ELEMENTS OF GENERAL DRAFTING

FOR

MECHANICAL ENGINEERS

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PREFACE.

THIS book is intended, by a representative course of progressive exercises found in the two hundred hour Course in Drawing in the first part of the book and by a systematically arranged compilation of precept found in the Manual of Drawing in the second part of the book, to convey the essentials of modern conventional drafting as practiced by the general profession of mechanical engineering.

The Course in Drawing is divided for convenience into five grades: The drawings of the first grade are to be practically copies of the four assigned plates and are to be made from detailed instructions in procedure.—The object of the work in this grade is to give the student the science of the elementary principles of drafting and instruction in the use of the materials and instruments and in the technic involved. The drawings of the second grade are to be detailed working drawings made from sketches of machine parts.—One of the most important acquirements for a draftsman is to be able to sketch machine details neatly, accurately and with facility; and, for a student, hardly anything is more interesting and instructive than working from something that has definite form and utility and, incidentally, a large amount of the form of good design may be acquired by absorption. The drawings of the third grade are to be assembly drawings made from sketches of machine parts. The drawings of the fourth grade are to be detailed working drawings and detailed assembly drawings from plates which are copies of commercial drawings.—It is excellent practice for a student to analyze drawings of standard machines and their parts in order to acquire facility in picturing in his mind the shape and proportions of the piece drawn. The drawings of the fifth grade are foundation drawings with their bolt templets, floor plans, and Patent Office drawings.—These drawings are in a distinct class by themselves, and conventions employed in their execution should be understood by all well equipped draftsmen, and a knowledge of the technic involved in Patent Office drawing is invaluable for any one whether he be layman or draftsman.

The drawing course has been extended by the addition of plates of complete detail drawings of a 15″ Pillar Shaper which are to be used in making assembly drawings. These plates are copies of a standard commercial machine

The Manual of Drawing describes the selection, use, and care of materials and instruments and all the essential technic employed in the execution of a complete commercial drawing. The object of the Manual is to put into definite form a single and standard drafting room system which shall be the average of the systems used by representative manufacturing concerns. For this purpose, data have been acquired from one hundred and thirty of the largest concerns in the United States in various lines of business.

Illustrations by line-cuts and half-tones are freely distributed through

the Manual to make clear the important points discussed in the text. In addition, twenty-one 9×12 zincograph plates are bound into the back part of the book to accompany the Course in Drawing.

An 8×11 pocket in the inside of the back cover of the book is provided for holding loose sketches and any detached material that may be used in connection with the book.

This book is specifically written for the use of the students in drawing in the present Sophomore class of Sibley College, for students in manual training schools, trade schools, and technical colleges, and for the amateur draftsman who is serving his apprenticeship.

The authors desire to thank all the manufacturing concerns who have so kindly lent assistance by contributing drawings and data.

The first nineteen zincograph plates in the back part of the book were made from copies of drawings executed by Mr. Freeman.

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ITHACA, N. Y., September, 1904.

COURSE IN DRAWING.

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INTRODUCTION.

SUPPLIES REQUIRED FOR THE COURSE IN DRAWING.

6 sheets 18×24 Keuffel & Esser's Duplex (or equivalent) Drawing Paper.
6 sheets 18×24 Crane's (or equivalent) Bond Paper.
1 sheet 18×24 Paragon (or equivalent) Drawing Paper.
2 sheets 18×24 Imperial Tracing Cloth.
1 sheet 10×15 two-ply Bristol Board.
8×10 book of Cross Section Paper.
½″×20″×26″ soft pine Drawing Board.
26″ pear-wood T Square, head fixed with five screws.
10″ 30°×60° transparent Triangle.
7″ 45° transparent Triangle.
12″ triangular Boxwood Scale (Sibley scale), graduated with scales as follows: ⅛″, $\frac{1}{10}$,″ ¼″, ⅜″, ¾″, ½″, 1″, 1½″, 3″, 6″, and 12″ to the foot.
5½″ Compass with fixed leg for needle point, detachable pencil- and pen-legs and lengthening bar.
5″ Dividers with hair-spring adjustment.
Bow Pen, Pencil and Spacer for scribing not over 1½″.
5″ Unhinged Ruling Pen.
A pocket case for instruments.
Scale Guard.
Beam Compass Clamps and Beam.
Transparent Logarithmic Spiral Curve—the equivalent of Keuffel & Esser's, Catalog No. 1861.
1 set of Hardtmuth's HHHHHH leads for Compass.
1 HHH and 1 HHHHHH Hardtmuth's Koh-i-noor Drawing Pencil.
Good Pencil Pointer. Sandpaper pad or 10″ float file.
Ink Eraser—Faber's Typewriter.
Pencil Eraser—Tower's Multiplex.
Package of 1 oz. Copper Tacks or a card of small head Thumb Tacks.
Arkansas Knife Oil Stone.
Pen Staff and ball-pointed Writing Pen.
Bottle of black waterproof Drawing Ink.
6″ Machinist Scale.
6″ Caliper.

The following Special Instruments of better quality, having improved and useful attachments, can be substituted for any of the above when they have identical use:

26″ Mahogany T Square, head fixed with five screws to tapered blade, ebony lined head and blade, and with working edge of blade beveled. (Get no transparent lined edges.)
8″ transparent combination Triangle, D. J. Kelsey, maker, New Haven, Conn.
3 12″ sheet steel, nickel plated, Brown & Sharpe Scales with the necessary graduations as found above on the Boxwood Scale.
5″ first quality, and first class designed hinged Ruling Pen with inserted pricker point in handle.

PROOF AND PREPARATION OF INSTRUMENTS.

Wipe all instruments clean with a lintless rag—chamois skin is best.

Prove the straightness of the working edge (the left hand edge is the working edge for a right hand person.—**Fig. 1.***) of drawing board by applying a standard straight-edge or the edge of a T square blade if it has been proved straight.

Prove the top surface of the drawing board for convexity or planeness by applying a standard straight-edge, or the edge of a T square blade to its surface.

Prove the squareness of the working edge of the drawing board to its lower edge by the following method: First, place T square head against working edge of board and draw two parallel lines, one about one inch from the upper edge of board, and the other about one inch from the lower edge of board. Second, with the T square head placed against the working edge of board, mark off on the T square blade a point whose distance from the edge opposite the working edge of board will be about the length of the T square head. Third, with the T square head placed against the working edge of board, sight and mark off from the point on the T square blade a corresponding point on each of the parallel lines. Fourth, place the T square head against the lower edge of board and draw a line through the point marked off on one of the parallel lines and note if it passes through the corresponding point on the other line. Absolute squareness is unnecessary.

Prove the straightness of the upper edge (the only edge used) of the T square blade by the following method: First, draw with it a line. Second, turn it end for end and place the edge of the blade to exactly coincide with each end of the line which was drawn. Third, draw another line. Fourth, note the coincidence of the lines drawn.

Prove the straightness of the T square head by applying a standard straight-edge or the long side of a triangle.

Prove the 90° angles of the triangles by the following method: First, place the short side of the triangle against the edge of the T square blade and draw a line with the 90° side of the triangle. Second, turn the triangle over and with same side of triangle draw another line directly over the first and note the coincidence of the lines.

Prove the 45° angles of the triangle by the following method: First, place one of the short sides of the triangle against the edge of the T square blade and draw on paper with a sharp and hard pencil a line through a point with the 45° side of the triangle. Second, place the other short side of the triangle against the edge of the T square blade and draw another line through the same point with the 45° side of the triangle. Third, draw a horizontal line across the extremities of the lines just drawn. Fourth, measure with dividers the inclined lines and note the isosceles triangle.—This should follow the proof of the 90° angle.

Prove the 30° and 60° angles of the triangle by the following method: First, place the short side of the triangle against the edge of the T square blade and draw a line through a point with the 60° side of the triangle. Second, turn the triangle over and with same side of triangle draw another line through the same point. Third, draw a horizontal line across the extremities of the lines just drawn. Fourth, measure with dividers the inclined lines and note the equilateral triangle.

Prove the scale by the following method: First, mark off on a straight line drawn on paper its equal subdivisions.—**Fig. 4.** Second, turn the scale end for end and note the coincidence of the equal subdivisions.

Set into the pencil leg of the compass a HHHHHH "lead" and adjust it to project not more than ¼". Sharpen the point of the compass "lead" to an edge that is slightly elliptical. Do this by moving the pencil back and forth for a short distance across the file or sandpaper while oscillating it about its axis. Set needle point into leg of compass and adjust it to the pencil point so that, when both are perpendicular, the shoulder of the needle point and point of the pencil will touch the paper.—**Fig. 9.**

If needle points of compasses, dividers, or bow instruments are blunt from ordinary wear, they should be ground on an oil stone until they

*Figures are found in Manual.

are sharp enough to offer a slight resistance to being withdrawn from the paper into which they are stuck under very slight pressure.

Set needle points and "lead" into bow instruments in the same manner as described for the compass.

Repair the ends of the nibs of the ruling pen by the following method: First, clean the pen thoroughly. Second, hold the pen to the light or over a piece of white paper and close the nibs until they are about to touch. Third, hold the pen with its axis perpendicular to the plane of the knife oil stone and move the stone over the points of the nibs until an arc of not over $\frac{1}{32}''$ radius is rounded on the points.—**Fig. 6.** Fourth, open the blades as wide as possible. Fifth, hold the axis of the pen at right angles with a line along the length of the stone and, with one blade at an angle of about 30° with its plane surface (**Fig. 7**), move the point of the nib about one half inch back and forth along the stone while the pen is being slightly oscillated about its axis to maintain the roundness on the back and grind the point of the nib to an edge as sharp as a pocket pen-knife.—This operation should be performed on each nib separately and with extreme care to avoid grinding off the end of a nib, thus making one nib shorter than the other. Sixth, rub lightly, with the thin edge of the stone, the inside surface of each nib to remove any possible burr. Seventh, test the pen thus: clean nibs thoroughly; close the nibs until they are about to touch; fill with ink to a depth of not over $\frac{3}{16}''$; hold the pen with its axis slightly inclined to the right and in a plane perpendicular to the plane of the paper and draw it lightly from left to right over drawing paper until the ink is exhausted (**Fig. 8**) and note that the pen never fails to make a line while it is moving across the paper and that the line is clean cut.

If the ink in the drawing pens refuses to flow, draw the pen once or twice across the little finger and, if this does not avail, clean the pen and refill.

Clean all pens the instant they cease to be used.

Sharpen both ends of both pencils, one end of each to a cone whose apex is slightly blunted, and the other to a wedge whose sides are flattened $\frac{3}{8}''$ from the point and whose edge is slightly elliptical but keen. The "lead" should project from the wood not less than $\frac{3}{8}''$ and not more than $\frac{1}{2}''$.—**Fig. 5.**

PRINTING.

Plate I.—Standard Printing, Lines, Form of Bill of Material, Form of Title.

Tack to the drawing board a sheet of 18×24 Paragon drawing paper with smooth side up.

Print in title shown on Plate I.

All letters and figures used on commercial drawings must be of a simple type, plain, of uniform height and composed of lines of uniform width and of the same width as the visible lines of the object shown on the drawing. The inclined straight line printing shown in the title on Plate I is recommended for use on the drawings, as that type is the simplest, plainest, and usually more easily done than any other type.

Draw parallel guide lines with the pencil before printing words and figures.

The writing pen, when used for printing, should be gripped not farther from its point than $\frac{1}{2}''$. The farther away the grip is from the point the more unsteady will be the pen and consequently the more irregular will be the printing.

Crowd the letters of a word close together and space the words.

Make the initial letters of all words except prepositions and conjunctions a little taller than the others.

Do not make figures or letters less than $\frac{1}{16}''$ in height.

FIRST GRADE.

Make finished inked drawings of Plates II, III, IV, and V. These drawings should be exact copies of the arrangement of every single detail within the margin lines of the plates.

Plate II.—Driving Stud, Worm, and Carriage Feed Screw and Plunger.

Tack to board sheet of 18×24 Paragon drawing paper with the rough side up.

Draw with HHH pencil horizontal and vertical lines to divide the sheet into one 12×18 rectangle on the left and into two 9×12 rectangles on the right.

In general draw all horizontal lines with the upper edge of the T square blade, and all vertical lines with the left hand edge of a triangle manipulated in combination with the T square.

Draw all lines with the **wedge end** of the **pencil.**

Draw all lines from **left to right** with the pencil slightly inclined to the right. The **principle is to drag** and not to push the pencil.

DRAWING OF DRIVING STUD.

Penciling.

Use HHH pencil for penciling drawings which are to be finished in ink.

Commence at the top and left hand side of a drawing and work to the right and down the drawing.

Draw border lines ½″ from the sides of rectangle.

Draw lightly a rectangle enclosing space for title.

Draw lightly a rectangle enclosing space for bill of material.

Draw an unbroken line for center line of stud.

Mark off directly from the full size **scale at one setting (Fig. 4), with** the **wedge end** of the **pencil,** points on the center line through which all the vertical lines of the stud and attached parts will pass.—Allow ¼″ for the diameter of split pin and ⅛″ for groove on right of collar.

Draw light vertical lines of indefinite length through points.

Mark off on each vertical line in order, commencing at the left, the points through which the horizontal lines cut the vertical lines.—Draw in proportionally the horizontal lines for the split pin.

The distance across the corners of he nut may be conventionally assumed as twice the diameter of its hole, and the distance across the middle face as a little less than the diameter of its hole.—**Fig. 17.**

Draw horizontal lines through points.

