

T H E S I S

M E C H A N I C A L D R A W I N G

A Proposed Course of Study in Mechanical Drawing
to Suit Vocational School Needs.

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STATE AGRICULT'L COLLEGE
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Submitted by

W. A. SCOTT

In partial fulfillment of the requirements
for the Degree of Master of Science
Colorado Agricultural College
Fort Collins, Colorado

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COLORADO AGRICULTURAL COLLEGE

Graduate Work

_____, 1930

I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY W. A. Scott ENTITLED A Proposed Course of Study in Mechanical Drawing to Suit Vocational School Needs, BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF Master of Science in Vocational Education, Majoring in Trade and Industrial Education.

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Approved by

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Committee on
Advanced Degrees

T H E P R O B L E M

This course in mechanical drawing is designed to meet the needs of pupils in the Ponca City, Oklahoma, Vocational School. In this school there are many boys studying mechanical drawing who do not intend to become draftsmen, but who are taking this work in correlation with their shop work.

Shop work in this school consists of trade courses in machine shop practice, foundry work, welding, electricity, sheet metal, and cabinet making. Machine shop work is the most popular course as the following table shows.

SCHOOL YEAR 1930-31.*

Trade Course	No. Enrolled
Machine Shop	33
Welding	14
Electricity	19
Foundry	8
Cabinet Making	9
Sheet Metal	18

* Official School Records of Ponca City, Oklahoma. Welding is more popular than the table shows, but the small number is due to the lack of shop equipment and the expense of the course.

This is undoubtedly due to the fact Ponca City is an oil center and over 60 percent of the boys who enter the trades upon leaving school go to work in the refinery or oil fields.* In all of these trade courses there must be, to some extent, skill in sketching, drawing, and the reading of blueprints (3). Skill in drawing is not emphasized so much as the ability to read blueprints.

It is admitted that some of these groups of students do not need drawing so much as blueprint reading. However, school organization often compels the teaching of large mixed groups and this is the case in Ponca City. In organizing and arranging the following course the author followed the theory that careful consideration of the common fundamentals (18) would give the maximum of carry-over to each trade group even though the projects themselves were selected in the major groups from objects from the machinist's field. This selection of functioning fundamentals permits the maximum amount of skill in reading blueprints and drawings with the minimum amount of formal drawing instruction (13).

During the six years that the author has been teaching drafting in the Ponca City, Oklahoma Vocational School, he has been in search of a text that is simple, practical, and of a related nature. Failing in this, he

* Statement by Mr. W. Fred Heisler, Supervisor of Vocational Education, Ponca City, Oklahoma.

has attempted to set up a series of interesting problems designed to meet the needs of pupils in this vocational school. Most of the text books, he has found, have emphasized the theoretical rather than the practical side, and have drilled too much upon nameless problems such as blocks and geometrical figures.

Seventy percent of the problems in this course have been taken from the machine shop, sheet metal shop, or the oil fields. The remaining thirty percent are problems of common usage in the drafting room. A great many drawings were tried out in the author's classes during the school year 1930-31. Eighty-two percent of these were accepted as typical problems which emphasized the fundamental essentials of drafting. Eighteen percent have been taken since from other sources (1), (4), (5), (6), (11). Emphasis was placed upon sketching in the belief that the best way to develop visualization is by sketching first and then drawing (16), (19). A greater degree of interest was noted and fewer dropouts occurred the past year than the previous year*. It was discovered that the subject matter was easier to teach and that more ground was covered because of the simplicity of the instruction sheets. The quality of the drawings was improved due, the writer believes, to the added interest in the work and the ability to better visualize the problems.

* Official School Records of Ponca City, Oklahoma.

In the preparation of this course the author is especially indebted to the students who have been in his classes the past few years, and to W. Fred Heisler, local Supervisor of Vocational Education, Ponca City, Oklahoma. They have suggested many of the practical problems and have cooperated in the work.

The author also gratefully acknowledges the inspiration given him by Dr. C. A. Prosser, Director of Dunwoody Institute, and Charles R. Allen, Educational Consultant, Federal Board for Vocational Education; by H. A. Tiemann, State Supervisor and Associate Professor of Trade and Industrial Education, Fort Collins, Colorado, and D. W. Rockey, State Supervisor of Trade and Industrial Education, Albuquerque, New Mexico, for having read this manuscript and suggested a number of changes and additions which their experience in trade and industrial education indicated as desirable.

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PROPOSED COURSE IN MECHANICAL DRAWING.

I N T R O D U C T I O N

The purpose of this course in mechanical drawing is to train the pupil to visualize and reproduce simple objects by sketches and drawings, to read and understand drawings, and to teach an appreciation of drafting.

Drafting is not alone useful in itself but is indispensable for the study of all engineering subjects. It develops exact thinking, systematic methods, and an appreciation of the relation of science and the practical arts to the progress of civilization (11).

Drawings must be read and understood by all who are associated in any way with the industries. Since this is an industrial age it is necessary for everyone to have some knowledge of, and some ability to read drawings, plans, and diagrams.

Each instruction sheet presents a definite problem to be solved. The plan permits the student to progress according to his ability and makes it possible for a late entrant in the class to start at the beginning regardless of the point of progress of the other members of the class. The lessons are based on the progressive development of the pupils' skills.

After the instructor has explained in detail to the group the problem to be studied, with the aid of the

instruction sheet, the pupil can proceed with the work without asking countless unnecessary questions. This encourages the pupil to develop his own reasoning power and to become self-reliant.

All of the drawings in this course are to be made in pencil only as the motive is to teach the reading of drawings and not the technique.

D R A F T I N G R O O M E Q U I P M E N T

Each student should have the following equipment for this course in drawing:

1. Drawing board.
2. T-square.
3. Two triangles, 45° and 30°-60°.
4. 12 inch architect's scale.
5. One dozen thumb tacks.
6. One 2H pencil and one 4H pencil.
7. Eraser and art gum.
8. Pencil pointer.
9. Drawing paper, 12"x 16".
10. Set of drawing instruments.
11. Cross section paper ruled in quarter inches.

U S E O F E Q I P M E N T

The drawing board should be somewhat larger than the paper used. One surface should be clean and smooth and one edge should be straight. The board should be placed so that the straight edge is on the left. Never mar or dent the surface or edge of the drawing board, as good work cannot be done on a rough, uneven board.

The purpose of the T-square is to guide the pencil in making horizontal lines. The head should be held firmly against the left edge of the drawing board. The upper edge of the blade is the working edge. Never use the lower edge. See Figs. 8 and 9, page 6.

Two triangles are necessary in drawing. One is called the 45° triangle and has two equal angles of 45° and one angle of 90° . The other is called the 30° - 60° triangle and has angles of 30, 60, and 90 degrees. See Fig. 1, page 5. They are used on the top edge of the T-square in making vertical and slant lines and are held in place with the fingers of the left hand. See Figs. 10 and 11, page 7.

The scale is not a ruler and must not be used as a guide for the pencil. It is only used in laying off measurements. There are eleven different scales found on the edges of this instrument. They are used to reduce the size of an object when it is too large to

DRAWING EQUIPMENT

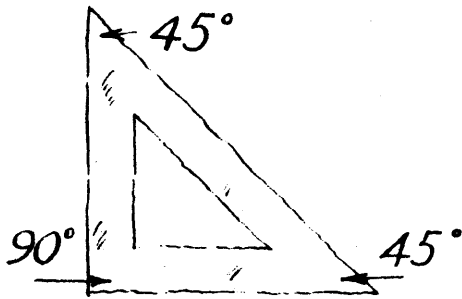
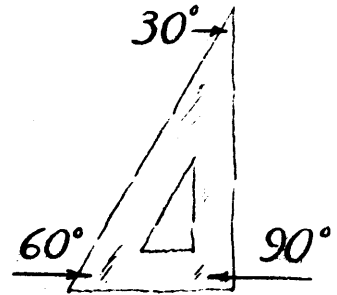


Fig. 1. 45° Triangle.



30°-60° Triangle.

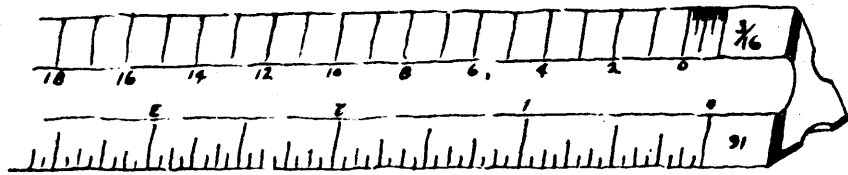


Fig. 2. Architect's Scale.

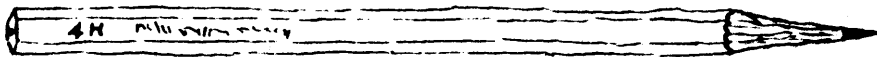
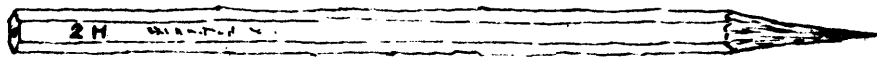


Fig. 3. Drawing Pencils.

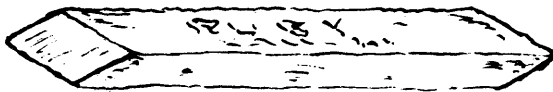


Fig. 4. Pencil Eraser



Fig. 5. Thumb Tack.

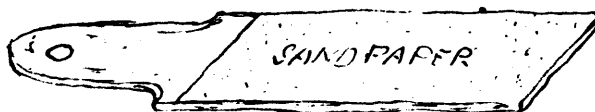


Fig. 6. Pencil Pointer



Fig. 7 Art Gum.

METHOD OF PLACING PAPER

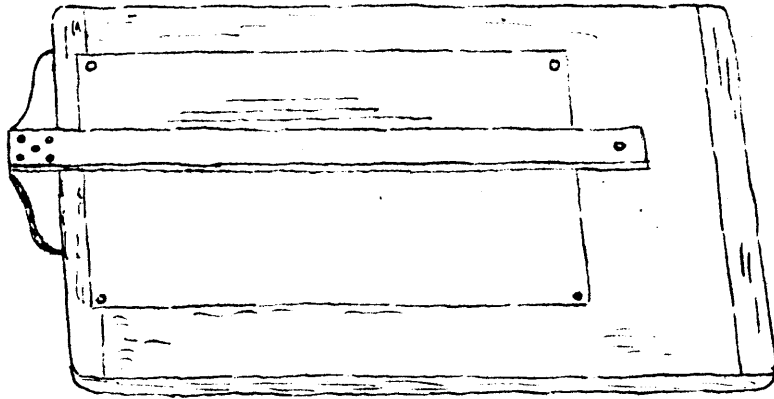


Fig. 8.

HORIZONTAL LINES

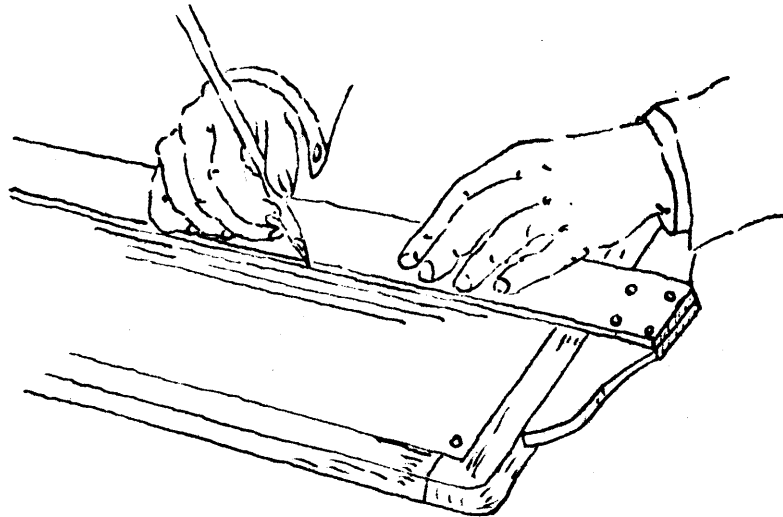


Fig. 9.

CORRECT USE OF TRIANGLES

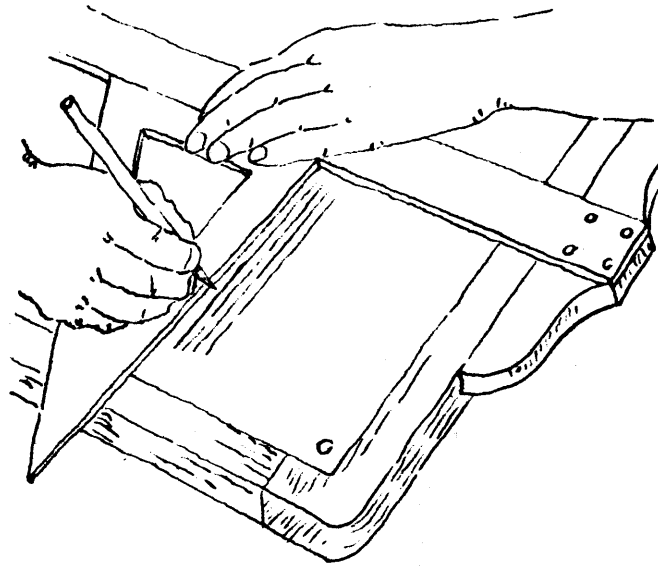


Fig. 10.

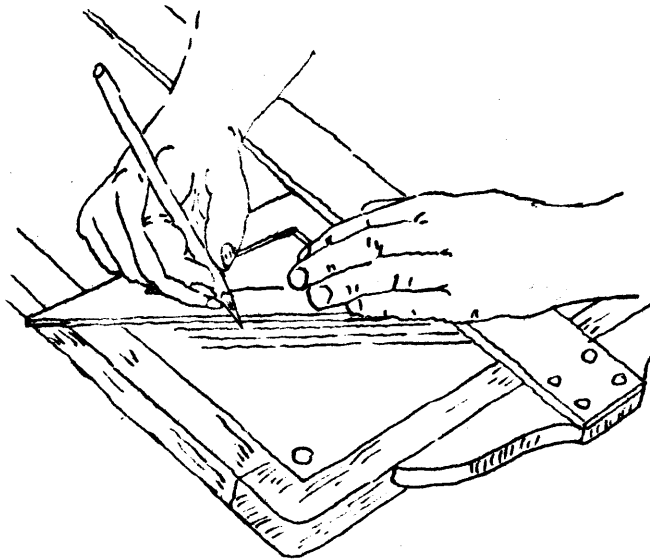


Fig. 11

draw full size. On one edge of the scale you will find full size inches and these are divided into halves, quarters, eighths, and sixteenths. This is the edge you will use mostly. Do not mark on the scale with your pencil as that makes the fractions hard to distinguish.

Thumb tacks are short large headed tacks used to hold the drawing paper on the board. One should be placed in each of the upper corners of the paper and, if you so desire, one in each of the lower corners.

Drawing pencils are graded according to the hardness of the lead in them. There are seventeen different degrees of hardness as follows, beginning with the softest: 6B, 5B, 4B, 3B, 2B, B, HB, F, H, 2H, 3H, 4H, 5H, 6H, 7H, 8H, 9H. For mechanical drawing the 4H is a very good pencil for making the light blocking out lines. The 2H is used for lettering, sketching, and retracing the object lines.

To sharpen the pencil cut the wood away with a sharp knife exposing about $1/4$ inch of the lead. Stroke the pencil on a sandpaper pencil pointer, rotating it each time, until you have a sharp, conical point. Some draftsmen prefer a flat chisel point in making very fine lines as it does not wear away as readily as a conical point. Always keep the pencil sharp. Have a pencil pointer handy and use it several times during the period.

The eraser is used to remove unnecessary lines.

The art gum is to clean the paper when it becomes soiled.

The pencil pointer is any small block of wood with sandpaper fastened upon it. The sandpaper should be a fine grade.

Drawing paper comes in rolls or sheets and is known as hot pressed, cold pressed, and rough. Hot pressed paper has a glossy surface and is used for fine line drawings. Cold pressed shows a slightly coarser grain and is used for either ink or color work, while rough paper has a very coarse open grain best adapted for soft pencil sketching and water color. The paper we shall use is cold pressed.

The set of drawing instruments should contain the following: compass, dividers, bow pencil, bow dividers, bow pen, and a ruling pen. The compass is used to make circles and must be kept in good working condition. The bow pencil is used for the same purpose but for smaller circles. The dividers and bow dividers are used to transfer measurements and to step off distances. The bow pen is used to ink circles and the ruling pen is to ink the straight lines.

L A Y O U T O F S H E E T

The following steps show the correct method of laying out the trim and border lines for the drawing sheet. Follow the steps closely each time you lay out a sheet until the process becomes automatic. After a little practice you will be able to make the layout in two or three minutes.

A trim line is necessary on a drawing for sometimes the edges of the sheet will not be straight nor square. When the drawing is finished, it is trimmed on the trimmer or with a pair of scissors. This makes the edges true, all of the sheets the same size, and eliminates the thumb tack holes.

A drawing will look better with a border line around it, just as a picture looks better with a frame, so inside the trim line place a border line. When making four drawings on the same sheet we divide the working space into four equal parts by a vertical and a horizontal line, called division lines. In making only one drawing on a sheet we leave the division lines out.

STEP 1. Place your paper on the drawing board near the center and pin down the upper left hand corner with a thumb tack. Place the head of the T-square against the left edge of the board and slide it up to the top edge of the paper. Move the paper until the top edge is

parallel with the top edge of the T-square. Then pin down the other corners.

Place your scale on the paper in a vertical position and make two short marks eleven inches apart. These marks should be about $1/16$ "* long instead of dots as the dots may puncture the paper. Place your scale on the paper in a horizontal position and make two marks fifteen inches apart. It makes no difference how far the marks are from the edge of the paper as this amount will be trimmed off.

STEP 2. With the aid of your T-square make two very light lines across the paper through the first two marks. With the aid of your T-square and triangle make two very light vertical lines through the other two marks. This completes the trim line. When the drawing is trimmed it will be 11" x 15".

STEP 3. Place your scale in a vertical position on the paper and measure down from the trim line $1/2$ " and then 10" more. Do not move your scale in making these measurements. Place the scale in a horizontal position and measure from the left trim line $1\ 1/2$ " and then 13" more. You will have to move the scale this time as it is not long enough to measure the 15" without moving.

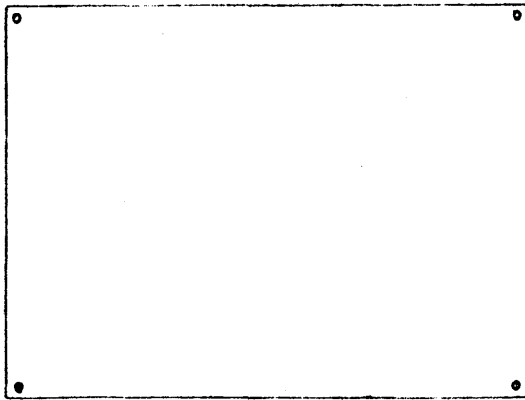
STEP 4. Draw horizontal and vertical lines through these marks allowing them to cross at the corners. Make very light lines at first. This completes the border

* The abbreviation for inches is made thus (").

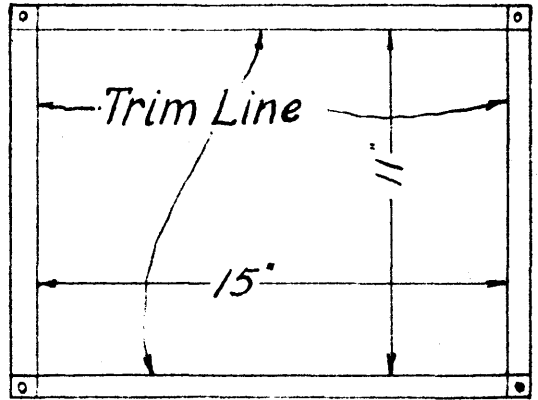
line and the working space will be 10"x 13" with 1 1/2" on the left and 1/2" on the other sides. See step 4 on page 14.

STEP 5. In order to get the letters the same height guide lines must be made for them. Measure up from the top border line 1/8" and then 3/16" without moving the scale. Through these marks make two very light horizontal guide lines about as long as the word PLATE 1. Measure down from the bottom border line 1/8" and then 3/16" and make two very light horizontal guide lines near the right hand corner. Make these lines about as long as your name. In order to keep the letters the same slant we must draw slant guide lines. Make short guide lines at an angle of 75° where the lettering is to be. It makes no difference how far apart these slant lines are, say about 1/4". See step 5 on page 13. The 75° angle may be made by placing the 45° and the 30° - 60° triangles together on the T-square. These horizontal and slant guide lines should be so light that they will not show noticeably when the lettering is finished.

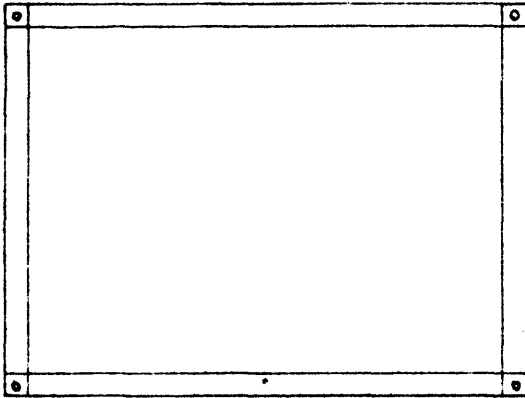
STEP 6. Divide the paper into four equal parts by drawing vertical and horizontal division lines across the working space. Retrace the border line making it heavier. See alphabet of lines on page 19. Also make division lines the same weight as the border line. This completes the layout of the sheet and you are now ready to begin the drawing.



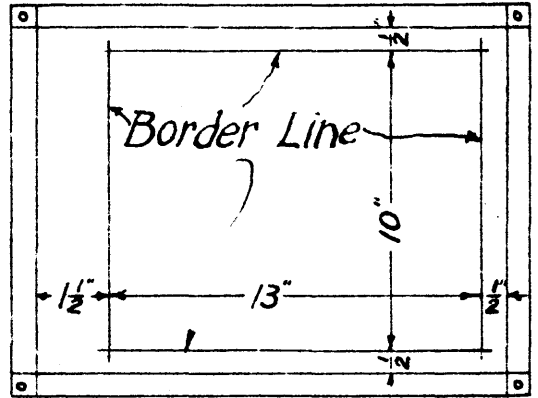
Step 1.



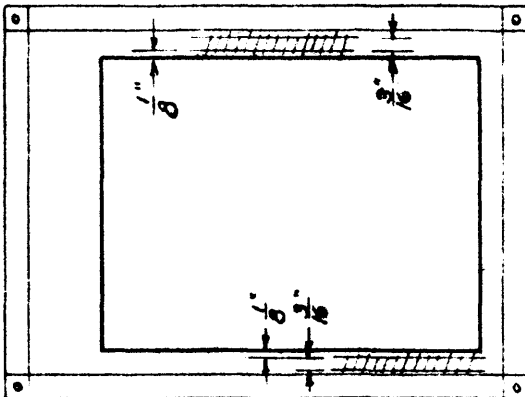
Step 2.



