle may be moved to the desired point for drawing of the perpendicular.

A quicker method follows: Set the triangle with the hypotenuse resting on the guiding edge. Fit one leg to the line. Slide the triangle to the desired point and draw the perpendicular. Never attempt to draw a perpendicular to a line by merely placing one leg of the triangle on the line, and drawing the perpendicular line along the other leg.

Geometric Problems

The draftsman should know several geometric theorems in order to work problems that come before him. Since there are so many, it is impossible to discuss all of them here, but we will consider some of those that are most commonly used. Each of the following problems should be worked and studied.

Problem No. 1 - Plate 8 - illustration No. 1

Given line AB, to find a perpendicular at the center.

Solution: With a compass opened to larger than half of line AB and using the point at A as center, swing arc DE. With the same opening of the compass, using the point at B as the center, swing arc GF. Draw a straight line between the points of inter-

section of the arcs and you have a perpendicular at the center of the line AB.

Problem No. 2 - Plate 8 - illustration No. 2

Given line AB, draw a perpendicular to a point on the line.

Solution: Make point C anywhere on the line AB. With the compass open to any given distance and with C as the center, swing arc DE. Then open the compass larger than half line DE and with center at D, swing arc MN. Without changing the compass and using E as the center, swing arc RS. From the point of intersection of arcs MN and RS, draw a line to point C and you have a perpendicular to the line AB at point C.

Problem Nos. 3 and 4 - Plate 8 - illustrations Nos. 3 and 4

Draw a perpendicular to the extreme point of a straight line AB. There are several methods by which this may be done, but we will discuss only two of them.

Solution - No. 3: Using B as the extreme point to draw the perpendicular, extend the line AB toward N. Using B as the same point C in Problem 2, the solution is the same.

Solution - No. 4: Make any point C above line AB. With C as the center, open the compass to the distance CA and swing arc DAE. From the intersection at D draw a straight line extending through point C long enough to intersect arc at E. From the intersection at E draw a straight line to point A and you have a perpendicular to line AB at the extreme point A.

Problem No. 5 - Plate 8 - illustration No. 5

Divide angle BAC in two equal parts.

Solution: Take A, the vertex of the given angle, as the center, and, with the compass opened any distance, swing arc ED. With

compass opened greater than half the distance ED and center at D, swing arc MN. Using the same opening and E as the center, swing arc RS so as to intersect arc MN. From the intersection of the two arcs, draw a straight line to point A and you will have an angle divided in two equal parts.

Problem No. 6 - Plate 8 - illustration No. 6

To find the center of a disc without extending outside the circumference.

Solution: Through a given disc draw any cord AB. With the compass opened a little more than half AB and using B as the center, swing arc MN. Without changing the opening and using A as the center, swing arc RS. Then open the compass greater than before, but still staying within the circumference of the disc, and using points A and B as the centers, swing arc UV and XY. Draw a straight line CD through the intersections of the two sets of arcs, extending to the circumference of the disc. This line will pass through the center of the disc. Through the disc draw another cord "BE" and proceed as before, striking arc PQ from E through arc MN and arc FG from B and arc JK from E from the intersections of arcs FG and JK draw a straight line HI through the intersections of arcs MN and PQ.

Problem No. 7 - Plate 9 - illustration No. 7

Draw an angle D like any given angle A.

Solution: Draw a straight line ED. With A of the given angle as a center and compass opened at will swing arc BC. With the same radius and center at D, swing arc FG. With radius BC and center at F, swing arc MN intersecting arc FG. A line drawn from this intersection to D will give the angle D equal to angle A.

Problem No. 8 - Plate 9 - illustration No. 8

Having base M and one side N draw isosceles triangle ABC. (Note: An isosceles triangle is a triangle having two sides and two angles equal).

Solution: Draw straight line AB equal to M. With a radius equal to the side N and the center at point A draw arc MN. Using same radius and point B as the center draw arc RS. From intersection at C draw lines CA and CB. This will give you an isosceles triangle with AC and CB equal sides.

Problem No. 9 - Plate 9 - illustration No. 9

Having base M and angle N draw isosceles triangle ABC.

Solution: Draw straight line AB equal to M at the two ends A and B draw angles X and Y equal to N as shown in Problem 7. By extending the sides of the angles as far as point C you have an isosceles triangle.

Problem No. 10 - Plate 9 - illustration No. 10

With one side M and two angles N and O given, draw a triangle.

Solution: Draw a straight line AB equal to M. At A draw angle equal to angle N and at B draw angle equal to O as shown in Problem 7. Lengthen the sides which will intersect at C and you have the triangle.

Problem No. 11 - Plate 9 - illustration No. 11

Having hypotenuse M and angle N draw right triangle EDF (Note: Right triangle is a triangle with one angle 90 degrees or two sides perpendicular to each other).

Solution: On a line EA construct angle N at E, as was done in Problem 7. Make side EF equal to M and from point F as center and with radius long enough to cut line EA in two places, draw

arc XY. Then with compass opened at any length and center at intersection H draw arc PQ, and with the same radius and center at I draw arc UV. Through the intersection of the arcs PQ and UV draw line through point F, cutting line EA at D. You then have completed the right triangle.

Problem No. 12 - Plate 9 - illustration No. 12

Having base M and angle N (angle made with base and hypotenuse) construct a right triangle.

Solution: Draw line AB equal to given base M. Draw perpendicular CB to line AB at point B (see Problem 4). On A draw angle equal to N (see Problem 7) and extend the line so it will intersect the perpendicular BC at point C. Then you have a right triangle.

Problem No. 13 - Plate 10 - illustration No. 13

To divide a line AB in any number of equal parts, (say for instance 6 equal parts).

Solution: From point A on line, draw a long line AC. On this line mark 6 equal points, any length, beginning at point A. Connect points 6 and B and from this draw parallel lines, as on Plate 1, illustration No. 1, passing through points 1, 2, 3, 4, and 5 forming points a, b, c, d, and e. You then have line AB divided in 6 equal parts.

Problem No. 14 - Plate 10 - illustration No. 14

To construct a Regular Hexagon with the distance AB, across corners given.

Solution: Bisect line AB at "O" as on Plate 8, illustration No. 1, with O as a center and OA as a radius draw a circle through AB. With the same radius and center at A draw arc CD and with center at B, draw arc FE. Connect the intersections at points

A, C, E, B, F, and D and you have a Regular Hexagon. This can also be done by dividing the circumference of the circle into 6 equal arcs as in Exercise 2, Plate 5. Connect these 6 points with straight lines which form the sides of the hexagon.

Problem No. 15 - Plate 10 - illustration No. 15

To inscribe a Regular Pentagon in a Circle.

Solution: Draw diameters AB and DC perpendicular to each other. Bisect radius OB with this point H as center and radius HD, draw arc DJ. With center at D and radius DJ, draw arc LJ. Then DL is one side of the pentagon. With DL as the radius, the circumference may be divided into 5 equal parts; by drawing arcs at M, N, P, D, and L connecting these points, you have a Regular Pentagon, or a figure with 5 equal sides. This can be done with dividers as in Exercise 2, Plate 5.

Problem No. 16 - Plate 10 - illustration No. 16

To draw a circle through three given points ABC.

Solution: Connect points AB and BC with straight line. Bisect line AB and line BC (see Problem 1, Plate 8) with points of intersection O of the perpendicular bisectors, as the center and radius OB, OV, or OA, draw circle. You then have a circle passing through points ABC.

Problem No. 17 - Plate 10 - illustration No. 17

Draw two tangents from a given point P to a given circumference.

Solution: Join A, the center of the circumference, with point P. Bisect this line AP (see Problem 1, Plate 8). With B as center and radius BA or BP, draw a circle passing through A and P. From point P draw straight line PE passing through the intersection at C, and from point P draw straight line PF passing

through the intersection at D. You then have the two tangents.