Draw freehand with light lines, commencing at the left, all arcs, extension lines with their included dimension lines and dimensions, notes, thread lines, and section lines taken separately in their order.

Inking.

Keep bottle of ink in drawer, not on desk.

Make the width of lines in the printing and the width of the different types of lines used in the drawing correspond with those on Plate I.

Draw arcs of from $\frac{1}{16}$″ to ½″ radius with the bow pen.

Fill drawing pens and writing pens **not deeper than** $\frac{3}{16}$″ and wipe perfectly clean the moment they cease to be used. A good **wiping-rag is an essential.** It should be free from lint. A good rag is usually found wrapped around the bottle of Higgins' prepared drawing ink. Tracing cloth soaked free from glazing makes a very desirable wiper.

Arcs on top of split pin are tangent to its sides, and the one at the bottom is made with a slightly larger radius. The small arcs and fillets on stud and washer are made with a radius of ⅛″.

Draw arcs of more than ½″ radius with the compass legs perpendicular to the plane of the paper. The compass should **never** be **steadied by** holding one of its **legs,** but it should be **gripped by the cylindrical handle** at the yoke and turned in a right hand direction or clockwise with a very slight inclination in the direction to which the compass is moving.—**Fig. 9.**

The large arc on the end of stud is drawn with a radius of 2″.

Take the radius of the arc directly from the scale by holding the compass parallel with its plane surface, with the needle point shoulder and pen-point just touching its edge.—**Fig. 10.**

Arcs on nut are drawn as follows: arc on middle face is drawn with a radius equal to the diameter of hole, with its center on center line, and tangent to the bounding line of nut.

Each of the end arcs is drawn through two points: one, at the point of intersection of the middle arc and the bounding line between the middle and end faces; the other, at the point of intersection of an imaginary center line through face and the bounding line of nut.—The radius of arc and its center should be found by inspection.—**Fig. 17.**

Draw with the ruling pen all the horizontal and vertical visible lines of the object in their order.

Draw 45° chamfer lines on corners of nut.

Draw visible thread lines on end of stud.

Space thread lines about as shown on the plate with a very slight inclination.

Parallel inclined lines are drawn with one straight-edge held fast and another sliding along it at the proper inclination.—**Fig. 3.**

Draw horizontal, vertical, and inclined invisible lines (this includes thread lines) of object in their order.

Make **dashes** in **invisible lines** of object short, of **exactly equal length,** and **almost joining.—Plate I.**

Draw center lines, extension lines, and dimension lines in their order.

Make with the writing pen the arrow heads, dimensions, notes, and witness lines. Make the arrow heads narrow and long, not broad and short.

Draw section lines with the 45° triangle placed against T square blade. Space the lines not over $\frac{3}{32}$″ and not less than $\frac{1}{16}$″ apart.

Print **identifying letters not less than $\frac{5}{16}$″ in height.**

Pencil lines of bill of material.

Ink outside lines, the top horizontal division line, and all the vertical division lines of bill of material to the same width as the visible lines of object, and the remainder of the horizontal lines to the same width as any auxiliary line, as, center line, extension line, etc.

Print bill of material.

Print title.

Print index marks in lower left hand corner.—Make same size as identifying letters.

Draw border lines to the same width as the visible lines of object.

DRAWING OF WORM.

Penciling.

Draw border lines.

Block out space for bill of material and title.

Draw center line of worm.

Mark off on center line the points through which the end vertical lines pass.

Draw indefinite lines through points.

Mark off the points on the left vertical line through which all horizontal lines will pass, including the top and bottom lines of teeth and a line through the middle of the teeth on each side. The depth of tooth is one half the pitch.

Mark off points $\frac{1}{2}$″ apart on the horizontal lines passing through the middle of teeth.

Draw 75° lines through the points on the middle lines of teeth and note that a tooth is opposite a space.

Draw 75° lines by holding fast the T square blade and 45° triangle and placing the 30° and 60° triangle against the 45° triangle.—**Fig. 2.**

Draw outside inclined lines of teeth connecting their corners.

Draw freehand the broken visible line of the object.

Draw freehand the extension, dimension, and section lines in their order.

Inking.

Draw visible and invisible lines of the object (the visible line representing the broken surface should be drawn with ruling pen), center, extension, and dimension lines in their order.

Make arrow heads, dimensions, notes, and witness lines.

Draw hatch lines.

Print identifying letter.

Make bill of material, title, and index marks.

Draw border lines.

DRAWING OF PLUNGER AND CARRIAGE FEED SCREW.

Penciling.

Draw border lines.

Block out space for bill of material and title.

Carriage Feed Screw.—

Draw center line.

Mark off on the center line the points through which all vertical lines in the side view pass.

Draw indefinite vertical lines through points.

Mark off on vertical lines the points through which the dimensioned horizontal lines pass.

Draw dimensioned horizontal lines.

Draw square in end view.

Draw circles in end view.—Take compass radii directly from side view.

Draw arcs of circle bounding square in end view.

Draw remaining horizontal lines of square in side view.

Draw key in side view proportional to size shown on plate.—The arc is less than a semi-circle.

Draw key in end view.—Key is about $\frac{3}{8}''$ wide.

Mark off points on top and bottom line of square threads directly opposite to each other and $\frac{1}{8}''$ apart.

Draw inclined lines through points and note that a tooth is opposite a space.

Draw bottom lines of teeth at a depth equal to the width of tooth.

Draw diagonal lines and the right hand line on bearing.—**Fig. 13.**

Draw freehand the remaining arcs and fillets and broken lines.

Draw freehand the extension, dimension, and section lines in their order.

Plunger.—

Draw center line.

Mark off on the center line the points through which all vertical lines pass.

Draw vertical lines of indefinite length through points.

Mark off on vertical lines the points through which horizontal lines pass.

Draw horizontal lines.

Draw top and bottom horizontal lines for center lines of spring coils $\frac{1}{8}''$ from body of plunger.

Mark off on top and bottom center lines centers of coils $\frac{3}{10}''$ apart.—The center of a coil on one side of plunger should be directly opposite the middle of the space between two centers on the other side of plunger.

Draw circles of coils with $\frac{1}{8}''$ radii.

Draw inclined lines tangent to circles.—Tangent lines incline in opposite directions on back of plunger.

Draw freehand the arcs and broken lines.

Draw freehand the extension, dimension, and section lines in their order.

Inking.

Plunger and Carriage Feed Screw.—

Draw small and large arcs in their order.

Draw horizontal, vertical, and inclined visible lines in their order.

Draw invisible lines.

Draw the diagonals and right hand line on bearing of feed screw.—Make fine lines.

Draw center, extension, and dimension lines in their order.

Make arrow heads, dimensions, notes, and witness lines.

Draw hatch lines of plunger and adjacent spring oppositely inclined.

Print identifying letters.

Make bill of material, title, and index marks.

Draw border lines.

Submit sheet of drawings to instructor.

Cross-check drawings with another draftsman.—**Every drawing should be thoroughly checked before it is filed as finished.** All mistakes found on the drawing after it has been finally filed should be charged against the checker. The original draftsman should make all changes and corrections.

Check drawings by steps.—

1. Note lines of object.
2. Note dimensions and working notes.
3. Note that the dimensions are to scale.
4. Note arrow heads.
5. Note accents, as, inch marks, foot marks, and degree marks.
6. Note center lines.

DRAWING OF LAYOUT OF PIPING.

Plate III.—Layout of Piping.

Tack to board a sheet of 18×24 brown detail paper.

Penciling.

Follow the same general order as instructed for penciling drawings on Plate II.

General hints on penciling lines of object.—

A piping layout is conventionally shown and may be drawn to approximate dimensions.

Commence at the top and left hand and work to the right and down the sheet.

Make piping drawing double the size shown on the plate.

Draw the tee fitting complete, then the connecting pipes, R and L coupling, pipe, globe valve, and so on in order.

Mark off distances on the drawing by doubling the distances transferred directly by the compass from the plate.

Inking.

Follow the same general order as instructed for inking drawings on Plate II.

The lines of object for "Acid Tank" are adjacent part lines.—**Plate I.**

Cross-check drawing.

DRAWING OF 5″×30″ PULLEY.

Plate IV.—5″×30″ Pulley.

Tack to board sheet of 18×24 brown detail paper.

Penciling.

Follow the same general order as instructed for penciling drawings on Plate II.

Hints on penciling lines of object.—

Make drawing to the scale: 6 ins.=1 ft. (Sibley scale is marked 6″ to the foot on the full scale).

In left hand view—

Mark off on center line points through which vertical end lines of hub and rim pass.

Mark off on center line a point midway between end lines of hub.

Draw indefinite vertical lines through points.

Mark off on vertical lines the points through which all the horizontal and the inclined horizontal lines of hub pass with the exception of lines of keyway.

Draw horizontal and inclined horizontal lines of hub.

Draw outside circular arcs of rim with a radius six times the width of rim.

Draw arcs of long radii with beam compass. If compass clamps are used, the compass legs should be gripped as close to their points as possible.

Mark off, on end lines passing through rim, points through which the inclined horizontal lines of rim pass.

Draw inclined horizontal lines of rim.

Draw arcs for beads on rim and hub with radii equal to semi-minor axes of respective ellipses in right-hand view.

Draw inclined lines tangent to bead arcs on rim and hub.

In right hand view—

Draw the three circles at rim.—Middle and inside circles represent under edge of rim and bead respectively.

Draw the two circles at hub.—Larger circle represents outside edge of hub.

Draw a light auxiliary circle to represent outside of bead on hub.

Draw light auxiliary lines 60° apart to represent center lines of arms.

Draw ellipses by use of circular arcs. When the major is twice the length of the minor axis, the side arcs of the ellipse can be drawn with radii which are three quarters the length of the major axis. The end arcs should be drawn tangent to the side arcs and pass through the end points of the major axis.—**Fig. 27.**

Draw arm tangent to ellipses and the remaining arms to correspond.

Draw freehand the fillets tangent to bead circles at top and bottom of arms.

Draw arcs of circles at top of arms about to the proportion shown on plate.

Draw keyway in both views.

Inking.

Tear off wrinkled edge and tack to board a sheet of 18×24 tracing cloth with rough side up.

Rub tracing cloth with blotter or a little chalk dust and brush off.

Follow the same general order as instructed for inking drawings on Plate II with the addition that "f" marks should be put on with the notes.

Cross-check drawing.

DRAWING OF 1½ P. 76″ P.D. 8″ FACE GEAR—SELF-OILING BUSHING.

Plate V.—1½ P. 76″ P.D. 8″ Face Gear—Self-oiling Bushing.

Penciling.

Tack to board a sheet of 18×24 brown detail paper.

Follow the same general order as instructed for drawings on Plate II.

Hints on penciling lines of objects.—

Make drawing to the scale: 3 ins. = 1 ft. Select graduations on the scale where one 3″ length is divided and marked in inches and the remaining 3″ lengths are marked in feet.

In top view—

Mark off on center line points through which horizontal end lines of hub and rim pass.

Draw indefinite lines through points.

Mark off on end lines of hub points through which all vertical lines of hub will pass, including lines bounding recess in hub and the bead on hub.

Draw indefinite vertical lines through points of hub.

Mark off on end lines of rim points through which all vertical lines of rim pass including bead on rim.—Make depth of teeth $1\frac{5}{16}$″.

Draw indefinite vertical lines through points of rim.

Mark off the width of beads on their vertical bounding lines on hub and rim.

Draw inclined horizontal lines connecting corners of beads.

Draw freehand all fillets.

In bottom view—

Draw the three circles at rim.—Middle and inside circles represent under edge of rim and bead respectively.

Draw circles at hub.

Draw a light auxiliary circle to represent outside of bead on hub.

Draw light auxiliary lines 60° apart to represent center lines of arms.

Mark off width of arms and their webs on the bead circles at hub and rim.

Draw inclined lines of the arms and their webs.

Draw freehand all fillets tangent to their respective lines.

Draw section of arm with taper on inside of flange to the proportions shown on plate.

Draw in both views pipe plug and the oil hole under it to the proportion shown on the plate.

Draw oil holes in bushing, locating them in about the position as shown on plate.

Inking.

Tear off wrinkled edge and tack to board a sheet of 18×24 tracing cloth with smooth side up.

Follow the same general order as instructed for inking drawings on Plate II with the addition that "f" marks should be put in with the notes.

Cross-check drawing.

SECOND GRADE.

Make, from sketches of machine parts, finished penciled detail drawings on 18×24 brown detail paper.

Use HHH pencil and 8×10 cross section paper for sketching.

An ideal sketch should have the appearance of a finished instrumental drawing, but all lines should be drawn without the use of a straight-edge and all notes should be plainly written and not printed.

Sketch objects by this method: First, draw main center lines for necessary views. Second, draw in proportion main lines of the object. Third, draw all inside and minor lines of the object. Fourth, put in dimensions. Fifth, write in all notes.

Refer to Manual of Drawing and learn **Articles: 153, 157, 159, 160–276, 286–296.**

Cross-check all drawings.

THIRD GRADE.

Make, from sketches of the parts of a section of a machine, finished inked assembly drawing on 18×24 bond paper.

Refer to Manual of Drawing and learn **Articles: 288–295, 297–305.**

Cross-check drawing.

FOURTH GRADE.

DRAWING OF ENGINE ECCENTRIC.

Plate VI.—Engine Eccentric.

Make finished inked detailed drawing on 18×24 bond paper of Eccentric.

Refer to Manual of Drawing and learn **Articles: 153, 157, 159, 160–276, 286–296.**

Note.—Separate straps and sheave and draw the two halves of each together.