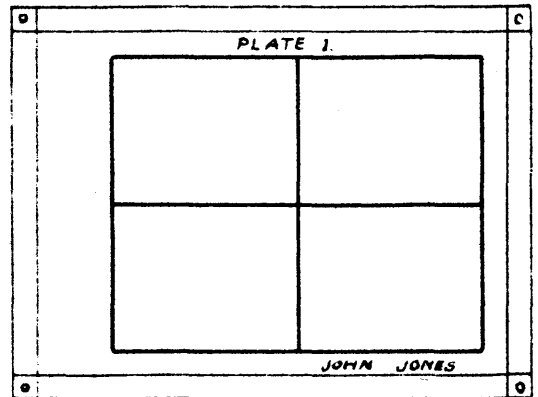
Step 3.



Step 4.



Step 5.



Step 6.

Steps in Laying Out a Sheet.

P L A C I N G D I M E N S I O N S

The principal uses of a drawing are to describe shape and to specify size. Both are very important. It is difficult to make set rules in dimensioning but there are a few general rules that have become standard through practice and should be followed (15), (17).

Study carefully the ones that are given below and apply them to your drawings.

1. Extension and dimension lines should be drawn first, beginning with the view which shows the characteristic shape of the piece, and always bearing in mind the convenience and ease of reading the drawing.

2. Be careful not to crowd the dimension lines. It is generally possible to keep them at least 1/4" away from the lines of the drawing and from each other.

3. Dimensions should read from the bottom or the left side of the sheet no matter what part of the sheet they are on.

4. Preferably keep the dimensions outside the view unless added clearness, simplicity, and ease in reading will result from placing them inside. They should, to improve the appearance, be kept off the cut surfaces of sections. When necessary to be placed within the surface, the section lining is omitted to permit space in which to write the dimensions.

5. Dimensions should generally be placed

between views.

6. Do not repeat dimensions, unless there is a special reason for it.

7. Keep parallel dimension lines at equal distances apart and "stagger" the figures.

8. Never give dimensions to the edge of a circular part but always from center to center.

9. Never use a line of a drawing as a dimension line.

10. Never use a center line for a dimension line.

11. Do not allow a dimension line to cross an extension line unless unavoidable.

12. In case of holes in flanges, the diameter of the "bolt circle" is given, with the number and size of holes.

13. Give the diameter of a circle, not the radius.

14. Give the radius of an arc marking it R or Rad.

15. A number of dimensions in a row may be either continuous or staggered, continuous preferred.

16. The light line which locates the arrow head is called an extension line and is never attached to the object.

17. Extension lines are always perpendicular to the line to be dimensioned.

18. Do not place dimensions on a center line.

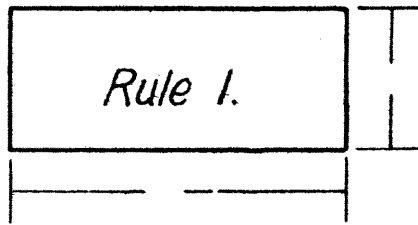
19. Inches are indicated thus ("), feet thus (')

20. The bar of fractions should be made with a horizontal line.

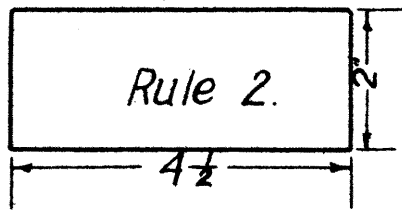
21. Figures should be large enough to be legible.

22. Have dimensions so complete that the workman will not have to add or subtract in order to find an essential dimension.

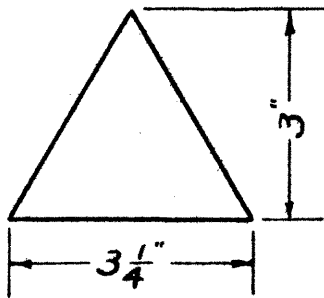
RULES FOR DIMENSIONING



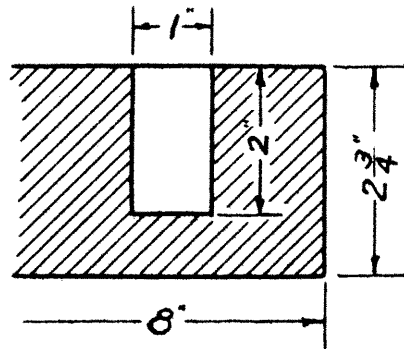
Extension and Dimension Lines First



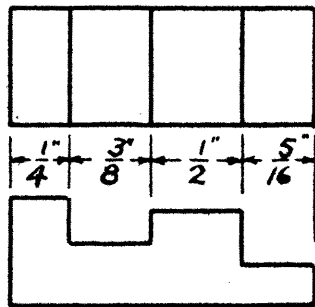
Dimensions Too Close.



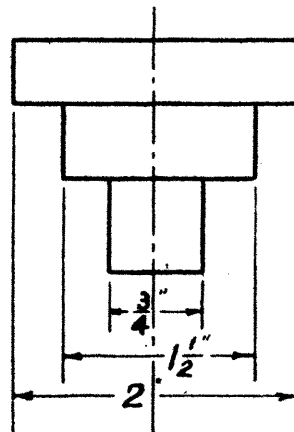
Rule 3



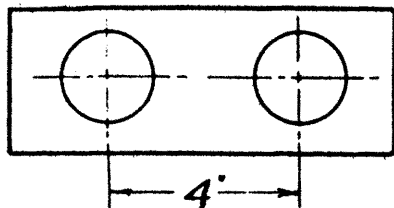
Rule 4.



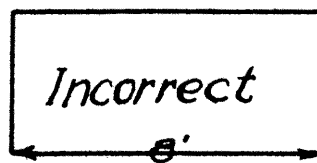
Rules 5 and 15.



Rules 7 and 18



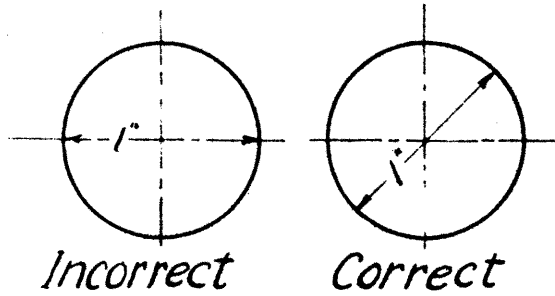
Rule 8.



Incorrect

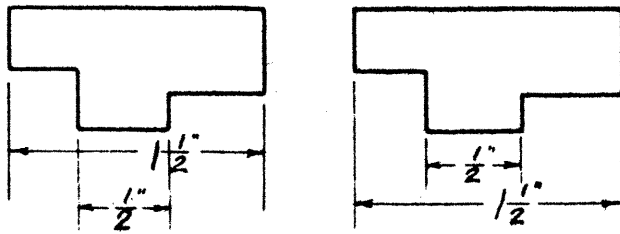
Rule 9.

Fig. 13.

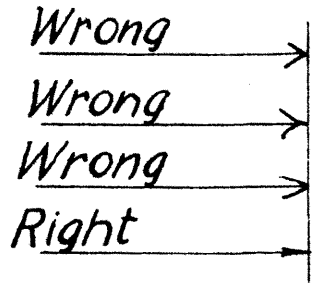


$\frac{3''}{4}$ $\frac{3''}{4}$
 Correct Incorrect
 Rule 20.

Rule 10.

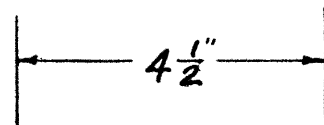
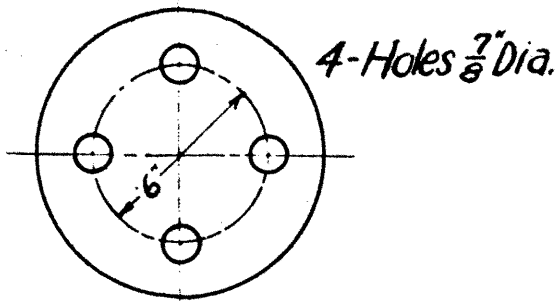


Incorrect Correct

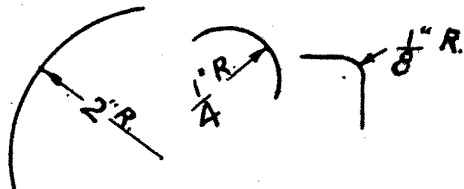


Arrow Heads.

Rule 11.

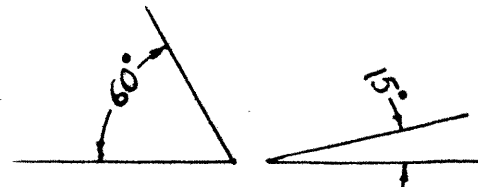
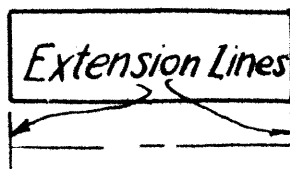


Rules 12 and 13.



Rule 14.

Method of dimensioning when there is not enough space for arrows on inside.



Rules 16 and 17. Fig. 14. Dimensioning Angles.

T H E A L P H A B E T O F L I N E S

As the basis of the drawing is the line, a set of conventional symbols covering all the lines needed for different purposes may properly be called an alphabet of lines (12). There is as yet no universally adopted standard but that given on the following page is adequate, and represents the practice of a large majority of the larger concerns of this country.

It is not possible to set an absolute standard of weight for lines, as the proper size to use will vary with different kinds and sizes of drawings, but it is possible to maintain a given contrast.

Each kind of line means something different on a drawing. Visible lines should be strong full lines, at least $1/64$ " wide on paper drawings, and even as wide as $1/32$ " on tracings. The other lines should be in correct proportion to the visible outline as given on the following page.

THE ALPHABET OF LINES.


Visible Outline 

Invisible Outline 

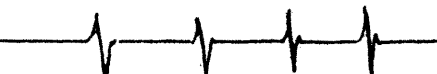
Center Line 

Dimension Line 

Extension or Witness Line 

Cutting Plane 

Broken Material. 

Limiting Break (Arch) 

Cross Hatching Line 

Border Line 

Fig. 15.

L E T T E R I N G

PROBLEM: Make a lettering plate like the one shown on page 25.

APPLICATION: All words and figures on a mechanical drawing are printed or lettered by hand (2). This plate is to give you practice in making the correct forms of letters and figures and to teach you the method used to keep them in a straight line and to make them of uniform slant. There are two kinds of lettering, the vertical and the inclined or slant. We shall use the slant lettering as it is most widely used by draftsmen. There are two different types of each kind of letters, namely, the capitals or upper case letters and the small or lower case letters. The capitals are used for titles and the lower case are used for notes and explanations of drawings.

Follow the instructions carefully and try to get the correct forms of the letters and figures, as an incorrect habit is hard to break.

PROCEDURE:

1. Lay out trim and border lines as suggested on page 10, but do not divide the working space into four equal parts. Use the 4H pencil for laying out your work and for guide lines.

2. Beginning at the top of the border line measure down $1/4$ ", then $3/16$ ". This is for the title of

the plate which in this case is LETTERING. Through these points draw very light horizontal lines a little longer than the title will occupy. This establishes the height of the title. In order to get the correct slant we must draw slant guide lines. This is done by placing the 45° triangle and the $30^\circ - 60^\circ$ triangle together to get a 75° angle. When this is done draw very light 75° lines where the title is to go which will be near the middle of the working space. Do not measure distances between these slant lines but make them as near $1/4"$ as possible. See page 23. You may now print the title using the 2H pencil.

3. Beginning $1/4"$ below the title lay off guide lines the following distances: $1/16"$, then $1/8"$, then another $1/8"$. Repeat these measurements down across the working space without moving the scale.

4. Draw very light horizontal guide lines almost across the working space, through the measurements laid off.

5. Draw 75° lines as you did for the title.

6. With the 2H pencil print the letters as given on page 25. Take plenty of time to get the correct form of the letters.

7. To make guide lines for your name measure down from the lower border line $1/8"$, then $3/16"$. This should be in the lower right hand corner below the

PLATE NO. 1

LETTERING

ABCDEFGHI

abcdefghijk

To give all the information necessary for the complete construction

JOHN JONES

Fig. 16.

border line. Draw horizontal guide lines about as long as your name will be. Draw 75° guide lines, then print your name.

8. For the plate number measure up from the top border line $1/8"$, then $3/16"$, Draw horizontal and 75° lines. Print PLATE NO. 1.

9. Retrace the border line with the 2H pencil.

10. Erase unnecessary and overhanging lines.

11. Your plate should now resemble that on page 25.

PLATE NO. 1.

LETTERING

ABCDEFGHIJKLMNOPQRSTUVWXYZ - 1234567890

abcdefghijklmnopqrstuvwxyz - 1234567890

To give all the information necessary for the complete construction of a machine or structure, there must be added to the lines that describe the shape, the figured dimensions, notes on material, and a descriptive title, all of which must be lettered, free-hand, in a style that is perfectly legible, uniform and capable of rapid execution. So far as its appearance is concerned, there is no part of a drawing so important as the lettering. A good drawing may be ruined, not only in appearance but in usefulness, by lettering done ignorantly or carelessly, as illegible figures are very apt to cause mistakes in the work.-

abcdefghijklmnopqrstuvwxyz-1234567890

O R T H O G R A P H I C P R O J E C T I O N

There are two general methods of representing an object. The first method is called Perspective Drawing which shows an object as it appears to the eye. The length, width, and thickness can usually be seen at the same time but not in their true shape or size.

The second method, and the one we will follow, is called Orthographic or Working Drawing. It is more useful to the mechanic as it does show the true size and shape of the object. However we see only one side at a time. Therefore it becomes necessary to draw two or more views to show the exact shape and size of the whole object. These views are named according to the direction from which we look. For instance, the view seen when we look directly down on an object is called the top view. The view seen when we look directly at the side of the object is called the side view, and the view seen when we look at the end of the object is called the end view. See Fig. 17 on page 27.

Usually two or three views are enough to show everything about the object and it is for the draftsman to determine which views and how many should be made (14).

Fig. 17, on page 27, shows an object enclosed in a glass box. Now just imagine that you looked directly down on top of this box and drew the top view the exact

RELATION OF VIEWS

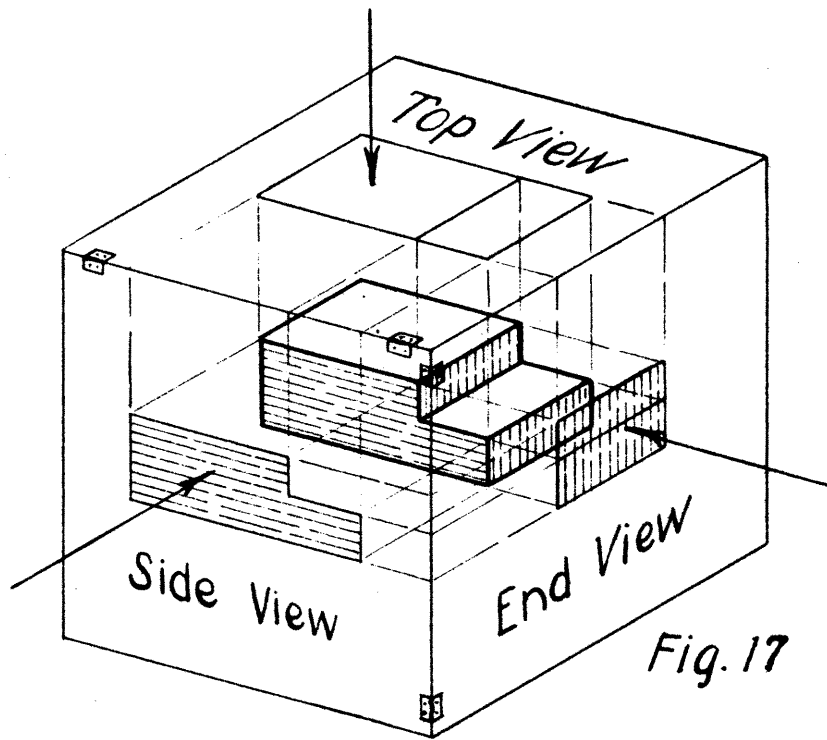


Fig. 17

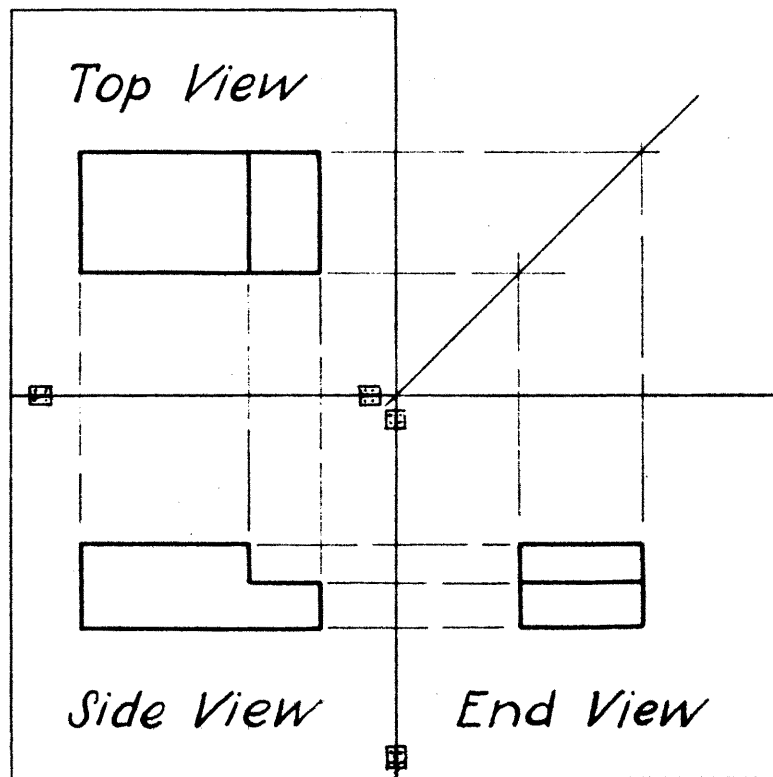


Fig. 18.

size and shape on the glass. Then suppose you did the same for the side view and the end view. When the glass box is opened out as flat as a sheet of drawing paper, the views would appear as in Fig. 18. Notice the relation of the top and side views, the side and end views, and the top and end views (16). What dimensions do they have in common?

The important thing to remember in orthographic projection is that the side view is placed directly beneath the top view and every line and point of the side view is directly beneath the same lines and points of the top view. Also every line and point on the end view is in direct line with itself on the side view (14).

M E T H O D S O F P R O J E C T I O N

There are three ways of projecting for the third view. Any one of the three ways is correct but to have a uniform method let us use the first or No.1 method. See page 30. It is the simplest and easiest to use. A sample problem is used on page 30 to illustrate the method of obtaining the third view when a third view is necessary. Always keep the following in mind:

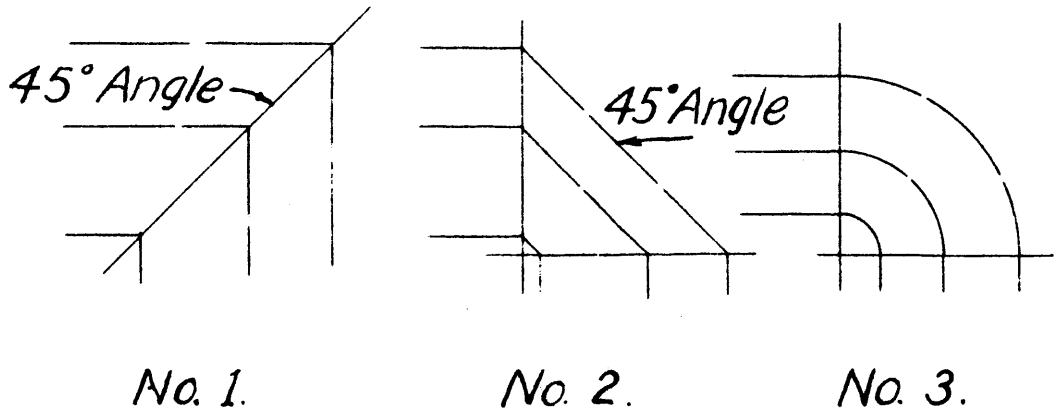
1. The length of the side view is the same as the length of the top view. It may be obtained by projecting down from the top view if the top view is drawn first.

2. The height of the end view is the same as the height of the side view. It may be obtained by projection from the side view. The height of the side view has to be measured or laid off with the scale if it is drawn before the end view.

3. The width of the end view is the same as the width of the top view. It may be obtained from the top view by projection by the 45° angle method illustrated.

Until you become used to this method you may have a little difficulty in the location of the 45° projection angle. The way to locate it is to draw a light horizontal line from the bottom of the top view, as in line A on the illustration. Now draw a light vertical

METHODS OF PROJECTION



Below is an illustration of the method of constructing the end view by projecting from the top view.

Method No. 1 is used.

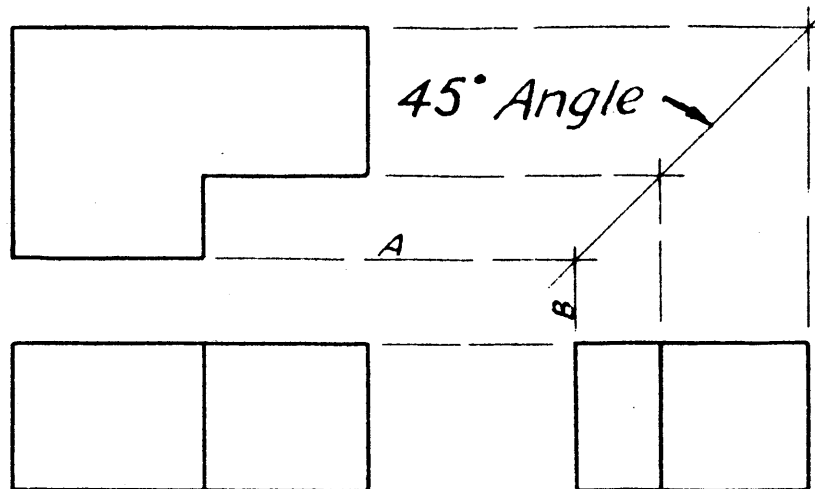


Fig. 19.

line where you want the left edge of the end view to be as in line B on the illustration. Where these lines A and B cross draw the 45° projection line. The other lines of the object will then fall where they are supposed to be.

O R T H O G R A P H I C S K E T C H I N G

By this term we mean simply a working drawing consisting of two, three, or more views made freehand, without the instruments, but containing adequate and complete information. A complete understanding of the problem is necessary before the actual drawing is made and this is accomplished by the freehand sketch (19).

A good deal of practice in drawing lines with a pencil is necessary until the hand obeys the eye to a reasonable extent. Form and proportion are the two major objectives in freehand sketching and they will come only with practice and experience. A sketch is the medium of expression among workmen in the shop.

The materials necessary for sketching are a 2H pencil sharpened to a long conical point but not too sharp, a pencil eraser, and some sheets of coordinate paper ruled in quarters of an inch. This cross section paper will aid in getting the correct proportion.

Before attempting to make the mechanical drawing make the freehand sketch on the cross section paper. It should be as neat, accurate, and fully dimensioned as possible. Have the sketch checked by your instructor before beginning the drawing and then hand it in with your finished drawing.

W O R K I N G D R A W I N G S

PROBLEM: Make three views of each of the keys shown on page 38. Dimension the drawing. You need not draw the pictures.

APPLICATION: A steel key such as you are about to make is used for fastening wheels and cranks to shafts. There are many types of keys used but at this time only four will be considered. Square and flat sunk keys are most commonly used in pulleys and wheels. They resist the tendency of the wheel to turn on the shaft as half of the key is sunk into the shaft and the other half into the hub of the wheel.