Problem No. 18 - Plate 10 - illustration No. 18

Having the two converging lines AB and CD, draw the bisecting line of the angle which the two converging lines would make if they came to a point of intersection.

Solution: From any point F on line AB draw line FG parallel (see Exercise 1, Plate 5) to line CD. Bisect angle AFG (see Problem 5, Plate 8) and extend the bisecting line to intersect line CD at point E. Draw the perpendicular bisector of line EF (see Problem 1, Plate 8) and you have the desired bisecting line RS.

The exercises illustrated on Plate 11 should be practiced and worked out by the student from the exercises given in the preceding pages, using his own initiative in the type of instruments necessary to construct successfully the problems illustrated on this page.

PRACTICE EXERCISES (INK)

Ruling Pen

Since the ruling pen is an essential and one of the most frequently used instruments, the beginner should practice in order to develop proficiency in its handling, as discussed heretofore. For practice with the use of the ruling pen, the figures on Plate 3, which were made in pencil by use of the T-square and triangle, should again be made in ink. In doing this exercise the lines should be evenly spaced by using the dividers, and the figures should be made in pencil before starting to ink. The beginner should practice inking until proficiency in the use of the instrument has been gained.

Compass

For the beginner to become familiar with the use of the compass in making ink drawings, he should make the same figures as those in pencil on

Plate 6. These figures should be practiced until the use of the instrument is mastered.

Lettering

In practical work most of the lettering is penciled first and later finished in ink. Faults in letters which may not be noticed in the penciled work stand out clearly after inking. Therefore it is not advisable to ink the penciled letter exactly as penciled, but rather to improve the appearance.

For lettering, a pen should be used which will make the full weight of a line desired without much pressure. Always wet a new pen and wipe it thoroughly before using, to remove the oil film. Some draftsmen prepare a new pen by holding it in a match flame for a second or two. A lettering pen broken in is better than a new one. It should be kept carefully and never loaned. When in use a pen should be cleaned frequently with a cloth.

A pen holder with a cork grip (small size) should be chosen and the pen set in it firmly. It is best to ink a pen with the quill filler touching the quill to the underside of the pen point, rather than dipping it into the ink bottle. When a pen is dipped, the surplus ink should be shaken back into the bottle or the pen touch against the neck of the bottle as it is withdrawn to remove the surplus ink. Too much ink on the pen causes uneven lines in the letters and ruins their appearance.

The first requirement in lettering is the correct holding of the pen. The pen holder should rest loosely, rather than be held, in the fingers, so that it could be pulled out easily with the other hand. It should never be held in a cramped or tightened grip of the fingers. The strokes should be drawn with an even motion and a light

uniform pressure, not heavy enough to spread the points of the pen. Guide lines for both tops and bottoms of letters should always be measured and drawn with pencil and straight edge, or spaced and drawn with lettering triangle before starting lettering.

For practice in inking letters with the pen, the exercises recommended to be done in pencil on page 3.4.3 should be repeated and then inked. After ink has dried thoroughly, clean the entire page lightly with a soft eraser or art gum.

Mechanical Lettering

There are several different types of mechanical lettering devices including the Wrico and Leroy. All are based on the same principle of a special pen guided by a sliding master plate with letters cut out by machinery. With their use and a little practice, satisfactory lettering can be done by an unskilled person.

Chapter 5

PLOTTING

Plotting is the making of plats by using the bearings and distances of lines taken from the field notes of a survey. There are several methods used in plotting a survey, but, since the most common method is by the use of bearings and distances, this will be the only one discussed.

Protractor

A protractor is a graduated are made of metal celluloid, paper, or horn, and is used for measuring angles. There are many varieties of the protractor but those most commonly used are the semicircular, circular, and the limb, all made of metal. The semicircular and circular are usually divided into degrees, half-degrees, and sometimes into quarter-degrees. The limb protractor is a more precise instrument and is provided with an arm and vernier reading to five minutes.

There are several methods of plotting angles, the most common being by the use of the protractor. Every traverse, whether closed or open, consists of a series of straight lines and angles which can be plotted by a protractor and the engineer's scale in the following manner. The survey to be mapped should be sketched roughly in order to ascertain its extent and shape, to determine the size of paper necessary for any given scale of drawing, and thus to determine a starting point on the sheet.

The method of plotting traverses with given bearings and distances, as N 80° 20' E, 235 feet, using the semicircular protractor and engineer's scale, is as follows. Place the drawing board with one and directly to the front, the back end raised about three inches, and the head of the T-square resting against the back edge of the board. Attach a sheet of drawing paper near the lower center of the board with two

small pieces of scotch tape. Using the T-square as a guide, draw a north-south line in one corner of the paper. Then with a triangle against the T-square, draw a line at right angles through the first line. Letter the four ends of the lines: Top, "N", bottom "S" , left "W" , and right "E". This is done to avoid confusion in directions by the draftsman and to aid in orienting the plat by others who use it. If the first boaring is to the west, place the T-square so that the left edge cuts the center of the starting point. Place the index line which is through the center of the straight side of the protractor exactly on the center of the starting point. With a sharp pointed pencil dot on the paper at the outside of the graduated arc of the protractor the exact angle of the first bearing reading from N or S zero. Remove the T-square and protractor and place one edge of the triangle so that the pencil point following this edge as a guide will cut the centers of the two dots thus determined. Then starting at the beginning point draw line towards or through the second dot, being sure that the line is drawn long enough to take the stated distance of that call. Now remove the triangle and measure with the scale desired on the engineer's scale the exact distance, placing a pencil point lightly on the line at the correct measurement on the scale. Be sure to hold the pencil vertically. This point now becomes the turning point for the second line, which is drawn in the same manner as the first, except that for all directions to the east the right edge of the T-square is used.

Before using this method check both edges of the T-square for parallel by drawing a line along full length of one edge. Then shift the T-square until the other edge touches the line at one end. If it touches the line throughout its length, the T-square can be used. In order that all turning points on a plat stand out clearly, and the

beginning point can be identified easily, enclose the beginning point with a small, lightly drawn square and all other turning points with tiny circles. This can be done freehand.

The Limb Protractor as stated before, is similar to the other protractors and is now used in drafting rooms to a great extent. A traverse can be plotted more quickly and accurately when this protractor is employed. The method of plotting is the same principle as that of the semicircular or D protractor except that the blade of the T-square becomes the East and West line instead of the North and South line.

The limb protractor consists of an arm and a vernier which may be read to 5 minutes. In plotting, the index of the vernier is set to the desired bearing and the protractor is placed against the blade of the T-square. The arm then lies in the direction of the line to be plotted, which is done by sliding the protractor along the T-square until the edge of the arm coincides with the point from which the line is to be drawn. A line is drawn from the point in the direction of the bearing. Always use the upper edge of the T-square. The distance is then scaled, and the point from which the second bearing starts is located. This is continued until the complete traverse is plotted.

In plotting a closed traverse such as a farm boundary the drawing should close if the survey was accurately made. If it does not close the draftsman should check his plotting of each angle and also the scaling of the distances. In any case a draftsman should not allow a drawing to leave his hands which has not been properly checked or which is not known to be accurate as the survey itself.

PRACTICE EXERCISES

The following traverses should be plotted by the use of the semicircular or D protractor to a scale of 1" = 600'.

Bearing	Distance	Bearing	Distance
N 80° W	2400 ft.	S 75° E	1872 ft.
S 10° W	3600 ft.	N 50° E	1169 ft.
S 80° E	2400 ft.	N 10° E	1400 ft.
N 10° E	3600 ft.	N 60° W	1550 ft.
		S 70° W	1250 ft.
		S 20° W	1000 ft.
		S 5° W	1060 ft.