Cross-check drawing.

DRAWING OF MAIN CONNECTING-ROD FOR TEN WHEEL LOCOMOTIVE.

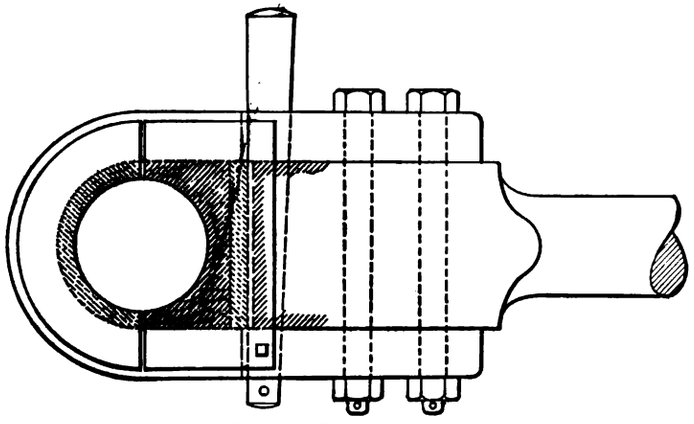
Plate VII.—Main Connecting-rod for Ten Wheel Locomotive.

Make finished inked detailed assembly drawing on 18×24 bond paper of Connecting-Rod.—**Figure below.**

Refer to Manual of Drawing and learn **Articles: 154, 163, 173–179, 181–186, 188, 190–276.**

Note.—Draw top and side views. Be careful and put in every necessary dimension clearly and do not crowd dimensions. Put in dimensions between center lines of brasses.

Cross-check drawing.



STUB END OF CONNECTING ROD.

DRAWING OF ENGINE CROSSHEAD.

Plate VIII.—Engine Crosshead.

Make finished inked detailed drawing on 18×24 bond paper of Crosshead.

Refer to Manual of Drawing and learn **Articles: 153, 157, 159, 160–276, 286–296.**

Note.—See isometric of Crosshead parts.—**Plate XX.**

Cross-check drawing.

FIFTH GRADE.

Make finished inked drawing on bond paper of foundation with bolt templet for the Air Compressor shown on Plate X.

Refer to Manual of Drawing and learn **Articles: 145–147, 253, 254, 288–295.**

Note.—Make drawing of foundation with bolt templet to type of foundation shown on Plate IX.

Cross-check drawing.

Make from sketch of room a finished inked drawing on bond paper of a Floor Plan.

Refer to Manual of Drawing and learn **Articles: 142, 288–295.**

Note.—Make floor plan to type shown on Plate XI.

Cross-check drawing.

Make Patent Office drawing from sketch of a machine part.

Refer to Manual of Drawing and learn **Articles: 277–285, 288–295, 307.**

Note.—Make Patent Office drawing to type shown on Plate XXI.

Cross-check drawing.

EXTRA DRAWING.

Make a 12×18 blue print diagram drawing of the 15″ Pillar Shaper omitting Countershaft.

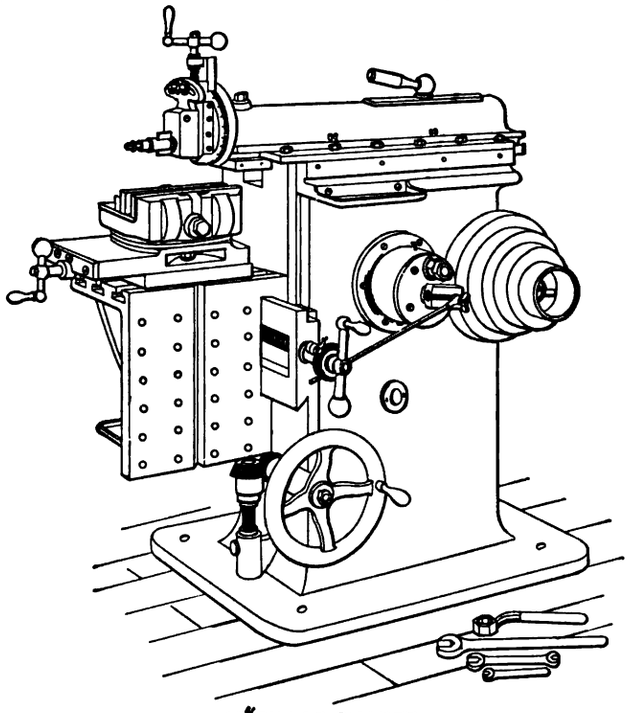
Refer to Manual of Drawing and learn **Article: 306.**

DRAWINGS OF 15″ PILLAR SHAPER.

Plates XII–XIX.—15″ Pillar Shaper.

Make an assembly drawing of the 15″ Pillar Shaper or some section of it.—**Figure below.**

Refer to Manual of Drawing and learn **Article: 297.**



15″ PILLAR SHAPER.

MANUAL OF DRAWING.

MANUAL OF DRAWING.

MATERIALS.

1. The **materials** used in drawing may be divided into two distinct parts. One part would represent the materials on which drawings are made and reproduced before any substances are applied to make that contrast which pronounces it a drawing for the use of the manufacturer or builder in commercial mechanical lines who produces, by means of it, that which has utility and a commercial value. The other part would represent such substances as are necessary to apply to the drawing materials, for the purpose just described.

The materials on which drawings are made and reproduced would include drawing paper, bond paper, tracing paper and cloth, print-paper, etc.

2. The **substances applied** for making drawings would include lead, ink, chemicals for prints, etc.

3. **Drawing Paper.**—The **ideal** drawing paper should be of tough fiber, of uniform thickness and surface, neither repel nor absorb ink before or after it is rubbed with an ink eraser, and take the ink without wrinkling the surface.

4. **Whatman's hand-made paper** approaches most nearly the ideal drawing paper. It is about the most expensive drawing paper made and for that reason it has a very limited use in commercial establishments.

5. **Manilla** wrapping **paper** is a brown paper and one of the cheapest brands of paper made. It should never be used for finished inked drawings.

6. Keuffel & Esser's **Duplex** (or equivalent) drawing **paper** is a brown or cream colored drawing paper and is a little better quality than the average commercial grade. It will bear a fair amount of careful rubbing and inking.

7. **Egg-shell paper** with a linen back and rough surface is occasionally used for a drawing made to stand out in bold relief for pictorial effect. It is a very durable paper and will bear very rough handling.

8. So-called **indestructible paper cloth** is made of paper pulp on muslin, is very durable and will bear rough handling.

9. **Bond paper** is a thin and comparatively translucent white paper which has the distinctive advantage that the original drawing can be directly printed from on print paper or cloth, and thus avoid mistakes of omission and commission made in tracing from a drawing.

Bond paper is very easily wrinkled and can be rubbed through very quickly. Therefore it requires most careful handling, and an inked drawing on bond paper should not, as a rule, be **rubbed with** anything except a fine **ink-eraser.**

10. **Cross-section paper,** whose checks are conveniently spaced, has the advantages found in bond paper and the added advantage of drawing on it without the assistance of a scale.

11. **Drawing paper,** when it comes in rolls, should usually be **laid** with the convex surface next the drawing board and the water-mark should always be on top.

12. **Drawing paper** is occasionally **stretched** on the board when it is not to be taken off for some days; but after it is taken off, the paper usually contracts and the scaling is affected.

13. The paper is stretched on the board in the following manner:

first, clip off the corners so that the four edges can be folded over for three fourths of an inch; second, wet all the surface, except the turned edges, with a sponge; third, lay the wetted surface next to the drawing board; fourth, smooth the paper by rubbing from the center out to the edges; fifth, glue down the edges with very strong gum arabic or like material.

14. A paper **drawing** may be longer **preserved** by **mounting** on straw board and varnishing its surface with white shellac.

15. **Tracing Paper.**—Tracing paper is a firm and transparent paper having a smooth and glossy or oily surface and can be easily printed from on print paper. It should be of tough fiber, uniform thickness and surface, neither repel nor absorb ink before nor after it is rubbed with an ink eraser, and take ink without wrinkling the surface.

Tracing paper should not generally be used when permanency of a drawing is the chief object.

In order to facilitate a design, tracing paper is used sometimes for **tracing alternate positions** of a piece of mechanism, when the relation of the piece to the other parts of the machine is known.

16. **Tracing Cloth.**—Tracing cloth or linen should have one of its surfaces well glazed and no open pores. It possesses the same properties and uses as tracing paper, besides being more permanent. It has a more extensive use commercially.

Before tracing cloth is laid on the board the **wrinkled portion** along the edges should be **torn off** and its surface should be stretched smooth. (Tracing cloth will tear straight parallel to its edges only.)

17. There is considerable discussion and contention as to whether the glazed or unglazed side of tracing cloth should be used. There are **advantages** and **disadvantages** in using either. It must be admitted that the glazed side was primarily intended for use; that drawing ink, especially red ink, will eat deeper into the unglazed surface with consequent difficulty in rubbing; that it is usually rolled with the glazed side in, which would naturally bring the glazed side on top, as the convex surface is placed next the board; that the tracing does not curl so much when inked on the unglazed side as on the glazed side; and also that the tracing will eventually smooth itself out when inked on the glazed side if placed in the drawer with the glazed side down. Therefore, the writer must insist that, from his present knowledge and past experience, no change from ancient custom should be made unless a drawing is penciled on the cloth, when it is absolutely necessary that the unglazed side should be used in order to see the pencil lines clearly.

18. Before using tracing cloth and especially if its surface has been exposed to the air, it should be **rubbed** with a fine powder or blotter and then brushed off thoroughly.

19. Tracing cloth is very **susceptible to moisture** in the atmosphere, and it will become taut or loose with a change of weather.

Water will **ruin tracing cloth** and care should be taken that perspiration from the hands is prevented from coming in contact with its surface.

The sizing can be dissolved or soaked off, and the linen left makes a very **desirable pen wiper**.

20. **Tracings** can be **cleaned** with gasoline, ether, benzine, or any highly volatile substance.

21. **Sheet Celluloid.**—Sheet celluloid is used in the same manner as tracing paper for tracing alternate positions of a piece of mechanism. It is more durable than either tracing paper or cloth, and is handled more easily.

22. **Print Paper.**—Print paper should be of tough fiber to admit of considerable handling, and should print quickly with clean-cut lines in ordinary sunlight.

23. To print from a drawing proceed as follows: Lay the drawing in the printing frame with the ink lines next the glass; then lay the sensitized surface of the print paper next the drawing; expose for a suitable time to the sunlight and then remove the print and place in a fixing solution for a suitable time, which will vary with the kind of print paper used.

24. If there are **certain lines, figures,** etc., on the tracing that are **not desired** on the blue print, they can be retained on the tracing and left off of the print by placing a piece of **opaque paper over them** when printing.

25. The **principle** involved in **printing** lies in the chemical change after the sensitized surface of the print paper has been exposed to the

light and passed through a fixing solution. That part of the surface of the print paper under the inked lines, figures, etc., on the drawing is shielded more or less (depending on the color of ink used) from the light; therefore after the fixing solution is used, the necessary contrast, which is desirable on the print, obtains. It is thus evident from the known relation of colors to light, that, when the most distinct lines are required on the print, the blackest and most opaque ink must be used to entirely exclude light from the surface of the print paper.

26. **Colored inks,** which are of course **not so impervious** to the light as black ink, are occasionally designedly used on drawings to give a less distinct line on the print; but, for commercial use, thin black lines of different character from the lines of projection on the drawing are far more desirable for many reasons which are noted through the text, and serve the same purposes that colored lines usually do in commercial mechanical drawings.

27. In a *resumé* of the foregoing it is evident that the time of exposure of the print paper to sunlight varies according to the sensitiveness of the chemicals used; with the material upon which the drawing is made; with the substances applied in making the lines, figures, etc., on the drawing; and with the intensity of sunlight (which is usually more effective in Winter than in Summer) or artificial light.

28. Apparatus of several designs have been devised in which the **electric light** is used **for printing** and they are especially convenient in cloudy or stormy weather.

29. All **print paper** should evidently be as **fresh** as possible; and, when not in the printing frame, it should be kept from the light in a covered can or case placed in a dark room.

30. It must be borne in mind that print paper usually un-uniformly **shrinks**, and, therefore, it must *never* be scaled for actual dimensions.

31. **Blue print paper** is decidedly the most used commercially. It produces a white line on a blue field.

32 The field of a blue print darkens according to the amount of exposure, and, as none of the black drawing inks are absolutely opaque, the value of a print can be annulled by **over exposure.**

33. After exposure to sunlight, **blue print** paper is immediately **immersed in water** (which is the fixing solution), and then all loose substances on the printed surface should be washed off with a hose filled with water under pressure. The print should remain in the water for at least ten minutes.

34. The ordinary blue print paper requires about **four** or **five minutes' exposure** to bright sunlight.

35. There is a **quick blue print paper** which requires about two minutes' or less exposure in bright sunlight when printing from a drawing made on tracing paper or cloth or their equivalent.

36. In **printing from bond paper and cross section paper,** a longer exposure to the light is required than for printing from tracing paper or tracing cloth.

37. A **good print** shows everything distinctly regardless of the color of the field. A **print with a light field** may be more desirable, since it requires less time to print, and additions and corrections can be made with black drawing ink.

38. **Blue print cloth** is printed in the same manner as blue print paper It is much more permanent than blue print paper as it will bear rougher usage.

39. **Black print paper** produces a black line on a white field and is immersed in a chemical bath first, if there is no chemical developer in the coating of the paper. It is afterward carefully washed in water in the same manner as blue print paper.