When a wheel is to be removed from a shaft the key must first be removed. This is done by driving it out from the small end. A gib key is used instead of a flat or square key when its position is such that it cannot be conveniently driven out.

PROCEDURE:

1. Lay out trim and border lines and divide the working space into four equal parts as explained on page 10.

2. On a sheet of cross section paper sketch the views to be drawn. Have the sketch approved before beginning the drawing. Hand this in with your drawing.

3. Figure out on a scrap of paper the

proper spacing of the views. By the proper spacing of the views we mean placing them so that there will be approximately the same amount of space on the left as on the right and about the same amount at the top as at the bottom. If there is to be any difference leave a little more at the top as the name of the drawing will take $3/16$ ".

4. The following is an example of the method of figuring the spacing of the square key.

First notice that the working space that is to contain the three views of the key is $5" \times 6 \frac{1}{2}"$. Now ask yourself how much of this $6 \frac{1}{2}"$ the drawing will occupy. The front view will take $3 \frac{1}{2}"$ and the end view will take $1"$. Add these. $3 \frac{1}{2}" + 1" = 4 \frac{1}{2}"$. Subtract this from the distance across the working space to find the amount left for spacing. $6 \frac{1}{2}" - 4 \frac{1}{2}" = 2"$. This $2"$ distance must be divided into three parts as there must be some space at the left, some in between the views and some at the right side. These three distances need not be the same however. A good way to divide this $2"$ distance would be to leave $3/4"$ at the left, $1/2"$ between the front and end views, and the remainder which is $3/4"$ at the right.

Now in the same way let us figure the vertical spacing. Add the width of the top view and the height of the side view and subtract this from the verti-

METHOD OF BLOCKING OUT PLATE 2.

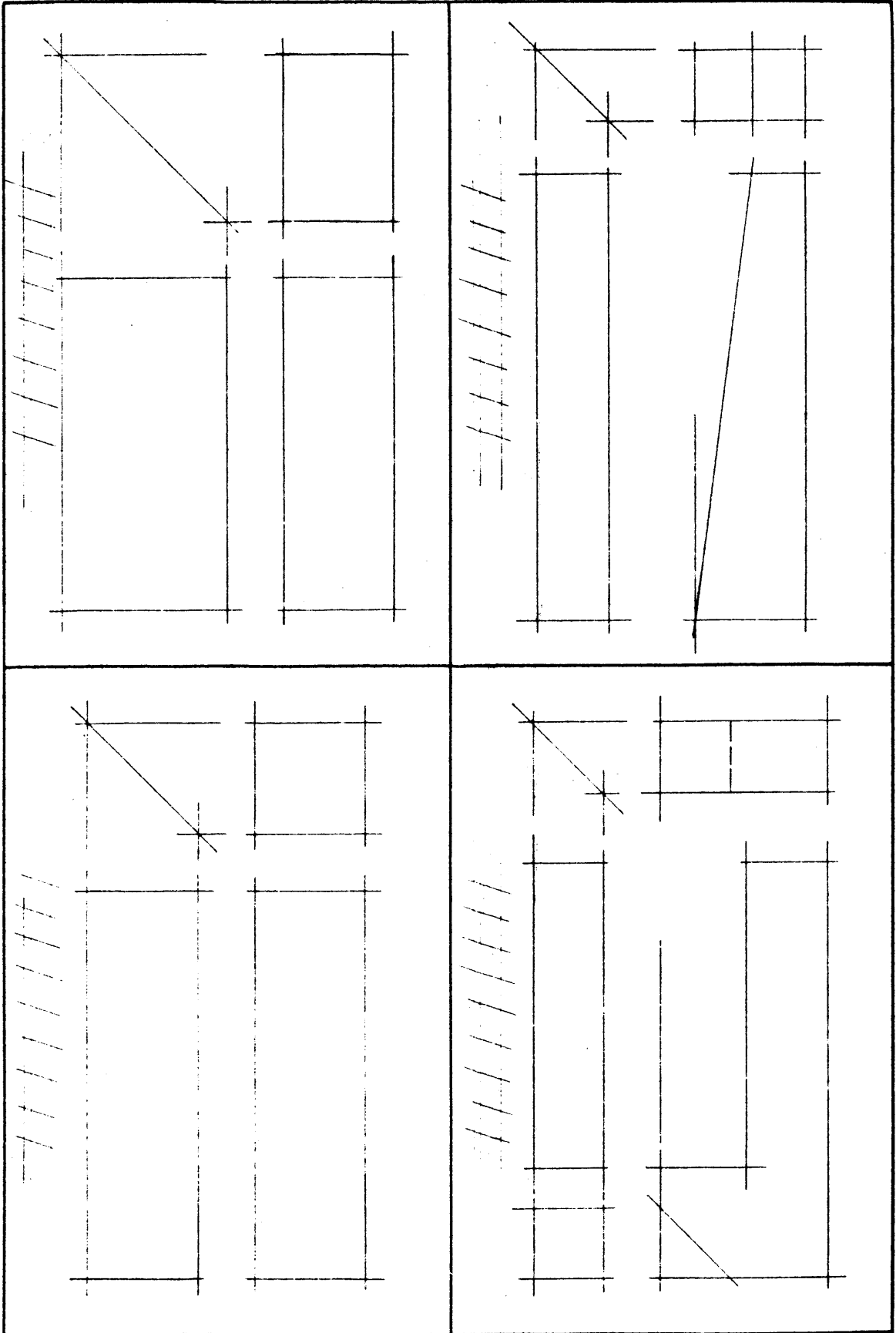


Fig. 20.

cal distance across the space. $1" + 1" = 2"$. $5" - 2" = 3"$. This will very conveniently divide into three equal parts, so let us put 1" at the top, 1" between, and 1" at the bottom.

5. We are now ready to "block out" the drawing. Beginning at the top border line measure down the following distances: 1" for spacing at the top, then 1" for the top view, 1" for the space between views, and 1" for the side view. In marking these distances it is better not to move the scale each time but make all the measurements that you can while the scale remains in the same position. Instead of making a dot for a measurement make a short line about $1/16"$ long. A dot is likely to make a small hole in the paper. Through these four marks draw light horizontal lines almost the full distance across the working space.

Beginning at the left border line mark off the following distances: $3/4"$, then $3\ 1/2"$, then $1/2"$, then 1" and draw very light vertical lines through these marks almost the full distance across the working space. Now we have the three views "blocked out".

6. With an eraser remove the unnecessary and overhanging lines.

7. Dimension the drawing as explained on page 14.

8. Retrace all object lines making them

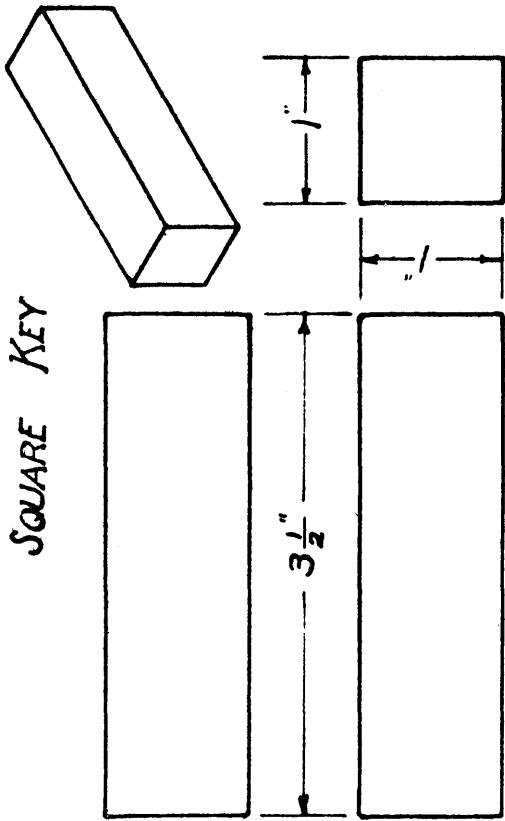
heavier than the dimension lines and of even weight and thickness.

9. Letter the drawing. Print your own name in the lower left hand corner $1/8$ " below the border line. Make letters $3/16$ " high.

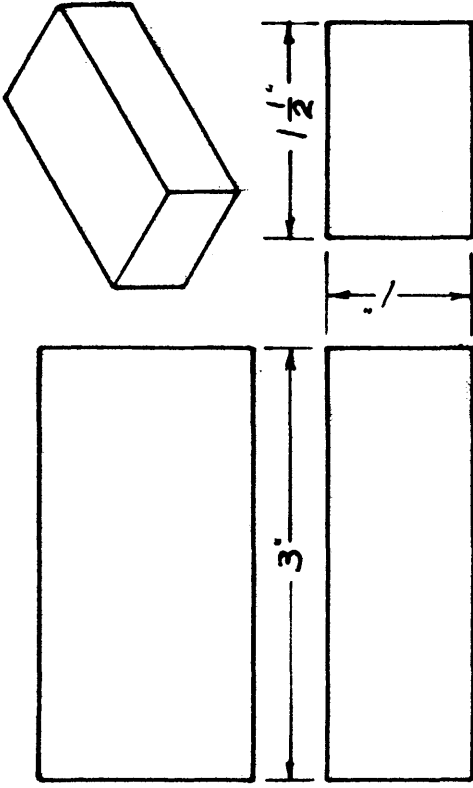
Exactly the same procedure is used for the other three drawings of this plate.

PLATE NO.2.

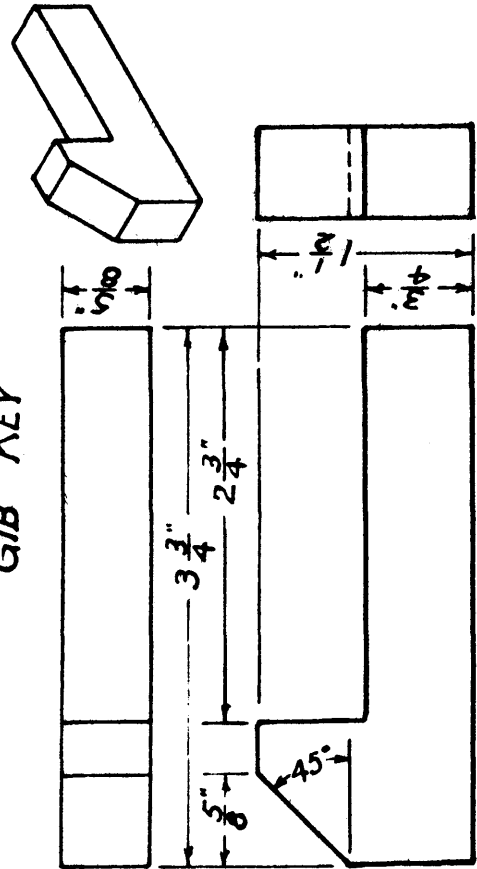
SQUARE KEY



FLAT KEY



GIB KEY



TAPERED KEY

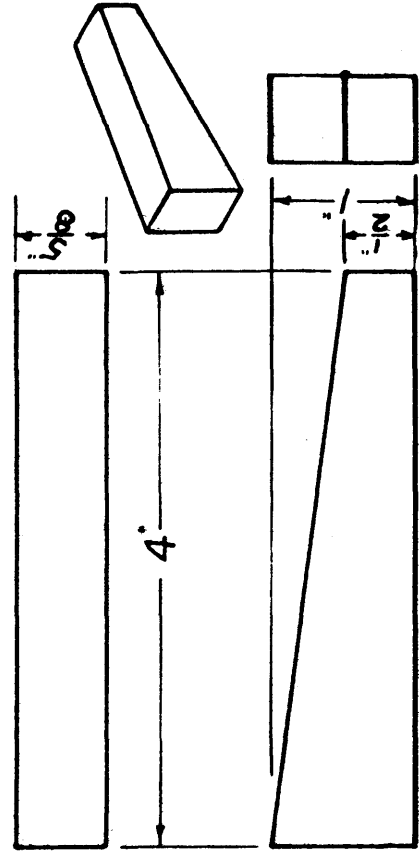


PLATE 3.

PROBLEM: Make a three view drawing of each of the problems on plate 3. Dimension fully. Do not draw the pictures.

APPLICATION: A V-block is used to support round objects so that they cannot roll while the machinist does some work on them.

A cord winder is used to wind string upon. You probably have used one for your kite string.

A wedge is used between two objects to remove the play so that they are firmly held in place.

A paperweight is usually made of some heavy material and is used to hold down a stack of papers.

PROCEDURE:

1. Lay out trim and border lines and divide the working space into four equal parts.
2. On a sheet of cross section paper make the sketches of the views to be drawn. Notice that the side views of the last two problems are missing. From the picture you are to draw the missing views. Hand this in with your drawing. Have it approved before you draw it.
3. Figure the proper spacing of the views the same as you did in plate 2.
4. When you have the spacing figured

block out the views as you did in plate 2. Make lines very light when blocking out.

5. Make the 90° V in the end view of the V-block before making the dotted line in the side view or the three lines in the top view. After making this V it is easy to project to get the other lines. From your previous study of the alphabet of lines what does the dotted line in the V-block indicate?

After blocking out the cord winder complete the top view before making the dotted lines in the side view or the three lines in the end view.

Complete the end view of the wedge before making the middle line in the top view.

Complete the top view of the paper weight before making the chamfer on the other two views. The edges of this paperweight have been planed off completely around the block to form a chamfer. Use your 45° angle to make the chamfer.

6. Remove the unnecessary lines with the eraser.

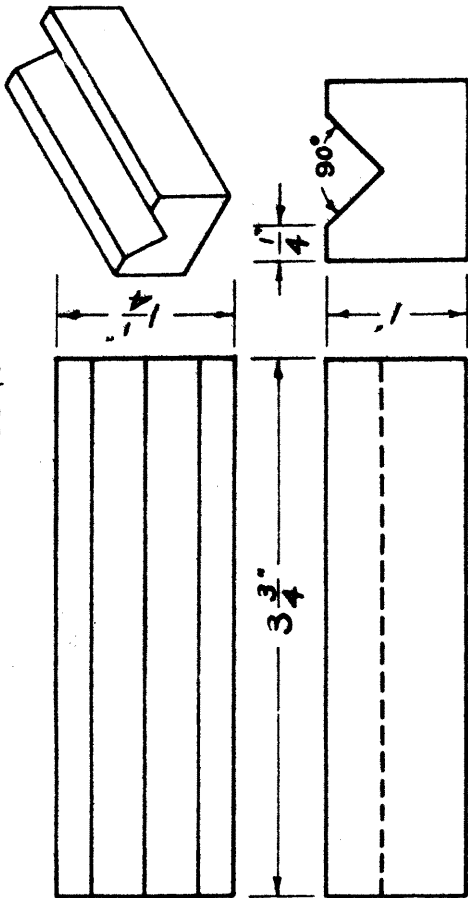
7. Dimension the drawing.

8. Retrace the object lines. Be careful to get all the object lines an even weight or thickness.

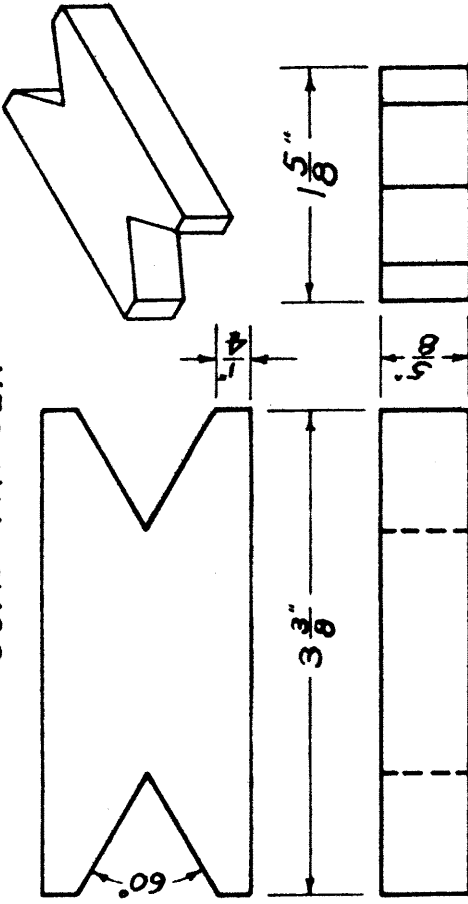
9. Letter the drawing. Use your triangles to make the slant guide lines. Print your name exactly as you did on plate 2.

PLATE NO. 3.

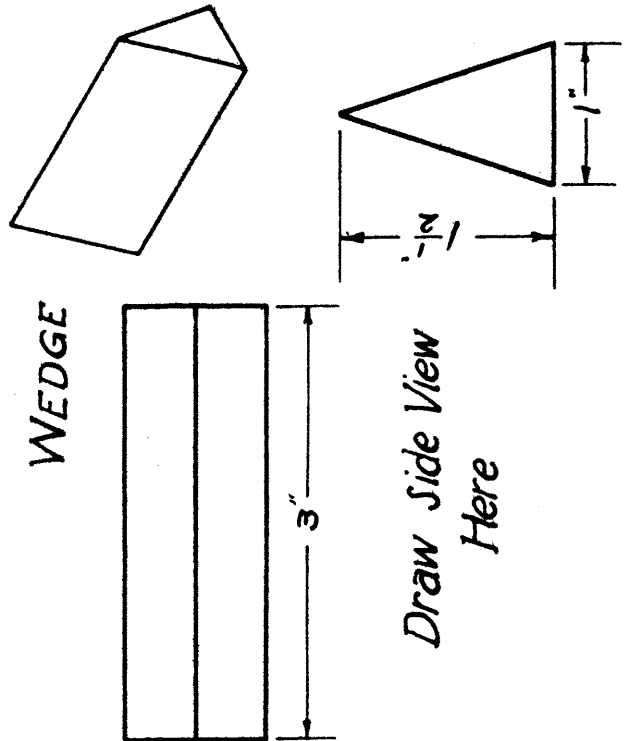
V BLOCK



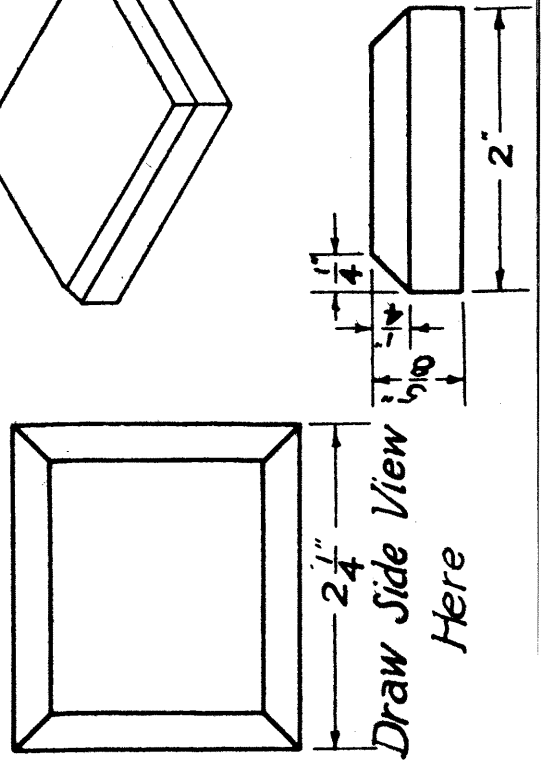
CORD WINDER



WEDGE



PAPERWEIGHT*



Draw Side View Here

Draw Side View Here

PLATE 4.

PROBLEM: Make a two view drawing of each of the problems on plate 4. Dimension. Do not draw the pictures. Two views are sufficient to show all that is required in these problems. If a third view was drawn it would be exactly like one of the other views.

APPLICATION: A washer is a circular piece of iron with a hole in it. It fits on the end of a bolt or a shaft directly beneath the nut and provides a smooth turning surface for the nut.

A collar is very much like a washer except that it is thicker. Its purpose is to take up space between two wheels or two parts of a machine.

A bushing is a part of a machine that fits directly around a revolving part such as a shaft. It is usually made of some wear resisting material as bronze or babbitt.

A gland is very similar to a bushing except that there is provided a place to wrap packing which makes it water tight.

PROCEDURE:

1. Lay out trim and border lines and divide working space into four equal parts.
2. Make a freehand sketch on cross section paper to hand in with your drawings. Have it approved.
3. Figure the spacing of the views. This

will be slightly different as there are to be only two views of each problem. In figuring the spacing of circular objects always figure from the border line to the center line instead of to the edge of the object. For example in the spacing of the washer suppose we find that we should leave $1\frac{1}{4}$ " between the border and the front view. Now add half of the diameter of the washer to the $1\frac{1}{4}$ " to get the distance from the left border to the center of the washer. Remember in making views of a circular object always make the center lines first, then the circles, and then project off the circles to get the other view.

4. Draw the horizontal center line then the vertical center line.

5. With a compass draw the two circles. Be sure the lead in the compass is sharpened to a fine edge and is in working condition.

6. Project from front view to get side view.

7. Remove the unnecessary lines with the eraser.

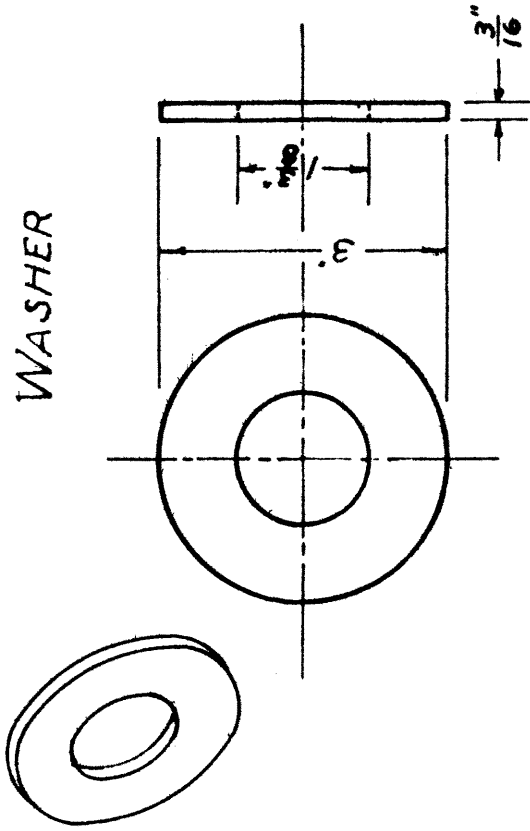
8. Dimension the drawing.

9. Retrace the object lines.

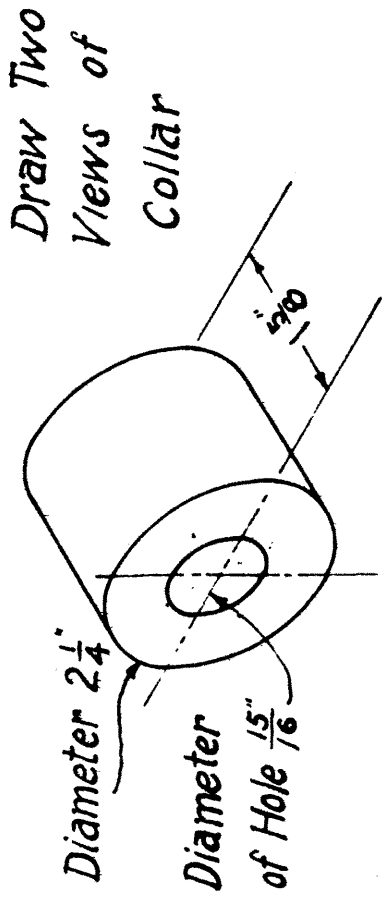
10. Letter the drawing.