The following traverses should be plotted by the use of the limb protractor to a scale of 1" = 600'

Bearing	Distance	Bearing	Distance
East	1174.1 ft.	N 77° W	2060 ft.
N 58° 15' E	869.3 ft.	S 40° W	880 ft.
N 1° 30' E	2139.7 ft.	S 50° E	467 ft.
S 85° 45' W	1570.8 ft.	S 70° E	400 ft.
S 23° 30' W	2046.0 ft.	S 78° E	1150 ft.
S 32° 15' E	737.9 ft.	S 41° E	610 ft.
		N 60° E	495 ft.
		N 5° E	574 ft.
		N 18° W	546 ft.

Bearing	Distance	Bearing	Distance
N 55° E	1380 ft.	N 30° E	1800 ft.
N 37° W	1630 ft.	S 88° E	1600 ft.
N 88° W	1265 ft.	S 40° E	620 ft.
N 26° W	400 ft.	S 12° W	1250 ft.
S 30° W	1250 ft.	N 38° W	1574 ft.
S 66° E	1200 ft.	S 58° W	1969 ft.
S 1° E	1250 ft.		
N 70° E	830 ft.		

The following traverses should be plotted by the use of the limb protractor to a scale as shown:

Bearing 1" = 50'	Distance	Bearing 1" = 500'	Distance	Bearing 1" = 300'	Distance
North	299.3 ft.	S 32° 15' E	11.18 chains	N 80° E	1181 ft.
N 87° 30' W	179.3 ft.	East	17.79 chains	S 37° E	738 ft.
S 1° 15' W	164.7 ft.	N 58° 15' E	13.58 chains	N 61° W	739 ft.
N 87° 00' W	99.7 ft.	N 1° 30' E	32.42 chains	S 14° W	776 ft.
S 1° 00' W	169.4 ft.	S 85° 45' W	25.8 chains	N 62° W	1303 ft.
N 85° 45' E	286.3 ft.	S 23° 30' W	31.00 chains	N 66° E	415 ft.

Chapter 6

MAPPING

The preparation of a map proceeds through various stages. First the data from which the map is to be made must be collected. Next the scale and projection must be considered. The scale which is selected depends on the size of the area to be mapped and the final size of the map desired. The projection used for controlling the map depends on several things. The chief considerations are the size of the area and the degree of accuracy desired. In most cases the draftsman will copy the projection used from some existing maps of the area. Often, however, the construction of a suitable projection amply repays the draftsman for the time spent.

In the actual process of making a map the parallels and meridians come first. It is advisable to use a hard pencil so that these lines will not disappear entirely after every erasure. This is very important since the accuracy of the map depends on these lines. The shore lines, rivers, and lakes are then drawn. The same accuracy is important in the drawing of these since they are the main references for locating cities, mountains, and other features appearing on the map. With these lines and a few boundary lines it is possible to lay out the frame of the map. Next come the other features of the map which are roads, railroads, boundaries, and cities. Great care must be taken in drawing these features, being sure to locate them in their proper places on the map. The final step in making the map in pencil is the lettering. Names of counties, mountains, and large political divisions are lettered first since they are more difficult to place. Next come the names of cities and rivers. The rivers are last since they can be placed, except in the case of small streams, anywhere along their course. The placing of the titles, scale, insets, legends, and other accessories completes the pencil work on the map. The inking is usually done in the reverse sequence of the

pencil work, the lettering first, followed by the symbol content of the map, the parallels, meridians, borders and accessories. The order in which to ink a map is very important, because the lettering has the right of way over everything else, and the parallels, meridians, and borders must be interrupted where any symbols require the space.

PRACTICE EXERCISES

Map Symbols

Since there are symbols which indicate different features on the map, it is necessary for the draftsman to know them before starting a map.

On plate 12 is a list of the principal symbols used in the construction of a map, which should be learned and practiced by the beginner.

Pantograph

The pantograph is an instrument used for the reproduction of drawings either by reducing or enlarging the scale. It consists essentially of four bars, which for any setting must form a parallelogram and have the pivot point, tracing point, and the marking point in a straight line. By changing the positions of the points, moving them either up or down the arms of the parallelogram and keeping them in a straight line, the scale of the reproduction can be made to bear any desired relation to the scale of the original drawing. These instruments are usually provided with either scale or ratio markings on the arms, indicating the proper settings for various reductions or enlargements.

The use of the instrument is very simple. Greater care must be exercised in enlarging a drawing than in reducing one. The reason for this is that while enlarging, any error made with the tracing point on the original drawing will be multiplied on the reproduction. In reducing a drawing the error will be reduced.

To enlarge a drawing it is placed under the tracing point which is the middle point of the three in a straight line, and the drawing paper on which the reproduction is to be made is placed under the marking point in such a position that when the tracing point is moved around the boundary lines of the original drawing, the marking point will stay within the limits of the drawing paper. The boundary lines of the drawing are then followed very accurately with the tracing point. The marking point will then reproduce the drawing at the scale or ratio for which the instrument is set on the drawing paper.

The reduction of a drawing is obtained in the same manner, except that the tracing point and marking point are reversed. The marking point is then the center point of the three in straight line rather than the tracing point.

Use of the pantograph differs little from that of other drafting instruments in that while the beginner may know the principle, practice is required to acquire facility in its use. For practice, figures which were platted by the use of the protractor should be enlarged to a ratio of 2 to 1, and also 4 to 1. The same figures should also be reduced to a ratio of 1 to 2.

Planimeter.- The planimeter is a delicate instrument consisting of an arm carrying a tracing point which is fastened to the frame of the instrument. It is used to determine the area of a figure by moving the tracing point around the plotted area.

The frame of the instrument touches the paper at three points: the anchor point, the tracing point, and a small wheel which is free to revolve. On the rim of this wheel is a scale and beside it is a vernier which is used in reading the scale. There is also a disk attached to the instrument, which records the number of full revolutions of the

wheel.

The most common planimeter is the polar type, which is set to measure area in square inches so that the ground area of a map at any scale may be determined by multiplying the planimeter reading by the square of the scale. There is another type used in some drafting rooms, consisting of an adjustable arm which may be set at the proper reading on a scale marked on the arm so that a unit on the wheel scale will represent any desired unit area on the drawing. The result of the scale reading of the instrument will usually be in four figures. The first is taken from the disk which represents thousands, the second and third on the wheel which are the hundreds and tens, and the fourth by the use of the vernier which represents the unit of the reading. For example, if 9 was read on the disk, 6 and 7 on the wheel, and 4 on the vernier, the reading of the instrument would be 9674. In using it, the anchor point is set outside the area to be measured in a position which will allow the tracing point to run around the boundary line of the area. For best results the arm holding the anchor point should make as nearly as possible a right angle with the arm on which the tracing point is attached, when the tracing point is at the center of the area to be measured. A starting point is selected and the tracing point set exactly on it. The reading of the instrument is then recorded. When this has been done the boundary line of the area is followed accurately with the tracing point in a clockwise direction, stopping exactly on the point of beginning. The instrument is read again and the difference between the second and first reading indicates the area, expressed in a unit depending on the length of the tracing arm.

The planimeter is a very sensitive instrument and should be handled with great care. It should be lifted or moved only by its arms, and

care should be taken not to lift or move it by touching either the vernier, wheel, or the disk because they are the most sensitive parts of the instrument. The wheel should be protected from the possibility of blows or scratches by the careful removal of all hard objects from its path, and by cleaning away all dust from the paper before the instrument is set up. The wheel's edge is slightly roughened to insure proper traction with the surface on which it is moved. Its movement is both sliding and rolling, and any dirt or dust will act as a grinding agent and soon wear the edge smooth. This wear affects the accuracy of the instrument making a replacement of the wheel necessary. The instrument when not in use must always be replaced in its case to protect it from dust, oxidation, and accidental blows. To drop the instrument may result in a total loss of its usefulness.