40. **Brown print paper** produces a white line on a brown field. It should be immersed in a fixing solution and then washed in water in the same manner as the other print papers.

41. **White prints** or **"Vandykes"** may be made by printing on blue or brown print paper from a negative made on brown print paper. The negative is made by placing the drawing in the printing frame with its ink lines next the sensitized surface of the brown print paper. The positive white print is then made by placing the negative in the printing frame with the print next the sensitized surface of the brown print paper.

42. A print may be longer preserved by **mounting on straw board** and varnishing the surface with white shellac.

43. **Inks.**—Black drawing ink should be opaque, waterproof and non-decomposable; and should flow freely, dry quickly, and not eat into the surface of the drawing material.

44. Black drawing ink can be **prepared from stick** India ink, but it is more convenient when purchased in the bottles of the prepared commercial waterproof drawing ink.

45. The commercial prepared waterproof drawing ink must **never be thinned.** If the ink does not flow satisfactorily, examine the pen for the source of the trouble, or if the ink has actually changed (which is almost invariably not the case), procure another bottle.

46. **Red** or carmine **drawing ink** (used only when absolutely necessary) should be waterproof and non-decomposable. It should flow freely, dry quickly, and not eat into the surface of the drawing material.

47. All ink, when in use, should be **kept in** an open **drawer,** within convenient reach, or at a sufficient distance away from the drawing to prevent it from being upset on the drawing.

48. When the **fibers** of a surface have been **torn up** by careless rubbing, the prepared varnishes painted on it or the **rubbing** of the affected surface **with soapstone,** hard beeswax, bone, or the end of the finger nail, will effectually **prepare** it for **inking.**

49. **Substances used in Preparing and Altering Blue Prints.**—The **sensitizing chemicals** for **blue prints** are prepared from several formulæ in varied proportions.

A good sensitized surface is prepared as follows: In a dark room, make a solution by weight of

Citrate of Iron and Ammonia	1 part.
Water	5 parts.

Then make a solution of

Red Prussiate of Potash	1 part.
Water	7 parts.

Mix equal parts of the two solutions and apply with a sponge for about two minutes to a paper having a hard and smooth surface, then drain off the superfluous liquid and hang up to dry. The paper thus prepared will have a bright yellow hue.

The sensitizing **solutions** can be kept separately for a long time, but when mixed must be **kept from** the **light.**

50. Soda, Potash, Quick-lime, or **any alkali in solution with water** and a little gum arabic added to keep the li uid from spreading on the paper, will produce a white mark on the surface of a blue print. Such solutions are **used for making alterations on** the **print.**

Chinese white and other commercial pastes are also used for making alterations, but the writer believes that there is nothing more satisfactory for the purpose of **making corrections** or additions on a print, than to **use black ink on** a **light print** and **red ink on** a **dark print.**

INSTRUMENTS.

51. The proper **selection of instruments** is of prime importance. It is universally conceded by first-class draftsmen that good instruments are absolutely essential for the best execution of drawings in the shortest time.

The term **"good instruments"** does **not necessarily** imply that a draftsman should have all the new-fangled specifics that are afloat on the market; as, **section liners, dotters,** etc. A *good instrument*, legitimately interpreted, is one which is indispensable and of the best grade.

52. **Drawing Board.**—The drawing board should be made of soft and well-seasoned wood of uniform grain; should have two adjacent edges straight and at right angles to each other; should have its working surface very slightly crowning in the center; and should be designed to allow for the changes due to atmospheric conditions.

53. If a permanent **working straight-edge** on the board is desired, a heavy cast-iron or steel strip may be securely fastened to it.

54. The **truth** of the **straightness** of the working edge of the board can be tested by applying a standard straight-edge.

55. The **convexity** or planeness of the **top surface** of the drawing board can be proved by applying a standard straight-edge or the edge of a T square blade to its surface.

56. To **prove** the **squareness** of the **working edge** of the drawing board to its lower edge (**Fig. 1**) proceed as follows: first, place T square head against working edge of board and draw two parallel lines, one about one inch from the upper edge of board, and the other about one inch from the lower edge of board; second, with the T square head placed against the working edge of board, mark off on the T square blade a point whose distance from the edge opposite the working edge of board will be about the length of the T square head; third, with the T square head placed against the working edge of board, sight and mark off from the point on the T square blade a corresponding point on each of the parallel lines; fourth, place the T square head against the lower egde of board and draw a line through the point marked off on one of the parallel lines and note if it passes through the corresponding point on the other line. Absolute squareness is unnecessary.

57. **T Square.**—A T square of the best grade and design should have a fixed head and blade, with ebony lined edges.

The **blade** should be dovetailed or let into the head, but the upper surface of the head should always be flush with the working surface of the drawing board.

If the **blade** is **fixed** to the head **with** screws, not less than **five screws** should be used.

58. As a rule, **adjustable heads** are undesirable; but a design having a double head is practicable and is recommended, when one head is permanently fixed, as specified above, and the other detachable, adjustable, and fastened with two binders.

59. The **blade** should have its working edge **beveled** to not over one sixteenth of an inch thick, and the ebony lining well secured.

60. Experience has proved that the **celluloid lining,** while possessing some slight advantages, warps and loosens, which fact makes it unsatisfactory.

61. To **prove** the **straightness of** the **edge** of the T square blade, proceed as follows: first, draw with it a line; second, turn it end for end and place the edge of the blade to exactly coincide with each end of the line which was drawn; third, draw another line; fourth, observe the coincidence of the lines which were drawn, to prove the truth of the straightness of the edge.

62. The truth of the **straightness of** the **head** can be tested by applying a standard straight edge.

63. A good **pear-wood T square,** designed as above, makes a cheap and altogether decent instrument.

64. A **nickel plated** steel **T square** has the decided advantage of maintaining its truth; but its surface gathers dirt and smuts the drawing, which fact makes it less desirable than the other types.

65. **Parallel Straight-edge.**—A parallel straight-edge is fastened to a cord or wire running in grooved rolls which are secured to the corners of a drawing board, replaces the T square, and, consequently, the working edge on the drawing board.

There are other arrangements of the parallel straight-edge and nearly all of them are most desirable.

66. **Triangles.**—The **transparent** triangle appears to be the most popular triangle used at present. It is subject to change in planeness and accuracy and the very best material used in its manufacture is none too good. It possesses the advantages of not obstructing the view of anything on the drawing when in use, and of keeping a drawing cleaner than other triangles.

67. The **hard rubber** triangle warps somewhat, but usually keeps its planeness longer than the transparent one, and smuts the drawing more.

68. The **pear-wood** triangle is cheaper, but subject to change due to atmospheric conditions. It does not smut the drawing like rubber.

69. The **nickel plated steel** triangle maintains its planeness and truth, but, like other steel instruments, it gathers dirt and smuts the drawing.

70. The **30°×60°** and **45°** triangles are most commonly used, but there are a large variety whose sides make other angles with each other.

71. If the central portion of a triangle is cut out, the **inside edge** may be **beveled** on one side to facilitate handling when it is transferred from one part of the drawing to another.

72. An **inserted knob** is sometimes used and perhaps is more convenient than the beveled edge for picking up the triangle.

73. Triangles should be of **uniform thickness** and their **outside edges** should **not** be **recessed** to avoid the danger of ink being drawn from the ruling pen upon the drawing.—The pen should be free from ink on the outside and always held with its axis in a plane perpendicular to the plane of the paper.

74. The **combination triangle** designed by D. J. Kelsey, New Haven, Conn., combines all the functions of the common 30°×60° and 45° triangles, except the drawing of parallel lines, lines perpendicular to each other, and a line making 75° with the horizontal. It has the inserted knob and generally takes the place of 30°×60° and 45° triangles, when used in combination with the T square.

75. By properly combining the T square and the 30°×60° triangle, **lines** can be drawn **making 30°, 60°,** and **90° with** the **horizontal** and **vertical.**

76. By properly combining the T square and 45° triangle, **lines** can be drawn **making 45°** and **90° with** the **horizontal** and **vertical.**

77. By properly combining the T square, 30°×60° triangle and 45° triangle, **lines** can be drawn **making 15°** and **75° with** the **horizontal** and **vertical.—Figs. 1, 2.**

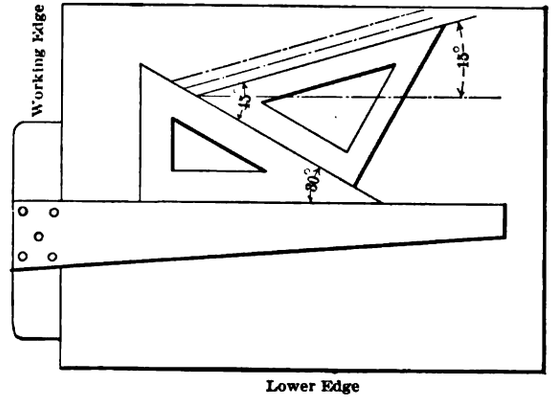


FIG. 1.

78. By properly combining a triangle and T square or the 30°×60° and 45° triangles, **parallel** and **perpendicular lines** can be drawn.—**Fig. 3.**

79. Both triangles are **proved for** the truth of their **90° angles** as follows: first, place the short side of the triangle against a straight-edge; second, draw a line; third, reverse the triangle and draw another line

directly over the first; fourth, observe the coincidence of the lines, which will prove that the angles are correct.

80. The **30° and 60° angles** can be **proved** for their truth as follows: first, place the short side of the triangle against the edge of the T square

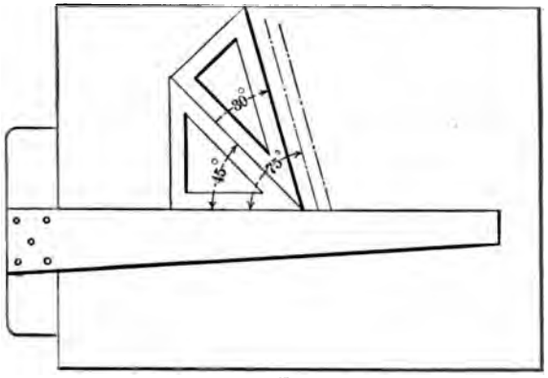


FIG. 2.

blade; second, draw a line through a point with the 60° side of the triangle; third, turn the triangle over and with same side of triangle draw another line through the same point; fourth, draw a horizontal line across the extremities of the lines just made; fifth, measure with

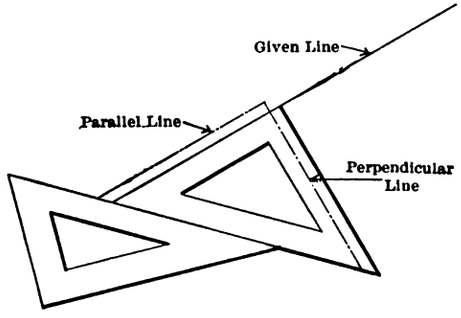


FIG. 3.

dividers the inclined lines to prove the equilateral triangle which obtains for a true 60° angle.

81. The **45° angle** can be **proved** for its truth as follows: first, place one of the short sides of the triangle against the edge of the T square blade; second, draw a line through a point with the 45° side of the triangle; third, place the other short side of the triangle against the edge of the T square blade and draw another line through the same point with the 45° side of the triangle; fourth, draw a horizontal line across the extremities of the lines just made; fifth, measure with dividers the inclined lines to prove the isosceles triangle which obtains for a true 45° angle. (This should follow the proof of the 90° angle.)

82. The triangle should always be **used** with its **working edge next** to the **light** to avoid shadows.

83. The **working edge** for a right hand person is naturally on the left; and the drawing table should be arranged accordingly in order to have the light on the proper side of the triangle.

84. **Northern exposure** and diffused light through skylight windows is undoubtedly the ideal light **for** a **drafting room.**

85. **Scale.**—The scale is made in many forms but probably the **triangular boxwood scale** is the most popular. It is easily read and manipulated and will admit of combining, in one scale, all the graduations which are usually used in making any particular type of commercial mechanical drawing.

86. A **scale guard** should be used with the triangular boxwood scale to obviate the usual experience of inconvenience from placing the scale on the wrong side when it is in use.

Undoubtedly the **nickel plated sheet-metal steel** scale conduces to most accurate work, which is vitally essential in well made drawings.

87. The **marking off** of **distances** is greatly facilitated by running the pricker point or pencil point down the indents on the steel scale which indicate the graduations.—**Fig. 4.**

As there are but two graduated edges on the steel scale, the annoyance of frequently **turning** the **scale** is eliminated.

The ancient cry, that the eyes are injured by the **reflection of light** from the nickel plated steel scale, has been unsubstantiated. The writer sees no reason why a steel scale should injure the eyes more than a white enameled one.

88. A **flat boxwood scale** with beveled edges has less pitch on its sides, and, for that reason, is considered by some to be more quickly and easily

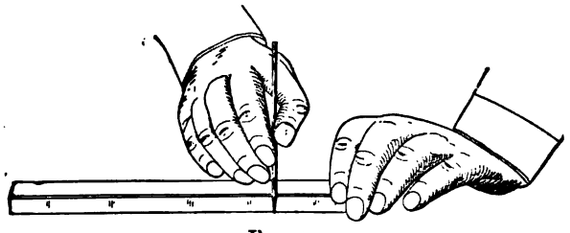


FIG. 4.

read than any other form. It is not, however, as readily manipulated as any of the others.

89. Both sheet steel and boxwood **scales** can be obtained **in sets** to suit the requirements, but the former scale is recommended as superior to all others.