PLATE NO. 4.

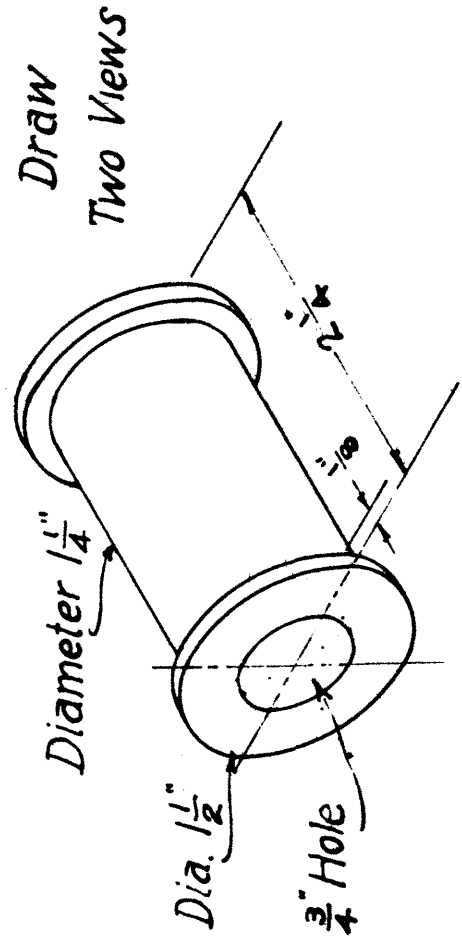
WASHER



COLLAR



BUSHING



GLAND*

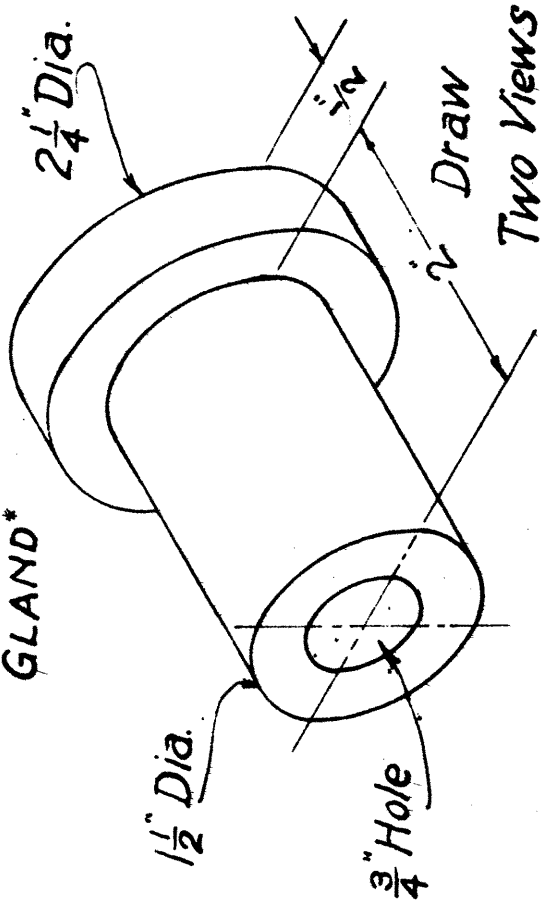


PLATE 5.

PROBLEM: Make a three view drawing of each of the problems on plate 5. Dimension. Do not draw the pictures.

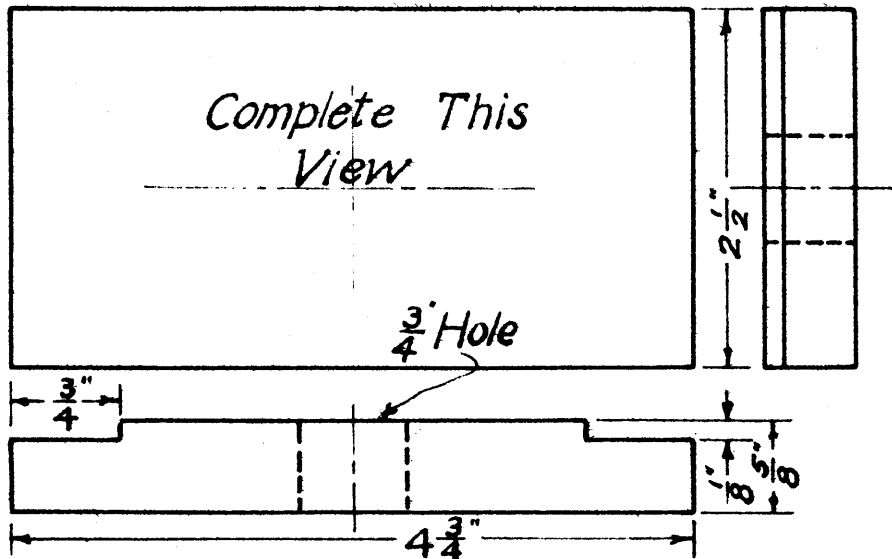
APPLICATION: These four problems are of simple objects in the machine shop. They are parts of machines.

PROCEDURE:

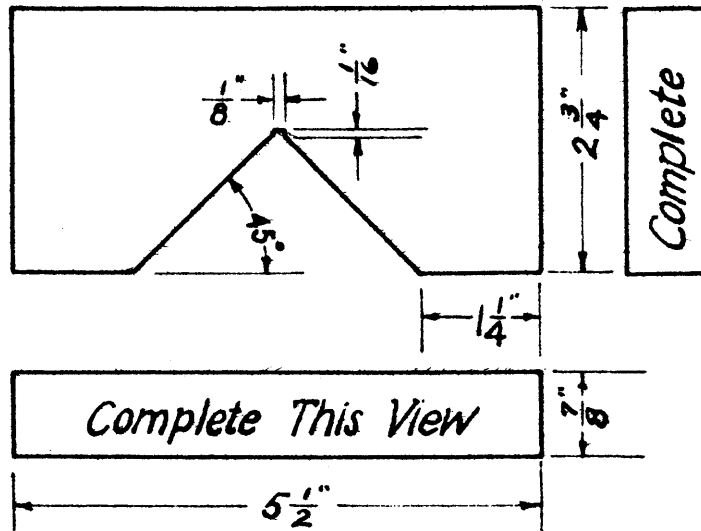
1. Lay out trim and border lines as usual and divide the working space into four equal parts.
2. On a sheet of cross section paper make a freehand sketch of the views to be drawn. Hand in with the finished drawing. **Have it approved first.**
3. Figure the spacing of the views.
4. Block out the views.
5. Draw center lines and then make the circles and semi-circles.
6. Project thes circles and semi-circles to the other views.
7. In the third problem make the solid lines first and then project from them to get the dotted lines.
8. Remove the unnecessary lines.
9. Dimension the drawing.
10. Retrace the object lines.
11. Letter the drawing.

PLATE No. 5.

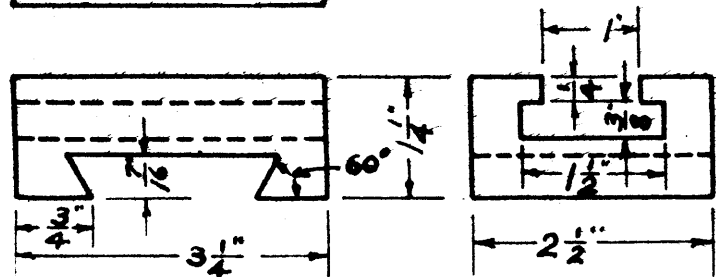
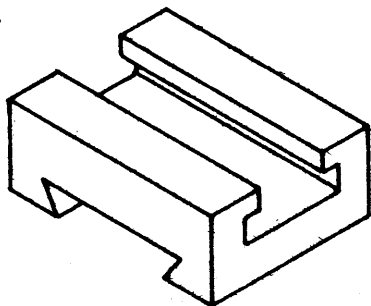
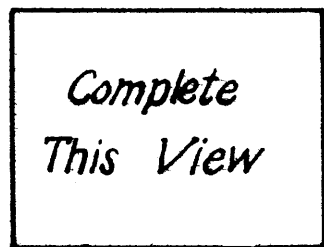
CLAMPING PLATE*



V BLOCK



TOOL POST SLIDE



CORE BOX

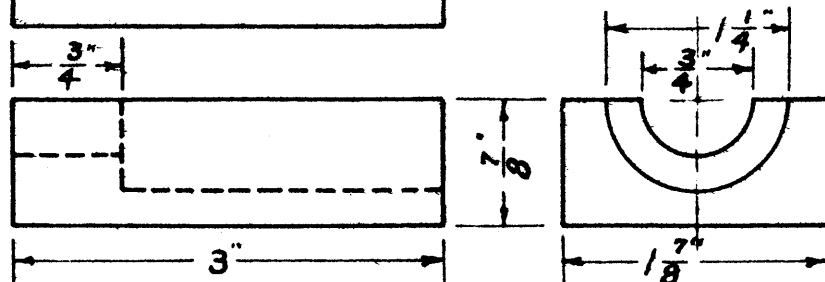
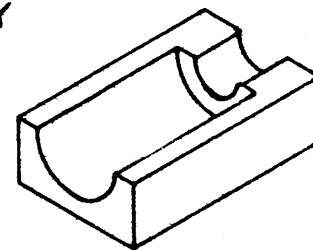
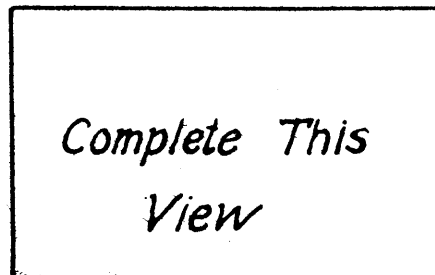


PLATE 6.

PROBLEM: Make a two view drawing of each of the problems on plate 6. Dimension. Why are the two views all that are necessary?

APPLICATION: As the name indicates a spacer is used to fill in the space between two machine parts.

A pump valve is usually made of leather or rubber and fits snugly into a pipe or cylinder. It creates the suction in the operation of the pump.

A pillow block is used to hold a round piece of steel called a shaft in a certain position in a machine and still allow the shaft to revolve.

Calipers are used to get the measurements of cylindrical objects. They have a movable joint at one end and by adjusting them to fit over a cylinder the diameter can be obtained.

PROCEDURE:

1. Lay out trim and border lines and divide the working space into four equal parts.
2. Make the freehand sketch to hand in with the drawing. Have it approved before drawing.
3. Figure the spacing as you did in plate 4. Remember in circular objects figure from the border line to the center line.

Do not block out the objects but make the center lines and then draw the circles and arcs. Arcs

are parts of circles. Make the arcs very light and farther around than they will be when they are finished. This makes it easier to draw the tangent lines. Draw the straight lines tangent to the arcs. By a tangent is meant a line that touches a circle or arc at one point only. After drawing the tangent lines find the point of tangency by making a line from the center of the arc or circle perpendicular to the straight line. Mark this place so when inking you will know where the arc ends and the straight line begins.

5. Remove the unnecessary lines with the eraser.

6. Dimension the drawing.

7. Retrace the object lines.

8. Letter the drawing.

PLATE NO. 6.

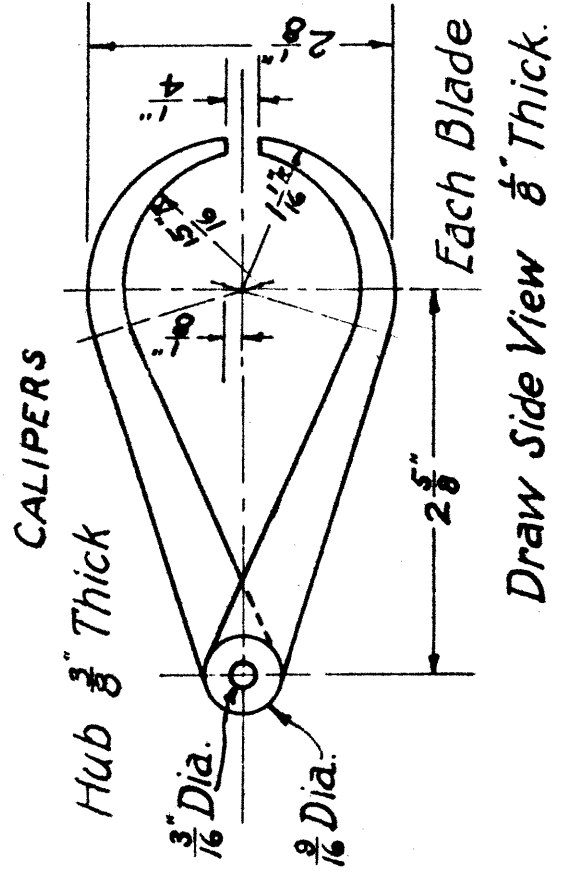
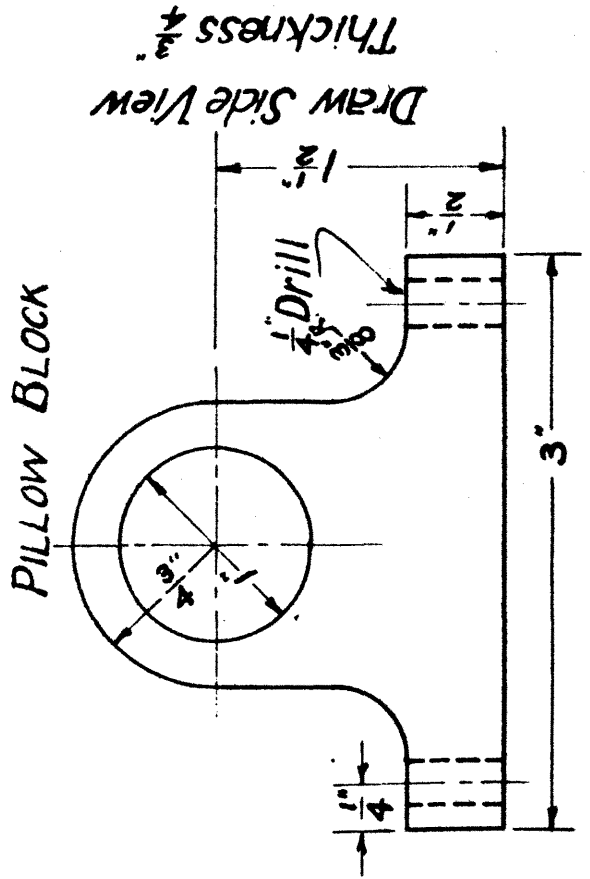
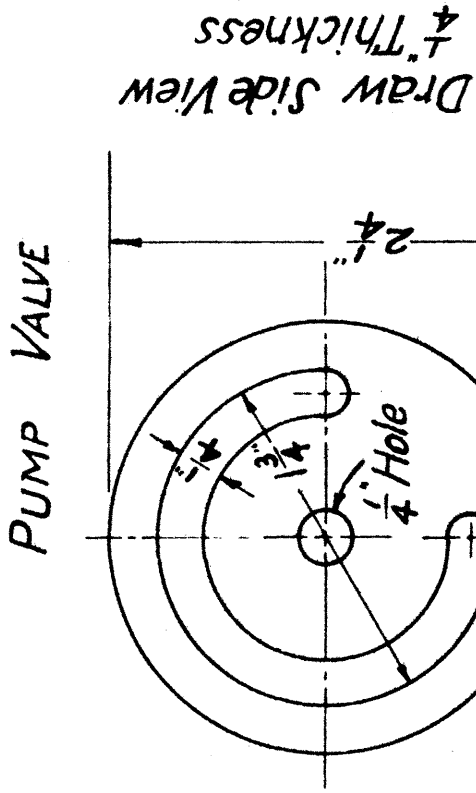
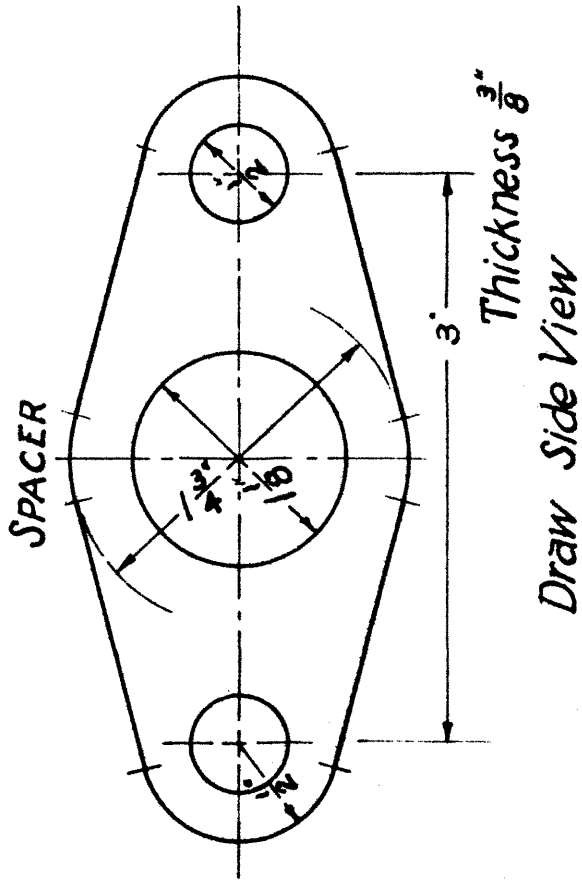


PLATE 7.

PROBLEM: Make a three view drawing of the riveting hammer and the bearing cap. Make a two view drawing of the link and the rocker arm. Dimension.

APPLICATION: A riveting hammer is used to smash over the ends of rivets. It is made of cold rolled steel.

A bearing cap is a cap that fits over a shaft. A similar part fits under the shaft. This holds the shaft in position and allows it to revolve. It is oiled by means of the small hole in the top.

A link is used to connect two wheels or two parts of a machine so they will turn together.

A rocker arm is used to give an eccentric motion to another part of a machine called a connecting rod.

PROCEDURE:

1. Lay out trim and border lines as usual.
2. Make a freehand sketch to hand in with the finished drawing. Have it approved before drawing.
3. Figure the spacing. Remember in the link and the rocker arm to figure to the center lines.
4. Block out the riveting hammer and the bearing cap and draw the center lines for the link and the rocker arm.
5. Draw end view of hammer before finish-

ing the other views. Mark the points of tangency in the link and rocker arm.

6. Remove the unnecessary lines with the eraser.

7. Dimension the drawing.

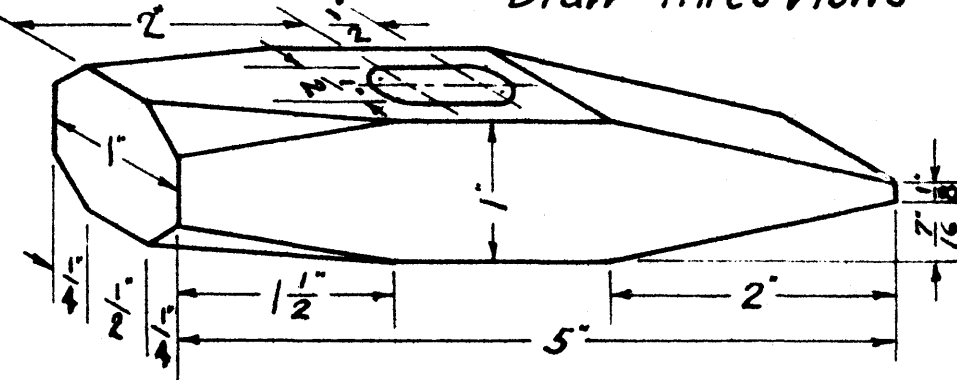
8. Retrace the object lines. Be careful to get the compass curves and the straight lines the same weight.

9. Letter the drawing.

PLATE NO. 7.

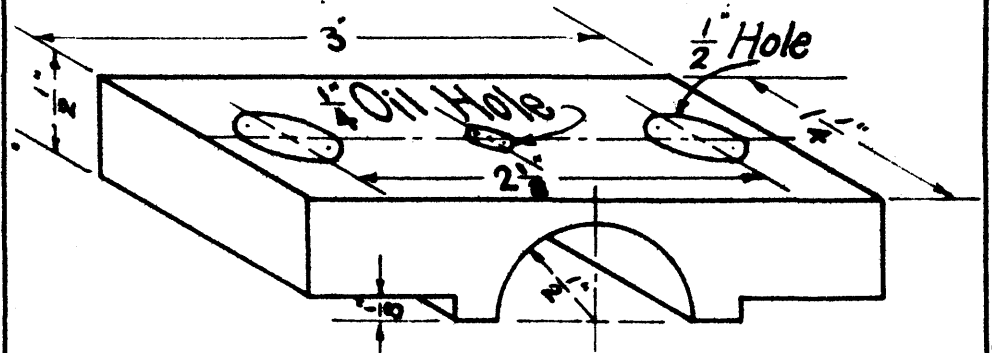
RIVETING HAMMER*

Draw Three Views



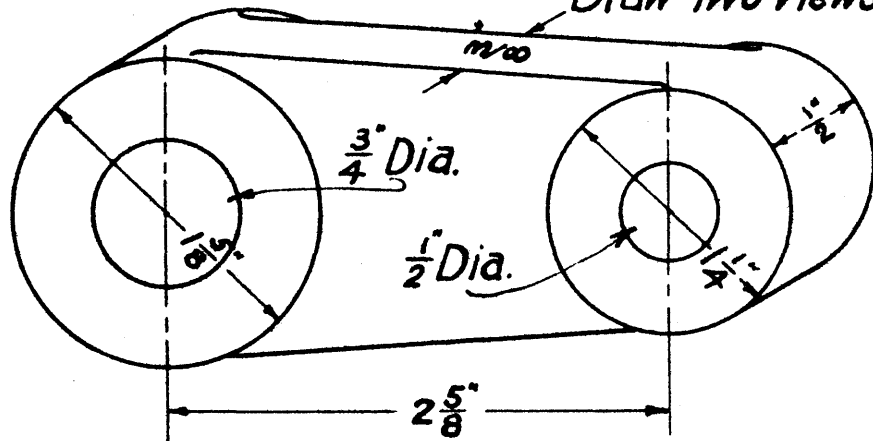
BEARING CAP

Draw Three Views



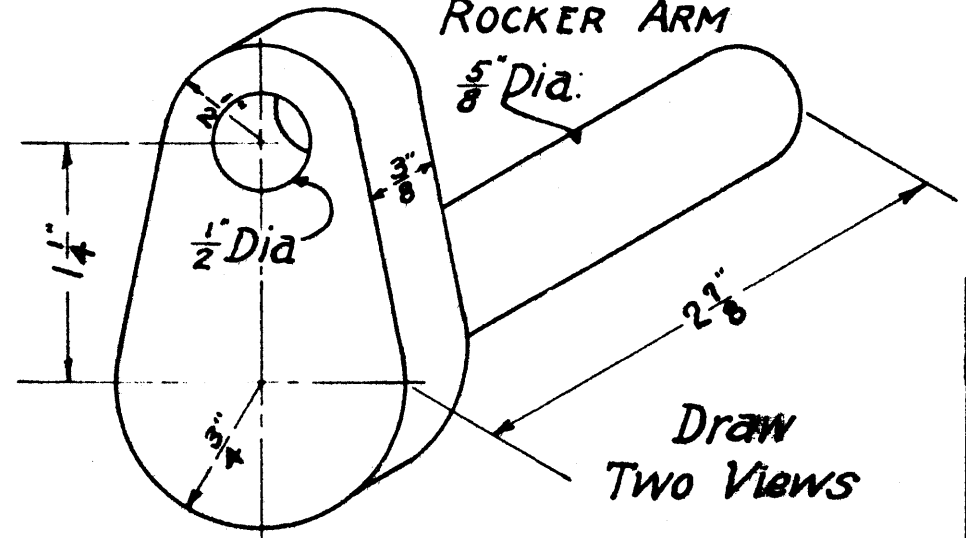
LINK

Draw Two Views



ROCKER ARM

5/8 Dia.