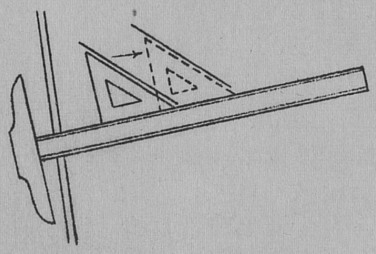
PRACTICE EXERCISES

Planimeter.- The area of the plats drawn with the protractor should be measured, checking the results several times.

METHODS OF DRAWING LINES

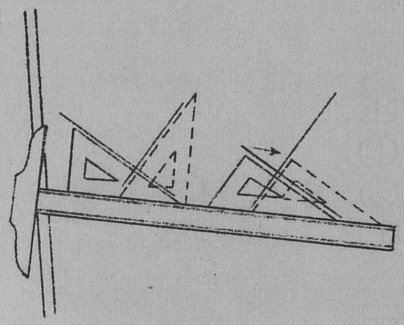
1

PARALLEL LINES



2

PERPENDICULAR LINES



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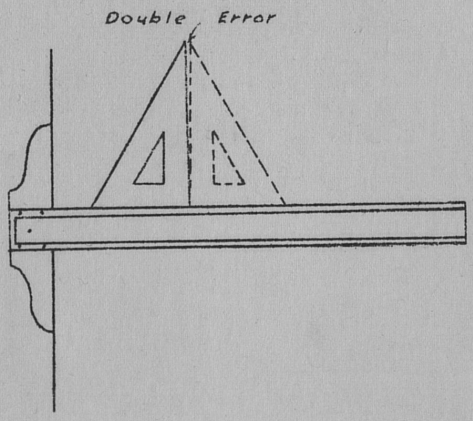
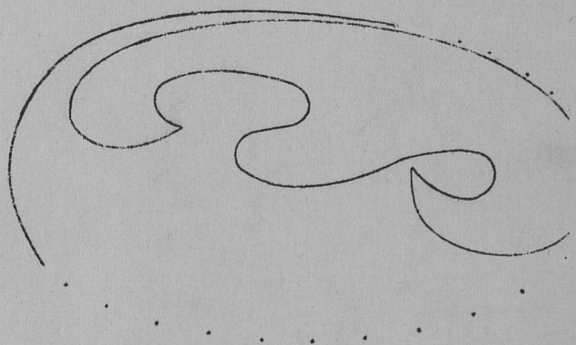


TESTING TRIANGLE

4



IRREGULAR LINES BY USE OF FRENCH CURVE

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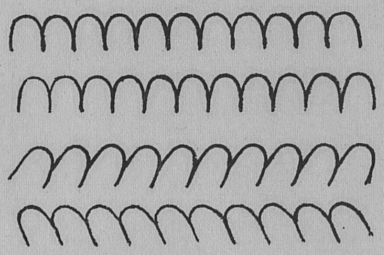
PLATE – 2

FREE-HAND PENCIL

1



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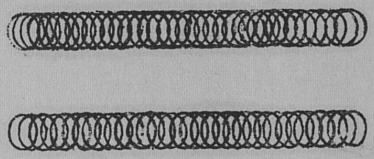

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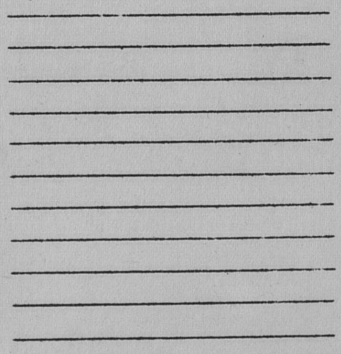

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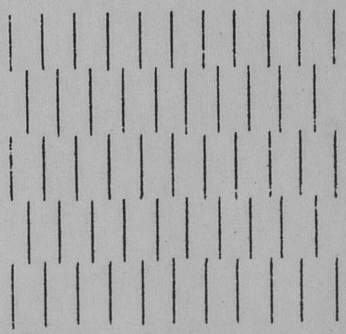

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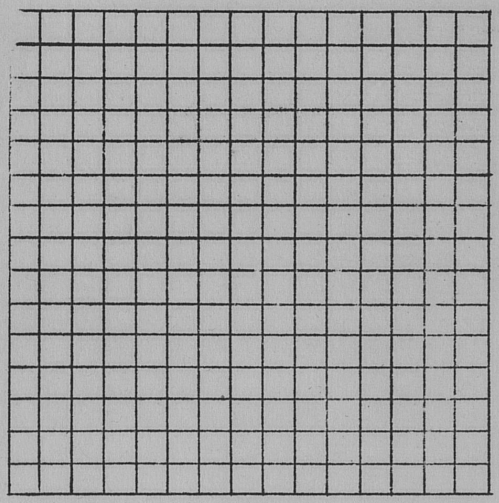
PLATE – 3

USE OF T-SQUARE

DRAW THE FOLLOWING

1



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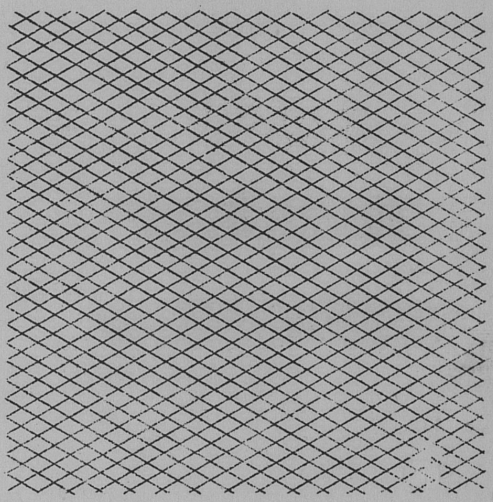

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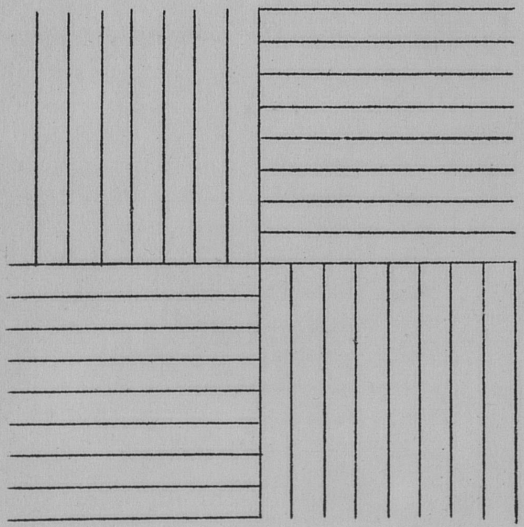

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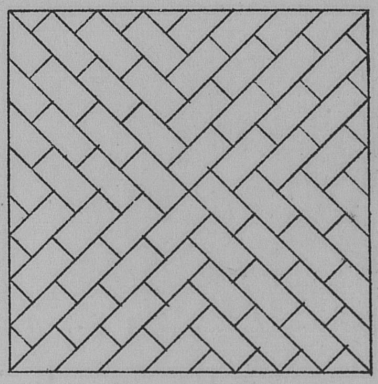

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PLATE – 4

LETTERING

UPPER CASE

A B C D E F G H I J K L M
N O P Q R S T U V W X
Y Z & 1 2 3 4 5 6 7 8 9 0

lower case

a b c d e f g h i j k l m n o p q r s t u v
w x y z & 1 2 3 4 5 6 7 8 9 0

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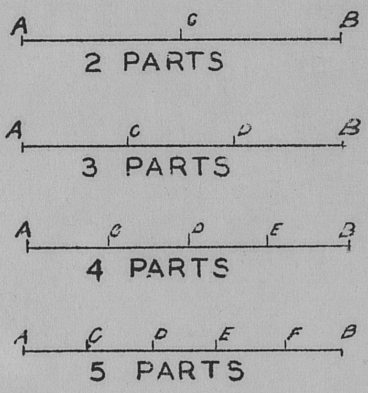
USE OF DIVIDERS