The ordinary **scale** was **never designed for** a **straight-edge** or ruler, or for any other purpose than to take distances from.

90. When a **drawing** is made **on reduced scale,** the full size scale *should not* be used, but the particular scale which is arranged and adapted for the purpose. For example: a drawing may be made one fourth size in English measure, or its equivalent, three inches to the foot, which indicates that a graduation is to be found where every three inches in length is marked in feet; and also, one three inch length is subdivided into twelve equal parts which are marked inches.

Such **terms** as $\frac{1}{4}$ scale or size, and $\frac{1}{4}$ inch to the foot must not be confounded when the proper graduations are being sought on the scale. A moment's reflection will make it clear that the former stands for three inches to the foot and the latter for one fourth of an inch to the foot; and their respective scales will be graduated as indicated above.

91. A **scale** can be **proved** for accuracy as follows: mark its equal subdivisions off on a straight line and then reverse the scale and note if the equal subdivisions coincide.

92. The **limit** of **accuracy** in scaling should be, in commercial mechanical drawing, not more than one-hundredth of an inch.

93. If any number of equal or unequal **distances** are to be divided off on a right line, they should always be **marked** off **directly from** the **scale.—Fig. 4.**

When several distances within the limits of the scale are laid off where there is no line on which to lay the scale, a **straight-edge** should be placed **against** the **scale.**

Consecutive distances within the limits of the scale should be laid off at **one setting.**

94. **Protractor.**—The protractor is legitimately used for laying off angles which cannot be gotten from the triangles.

A **steel protractor** should be of first class design and should have as little surface as possible to come in contact with the paper.

Cheap German silver and celluloid protractors are not recommended.

95. **Universal Drafting Machine.**—The Universal Drafting Machine is a device which is advertised to combine all the functions of the T square, triangles, protractor and scales. There is a great deal claimed for it and it is well recommended by practical men.

96. **Curved Ruler.**—The curved ruler is often needed for delineating certain irregular lines, but it should not be used if circular arcs can be practically substituted.

A set of curves is often selected for a certain class of work, but one **universal curved ruler** will often meet most of the requirements. An average logarithmic spiral curve is recommended for general use.

Curved rulers are usually made of such **materials,** with the exception of steel, as are found in triangles; and, consequently, they have the same advantages and disadvantages, as regards convenience, etc.; hence, unquestionably, a transparent curved ruler is ultra-superior to any other.

97. **Drawing Pencil.**—A good drawing pencil or "lead" (misnomer and conventional) is essential for producing plain, clean cut and uniform lines.

The pencil should be made of a **uniform grade** of material throughout; and a suitable grade of hardness should be selected for the type of drawing which is to be made.

A **soft pencil** draws **smoother,** easier and faster than a hard pencil.

A drawing which is to be either inked or traced over should be made with a soft pencil of HHH or HHHH **grade.** A drawing made for permanent use and not to be inked or traced, should be made with a HHHHHH to HHHHHHHH grade pencil.

98. The **form** of the wood, which encases the lead, should not be circular in section.

Sharpen both ends of both pencils, one end of each to a cone whose apex is slightly blunted, and the other to a wedge whose sides are flattened $\frac{3}{8}''$ from the point and whose edge is slightly elliptical but keen. The "lead" should project from the wood not less than $\frac{3}{8}''$ and not more than $\frac{1}{2}''$.—**Fig. 5.**

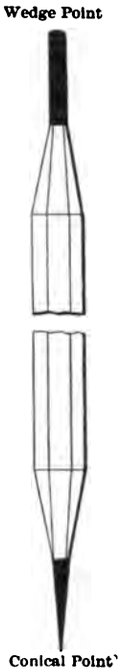


FIG. 5.

99. The flat **point** should be **used** for drawing lines and the conical point for free hand work.

When lines are drawn with the **flat point** of the pencil, it should be used for **marking distances** from the scale.—**Fig. 4.**

The **pencil, when in use,** should have all of the available surface of the lead in contact with the straight edge which guides it; and it should be held slightly inclined in the direction to which it is being drawn.

The pencil should be pressed lightly down and drawn from left to *right* and away from the manipulator.

100. The **Artist's Pencil** with movable lead is a very desirable substitute for the ordinary drawing pencil. Two of them should be procured for convenience; one with a conical pointed and the other with a chisel pointed lead in it.

101. **Ruling Pen.**—The ruling pen is about the most important instrument found in what are known as the case instruments.

It is of **prime importance** that the **greatest care** should be exercised in the **selection of the pen,** and it is of more importance to keep the pen in first class working condition.

Poor execution is often due to poor material in the ruling pen or to negligence in repairing it.

The ruling pen should have its blades made of the best tempered steel. It can be **tested** for the softness or hardness of the material by drawing a Swiss file lightly across its nibs.

The insides of the **blades** of the ruling pen should be as little concave as possible.

One blade should be arranged with a properly designed hinge or a device for **opening** the **blade** quickly and widely.

Many draftsmen oppose the **hinged ruling pen** on the ground that the joint for the hinge impairs a certain rigidity which is essential when the pen is in use. It is undeniably true that a blade is more rigid when not jointed, but hinged ruling pens have been designed, and there are some few on the market, which meet all the essential requirements of rigidity. It is vitally necessary that the hinged ruling pen be designed with an effective device for taking up the wear at the joint.

102. A **pen must be kept** thoroughly **clean,** and a pen is not necessarily thoroughly cleaned by drawing a rag through it when the nibs are close together, but, if it is necessary, each nib should be rubbed off and smoothly polished. Hence, the convenience gained from a common sense wide-opening pen.

103. The **handle** should be made of a material that is not easily broken. Bone or ivory handles are undesirable because they are easily broken, but an aluminum or ebony handle is very satisfactory, particularly the former.

104. The ends of the **nibs** must be kept in prime condition. Such a condition obtains when the ends of the nibs are perfect arcs whose radii are not over one thirty-second of an inch; are sharp as a pocket penknife; and both touch the paper when the pen is placed with its axis in a plane perpendicular to the plane of the paper.

105. To **repair** the ends of the **nibs,** proceed in the following order: first, clean the pen thoroughly; second, hold the pen to the light or over a piece of white paper and close the nibs until they are about to touch; third, hold the pen with its axis perpendicular to the plane of the knife

oil stone and move the stone over the points of the nibs until an arc of not over one thirty-second of an inch radius is rounded on the points (**Fig. 6**); fourth, open the blades as wide as possible; fifth, hold the axis of the pen at right angles with a line along the length of the stone and,

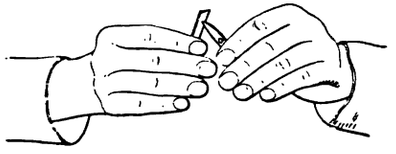


FIG. 6.

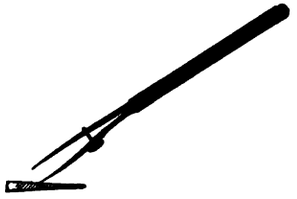


FIG. 7.

with one blade at an angle of about 30° with its plane surface (**Fig. 7**), move the point of the nib about one-half inch back and forth along the stone while the pen is being slightly oscillated about its axis to maintain the roundness on the back and grind the point of the nib to an edge as sharp as a pocket pen-knife.—This operation should be performed on each nib separately and with extreme care to avoid grinding off the end of a nib, thus making one nib shorter than the other; sixth, rub lightly, with the thin edge of the stone, the inside surface of each nib to remove any possible burr; seventh, test the pen thus: clean nibs thoroughly; close the nibs until they are about to touch; fill with ink to a depth of not over three sixteenths of an inch; hold the pen with its axis slightly inclined to the right and in a plane perpendicular to the plane of the paper and draw it lightly from left to right over the paper until the ink is exhausted.—**Fig. 8.** The pen should not fail to make a line while it is moving across the paper and the line should be clean cut.

106. The pen should always be **set** the proper width by the eye, which is done by holding it to the light or over a piece of white paper.

107. The pen should ordinarily be **filled** not deeper than three sixteenths of an inch unless an extra wide line is to be drawn.

If the ink does not flow, do not ruin the pen by jabbing it into a piece of wood or paper, but start the flow by drawing it across the little finger or a wet sponge; then if the ink fails to flow, wipe out and refill the pen.

108. When a line is being drawn, the **pen should be held** with its axis in a plane perpendicular to the plane of the paper, slightly inclined in the direction to which the pen is being drawn, and, with slight pressure on the pen, drawn from left to right and away from the draftsman.—**Fig. 8.**

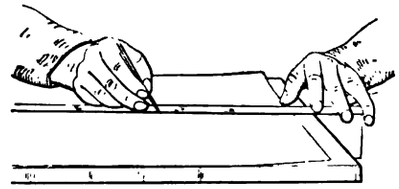


FIG. 8.

When a pen is in use, care should be taken that no **ink** is on the **outside of the nibs** and that the guiding straight-edge does not come in contact with the inked line. Carelessness and disregard of this advice will usually be followed by ink flowing under the straight-edge.

Since most drawing inks dry quickly and corrode steel, they must always be **wiped thoroughly** after use, even if it is only for a short interruption.

It behooves every draftsman to read that part of the catalogue of Theo. Alteneder & Sons, Philadelphia, Pa., which gives an admirable discussion of the ruling pen and other instruments.

109. A medium size **pen** can be used to advantage for **lines of all widths**; and the belief held by many, that a fine line and a coarse line are necessarily drawn with a small and large pen respectively, is a fallacy.

110. If red ink must be used, since it is very corrosive, a **separate pen** should be **reserved** for it.

111. **Compass.**—The best compass of to-day has its main legs, lengthening bar, needle point leg and pencil leg made of a fine, uniform grade of German silver. They should be sufficiently rigid to prevent any bending when ordinarily handled, and not easily broken or cracked when accidentally dropped.

All **joints** should have large, dustless and non-bruisable bearing surfaces and simple and well-designed devices for taking up wear.

The compass should have simple and effective **means for holding detachable parts.** Undoubtedly the round shank and corresponding split socket with its clamping screw is the best design obtainable for connecting and disconnecting the detachable parts of the compass legs.

The cylindrical **handle,** on the yoke which straddles the joint at the top of the legs, is indispensable for facilitating the manipulation of the compass.—**Fig. 9.**

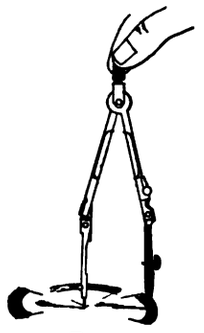


FIG. 9.

The pen, pencil, and needle point legs should be provided with **flexible joints,** designed according to the specifications given for corresponding joints in the compass legs; and also, the joints should be as near to the working points as practical.

The **pen** should be designed and cared for in the same manner as specified above for the ruling pen.

The **pencil** should be of a material described above in "Substances Applied, etc." and of nothing softer than a HHHHHH grade. It should be so sharpened that the point has a very flat elliptical section.

112. The **needle points** should be made of the best tempered steel with one end conical, and the other end with a very short, sharp, and fine point, terminated by a square shoulder.

The needle point and lead should be a good fit in a split socket and held in place with a clamping screw. The **device** for **securing a needle point** by the point of a screw should be shunned.

A **needle point** should **not be screwed** into the socket.

113. The **shoulder end** of the needle point **should** always **be used** when drawing circular arcs, and should be adjusted so that both the shoulder and pencil or pen points touch the drawing, when they are perpendicular to the plane of the paper.—**Fig. 9.**

The **needle point** should be occasionally **ground** on the oil stone until it is sharp enough to enter the drawing paper when a pressure due solely to the weight of the compass is applied.

114. If a screw in the compass or bow instruments works hard or becomes rusty, a little **graphite** rubbed off the drawing pencil will **lubricate** it.

115. When a scale distance is used by the compass, it should be taken by it directly from the scale, which is accomplished by holding the compass level with the surface of the scale and applying the compass so that the shoulder of the needle point and the end of the pencil or pen point just touch the edge of the scale.—**Fig. 10.**

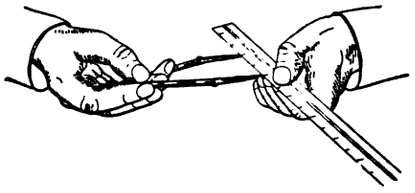


FIG. 10.

116. When a large **circle** is being **drawn with** the **lengthening bar** inserted, the compass should *never* be steadied by taking hold of one of the legs; but it should be gripped, as before, by the cylindrical handle at the yoke, and very slightly inclined in the direction to which the compass is moving, which direction should always be right handed or clockwise.

117. **Beam Compass.**—The beam compass is used for striking large circular arcs.

118. The **trammel points** and their attachments should be made of materials used for similar purposes in the compass and cared for after the same manner as prescribed for the regular compass.

The needle point leg should be fixed; the pen and pencil legs should be interchangeable; and the compass should be provided with a **micrometer** adjustment **attachment.**

The **beam** should be designed for stiffness and to permit of smooth running of the trammels along its length.

The trammels should be provided with a strong and rigid **fastening** device.

119. The metal **tubular beam** with a split socket on the trammels for binding is recommended.

When an arc of long radius is drawn a spring wheel attachment should be used close up to the pencil or pen point.

120. If a set of good trammel points cannot be had, it is recommended that the **beam compass clamps** listed in the "Supplies required for the Course in Drawing" be procured. The clamps make use of the ordinary case instrument attachments and can be procured from the Cornell Co-op store.