Draw Two Views

PLATE 8.

PROBLEM: Make a lettering plate using the paragraph below for the copy.

APPLICATION: In order to become proficient in lettering much practice is necessary. A good drawing must have good lettering and figures or a mistake may be made by the workman who reads the drawing. This lettering plate is to give you more practice in the correct formation of letters and figures. Try to improve over the first lettering plate you made.

PROCEDURE:

1. Lay out trim and border lines but do not divide the working space into four equal parts.

2. Make the horizontal and slant guide lines as you did in plate 1.

3. Print the following paragraphs:

A section drawing is one which shows the real outline and the interior construction of an object, as though it had been cut open along a certain line usually through the center. The cutting line is made like this _____ . See the alphabet of lines.

A full section is one in which the cutting line extends the entire distance across the object. In other words it appears as though the object had been cut open through the center and one half of it removed.

A half section is one which appears to have one fourth of the object cut away. One half of the side view appears as an exterior view, usually without showing dotted lines, and the other half shows the interior of the object. See page 55, Fig. 22. The cut surface is indicated by 45° lines called cross-hatch or section lines. See alphabet of lines on page 19.

4. Erase the unnecessary lines.
5. Retrace the border lines.
6. Print your name.

SECTIONS

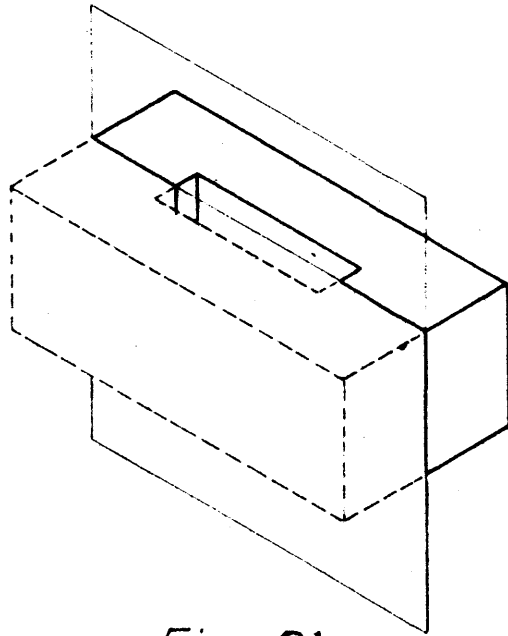
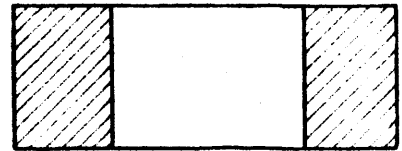
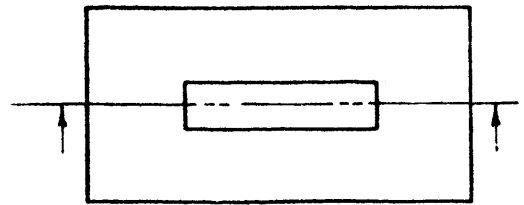


Fig. 21.



Full Section

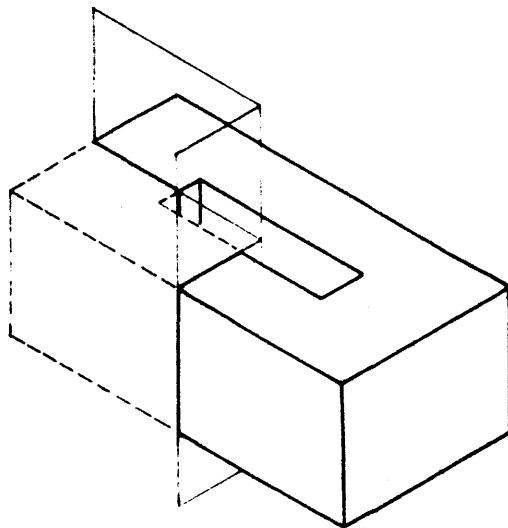
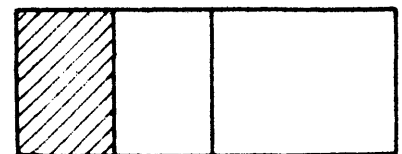
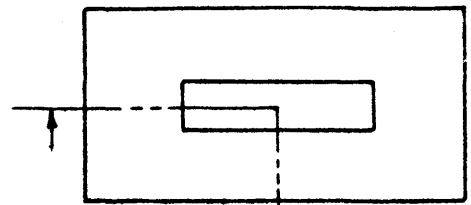


Fig. 22



Half Section

S E C T I O N S

PROBLEM: Make two views of each of the objects on plate 9. One view in each problem is to be a full section. The cutting line indicates which view will be cross-hatched.

APPLICATION: A washer like this is often used on the side of an emery stone or grind stone. It makes a smooth turning surface for the nut besides strengthening the stone.

A bushing is very similar to the one on plate 4. It has the same purpose.

The slot in the link is made for adjustment purposes.

The purpose of the shaft support is to hold a shaft in position. It is usually lined with a bronze bushing to resist wear.

PROCEDURE:

1. Lay out trim and border lines and divide the working space into four equal parts.
2. Make a freehand sketch of each of the problems to hand in with the drawings. Have it approved.
3. Figure the spacing of the views.
4. Lay out center lines.
5. Draw circular views first.
6. Project to get sectional views.

7. Cross-hatch the cut surface. Remember holes are not cut surfaces. Make cross-hatch lines light and about 1/16" apart spaced entirely by the eye.

8. Dimension.

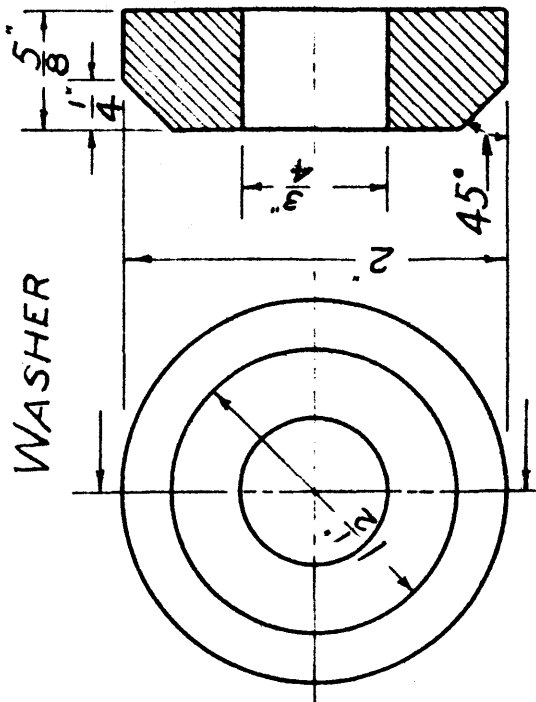
9. Erase unnecessary lines.

10. Retrace object lines.

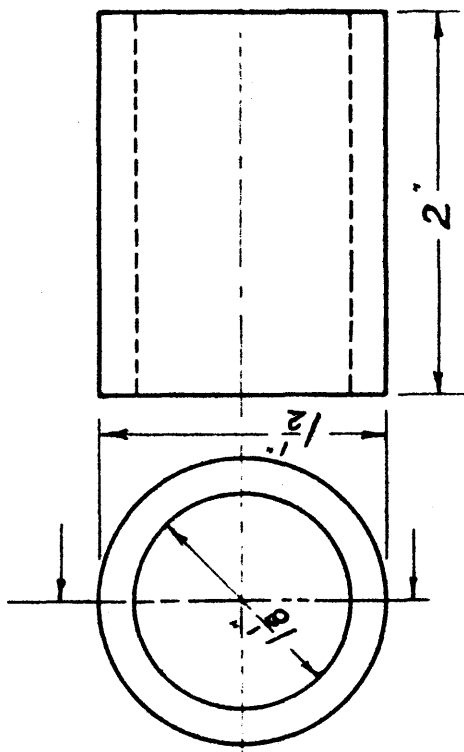
11. Letter the drawing.

PLATE NO. 9.

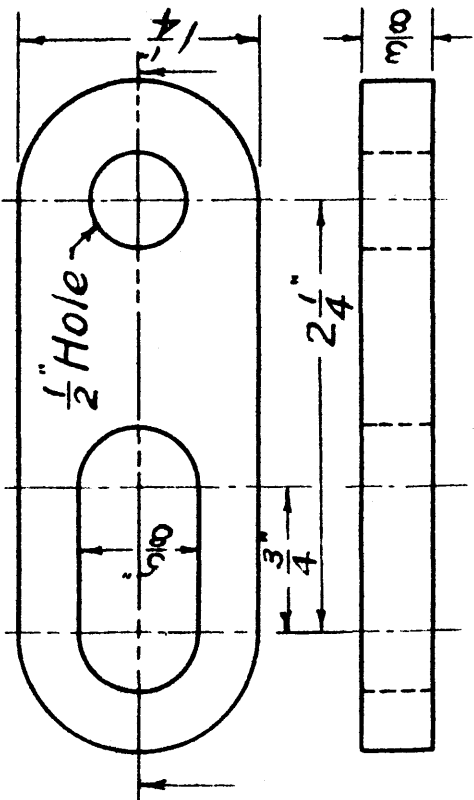
WASHER



BUSHING



SLOTTED LINK



SHAFT SUPPORT

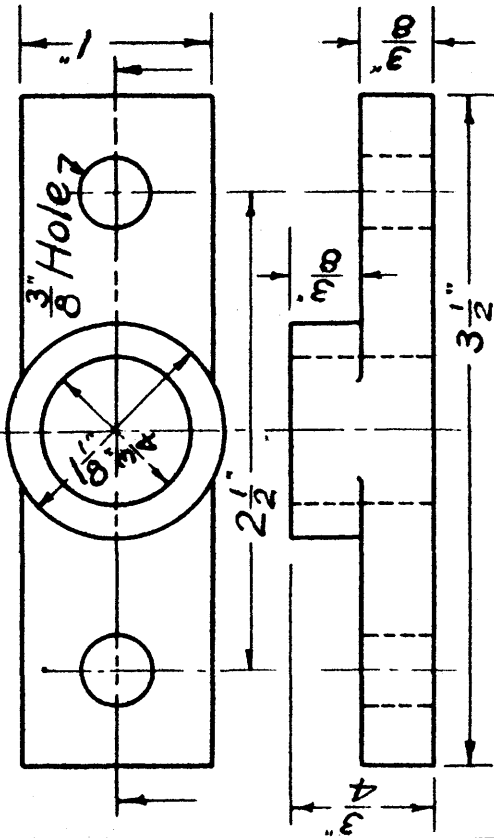


PLATE 10.

PROBLEM: Make a two view working drawing of each of the problems on plate 10. One view in each is to be a full section as indicated by the cutting line.

APPLICATION: An ink bottle holder as the name indicates is to hold an ink bottle so it will not upset.

A steam chest is a compartment on an engine for holding steam. The steam is distributed from the chest to the cylinders.

An adjustable clamp is used to fasten table tops to the legs.

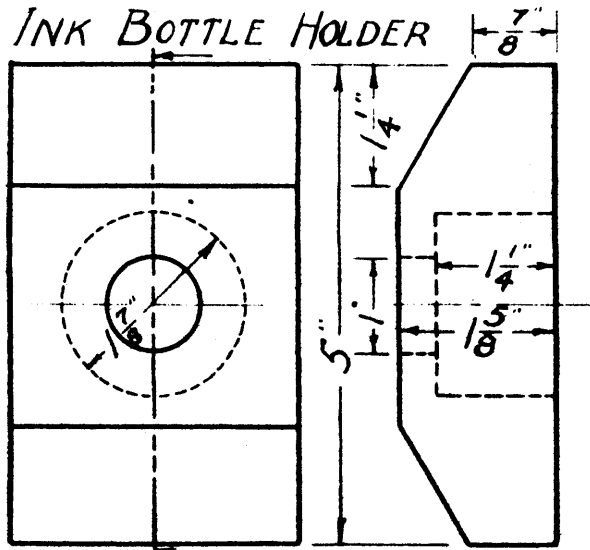
A slide has the same purpose as a washer. It is used on a lathe tail stock and slides in a groove in the bed of a lathe.

PROCEDURE:

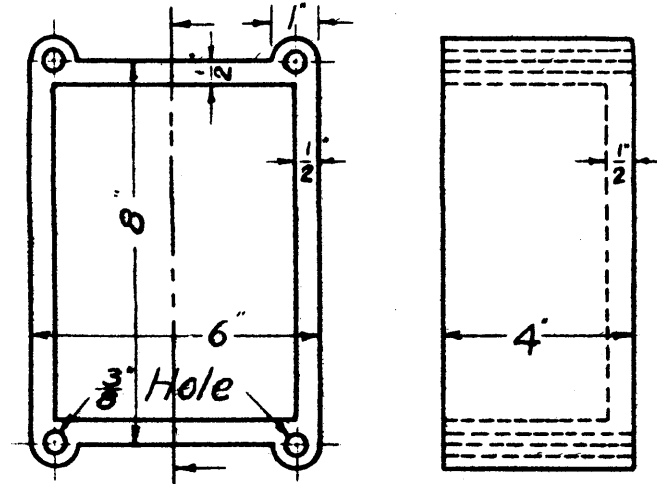
1. Lay out trim and border lines and divide the working space into four equal parts.
2. Make a sketch to hand in with the drawing. Have it approved before drawing.
3. Figure spacing.
4. Block out views.
5. Draw center and cutting lines.
6. Cross-hatch sectional views.
7. Dimension the drawing.
8. Erase unnecessary lines.
9. Retrace object lines and letter.

PLATE NO. 10.

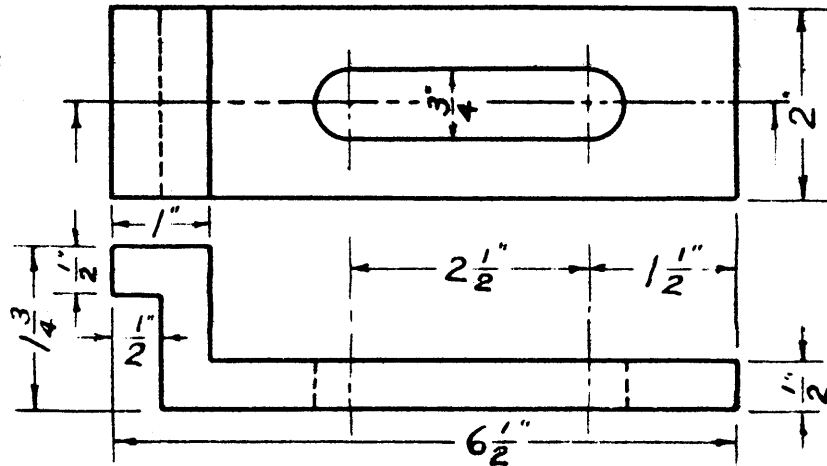
INK BOTTLE HOLDER



STEAM CHEST.



ADJUSTABLE CLAMP



SLIDE

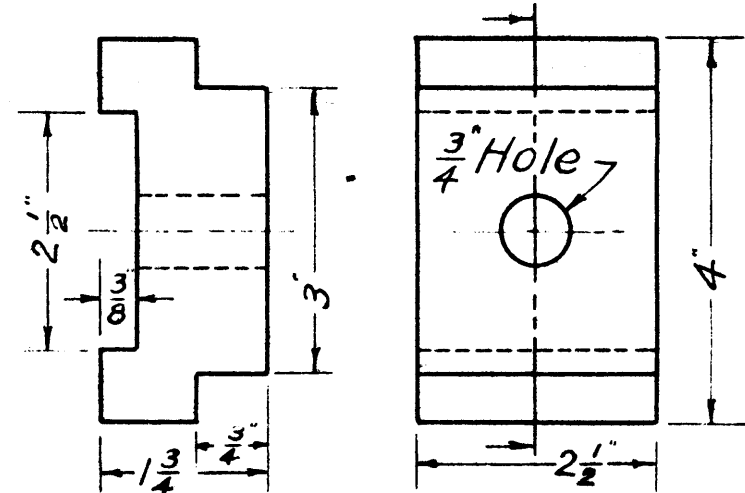


PLATE 11

PROBLEM: Make a two view drawing of each of the problems given on plate 11. One view in each problem will be either a full section or a half section. Notice the cutting lines.

APPLICATION: A piston is that part of a machine that is forced forward and backward by steam or some other power. It is circular in shape and fits very snugly into the cylinder.

A hand wheel is one used on a steam or water valve.

The jack-screw cap is that part of a jack-screw that fits directly under the load to be lifted. It remains stationary while the screw turns.

The pulley wheel is an ordinary belt wheel found on many machines run by power. A wheel of this kind usually has a crown, that is, it is raised slightly in the middle to keep the belt from coming off.

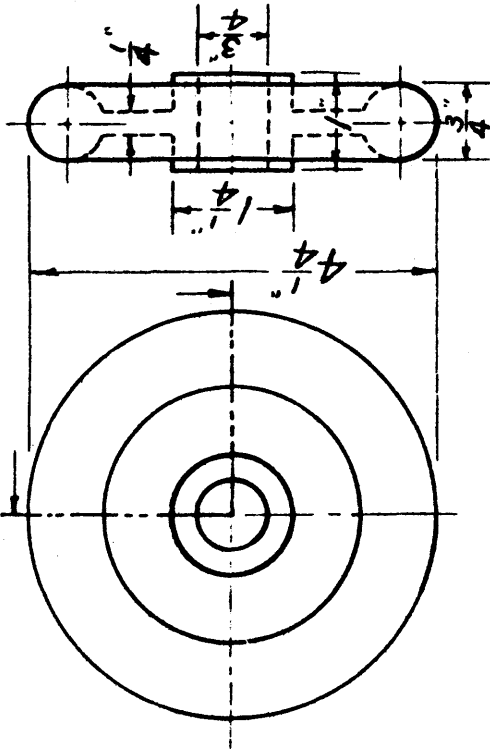
PROCEDURE:

1. Lay out the trim and border lines and divide the working space into four equal parts.
2. Make a sketch to hand in.
3. Figure the spacing.
4. Lay out center and cutting lines.
5. Draw the circular views..
6. Project from circles to get side views.

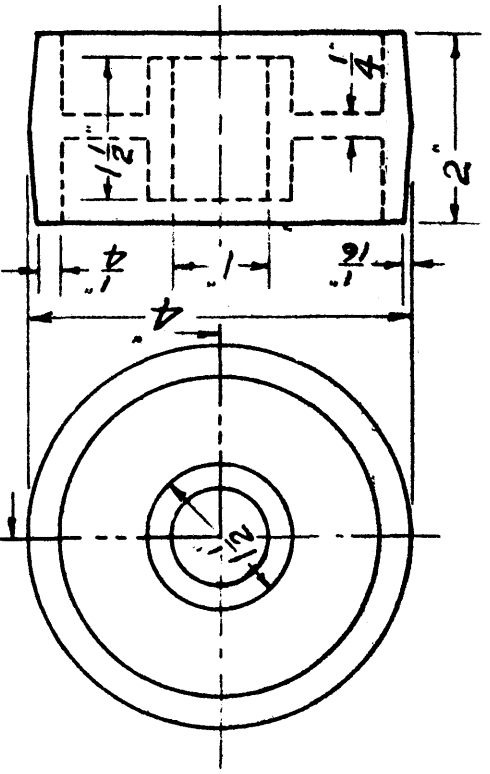
7. Cross-hatch the cut surfaces.
8. Dimension the drawing.
9. Erase the extra lines.
10. Retrace the object lines.
11. Letter the drawing.

PLATE NO. 11.

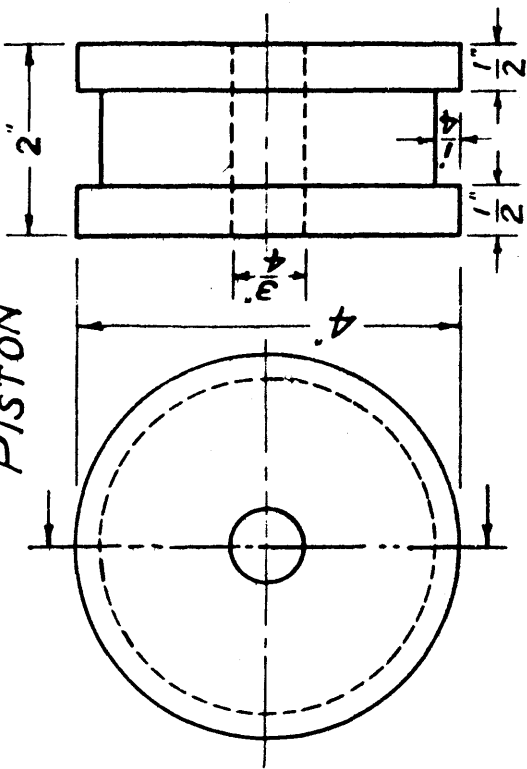
HAND WHEEL



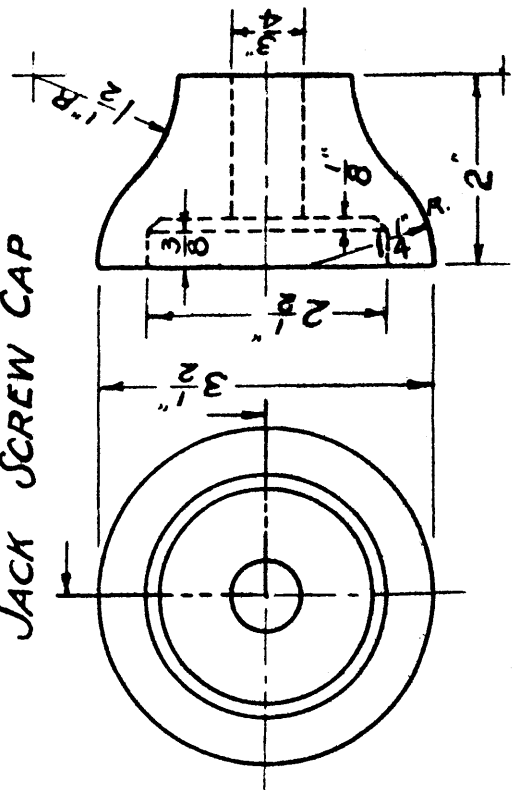
PULLEY WHEEL



PISTON



JACK SCREW CAP



A U X I L I A R Y P R O J E C T I O N

Sometimes a view of an object taken from another direction will show the shape and construction to better advantage than the three ordinary views. This is true of an object with an inclined surface or part of the surface inclined. By an auxiliary view is meant a view seen by looking directly toward the slanting surface. The auxiliary view often takes the place of one of the regular views or at least part of one of the regular views as in the figure on page 65.

Auxiliary views are worked from center lines or other reference lines and their dimensions are obtainable from the other views.(7).