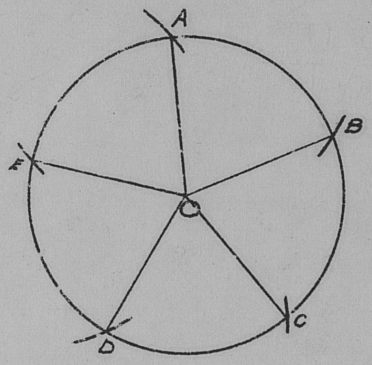
1

DIVIDE AS BELOW



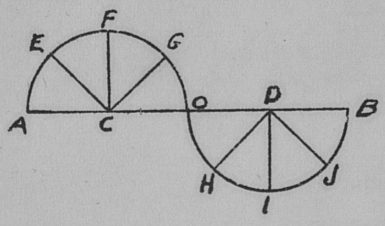
2

DIVIDE IN 5 PARTS



3

DIVIDE IN 8 PARTS



4

SPACE LINES $\frac{1}{2}$" APART

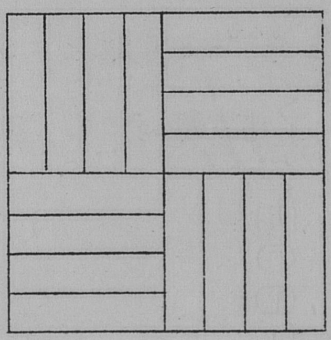


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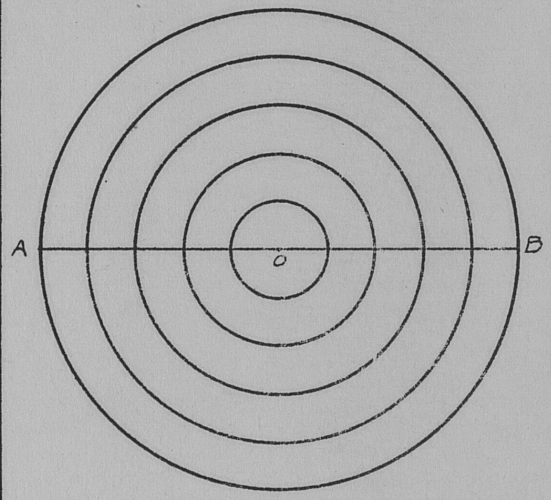
PLATE – 6

USE OF COMPASS

DRAW THE FOLLOWING

1



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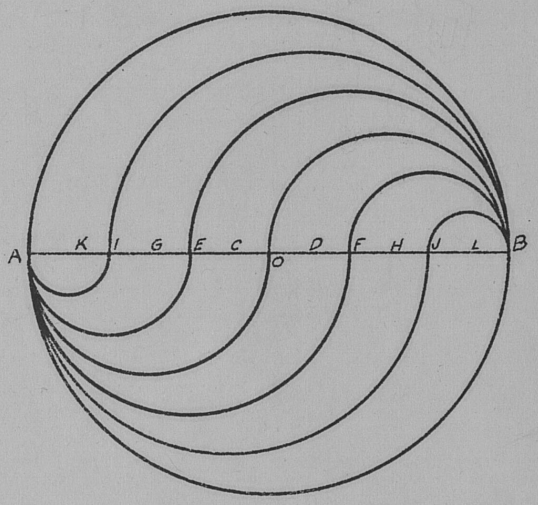

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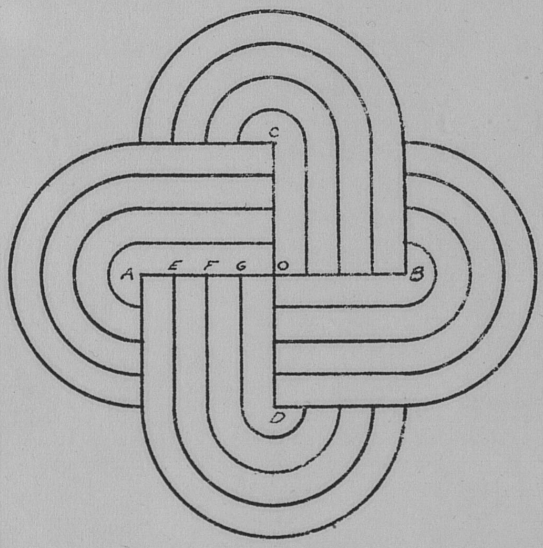

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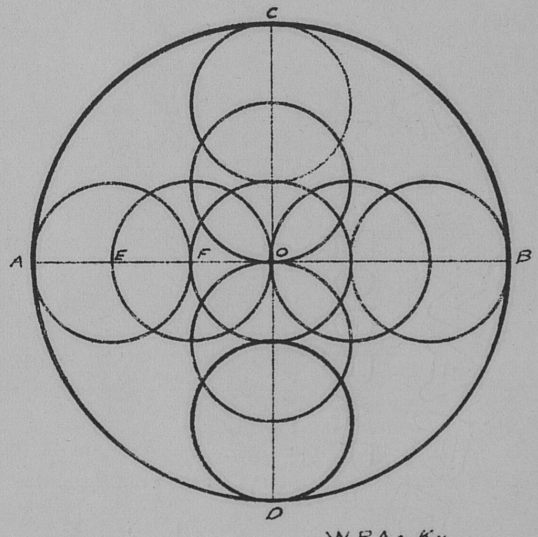

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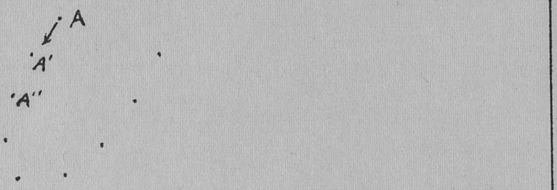
PLATE-7

FRENCH CURVE

DRAW THE FOLLOWING

1



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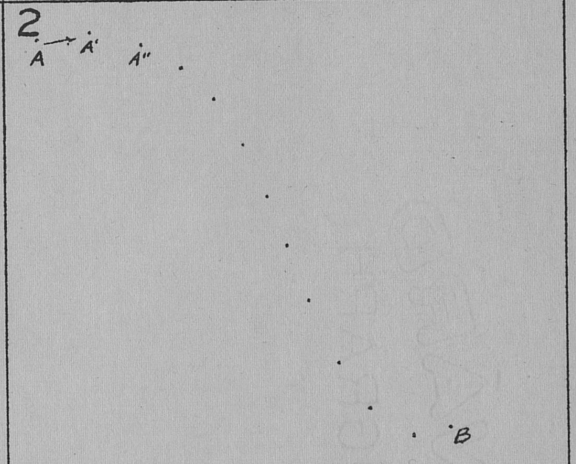

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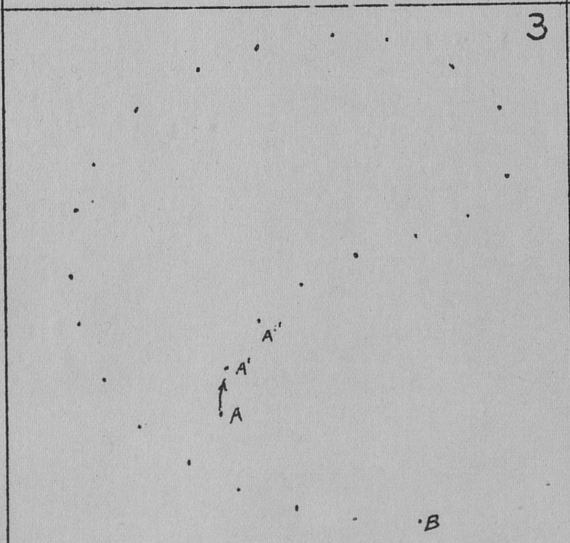