121. **Dividers.**—The dividers should be made of materials which are used for similar purposes in the compass, and should be cared for after the same manner as prescribed for the regular compass.

One **leg** should be without a joint, and the other leg should be provided with only a hair-spring adjustment.

The **needle points** should be conical.

122. If an **exact length** is to be **laid off** with the dividers, a large multiple of that length should be laid off first directly with the scale on a right line, and then exactly sub-divided into the desired exact length by the dividers.

123. **Bow Instruments.**—The bow instruments consist of the spacers, pencil, and pen. They should be made of the best tempered steel, with a metal handle and a center adjusting screw.

The spacers, pencil, and pen are used and cared for in the same manner as prescribed for the dividers and compass, but they are distinctly **designed for short lines and arcs** of short radii.

The so-called "self adjusting needle point" or **"drop" bow pen** has the particular advantage of requiring no adjustment of a needle point to suit the length of the pen or pencil but the needle point end should be made with a shoulder and not conical as is usually done.

124. **Pricker Point.**—The pricker point is used for marking off distance more accurately from the scale than can be done with the drawing pencil.

A fine **sewing needle,** with the eye end firmly driven into a non-cylindrical handle, **makes** a desirable **pricker point.**

A ruling pen, with the **pricker point** inserted **in** the **handle,** can be purchased for a few cents extra.

125. **Case for Instruments.**—A case should be procured for the ruling pen, compass and attachments, dividers, and bow instruments.

The folding **pocket case** is undoubtedly the most convenient, but a good case can be made of chamois skin by sewing pockets into it; and the chamois skin would be incidentally useful for cleaning the instruments, which should be done every time the instruments are used and laid aside.

126. **Writing Pen and Staff.**—The writing pen and staff are essential and important in a draftsman's outfit, for lettering, etc.

The pen staff should have a **bulging** cork **end** where the pen is inserted and should be gripped close to the pen when it is used for printing.

The pen should be comparatively **coarse** with a ball point for holding ink.

"Crow quill" and **"Falcon"** pens should usually be rarities in a commercial mechanical draftsman's outfit.

Care and common sense must be exercised in the **selection** of the writing **pen** for the different grades of work.

No more **pressure** should be applied to the writing pen than to the ruling pen, and the erroneous belief that a fine flexible point, when worked under pressure, is the proper pen, is as puerile as wetting the pencil point in the mouth.

127. A good **wiping rag** is an essential. It should be free from lint. A good one is usually found wrapped around the bottle of the prepared drawing ink.

Tracing cloth when soaked free from the glazing makes a very desirable **wiper.**

128. **Pencil Pointer.**—A good pencil pointer is found in a steel file or a sandpaper pad.

There are several good devices for **sharpening pencils mechanically** which should be selected with scrutinizing care and judgment.

A pocket-knife should never be used for finishing the point of a drawing pencil.

129. **Pencil Eraser.**—A pencil eraser should be of open rubber and

not the usual velvet type. It should clean the surface of a drawing with very little rubbing and leave it perfectly smooth.

130. A **sponge rubber** is found convenient for cleaning the surface of a drawing without obliterating the pencil lines.

Fine **crumbs from** stale **bread** effectually clean a drawing.

131. **Ink Eraser.**—An ink eraser should be made of a fine abrasive substance which is quick cutting and non-heating; it should leave the surface of the drawing perfectly smooth.

Fine pulverized **pumice stone** will very effectually take out ink lines when rubbed on a drawing.

132. A **steel eraser** is indispensable in the hands of a skillful draftsman and a pocket knife is no proper substitute for it. It should be made of the best tempered steel with a wooden handle and its edge must be kept keen.

When a steel eraser is used, the ink should be just taken off the drawing and no more.

It is much better for the unskilled person to **take off** only a **part of the ink with the steel eraser and finish with the ink eraser.**

When **lines** are erased from a tracing they should be **thoroughly rubbed** off to avoid vagueness on the print as to what was intended on the drawing.

133. **Eraser Shield.**—An eraser shield is sometimes found useful where only a particular and very small part of the drawing is to be rubbed.

An eraser shield can be made by slitting a piece of **sheet tin,** brass, or celluloid.

The straight-edge of a piece of brown **drawing paper** also answers very well **for a shield.**

134. **Oil Stone.**—An Arkansas knife oil stone should always be found in a draftsman's kit and should be used when necessary. It is always an index of a good workman when his tools are sharp and in prime condition.

135. **Tacks.**—The tacks for holding down drawings should have small heads.

The 1 oz. **copper tack** is recommended; but the 1 oz. iron carpet tack is a nuisance. Its head breaks easily and leaves the point in the drawing board to be picked out before the board can be planed off, as is often done when it is repaired.

Thumb tacks should have a small flat head rounded on the edge, and a sharp point.

136. **Tack Lifter.**—The tack lifter is a convenience and not a luxury. It will, doubtless, preserve the original shape of the blade point of the pocket knife, which is so often resorted to as a tack lifter. A piece of $\frac{1}{4}''$ or $\frac{5}{16}''$ steel wire, three or four inches long, with one end flattened to an edge and bent into a claw shape, will serve as a tack lifter.

137. **Machinist Scale and Caliper.**—A six inch machinist scale and a six inch reversible inside and outside caliper are often found convenient in taking measurements when a draftsman is required to sketch a piece of mechanism that is already made.

138. **Folding Rule.**—A six foot folding rule is a very useful article to have in many ways. It is often a suitable accompaniment to the caliper for getting the approximate dimensions of a piece of mechanism which is being sketched.

TECHNIC.

Commercial Mechanical Drawing.—A commercial mechanical drawing is fully defined when such conventions are present as to enable the manufacturer or builder in mechanical lines to erect his buildings; to select and arrange his equipment for most economical production; and to produce, by means of the drawing, and with the greatest facility, that which has utility and a commercial value.

Commercial mechanical drawings can be divided into **three general types** which may be termed: **General Plans, Machine Drawings,** and **Patent Office Drawings.**

139. **General Plans** would include such drawings as: **lay-out drawings, foundation drawings, piping drawings,** etc.

140. **Machine Drawings** would include: **working sketches, scheming sheets, detail drawings, assembly drawings,** and **diagram drawings** of machines.

141. **Patent Office Drawings** are in a class by themselves and are essentially such drawings as are required by the United States Patent Office when a claim for a patent on a mechanical invention is presented.

142. **General Plans.**—Drawing plans of buildings intended for mechanical purposes are often made with nothing more on them than a section of the walls; with the doors, windows and supporting piers for columns located; and sometimes a very general arrangement of the inside equipment shown in part or the whole.—**Plate XI.**

143. **Layout Drawing.**—A layout drawing is often a plan of a floor of a building with the positions of different parts of the equipment located to scale. It is also, sometimes, a preliminary drawing of a part or a whole of a machine and serves the same purpose as the scheming sheet which is defined below. The former sense, however, will be accepted in the Manual.

In **locating** a large number of **machines** or other equipment in a plant, they should be drawn first to scale on a sheet of fairly stiff drawing paper, cut out, and then moved on the proposed drawing until they are satisfactorily arranged; after which, they can be drawn to scale.

144. **Piping Drawing.**—A piping drawing shows the arrangement of the piping separately from other equipment in the building.

If there are **several kinds of piping;** as, steam pipes, hydraulic pressure pipes, water service pipes, etc., and they are to interpass each other, they should be all drawn on one sheet to show their relation; and then each class by itself can be drawn on a separate sheet for the use of the piper.

In laying out piping drawings, no attempt must be made to draw elaborate views of the fittings, but **simple and conventional lines should represent them.—Plate III.** All valves, unions, tees and important connections, must be plainly indicated.

Do not locate pipes too closely together but leave a little leeway for the piper.

Always **show an outline of the walls,** machines, etc., along which the pipes run and with which they are connected.

145. **Foundation Drawings.**—Foundation drawings should show the nature of the foundation upon which a machine or building stands; whether it is in wood, stone, concrete or brick; also the position of the anchor bolts, with their attached caps, anchor plates, washers, and nuts; and also the main outlines of the machines which set on them.—**Plate IX.**

146. A **templet drawing** usually shows a templet made of boards which are nailed together, and with holes bored in them, which have the relative dimensions between them that are required for locating the anchor bolts in the foundation.—**Plate IX.**

If **brick work** is shown in a foundation, a continuous right line and not the corbeling should show the outline of the foundation.—**Plate IX.**

147. Drawings of **boiler settings** would be included under the head of Foundation Drawings.

148. **Machine Drawings.**—When a new machine or any of its parts has been conceived, the next step is to develop it on drawings.

Naturally the most **simple drawings** will be **made first** and will be followed in logical sequence by more complete drawings.

A machine drawing must be made simple, clear and direct. All attempts to imitate the product of the camera or to display impractical rudimentary knowledge is foreign to the practice in the United States at present, and must be eliminated in order to harmonize with the existing state of affairs.

To make a machine drawing properly and most intelligently, the draftsman has no other recourse than to be a thorough mechanic himself, which implies a working knowledge of pattern making, molding, forging, and machining.

149. **Sketches.**—Preliminary freehand sketches should be made with a soft black pencil and only the essential outlines of the proposed piece are needed.

Several sketches may be required before one is satisfactory; and all **sketches** made should invariably be **saved** for possible future reference.

It is a rule, frequently followed by designers and inventors, to make **several sketches of** the **same thing** and it often happens that they return to and use the first sketch made.

150. **Cross-section paper** is invaluable **for sketching** as proportion is secured without the use of the scale.

151. **Copying-pencil sketches** are frequently made to serve the purpose of a small drawing or blue print. They should be made with a copying pencil on checked paper and duplicated by means of a damp cloth and a letter press.

152. **Scheming Sheet.**—A scheming sheet is made up of the accepted freehand sketches drawn to scale and with somewhat more detail shown.

They should be **drawn** in **with a HHH** or HHHH grade **drawing pencil** on drawing paper and no elaboration to completeness is usually needed.

153. **Detail Drawings.**—Detail drawings are undoubtedly the most important, and, surely, the most extensively used drawings.

The details in the execution of a properly made detail drawing are a complete history and exposition of the art of Machine Drawing. Therefore, what has been written, in the paragraph directly under the heading "Machine Drawings," distinctly applies to detail drawings and must be strictly adhered to.

After the parts on the scheming sheet have been made in a general drawing, they are then completely detailed for the various departments of the shop. Consequently, a detailed drawing is the **workman's drawing,** and, as such, it is his official order for doing the assigned work. He should be held responsible only for failure to work to the figures and Anglo-Saxon notes on the drawings.

The **projections** and conventions are **secondary** and only serve as illustrations to interpret what the figures and notes stand for.

The **number of parts** of a machine **detailed** on a drawing may depend on the methods used in doing the work; or upon the number of men who are to work from the drawing; or upon both.

Detail drawings are usually pencilled on light brown drawing paper and traced on tracing cloth or pencilled and inked on bond paper and printed on blue print paper in the order given.

For convenience of analysis, the considerations, methods, and technic involved in the complete execution of a detail drawing will be discussed under separate headings.

154. **Types of Detail Drawings.**—The **number of parts** of a machine detailed on a drawing should be according to the nature of the work and the methods of doing it. If a shop is manufacturing machines in lots, where six or more are built exactly alike and at the same time, not so many parts would be detailed on one drawing and the work would be distributed among a larger number of men.

It is the practice with some firms and the growing tendency with others to make **individual** or separate **drawings** of a great many of the parts.

It has been the custom with some firms to place the **casting details and forging details** on **separate** drawings and that scheme would **be** particularly advantageous to firms which build.

When a single new machine, or a section of it, is built for the first time, it is often advisable to show the **parts in partial assembly** and fully detailed on the drawing. Such an arrangement assists the mechanic to make his allowance for proper fits and adjustments. This type of drawing might serve as an assembly or general drawing, and, perhaps, it is more properly called an assembly detail drawing. A bill of material should accompany an assembly detail drawing.—**Plate VIII.**

155. **Sizes of Drawings.**—The size of the detail drawing is dependent on the type of drawing, the size or sizes of the part or parts detailed, and the scale to which they are drawn.

The following **sizes** are good average ones, as they can be **cut** very **economically** from the commercial widths of drawing paper: 6×9, 9×12, 12×18, 18×24, 24×36, 36×48 and 48×72.

156. **Border Lines.**—Border lines are of no material assistance to the mechanic or to any one else; except, possibly, to the draftsman who may comfort himself with a doubtful fact that the appearance of the drawing is enhanced.

The writer believes it to be the growing tendency to **leave off** all **border lines**, but, when they are used, they should not be over one thirty-second of an inch wide and have no fancy or elaborate corners.

157. The **border line** should be placed **one half inch from** the **edges** of the sheet; is the first thing to be drawn in a pencil drawing; and the last thing in an inked drawing.

158. **Match Lines.**—Short lines, drawn with the T square on each side of the drawing, are convenient for resetting a drawing after it has been removed from or accidentally shifted on the drawing board.

159. **Titles.**—A title is an essential part of any drawing and a particular and invariable place on the drawing must always be provided for it —**Plates I–V.**

A **place** at the lower right hand corner of the drawing should be blocked out **for** the **title** directly after the match lines are drawn.

The **title should comprehend:** first, the type of drawing, as, a sketch, assembly, or detail; second, the name of, or the part of the machine drawn, or both; third, the name of the firm which builds the machine; fourth, the address of the firm; fifth, the scale or scales used on the drawing; sixth, the name or initials of the person or persons who are responsible for the finished drawing, which includes everyone, from the pencilling draftsman, through the tracer and checker, to the approving engineer.