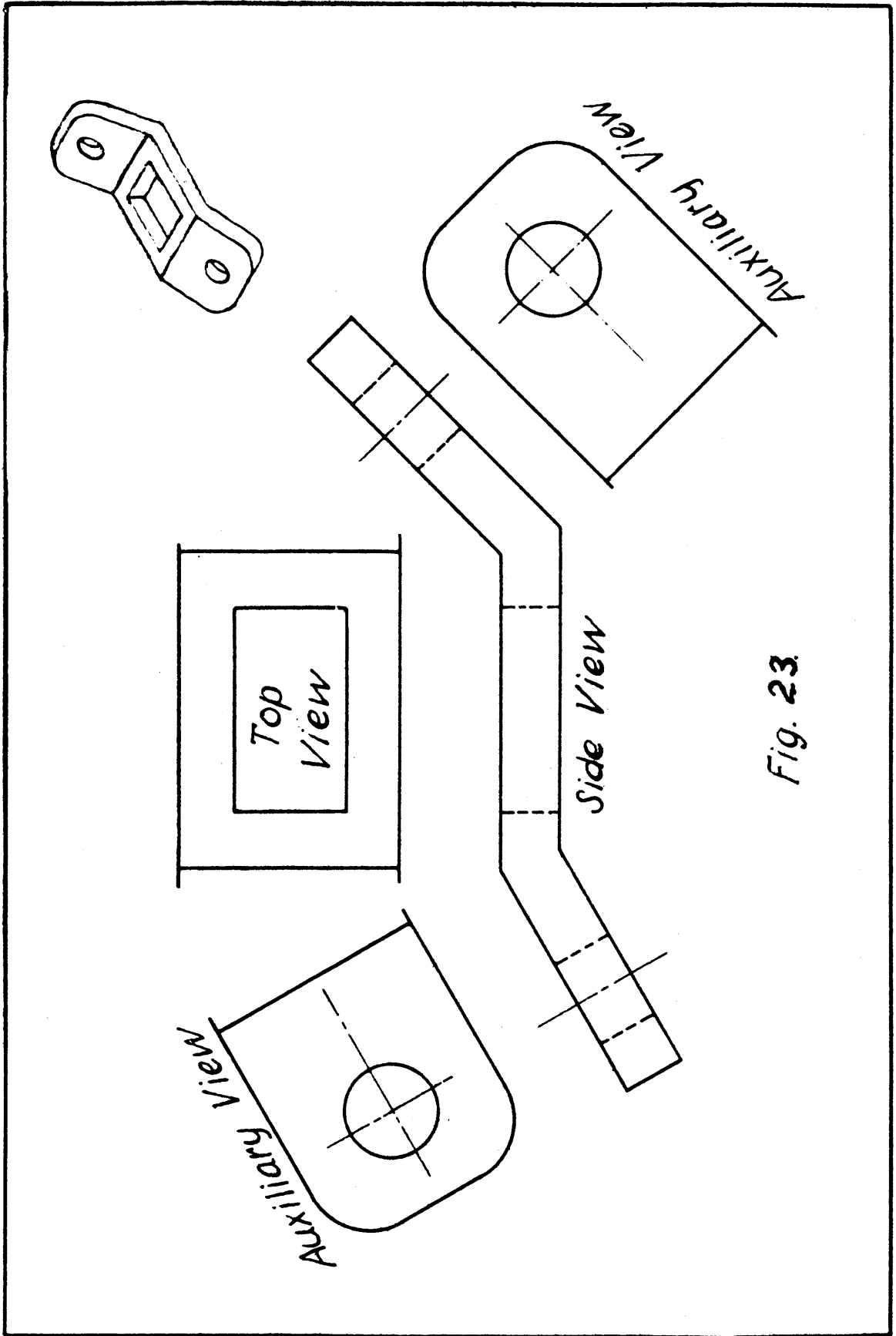


Fig. 23.

THE AUXILIARY VIEW

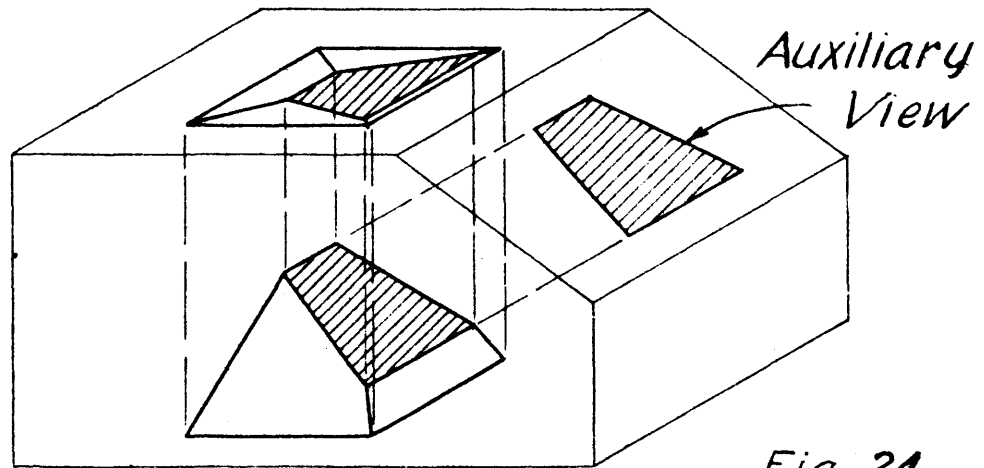


Fig. 24.

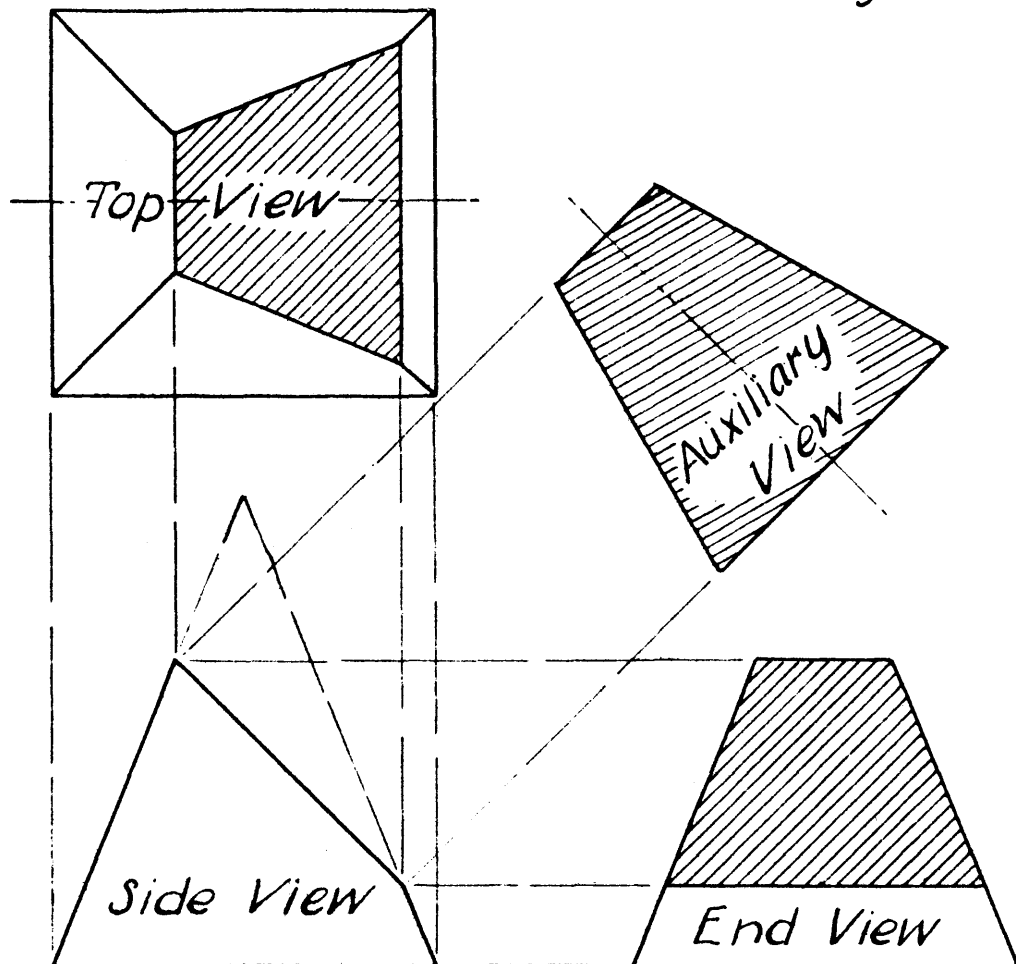


Fig. 25.

PLATE 12.

PROBLEM: Make a working drawing of the problems given on plate 12. In the first and second problems, the angle brace and the saddle base, the correct views will be a side view, a partial end view, and an auxiliary view. The auxiliary view will take the place of the top view and will show the true shape and size of the slanting surface which a top view would not.

In the third problem, the bent plate, make a side view, a partial top view, and an auxiliary view of the slanting surface. In the fourth problem make a side view, a partial top view, a partial end view, and an auxiliary view.

APPLICATION: These four objects are small parts of machines and are made of iron. Each object has a sloping surface and therefore requires an auxiliary view to show the true shape of the surface.

PROCEDURE:

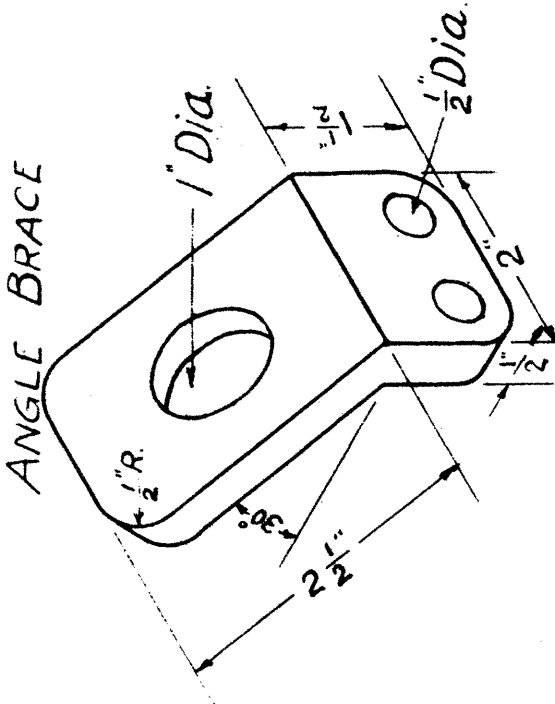
1. Lay out the trim and border lines and divide the working space into four equal parts.
2. Make a sketch of the problem to hand in with the drawing. Have it approved.
3. Figure the spacing. Remember to leave enough room for the auxiliary view.
4. Draw the side view first in each case,

then project to get the other views.

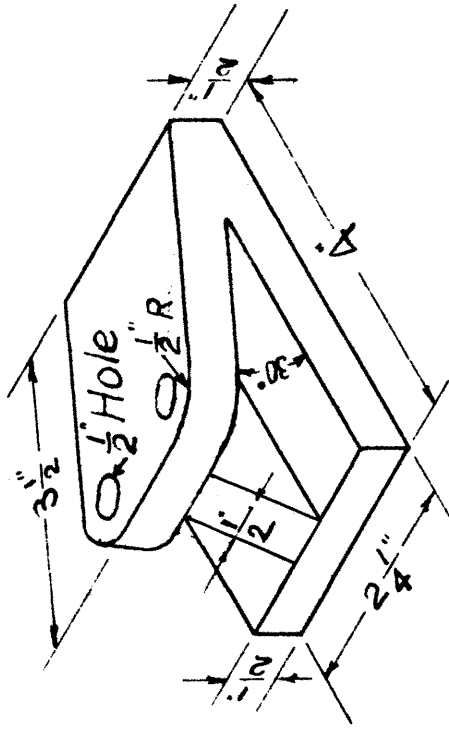
5. Dimension the drawing.
6. Erase the extra lines.
7. Retrace the object lines.
8. Letter the drawing.

PLATE NO. 12.

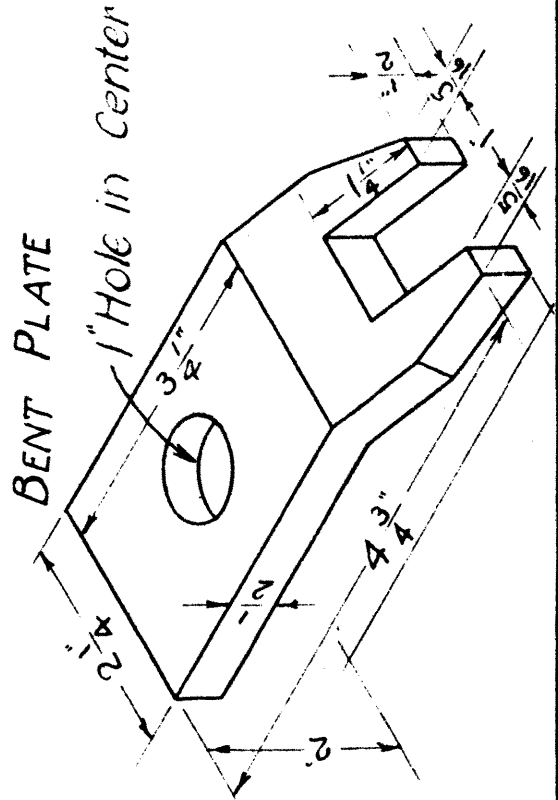
ANGLE BRACE



SADDLE BASE



BENT PLATE



ANGLE BRACKET

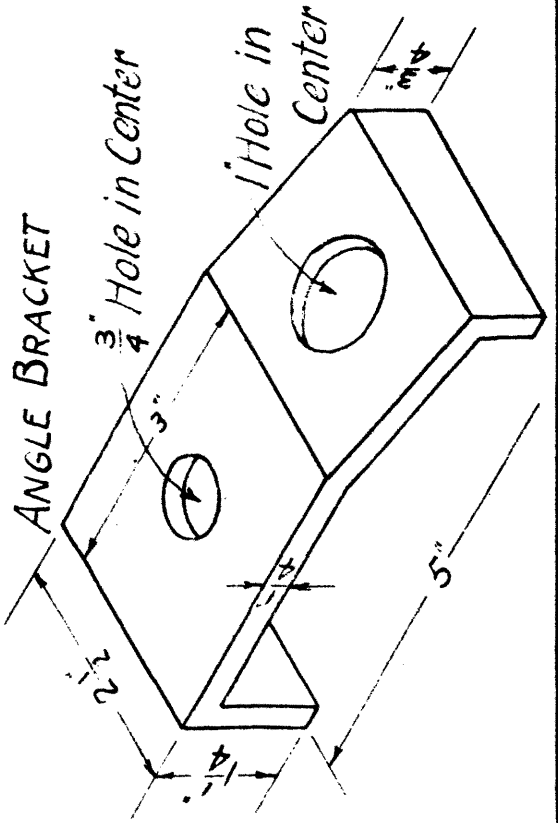


PLATE 13.

PROBLEM: Make a working drawing of the four problems given on plate 13. All that is necessary in the first problem of the lateral pipe, is a side view, a partial end view, and an auxiliary view.

In the second problem, the tank outlet, all that is needed is the sectional side view and an auxiliary view.

In drawing the rod holder make a side view, a partial end view instead of the complete end view which is shown, and an auxiliary view.

In the fourth view draw the side view, the complete end view, and an auxiliary view.

APPLICATION: The first problem is a pipe joint called a 45° lateral with which two pipes may be joined at an angle of 45° .

The second problem is an outlet of a tank by means of which a pipe or hose may be joined to the tank.

The third problem is a device by which a rod may be held in place at an angle to the horizontal.

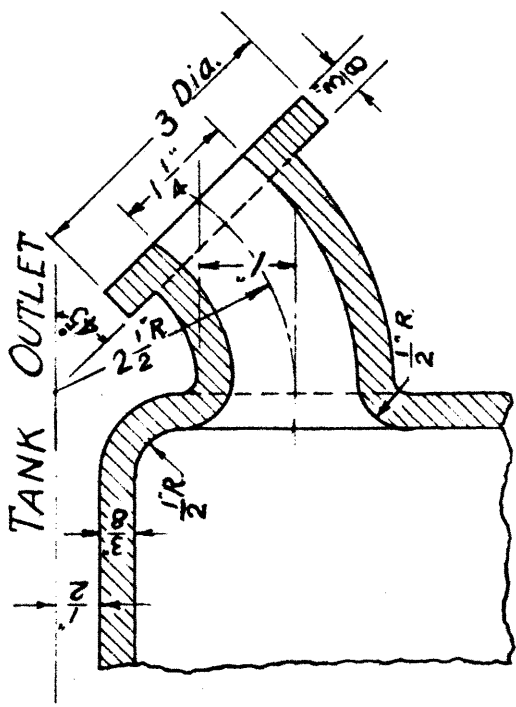
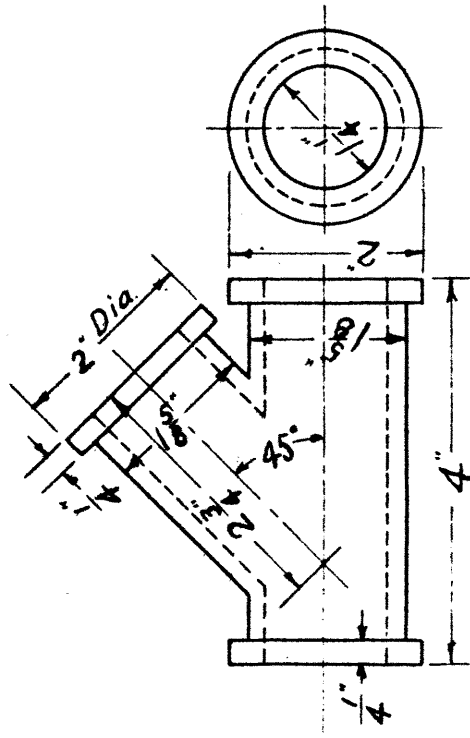
The fourth problem is merely a square pipe which might be used as a vent or an air pipe in a heating system.

PROCEDURE:

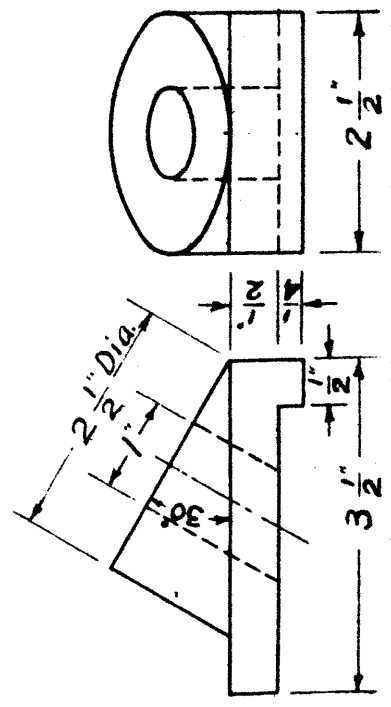
1. Lay out trim and border lines and divide the working space into four equal parts.
2. Make a freehand sketch of the problems to hand in with the drawings.
3. Figure the spacing and remember to allow sufficient space for the auxiliary view.
4. Draw the side view in each case first, then project for the other views.
5. Dimension the drawings.
6. Erase the unnecessary lines.
7. Retrace the object lines.
8. Letter the plate.

PLATE NO. 13.

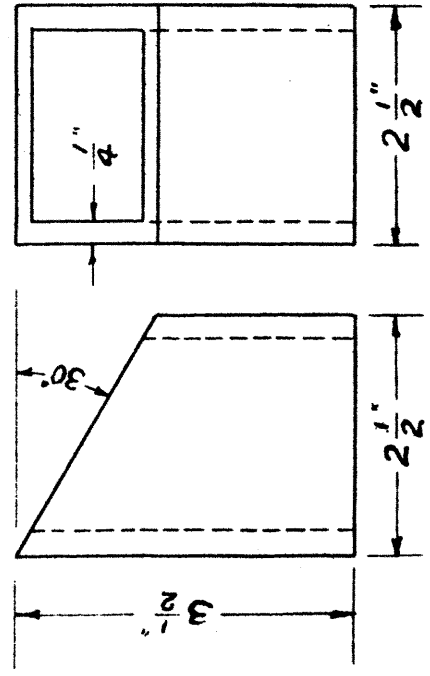
45° LATERAL PIPE



ROD HOLDER



SQUARE PIPE



D E V E L O P M E N T

A development is really a pattern of an object. The sheet metal worker has to have a pattern by which he cuts the metal. When rolled or formed this pattern makes the desired object. The operation of laying out the surface as a flat piece is called the development of the object.

The development of a square or round pipe will be a rectangle whose length is the circumference or distance around the pipe and whose height is that of the pipe. See page 74. The circumference of a cylinder can be calculated mathematically but is usually found by dividing the circumference into twelve or more parts and then laying off these parts with the dividers along the base line called the stretchout line. The height of each line may be projected from the side view.

When making a development first draw the top and side views. The top view is used to obtain the length of the pattern and the side view to get the height.

When a cone is unrolled to form a pattern the base or stretchout line will be a part of a circle and the pattern itself will be fan shaped. See page 74. The method of development is the same however, as that of a cylinder.

DEVELOPMENT

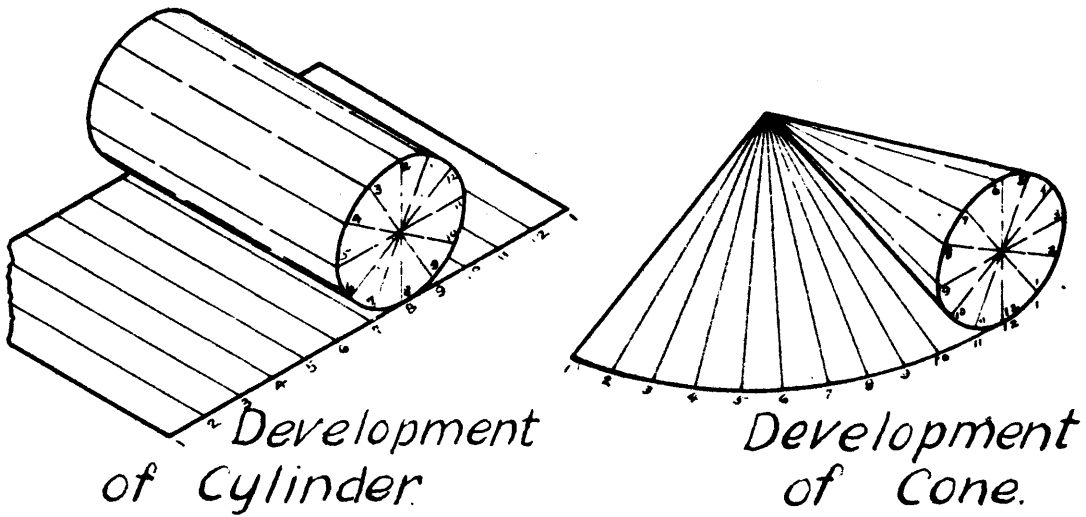
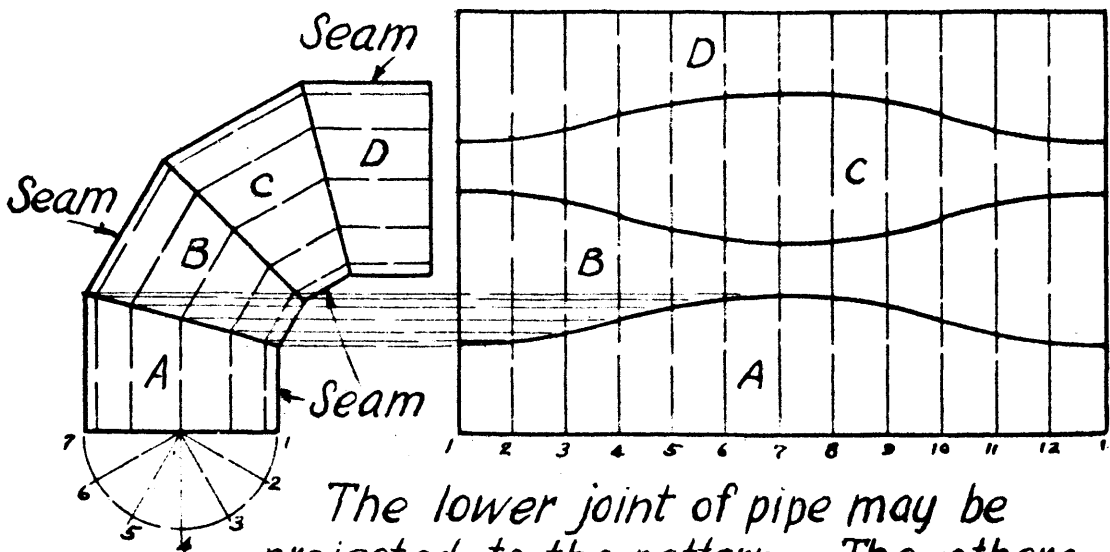


Fig. 26.