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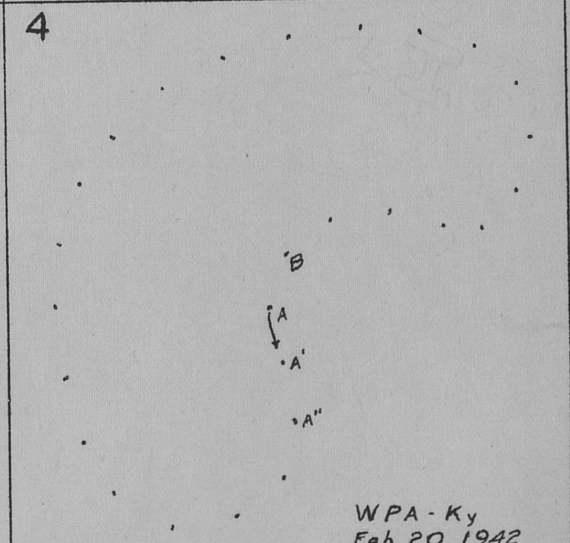

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GEOMETRICAL PROBLEMS

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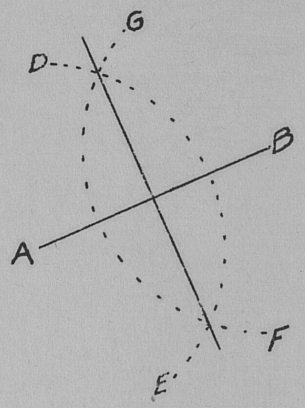

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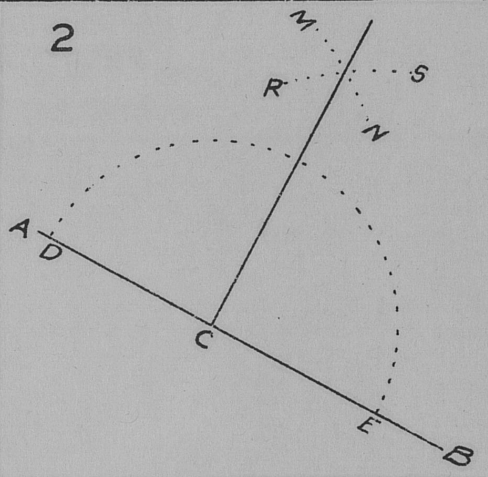

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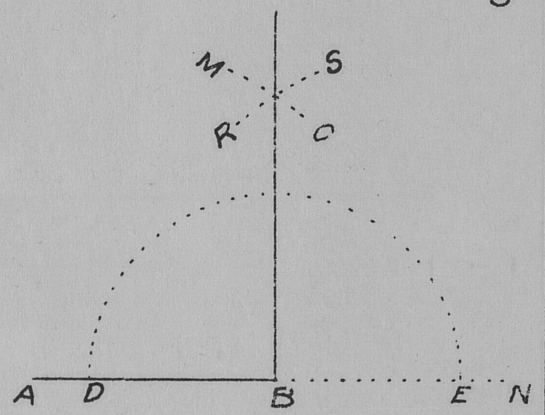

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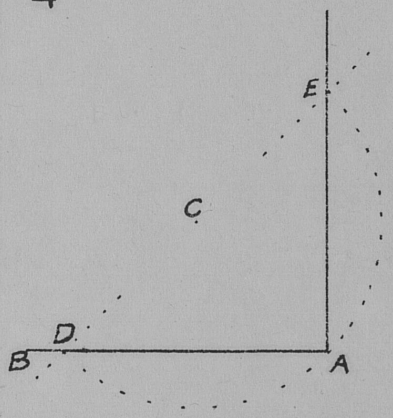

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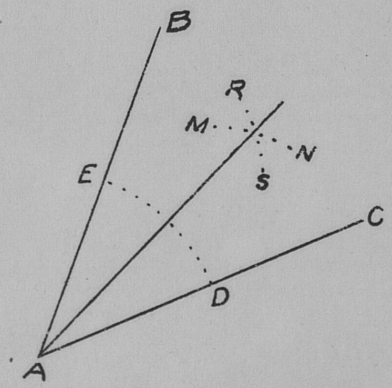

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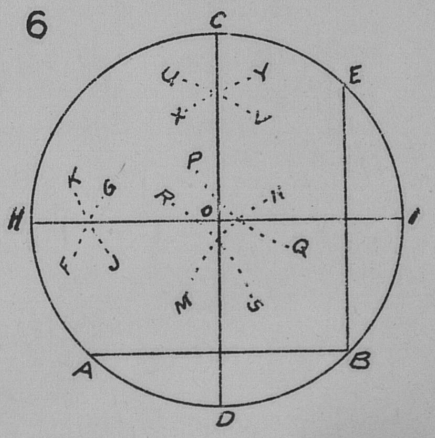

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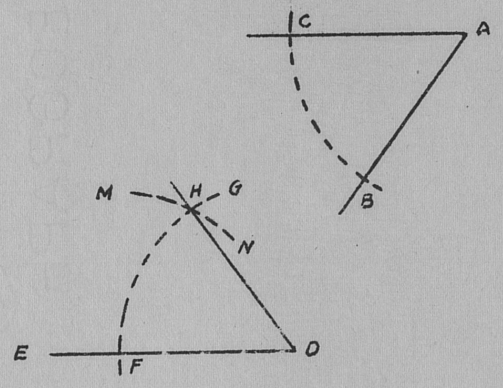
PLATE-9

GEOMETRICAL PROBLEMS

7



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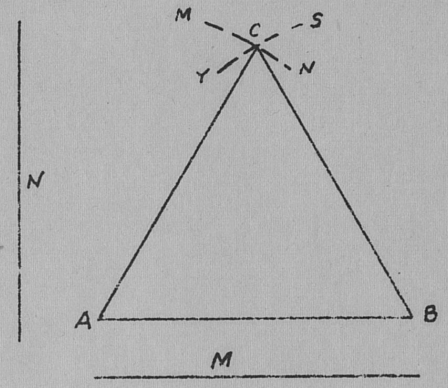

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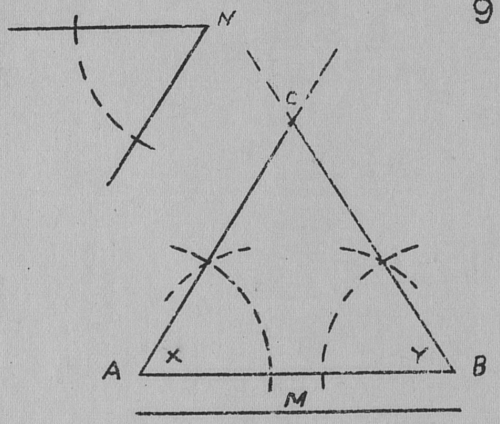

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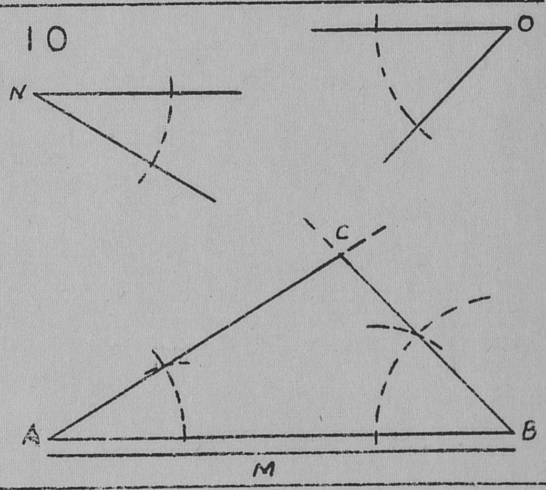