In addition to the above, there is occasionally placed, along with the title, the shop order number, the sheet number, the number of the drawing in the case where the drawings are stored, and the lot number, provided the machine is manufactured in large lots.

160. The words indicating the **name** of the **machine** must be in **larger letters** than the rest, since it should be the first or chief thing seen in a title.

The words indicating the type of drawing, the name of the firm, the address, and the scale, should be composed of **letters of the same size;** but they must be smaller than the letters in the words which indicate the name of the machine.

The words used to indicate the relative sizes to the true size of the objects as drawn, should be expressed preferably in the **terms of a scale;** as, so many inches to the foot or so many millimeters to the meter; or, if not, a proportionate size should be given; as, full size, one half size, etc.

The date and the **names** or initials **of the persons responsible** for the drawing should be in **very small letters.**

All lines in the title must be **arranged symmetrically** with reference to a center line.

The title or border lines, or both, are sometimes **printed** on in black **with an ordinary printing-press,** before the drawing is begun.

The title is occasionally **put in with a stamp,** which usually stamps the tracing in red ink; after which it is filled in with black drawing ink. The black drawing ink should be applied while the red ink is still wet.

161. In the lower left hand corner, there should be placed **a** letter and number for an **index mark** which correspond with the size of sheet

and serial number of the drawing respectively; as, for example, **A-2** will indicate that the sheet is 36×48, and it is the second consecutive drawing that has been made.—**Plates I-V.**

162. The letters which should be used with the corresponding **sizes of sheets,** are as follows: **A,** 36×48; **B,** 24×36; **C,** 18×24; **D,** 12×18; **E,** 9×12; and **F,** 6×9.

163. **Bill of Material.**—Every detail drawing should have a bill of material which should be placed directly above the title and it is a good plan to block out a space for it immediately after the title has been allowed for.—**Plate II.**

Every piece in a machine, or its parts, or in any structure, should be **accounted for** on the bill of material, so that any clerk in the office can order from it independently of anything else.

In the **table of the bill of material,** the first column should contain an identifying mark which is exactly the same as the one placed on the view of the piece as shown on the drawing and may be a letter or a number. The second column should contain the name of the piece. The third column should contain the number wanted of the same piece for one machine, or one composite structure of any sort. The fourth column should contain the name of the material of which the piece is made. And the last column should contain any further necessary description of the piece, which may be; for example, the pattern number, the dimensions of the rough stock from which it is made, the method of casting, etc., and in fact the last column should provide for any description of the piece not found in the first four columns and which would be essential for completeness in the order for the stock.

The name of the piece in the bill of material should be a **common shop term** used by the mechanics, and if there is none, a simple and suggestive one must be used.

Every piece that is cast from a pattern should have, and be given, a **pattern number** in the column under the head of "Remarks."

164. **Views.**—The number of views is determined by that judgment which serves common sense.

All the views **necessary** and no more should be drawn.

The selection of a view or views which shows the piece in the **most comprehensive** manner should always be made.

165. In simple and symmetrical pieces, as a round shaft, bolt and nut, plain gears, etc., **one view** is sufficient.—**Driving Stud, Plate I.**

166. If an object is symmetrical in every respect and it is required to show some irregularity, it is sometimes only necessary to show a **part of a view.—Plate V.**

167. In a very crooked piece, **several views** may be quite necessary.—**Fig. 11.**

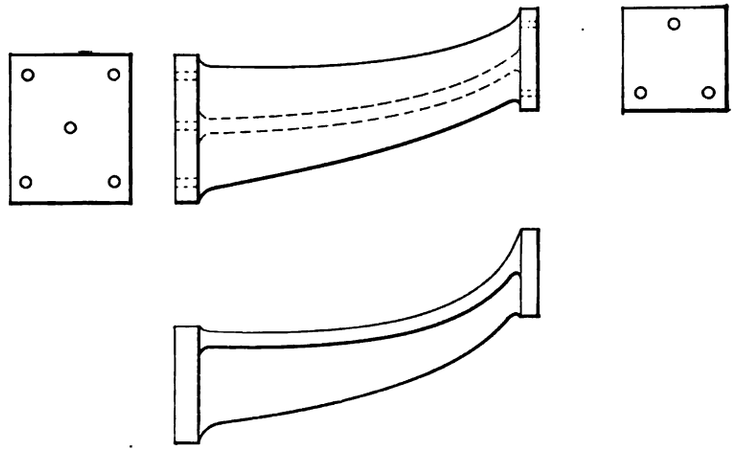


FIG. 11.

168. A **sectional view** is often clearer than an outside view to the mechanic who works from the drawing but it should not be made unless clearness obtains.

169. If an object is symmetrical, it is often better shown by making a **combined outside and sectional** view; usually making the division at the center line.—**Fig. 12.**

170. All **bent** and **unusual shaped plates** must have their **surfaces developed,** if it is necessary to show proper spacing of rivets, bolt holes, outline of cams, etc.—**Fig. 12.**

171. It is sometimes essential that an object, which is drawn on reduced scale, should have some important **section** of it shown **full size.—Plate XII.**

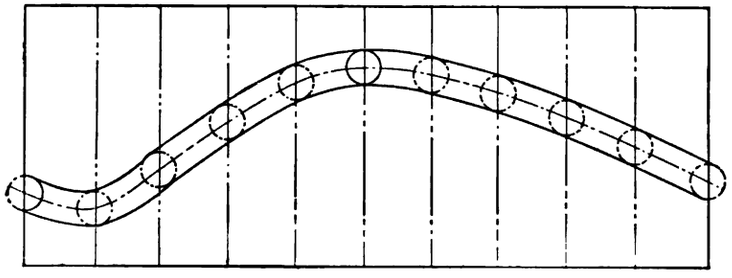


FIG. 12.

When there are **two pieces** that are exactly alike in every respect except that they are of **opposite hands,** one should be drawn in all of its views and a note should be added to indicate that they are *rights* and *lefts*.

172. In any view where there are a number of concentric **circles, show only a few,** as they are practically worthless for conveying any idea and only useful to fill space.

173. A **flat surface on** the body of a screw, stud, or **shaft,** is occasionally indicated, when there is only one view, by a rectangle with its intersecting diagonals.—**Fig. 13.**

174. Rectangles, with their intersecting **diagonals,** are often used **for indicating** the bearings on a round shaft; as, a line shaft, crank shaft, etc.—**Fig. 14.**

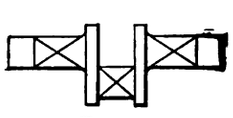


FIG. 14.

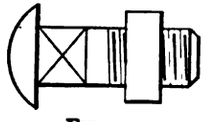


FIG. 13.

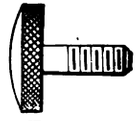


FIG. 15.

175. A **knurled** or milled **piece** should be shown conventionally in a view.—**Fig. 15.**

176. In all elevation views of **square bolt heads** and nuts show only one side.—**Fig. 16.**

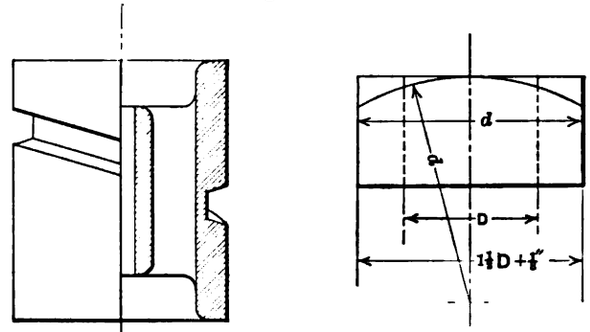


FIG. 16.

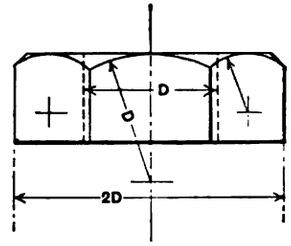


FIG. 17.

177. In all elevation views of **hexagonal bolt heads** and nuts show three sides.—**Fig. 17.**

178. If, in a side **sectional view** of any object having **holes** of any description, the cutting plane does not pass through one or more of them on a circle in another view, one hole in the section view should be shown actually cut by the plane and at its full radial distance from the center of the circle.—**Pipe Plug, Plate V.**

179. **Washers and collars** should generally be shown in section on the piece to which they belong.—**Driving Stud, Plate II.**

180. **Keys** should be shown in the piece into which they are fast.—**Feed Screw, Plate II.**

181. The **side views** of a **Sellers V-thread, pipe thread, square thread, bastard or acme standard thread, knuckle thread, buttress thread and**

FIG. 18.

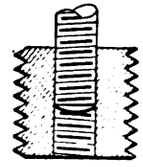


FIG. 19.

wood screw thread, are conventionally shown in the figure in their respective order.—**Fig. 18.**

182. If a **threaded piece is sectioned** nothing but the V's should represent the thread.—**Fig. 19.**

183. The **end views of a screw and tapped hole** are conventionally shown in the figure in their respective order.—**Fig. 20.**

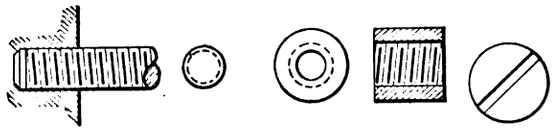


FIG. 20.

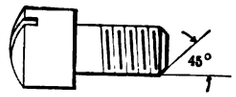


FIG. 21.

184. A **filister head screw** should show, in all views of the end, its slot making an angle of 45° with the horizontal and the slot should show, in the side views, a true projection of the end views.—**Fig. 21.**

185. **Spur, bevel, worm, and spiral gears** are shown in detail.—**Spur and Bevel Gears, Plate XVI; Worm Gear, Fig. 22; Spiral Gears, Fig. 23.**

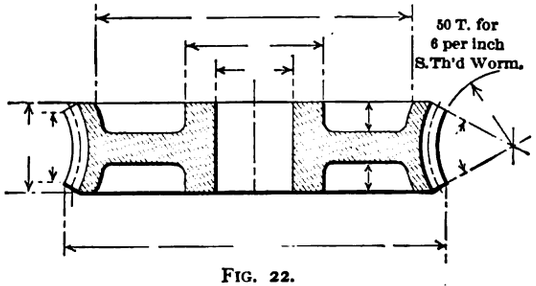


FIG. 22.

186. **Cast gears** made from a pattern should have, in addition to an ordinary view, one tooth completely detailed and the number of teeth specified.

187. The **arrangement of views** on the drawing demands, for the sake of clearness, system, and convenience: first, that they should not be crowded; second, that all views of the same piece should not be separated any further than necessary to show outside dimensions and notes clearly; third, that all views of different pieces be sufficiently separated to prevent any confusion as to their proper relations to views of other pieces; fourth, as far as possible, all pieces of a machine must be shown on the

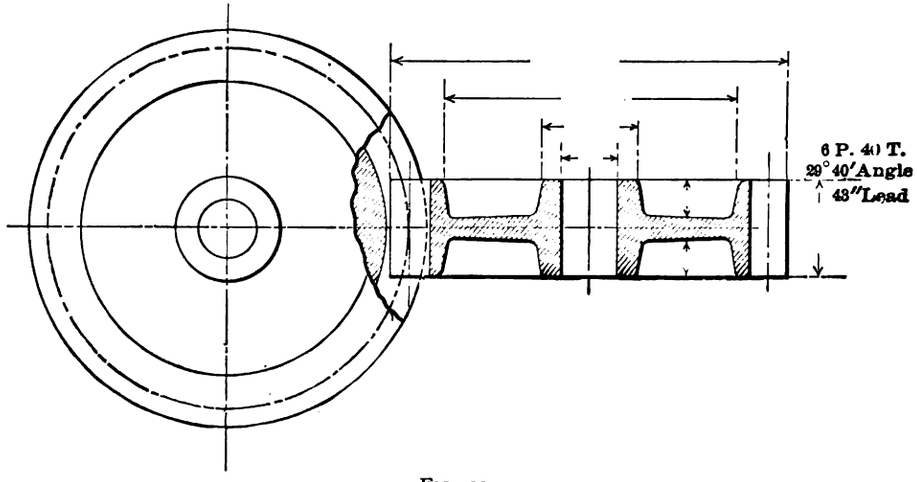


FIG. 23.

drawing in their natural relative positions in the machine and to each other.

188. **Sectional views** can be **placed,** if convenience demands it, **at any place** on the sheet provided they are properly noted.—**Fig. 24.**

189. To cover the drawing sheet properly with views, it is sometimes convenient to approximately **pre-arrange** the **location of all views** by enclosing them in a rectangle which is sufficiently large to include the outside dimensions and notes to the view. At other times it is not necessary to do much planning, but **commence at** the **upper left hand corner and work across and down the sheet.** This order of working across the sheet should always be followed.

190. The relation of views to each other must always be what is technically called **third angle projection** which, interpreted, means: that when there is a definite and natural top to an object, its projection should be the top view which is often called the plan; that the views of the elevation should be shown below the top view; and that, in addition, every

projection must be shown as the near side of the adjacent view from which it is projected.