The lower joint of pipe may be projected to the pattern. The others must be transferred with the dividers.

By alternating seams as shown it is possible to save material besides strengthening the pipe.

Fig. 27.

PLATE 14.

PROBLEM: Make a development of each of the four problems given on plate 14. Do not forget to make the top and bottom of each. In the truncated pipes the auxiliary view will be the top or lid.

APPLICATION: These problems are just short lengths of pipes of different shapes used in sheet metal work.

PROCEDURE:

1. Lay out trim and border lines as usual. Do not divide the working space into four equal parts as each problem will require a whole sheet. Number the plates 14A, 14B, 14C, and 14D.
2. Make a sketch of what you think the pattern will look like.
3. Figure the spacing. Remember the pattern will occupy a space as long as the distance around the top view.
4. Draw top and side views.
5. Draw stretchout line.
6. Lay off sides with the scale or the dividers along the stretchout line.
7. Erect vertical lines at these points.
8. Project from the side view to obtain the height of each of these lines.
9. Connect the top points.

10. Dimension the top and side views.
11. Erase the unnecessary lines.
12. Retrace the object lines.
13. Letter the drawing.

PLATE NO. 14.

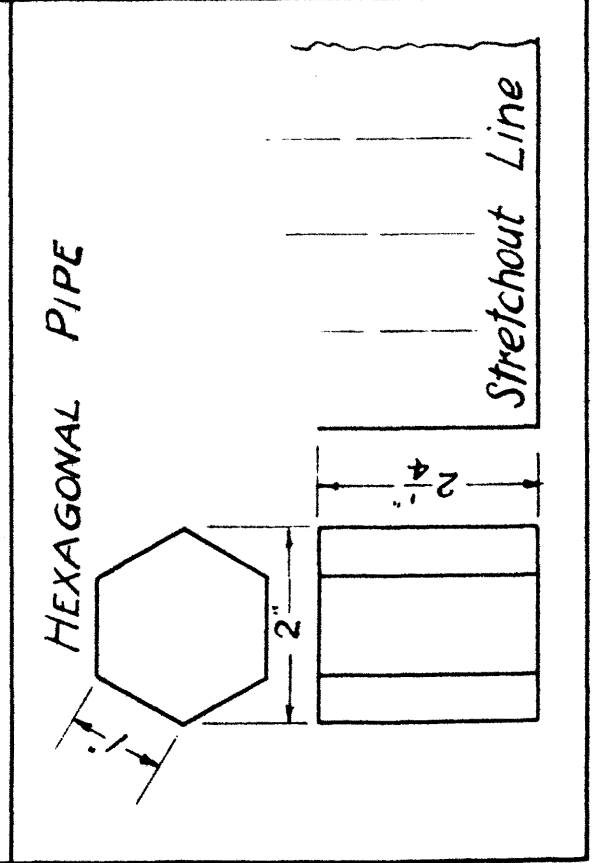
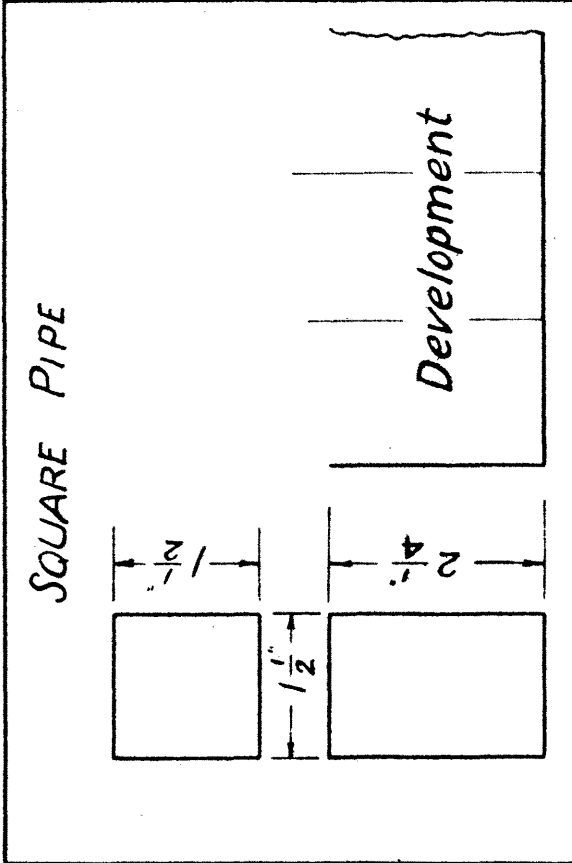
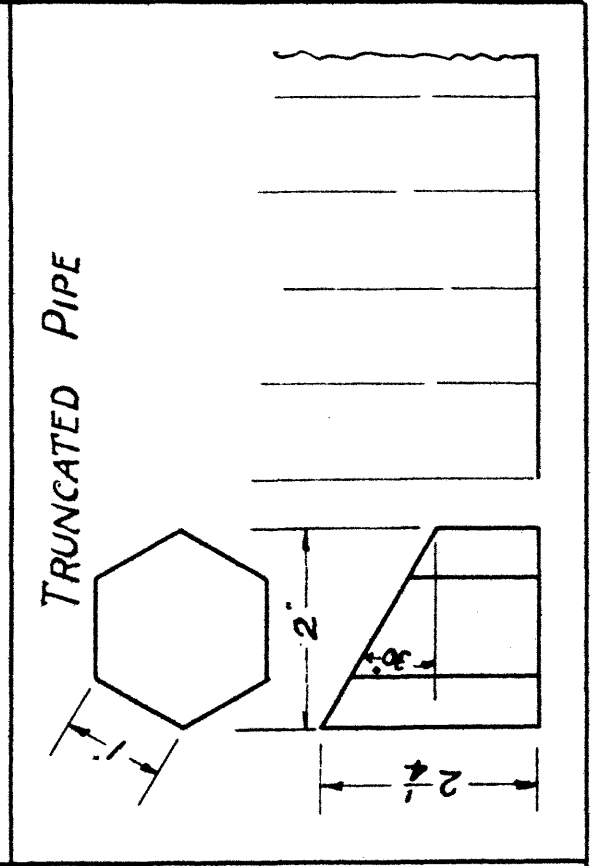
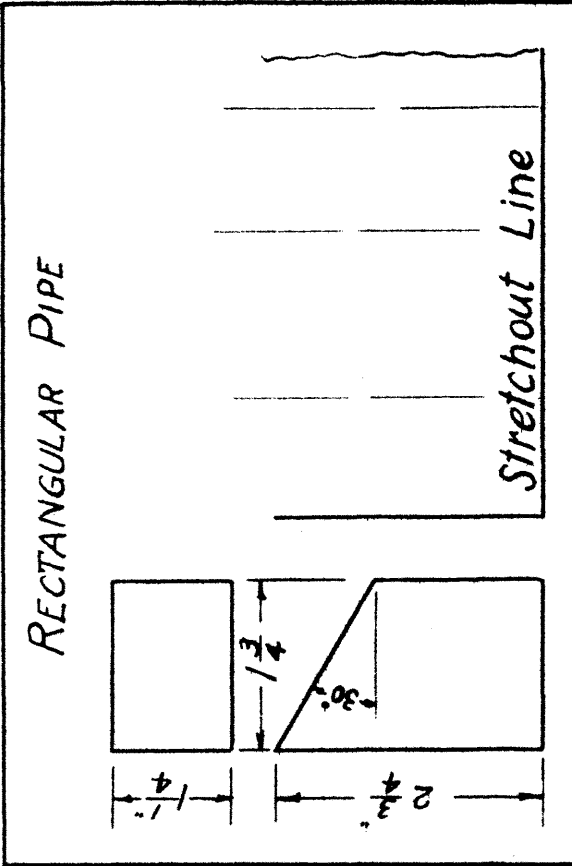


PLATE 15.

PROBLEM: Make a development of each of the problems on plate 15. The top and bottom views are not required.

APPLICATION: These are cylindrical pipes and cones such as the sheet metal worker has to lay out in pipe and funnel making.

PROCEDURE:

1. Lay out trim and border lines. Do not divide working space into four parts as each problem will require a whole sheet. Number the plates 15A, 15B, 15C, and 15D.

2. Make a sketch of the patterns.

3. Figure the spacing.

4. Draw top and side views.

5. Divide the top view into 12 or more parts by drawing lines through the center with the aid of the triangles.

6. Project these parts down across the side view.

7. Draw stretchout line.

8. With the dividers lay off on the stretchout line as many parts as there are on the top view. Remember the length of the pattern is the same as the circumference of the object.

9. Erect vertical lines at each point. In

the cones draw lines from each point to the center of the arc.

10. Project from the side view to get the correct height of each line. In developing the cones transfer the measurements with the dividers.

11. Dimension the top and side views.

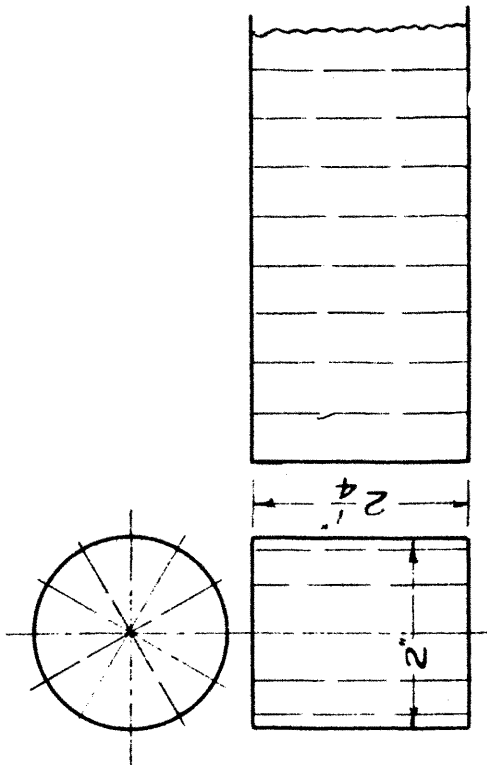
12. Erase extra lines.

13. Retrace the object lines.

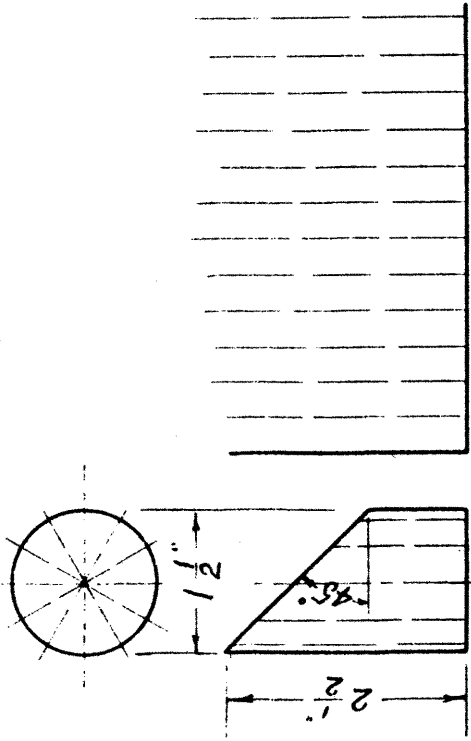
14. Letter the drawing.

PLATE NO. 15.

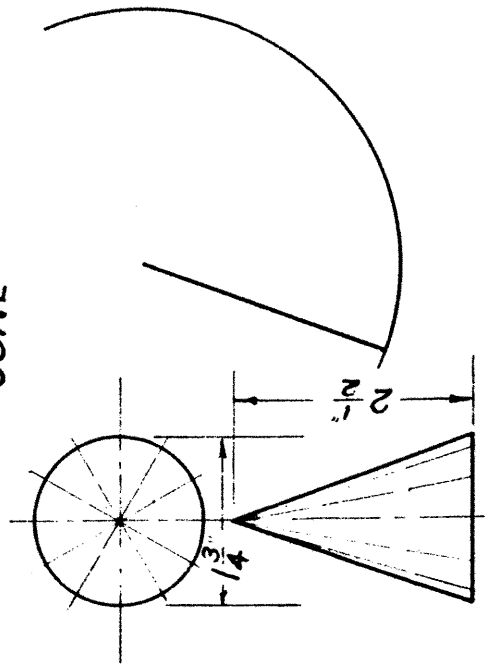
CYLINDER



TRUNCATED CYLINDER



CONE



TRUNCATED CONE

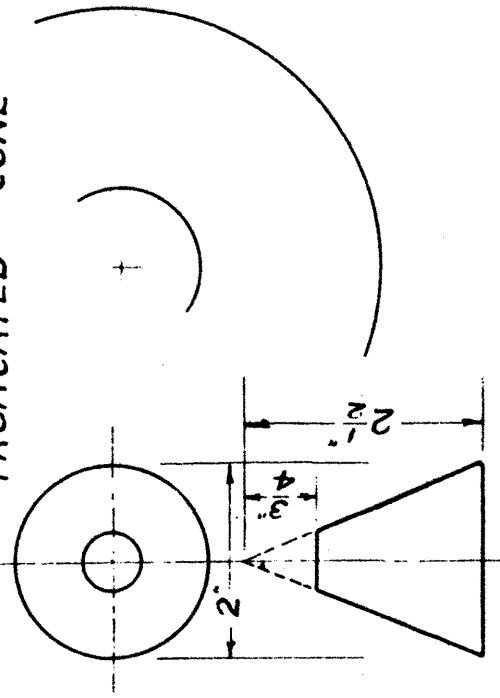


PLATE 16.

PROBLEM: Make a development of each of the objects shown on plate 16.

APPLICATION: These are objects with which you are familiar so no explanation is necessary.

PROCEDURE:

1. Lay out trim and border lines but do not divide the working space into four parts. It will take a whole sheet for each problem. Number the plates 16A, 16B, 16C, and 16D.

2. Sketch the pattern as you think it will be.

3. Figure the spacing.

4. In developing the funnel draw top and side views. A funnel is made up of two truncated cones, so there will be two patterns. Make these separately.

The scoop is made up of a portion of a cylinder and two truncated cones. Therefore there will be three patterns to this problem.

The elbow has four pieces and is developed the same as four cylinders. A sheet metal worker usually alternates the seams to save material. See page 74.

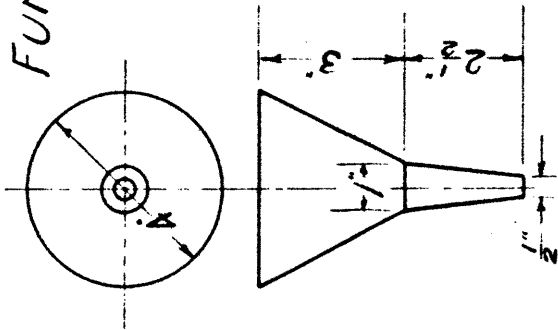
The dust pan has five sides which may be joined together in one pattern, but the handle which is a truncated cone should be made as a separate pattern.

5. Dimension the drawing.

6. Erase and clean drawing.
7. Retrace the object lines.
8. Letter the drawing.

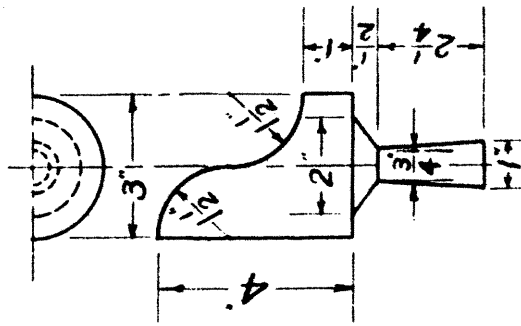
PLATE NO. 16.

FUNNEL*



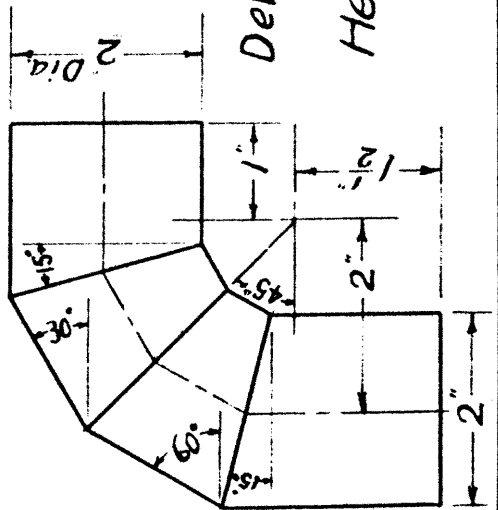
Develop
Here

SCOOP



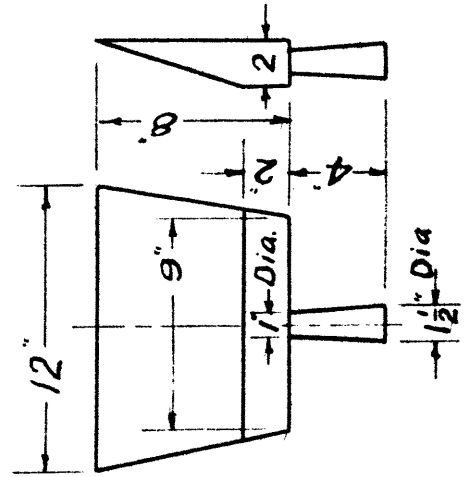
Develop
Here

4 PIECE ELBOW*



Develop
Here

DUST PAN*



Develop
Here

* FROM ERMELING, FISCHER & GREENE.

T R U E L E N G T H O F L I N E S

Before starting on the next drawing study this explanation carefully until you are sure you know what is meant by the true length of a line and how to find it.

The development of an object is, of course, the actual or true shape and size of the surfaces flattened out. Therefore the true lengths of all lines and surfaces must be shown on the pattern. Sometimes the top and side views of an object do not represent the actual size or shape. For instance the surface of the side view of the pyramid in plate 17 is a little more than 2 1/2" as it slants back away from the observer. In other words neither the top view of line OA nor the side view $O A^{11}$ show the true length. This presents the problem of finding the true length of a line. Here is the rule: Revolve or turn the top view of the line into a horizontal position. The TRUE LENGTH will then be found on the side view.

To further explain this, notice the pyramid on plate 17. We have revolved or turned the line OA to a horizontal position which is marked OA^2 . Of course O^1 is directly below O and A^1 is directly below A . When OA is revolved O remains in the same position but A moves out to A^2 . Therefore in the side view O^1 will remain in the same position but A^1 must move out to A^3 in order to keep directly beneath A^2 . Now OA^2 being in a horizontal position

TRUE LENGTHS

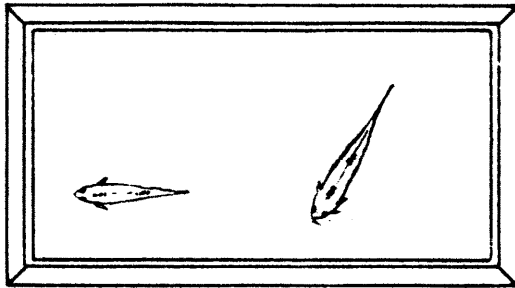


Fig. 28.

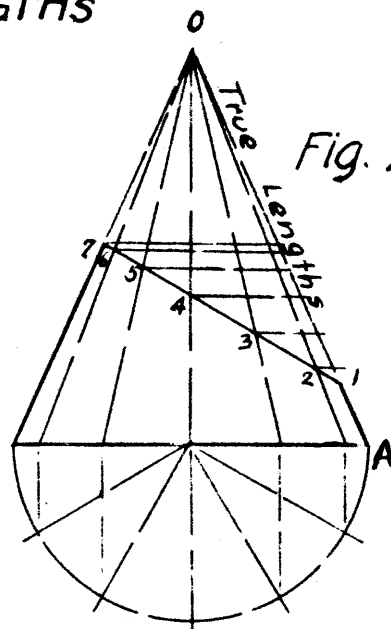
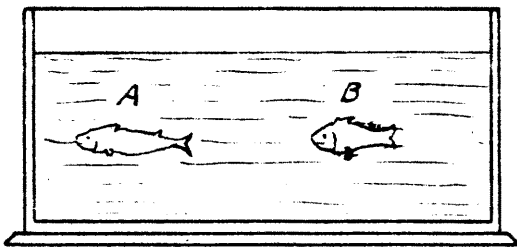


Fig. 29.

Which is the longer of the two fish A or B?

If fish B is turned so that top view is in dotted position does dotted side view show the true length?

A short method of finding the true length of O2, O3, etc. is to project them to line OA.

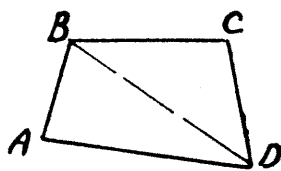


Fig. 30.

TRIANGULATION

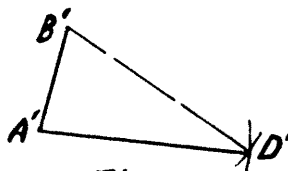


Fig. 31.

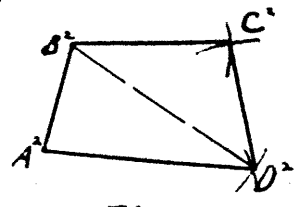


Fig. 32.

Divide object into triangles by line BD Fig. 24. Transfer line AB to desired place A'B' Fig. 25. With A' and B' as centers and radii AD and BD make intersecting arcs. Connect this point with A' and B'.

³
OA is the true length. This true length is the radius for the stretchout line of the pattern. See sketch on page 85. Can you answer the questions about the fish?

D E V E L O P M E N T B Y T R I A N G U L A T I O N .

Some problems are so irregular in shape that it is impossible to develop them except by a method called triangulation. The last two problems on plate 17 are not so difficult and might be developed the same as the first two but to learn the method let us make the development by triangulation. The side view of the hopper ADBC is an irregular shape and therefore hard to transfer to the pattern. But by dividing it into two triangles by the line AB, it becomes an easy matter to transfer each triangle to the pattern after the true length of each line is found. On page 85 is shown the method of transferring the triangles.

PLATE 17.

PROBLEM: Make a development of each of the problems on plate 17. You need not make a top and bottom for the hopper, or a top for a tin pan.