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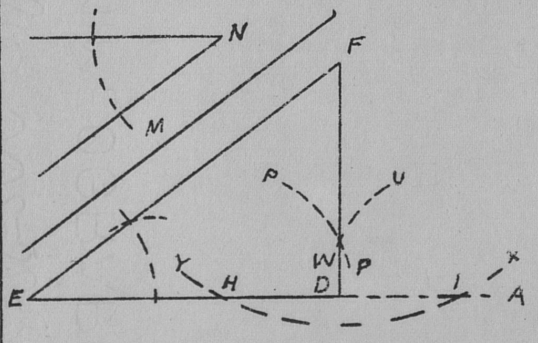

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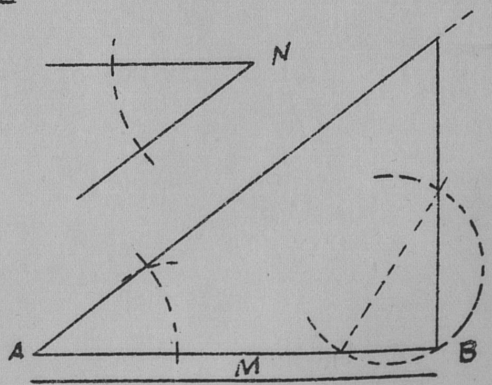
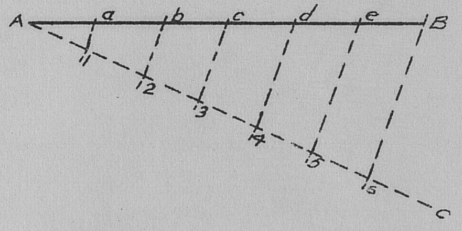


PLATE- 10

GEOMETRICAL PROBLEMS

13



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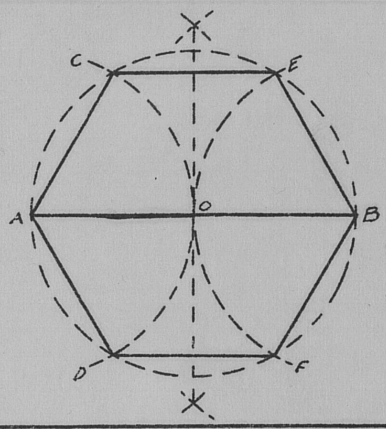

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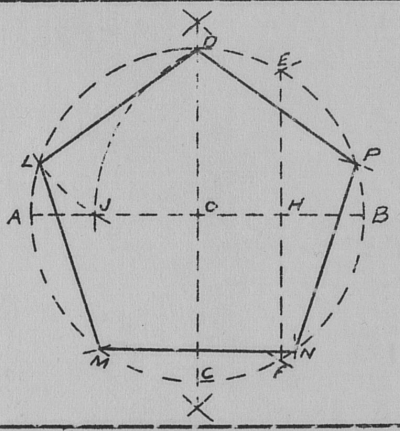

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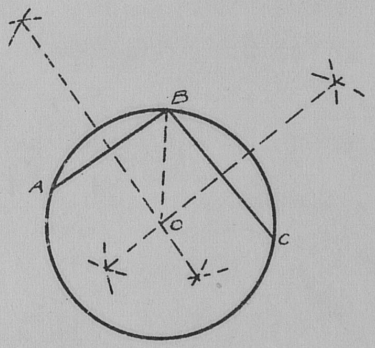

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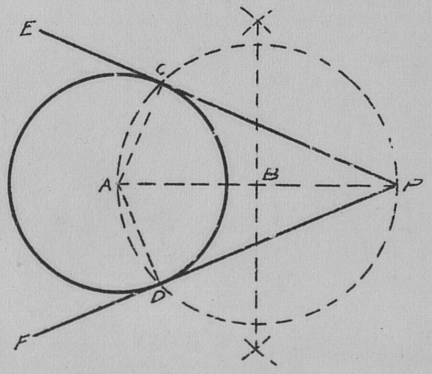

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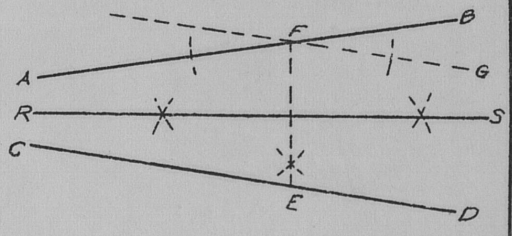

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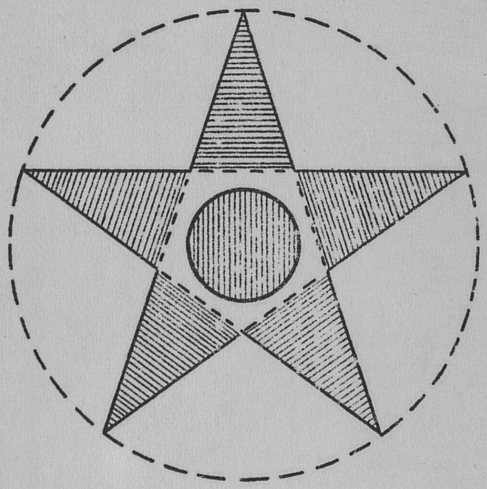
PRACTICE EXERCISE

1



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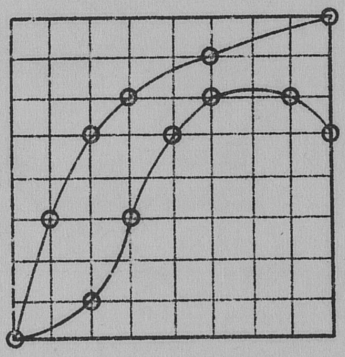

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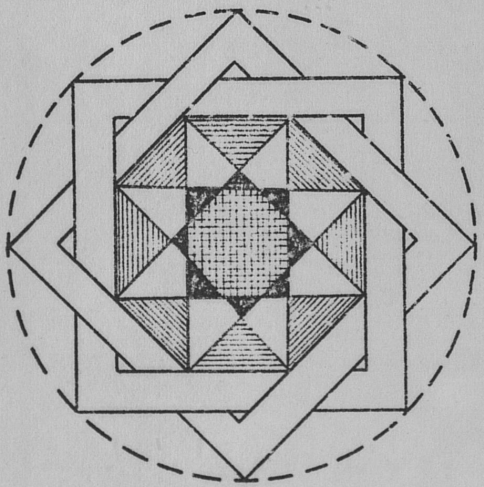

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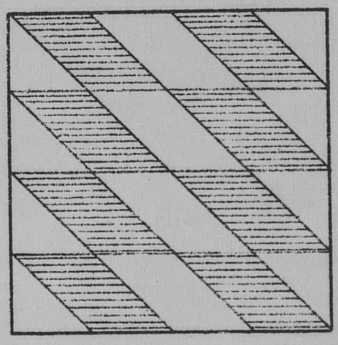

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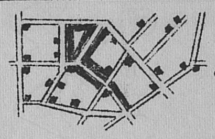
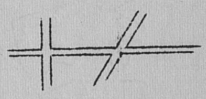
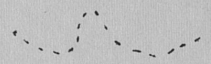
PLATE-12

SYMBOLS


City & Villages

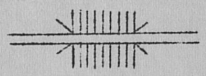

Roads

Secondary & Priv. Roads


Trails

Single Track R.R.

Double Track R.R.