APPLICATION: Simple problems in sheet metal.

PROCEDURE:

1. Lay out trim and border lines but do not divide the working space into four parts as each problem will require a whole sheet. Number the plates 17A, 17B, 17C and 17D.

2. Make a sketch of what you think the developments will be.

3. Figure the spacing.

4. Draw top and side views.

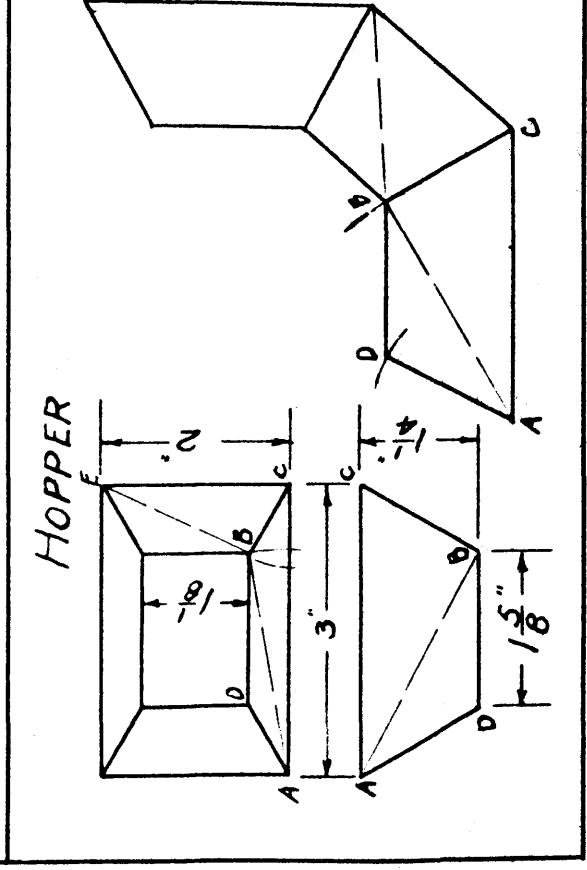
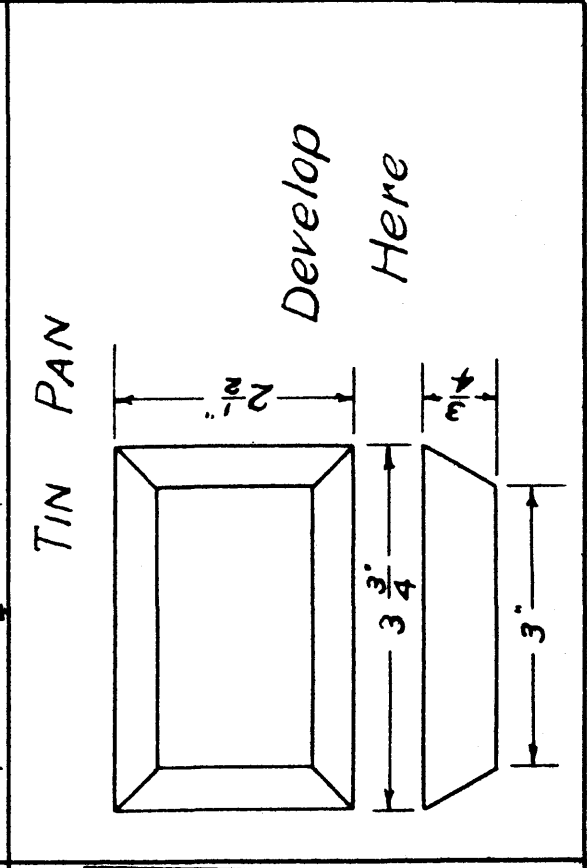
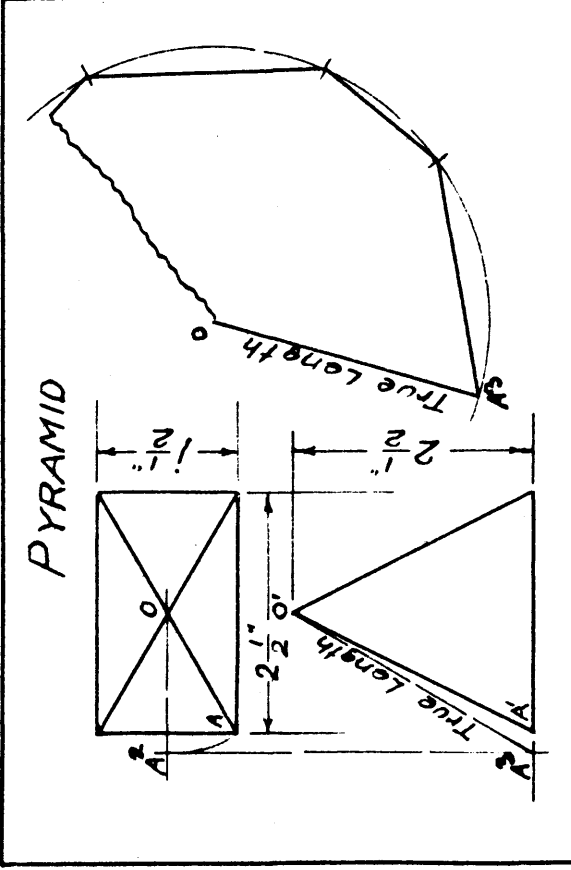
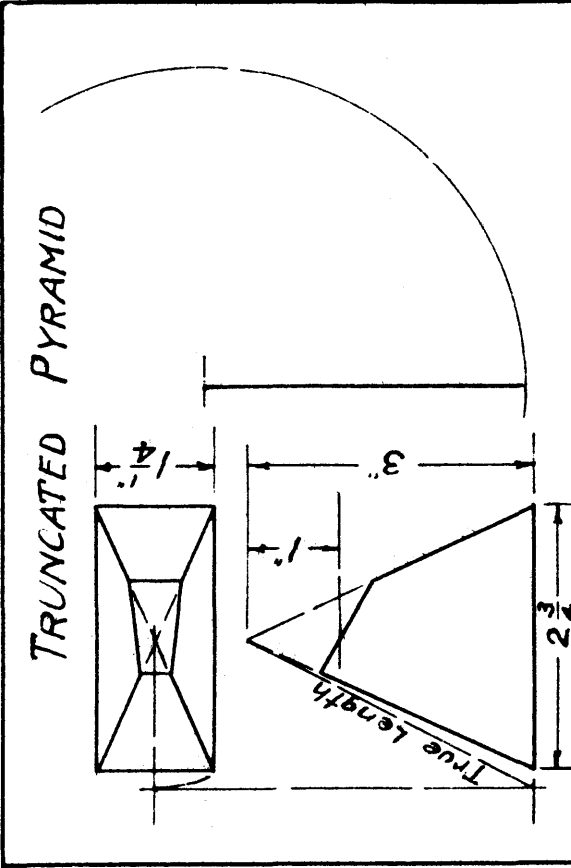
5. In making the pyramid and truncated pyramid find the true length of one of the edges as OA, then swing the arc or stretchout line. On the stretchout line step off the perimeter or distance around the top view. Draw lines from these points to the center. In the truncated pyramid the lines do not go all the way to the center. Find the true length of the missing part of the line and erase that much from the pattern.

In making the hopper and the pan divide the four sided figures into triangles as shown at AB. Find the true lengths of the lines and transfer the

triangles to the pattern as shown on page 85, Figs. 30, 31, and 32.

6. Erase and clean drawing.
7. Dimension top and side views.
8. Retrace object lines.
9. Letter the drawing.

PLATE NO. 17.



PROBLEM: Make a development of each of the problems on plate 18.

APPLICATION: A transition piece is used to join two pipes of different shapes or sizes. A three inch round pipe could be joined to a 6" square pipe by the transition piece in the first problem. In the second problem the transition piece could unite a rectangular pipe $3/4$ " by $1\ 1/2$ " and another rectangular pipe 1" by $1\ 5/8$ ".

A roof flange is used to support a cylindrical pipe on an inclined roof.

The chimney cap is used to prevent rain from entering a chimney.

PROCEDURE:

1. Lay out trim and border lines. Do not divide the working space into four parts. Each problem will occupy a whole sheet. Number the problems 18A, 18B, 18C, and 18D.

2. Make a sketch of each of the patterns.

3. Figure the spacing.

4. Draw the top and side views of each of the problems.

5. In the first transition piece divide the circle into 24 parts as shown so that the curveâ

part is divided into triangles of equal size. The remainder of the transition piece is already in triangles. After finding the true lengths transfer each triangle.

In the second transition piece the irregular shaped four sided surfaces must be made into triangles by diagonal lines. Find the true lengths and transfer.

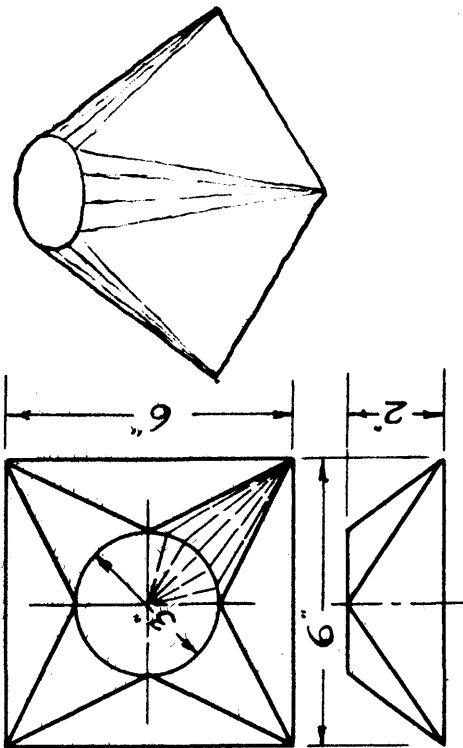
In developing the roof flange you may use the swing method that you used in the development of the cone. In finding the true lengths of each of the lines use the short method shown on page 85.

In the development of the chimney cap it is not necessary to draw the braces for the cap. Just develop the cap and the pipe that extends from the roof.

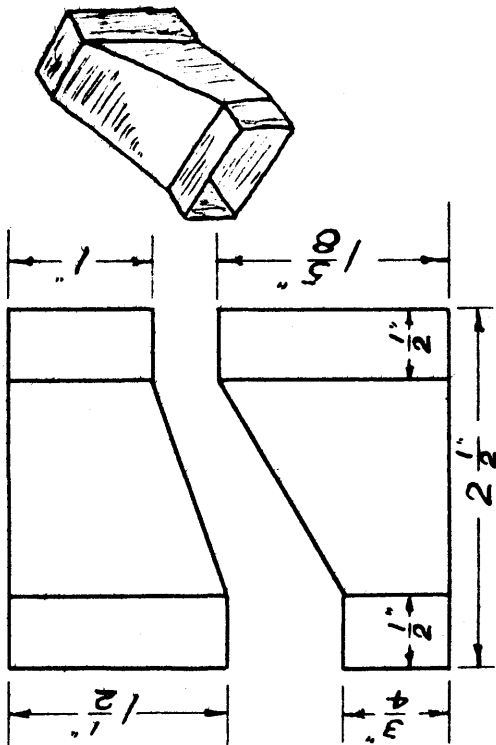
6. Erase and clean the drawing.
7. Dimension the top and side views.
8. Retrace the object lines.
9. Letter the drawing.

PLATE NO. 18.

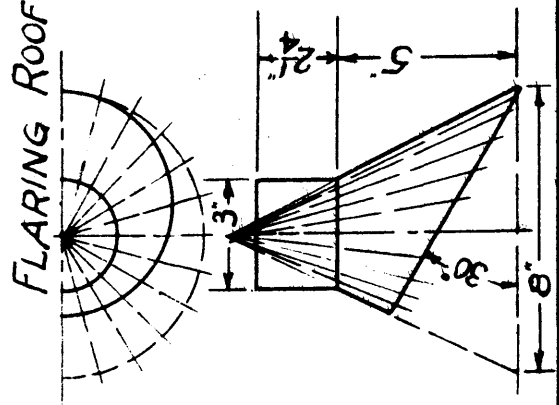
TRANSITION PIECE



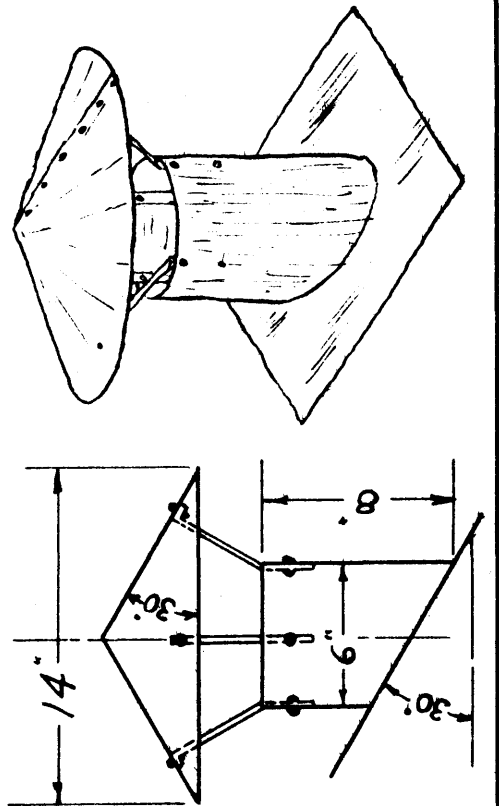
TRANSITION PIECE



FLARING ROOF FLANGE



CHIMNEY CAP



FROM ERMELING FISCHER & GREENE

G L O S S A R Y

1. HORIZONTAL - A line that is level or parallel to the horizon.

2. VERTICAL - A line that is at right angles to the horizontal or parallel to a plumb line.

3. INCLINED OR SLANT - A line that is neither horizontal nor vertical.

4. CURVED - A line that is constantly changing its direction.

5. PARALLEL - Lines that are always the same distance apart.

6. PERPENDICULAR - Lines or surfaces that are at right angles to each other. Perpendicular does not necessarily mean vertical.

7. RIGHT ANGLE - A square corner or an angle having 90 degrees.

8. ACUTE ANGLE - An angle less than a right angle.

9. OBTUSE ANGLE - An angle greater than a right angle.

10. RIGHT -ANGLED TRIANGLE - A triangle one of whose angles is a right angle.

11. EQUILATERAL TRIANGLE - A triangle which has three equal sides.

12. **SQUARE** - A figure which has four equal sides and four right angles.

13. **RECTANGLE** - A figure whose opposite sides are equal and parallel and whose angles are right angles.

14. **CIRCLE** - A curved line, every part of which is equidistant from a given point, called the center. A circle has 360 degrees and contains four right angles at its center.

15. **SEMI-CIRCLE** - Half a circle or 180 degrees.

16. **ARC** - Part of a circumference of a circle.

17. **CIRCUMFERENCE** - The distance around a circle

18. **DIAMETER** - The distance across a circle passing through the center.

19. **RADIUS** - The distance from the center of a circle to the circumference.

20. **TANGENT** - Any straight line that touches a circle at one point. It is always perpendicular to a radius drawn to that point.

21. **ELLIPSE** - A foreshortened circle. It is the figure that is formed by cutting a cylinder or cone at an angle to the axis.

22. **SPHERE** - A solid bounded by a curved surface every point of which is equally distant from a point within called the center.

23. **CUBE** - A solid bounded by six square sides.

24. **CYLINDER** - A solid bounded by a curved

surface and two opposite faces, equal in size, called bases.

25. CONE - A solid, one of whose surfaces tapers to a point and whose base is a closed curve.

26. PRISM - A solid having ends which are polygons of the same size and shape and connected by edges which are parallel.

27. PYRAMID- A solid whose base is a polygon and whose faces are triangles meeting at a common point.

28. TRUNCATED CONE, PYRAMID, OR PRISM - Solids cut by a plane either perpendicular or at an angle to the axis.

C O N C L U S I O N

The main objective of this study has been to set up a related course of study in drawing, with instruction sheets simple in nature but covering the fundamental principals of elementary drawing. It is not intended for a complete course but enough material has been compiled for one school year of work, one hour a day, five days a week. It is expected that a pupil in a trade course will continue this related study the following year when the course will branch into several lines more closely connected with the several trades.

It is the writer's opinion inasmuch as the fundamentals of drawing are the same, that pupils in trade machine shop, trade welding, trade electricity, trade woodwork, and sheet metal can be taught related drawing together in the elementary stage.

When a pupil has mastered this elementary course, he is then ready to proceed with a more advanced course which will pertain to the technical information of the particular trade he plans to follow.

Emphasis has been placed more upon sketching than upon technique of drawing so that the pupil will acquire some degree of skill in expressing his ideas in the shop. A minimum amount of lettering is required but enough to teach the value of a well lettered and well

dimensioned drawing. The greatest amount of time has been devoted to the relation of views in one, two, and three view drawings. It is this knowledge that enables a pupil to understand a blueprint.

With these things in mind the author has prepared this study to meet the requirements of his school in teaching mixed classes, and to convey to the pupil the commonly accepted medium of expression of thought among industrial workers.

B I B L I O G R A P H Y

BOOKS

- (1) Bennett, Charles A. Grammar Grade Problems in Mechanical Drawing. Peoria, Ill. The Manual Arts Press, 1916, p. 1 + 68.
- (2) Blessing, George F. and Darling, Louis A. Elements of Drawing. New York. John Wiley and Sons Inc., 1915, p. XVIII + 178.
- (3) Brahdy, Joseph. Blueprint Reading. New York. McGraw- Hill Book Co., 1909, p. 1 + 128.
- (4) Colvin, Fred H. Machine Shop Drawings. New York. McGraw-Hill Book Co., 1909, p. V + 176.
- (5) Ermeling, W. W., Fischer, F. A. P. and Greene, G. G. Mechanical Drawing. Milwaukee, Wis. The Bruce Publishing Co., 1924, p. 1 + 80.
- (6) French, Thomas E. Manual of Engineering Drawing. New York. McGraw-Hill Book Co., 1929 p. XV + 456.
- (7) French, Lester G. and Breath, William L. Drafting Room Practice. New York. Machinery's Reference Series, The Industrial Press, 1908, Vol. I.

- (8) Jordan, Harvey H. and Hollscher, Randolph.
Engineering Drawing. New York. John Wiley
and Sons Inc., 1928, p. XII + 394.
- (9) Kavanagh, M. R. and Beardsley, E. W. Systems
and Practice of the Drafting Room. New York.
Machinery's Reference Series, The Industrial
Press, 1909, Vol. III.
- (10) Rotmans, Elmer A. Instruction Sheets in Mechan-
ical Drawing. New York. Allyn and Bacon Co.,
1930, p. VI + 134.
- (11) Svensen, Carl Lars. Drafting for Engineers.
New York. D. Van Nostrand Co., 1927,
p. XI - 354.
- (12) Townsend, Clarence E. and Cleary, Stephen F.
Introductory Mechanical Drawing. New York.
John Wiley and Sons Inc., 1930 p. XI + 292.

PERIODICALS

- (13) Faber, John F. "Factors Determining a Course of
Study in Mechanical Drawing". Industrial
Education Magazine. p. 340. May 1925.

- (14) Faber, John F. "Placement of Views". Industrial Education Magazine. p. 245. Feb. 1925.
- (15) Faber, John F. "A Questionnaire on Mechanical Drawing Standards". Industrial Education Magazine. p. 23. July 1924.
- (16) Fullmer, L. D. "Helping the Beginner in Mechanical Drawing to Visualize". Industrial Education Magazine. p. 304. Feb. 1929.
- (17) Hanson, Elmer G. "Dimensioning Drawings". Industrial Education Magazine. p. 29. July 1926.
- (18) Hermann, C. C. "Points of Fundamental Knowledge Essential in a Young Draftsman". Industrial Education Magazine. p. 121. Oct. 1925.
- (19) Smith, James A. Jr. "Where Shall We Teach Sketching". Industrial Education Magazine. p. 263. Feb. 1927.

AN ABSTRACT

of the

THE S I S

M E C H A N I C A L D R A W I N G

A Proposed Course of Study in Mechanical Drawing
to Suit Vocational School Needs.

LIBRARY OF THE
STATE AGRICULT'L COLLEGE
FORT COLLINS, COLO.

Submitted by

W. A. SCOTT

In partial fulfillment of the requirements

for the Degree of Master of Science

Colorado Agricultural College

Fort Collins, Colorado

The writer of this thesis has prepared in detail a series of drawings and instruction sheets in mechanical drawing, which he believes includes the fundamentals set forth in simple language, capable of being understood by the average boy of high school age.

The problems in this course have been tried out in the author's classes and through much experimentation were accepted as typical problems in teaching the common fundamentals of drawing. It has proved its worth as a convenience in teaching classes in mechanical drawing in a way that removes much of the burden from the instructor and induces in the student a desire to produce the results expected from pupils of this age. The subject matter, based upon simplicity and interest, with a variety of concrete drawings related to the shops, should act as an incentive to the pupil to progress with his work in a natural way.

In the problem is stated the objectives of this study and the need of such a course in drawing in the Ponca City, Oklahoma, Vocational School. Mixed classes have made it impossible to teach courses in blueprint reading at the same time drawing is taught but if the ability of the student, his application to his work, and his execution of the drawings are all taken into

consideration by the instructor when the grades are given, fairness to the class in this type of instruction will be attained.

In the introduction is stated the specific purpose of a drawing course of this nature which is to train the pupil to visualize and reproduce simple objects by sketches and drawings, to read and understand drawings, and to teach an appreciation of drafting. The value of being able to draw, sketch, and read blueprints is emphasized. The ease of teaching mixed classes by means of instruction sheets is also pointed out. The progress of the student is not retarded by other members of the class as individual instruction must necessarily be given.

The first part of the course is devoted to an explanation of the use of equipment of a drafting room in order to familiarize the pupil with the instruments used in drafting. Names of the various instruments are mentioned along with the correct methods of use.

An explanation of the correct procedure in laying out a drawing sheet follows. Some time is given to the correct and incorrect methods of placing dimensions and the value of a well dimensioned drawing.

The alphabet of lines is illustrated to show the relation of different weights and kinds of lines used in drawing.

Before actually beginning the drawings a lettering plate is made, not only to teach the value of good letters, but to give some practice in using the instruments in laying out a plate.

The theory of orthographic projection is taken up next, and shows the relation of the views to each other and the method of projection. Orthographic sketching, which parallels the mechanical drawing throughout, is explained at this point. Each drawing plate is to be preceded by a freehand sketch in the belief that it will aid materially in clarifying the relation of the views.

Following this are the plates with the instruction sheets which instruct the pupil in spacing and laying out the views. Simple objects that illustrate the desired points in drafting are used. On the instruction sheet the problem is first stated, then the application made, and then the procedure to follow in making the drawing. The writer believes that the application of the problem to be drawn is of great value in creating and maintaining interest in the course.

Straight line drawings are first presented, then circles and curves, and following that a combination of straight lines and curves. Several plates of sectional views are given, both full and half sections.

The theory of the auxiliary view and the

method of projection to obtain it is given along with several plates involving that type of view.

The remainder of the plates pertain to the development of simple objects found in the sheet metal shop.

The conclusion states that this is not intended for a complete course nor a technical course in drafting but only the first year or elementary step where the pupil may be taught the fundamentals of drawing regardless of the trade course he is taking.

The writer has prepared this course of study to meet the requirements of his school in teaching mixed classes and to convey to the pupil the commonly accepted medium of expression of thought among industrial workers.