Bridge


Ferry


Ford


Dam

XB.M. Bench Marks

△ Trianglation Stations

CEM ⊞ Cemeteries


Church


School

—x—x— Wire Fence

- - - - - - - Property Lines Not Fence

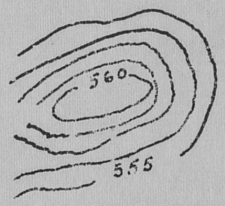
—— - - —— State Line

—— - —— County Line

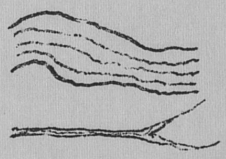
— — — — Township Line

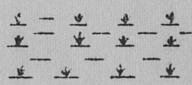
—·—·—·— City or Village Line

TTT Telephone or Telephone

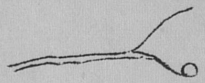


Contours


Streams


Fresh Marsh


Lakes & Ponds


Springs

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Chapter 8

CONVERSION TABLE FROM POLES TO FEET

Poles	Ft.	Poles	Ft.	Poles	Ft.	Poles	Ft.
1	16.5	26	429.0	51	841.5	76	1254.0
2	33.0	27	445.5	52	858.0	77	1270.5
3	49.5	28	462.0	53	874.5	78	1287.0
4	66.0	29	478.5	54	891.0	79	1303.5
5	82.5	30	495.0	55	907.5	80	1320.0
6	99.0	31	511.5	56	924.0	81	1336.5
7	115.5	32	528.0	57	940.5	82	1353.0
8	132.0	33	544.5	58	957.0	83	1369.5
9	148.5	34	561.0	59	973.5	84	1386.0
10	165.0	35	577.5	60	990.0	85	1402.5
11	181.5	36	594.0	61	1006.5	86	1419.0
12	198.0	37	610.5	62	1023.0	87	1435.5
13	214.5	38	627.0	63	1039.5	88	1452.0
14	231.0	39	643.5	64	1056.0	89	1468.5
15	247.5	40	660.0	65	1072.5	90	1485.0
16	264.0	41	676.5	66	1089.0	91	1501.5
17	280.5	42	693.0	67	1105.5	92	1518.0
18	297.0	43	709.5	68	1122.0	93	1534.5
19	313.5	44	726.0	69	1138.5	94	1551.0
20	330.0	45	742.5	70	1155.0	95	1567.5
21	346.5	46	759.0	71	1171.5	96	1584.0
22	363.0	47	775.5	72	1188.0	97	1600.5
23	379.5	48	792.0	73	1204.5	98	1617.0
24	396.0	49	808.5	74	1221.0	99	1633.5
25	412.5	50	825.0	75	1237.5	100	1650.0

To convert HUNDREDTHS of poles into feet read from above table and move the decimal point two places to the left.

Tenths of Pole				Fraction of Poles in Feet			
.1	1.65	.6	9.90	1/8	2.06	5/8	10.31
.2	3.30	.7	11.55	1/4	4.13	3/4	12.38
.3	4.95	.8	13.20	3/8	6.19	7/8	14.44
.4	6.60	.9	14.85	1/2	8.25	1.	16.5

Figure total distances to the nearest foot. If the decimal is less than .50 drop it from the total; if it is more than .50 raise the total to the next highest foot.

CONVERSION TABLE FROM CHAINS TO FEET

Chains	Ft.	Chains	Ft.	Chains	Ft.	Chains	Ft.
1	66	26	1716	51	3366	76	5016
2	132	27	1782	52	3432	77	5082
3	198	28	1848	53	3498	78	5148
4	264	29	1914	54	3564	79	5214
5	330	30	1980	55	3630	80	5280
6	396	31	2046	56	3696	81	5346
7	462	32	2112	57	3762	82	5412
8	528	33	2178	58	3828	83	5478
9	594	34	2244	59	3894	84	5544
10	660	35	2310	60	3960	85	5610
11	726	36	2376	61	4026	86	5676
12	792	37	2442	62	4092	87	5742
13	858	38	2508	63	4158	88	5808
14	924	39	2574	64	4224	89	5874
15	990	40	2640	65	4290	90	5940
16	1056	41	2706	66	4356	91	6006
17	1122	42	2772	67	4422	92	6072
18	1188	43	2838	68	4488	93	6138
19	1254	44	2904	69	4554	94	6204
20	1320	45	2970	70	4620	95	6270
21	1386	46	3036	71	4686	96	6336
22	1452	47	3102	72	4752	97	6402
23	1518	48	3168	73	4818	98	6468
24	1584	49	3234	74	4884	99	6534
25	1650	50	3300	75	4950	100	6600

To convert HUNDREDTHS of a chain into feet read from above rable and move the decimal point two places to the left.

Tenths of Chains in Feet

.1	6.6'	or	.4 of a pole
.2	13.2	or	.8 " " "
.3	19.8	or	1.2 poles
.4	26.4	or	1.6 poles
.5	33.0	or	2.0 poles
.6	39.6	or	2.4 poles
.7	46.2	or	2.8 poles
.8	52.8	or	3.2 poles
.9	59.4	or	3.6 poles
1.0	66.0	or	4.0 poles

Fractions of Chains in Feet

1/16	4.13	or	1/4 of a pole
1/8	8.25	or	1/2 of a pole
3/16	12.38	or	3/4 of a pole
1/4	16.50	or	1 pole
5/16	20.63	or	1¼ poles
3/8	24.75	or	1½ poles
7/16	28.88	or	1-3/4 poles
1/2	33.00	or	2 poles
9/16	37.13	or	2¼ poles
5/8	41.25	or	2½ poles
11/16	45.38	or	2-3/4 poles
3/4	49.50	or	3 poles
13/16	53.63	or	3¼ poles
7/8	57.75	or	3½ poles
15/16	61.88	or	3-3/4 poles
1	66.00	or	4 poles

Figure total distances to the nearest foot. If the decimal is less than .50 drop it from the total; if it is more than .50 raise the total to the next highest foot.

GLOSSARY

Abscissa:	The horizontal distance between any two consecutive points of a profile drawing, usually drawn to a smaller scale than the vertical distance between the same two points. (The horizontal distance on the ordinate).
Art Gum:	A cake of soft gum used in cleaning a drawing.
Cartographer:	Map Draftsman.
Cartographic:	Pertaining to maps.
Chamfer:	To bevel an edge of a piece of material.
Co-ordinates:	Both vertical and horizontal dimensions used in drawing a graph.
Mechanical Drawing:	The science of drawing with the use of drawing instruments.
Nibs:	The points of a ruling pen or compass pen which are adjustable by screw for drawing inked lines at different widths or weights.
Ordinate:	The vertical distance between any two consecutive points of a profile drawing, usually drawn to a larger scale than the horizontal distance between the same two points. (The vertical distance on the abscissa).
Orthographic Projections:	Different views of the same object, all drawn to the same scale and in their relative positions to the object on the drawing.
Quantitative:	Pertaining to numbers or amounts.
Quill Filler:	A quill usually inserted in a bottle stopper for use in filling a ruling pen or compass pen with ink.
Scale:	A rule graduated into a definite number of units to the inch and used to measure lines of a drawing in a predetermined ratio to the exact measurements of the object or area represented.
Scotch Tape:	Adhesive tape which can be used many times for sticking a sheet of drawing paper to the board.
Specifications:	A tabulation of the exact requirements in material and workmanship for the construction of an engineering or architectural project or the whole or any part or parts of a machine.

Straight-edge:	A flat strip of metal, wood, or celluloid with at least one edge perfectly straight, used as a guide for drawing straight lines.
Symmetrical:	Balanced
Symmetrical about the center line:	Exactly the same construction and dimensions for opposite half as for the half which is shown.
Tangent:	A straight line touching a curve without cutting it.

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The following publications were consulted in the compilation of this Manual. The student is referred to the references listed below for a more complete treatise on the subject of Mechanical Drawing.

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