191. **In a sectional view,** the portion of the object nearest the view is removed, and all of **what is left is shown in projection.**

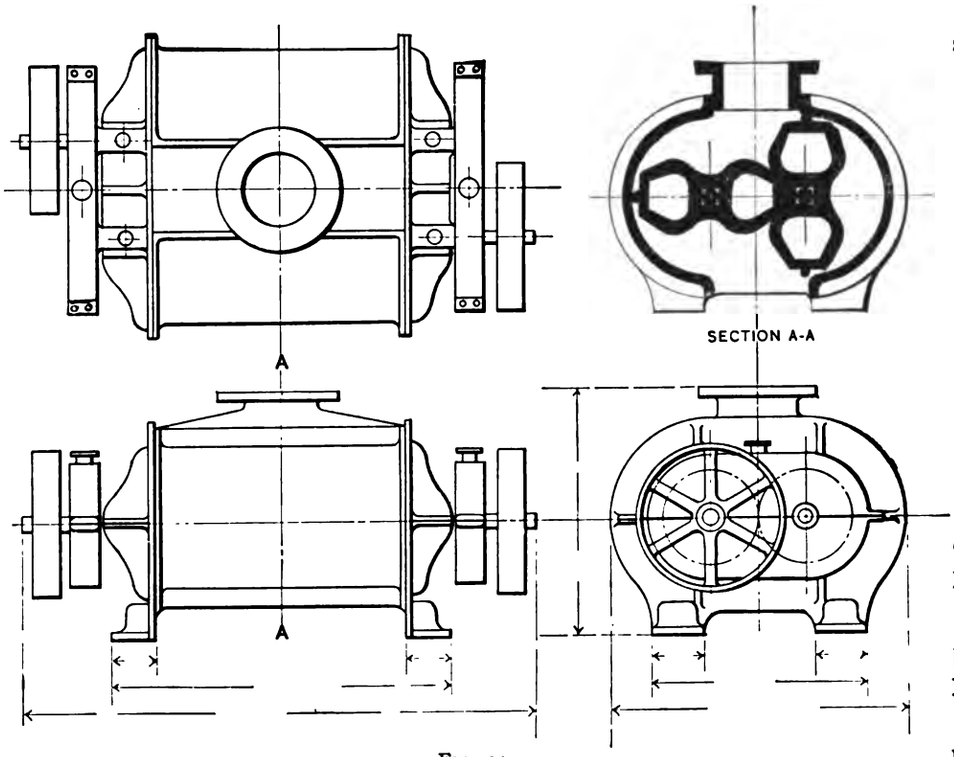


FIG. 24.

192. **Lines of Object.**—A **visible edge** of a solid should be represented by a full line, clean cut, comparatively wide to make it stand out in a bold effect, and of uniform width throughout its length.—**Plate I.**

193. Where a **corner** is not sharp, but rounded, it is admissible by convention to represent it in all views, if any clearness is gained thereby. —**Curve of intersection of pulley-arm with bead on rim, Plate IV.**

Always show **filletted or rounded corners** when finished adjoining surfaces do not forbid.

194. All lines bounding a **hexagonal figure** should be **drawn** tangent to a circle whose diameter is equal to the distance between parallel sides of the hexagon and by means of the triangles and T square.—**Fig. 25.**

195. When the three faces of a standard **hexagonal bolt** or nut is shown, make the **distance between the outside lines** equal to twice the

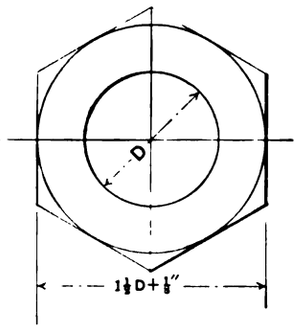


FIG. 25.

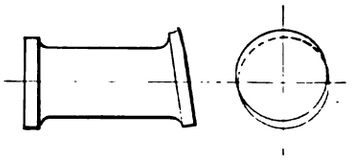


FIG. 26.

diameter of the body of the screw, and the **distance between the inside lines** a trifle less than the diameter of the body of the screw.—**Fig. 17.**

196. Curves of intersection should be put in as circular arcs when possible.—**Curve of intersection of pulley-arm with bead on rim, Plate IV.**

197. An **ellipse** in projection which is **not very flat** may be shown by convention, by a circle.—**Fig. 26.**

198. An **ellipse** whose **major** is about **twice its minor axis** may be drawn with circular arcs with radii of side arcs three quarters the length of major axis, and the end arcs tangent to the side arcs and passing through the ends of the major axis.—**Fig. 27.**

When the minor and major axes are known, to find **points on** the **true ellipse** proceed as follows: draw circles on minor and major axes from a center at the intersection of the axes; draw radial lines through

center of circles; draw horizontal and vertical lines through points of intersection of radial line and minor circle and of radial line and major

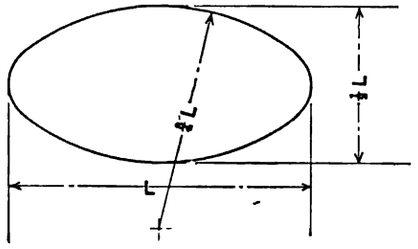


FIG. 27.

circle respectively. The points of intersection of the horizontal and vertical lines will be points on the ellipse.—**Fig. 28.**

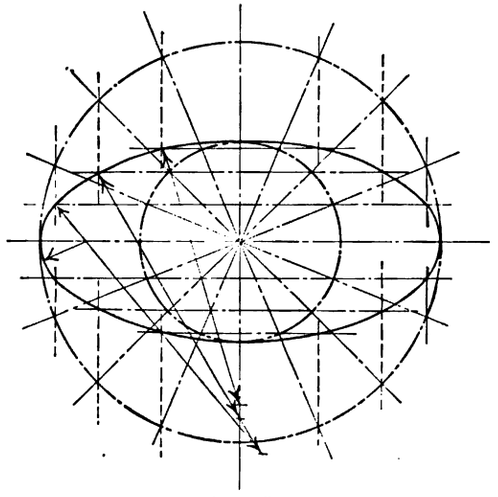


FIG. 28.

To draw **any ellipse with circular arcs** passing through predetermined points, proceed as follows: considering one quadrant, draw from a center on the major axis a circular arc which will pass through the end of the major axis and the first point; from a center on the line passing through the first point and the center of the first arc, draw a second arc through the first point and second point; continue in this order until all the points have circular arcs connecting them. Three points or four arcs to a quadrant is usually sufficient for a very close approximation of the ellipse. Care should be exercised in making good joints at the points of tangency of the arcs.—**Fig. 28.**

199. Make the **chamfers on bolts,** studs, shafts, etc., 45° lines.—**Fig. 21.**

200. **Oil holes and channels** are usually not shown, unless they are to be made in an unusual manner.

201. The **spacing of V-thread lines,** and their pitch, may not be absolutely exact but a fine thread naturally has its lines close together and has less pitch than a coarse thread.

202. The **spacing of** all **thread lines, except V-threads,** should be approximately close and always done by marking off distances directly from the scale.

203. Remember that **nuts,** when **sectioned,** theoretically show the pitch of the threads in reverse order to those on the screw which fits it.—**Fig. 19.**

204. When a **screw** is of **considerable length,** four or five threads should be drawn at the ends only, leaving the intervening length blank. —**Feed Screw, Plate II.**

205. An **invisible edge of a solid** should be represented by a broken line, which is clean cut and composed of comparatively short dashes of equal lengths. The dashes should be drawn as close together as possible, and not quite so wide as the visible lines of object.—**Plate I.**

An **invisible** line, composed of **more than one dash,** should always begin and end on the terminating lines which include it.—**Keyway of Worm, Plate II.**

If an **invisible line** is shown by **one dash** only, it should not begin or end at the terminating lines, but a short space should be allowed between the dash and terminating lines.—**Fig. 29.**

206. An **adjacent part line** is a line **in another object** which is adjacent to the one regularly shown on the drawing and simply serves the purpose of indicating, for some particular reason, what is attached to

the piece shown on the drawing. Therefore it should be a main outline, of sufficient length to indicate what is attached. It should be a fine, broken, clean-cut line composed of alternating dashes of one eighth of

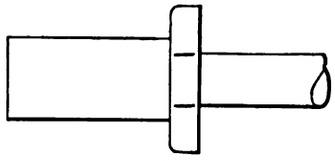


FIG. 29.

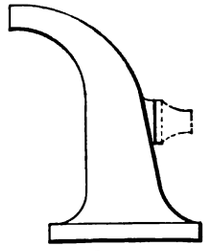


FIG. 30.

an inch and three eighths of an inch lengths respectively, drawn as close together as possible.—**Fig. 30.**

An **adjacent part line** is also used for **showing** some important **part** of an object that is **cut away** on the section view.—**Fig. 31.**

207. A **broken line** represents the visible edges of the part of a solid of a structure that is **broken off.** The width of this line should correspond

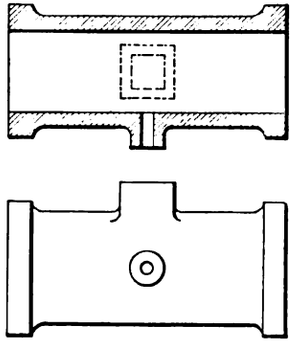


FIG. 31.

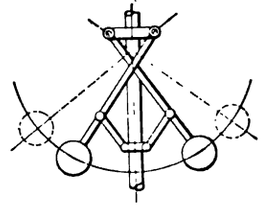


FIG. 32.

to the width of any visible line of the object and should be drawn with the ruling pen.—**Plunger, Plate II.**

208. An **alternate position line** is used for representing a limiting or important position of a moving part, other than is shown regularly on the drawing. An alternate position is sometimes represented by drawing the bare outlines of the object or by a center line. If the bare outlines are drawn, they should be fine, broken, clean cut lines, composed of alternating dashes of one eighth of an inch and three eighths of an inch lengths respectively, drawn as close together as possible.—**Fig. 32.**

209. **Sectioning.**—Where there is a section view, the trace of the cutting plane shown on the view of the object that is cut should be represented by a fine line whose character is that of a center line. The line is also to be notated at each end and the corresponding notation must be suitably placed and referred to, under that view which shows the section.—**Fig. 24.**

210. **Section lines,** which are sometimes called **hatch lines,** are oblique parallel lines at equal distances from each other. They are used to represent a surface which has been cut.

Uusally **hatch lines** make an **angle** of 45° with the horizontal but it is not criminal, but even sometimes desirable, to use 30° and 60° lines if the conditions warrant it.

211. The **spacing of sectioned lines** should be determined by the area of the sectioned surface on the drawing and the kind of material which is cut. But sectioned lines should not be over three thirty-seconds of an inch apart and softer material should be shown with section lines further apart than harder material.

Adjacent pieces shown **in section,** must be hatched with lines in reverse order.—**Plunger, Plate II.**

212. All **hatching** should be done **freehand on penciled drawings** which are to be inked.

When the surface is large, the **hatch lines** should be short and placed **along the edges only.**

There are **conventional lines to represent the different materials** that are cut, but they are often unintelligible to the mechanic and their relegation to oblivion is forcibly recommended. Diamond hatching to represent babbitt is perhaps universally used.—**Fig. 33.**

213. A **soft drawing or crayon pencil** is often **rubbed on the surface of the drawing** to represent the section, but a blue crayon pencil should

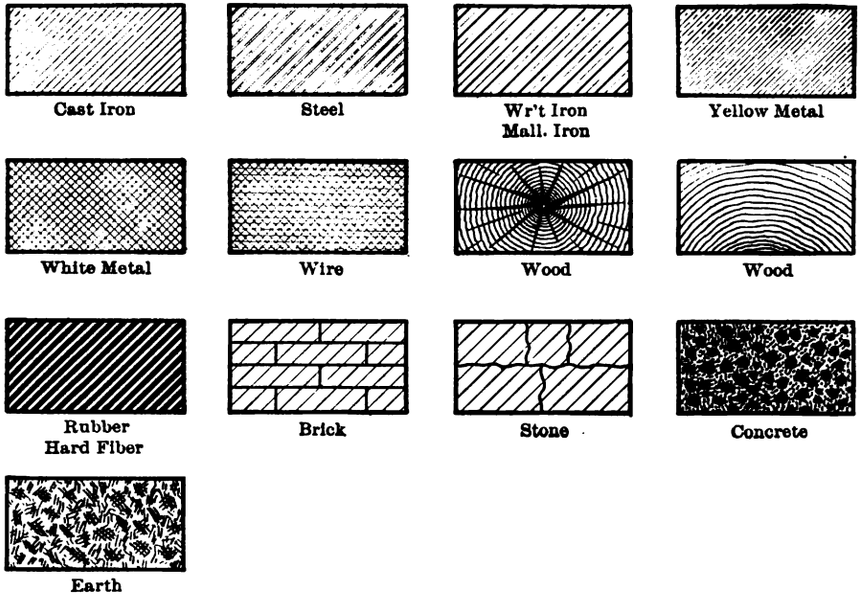


FIG. 33.

never be used for the purpose when a print is to be taken from it.

214. A **rib,** an arm of a pulley, or any comparatively thin piece,

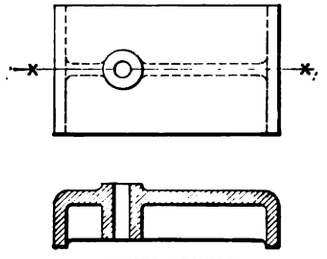


FIG. 34.

should not be sectioned by a cutting plane parallel to its largest bounding surfaces.—**Fig. 34.**

215. A **solid round piece** should not be shown in section when the cutting plane is taken through its axis.

216. A **turned section** placed on a view is convenient, more direct, and often clearer than when placed off at one side.—**Section of Arm, Plate IV.**

217. A **keyway** in a hole should not, as a rule, be sectioned, but should be shown by an invisible line.—**Plate IV.**

218. **Pieces** that are **broken** at the ends are shown conventionally in the figure.—**Fig. 35.**

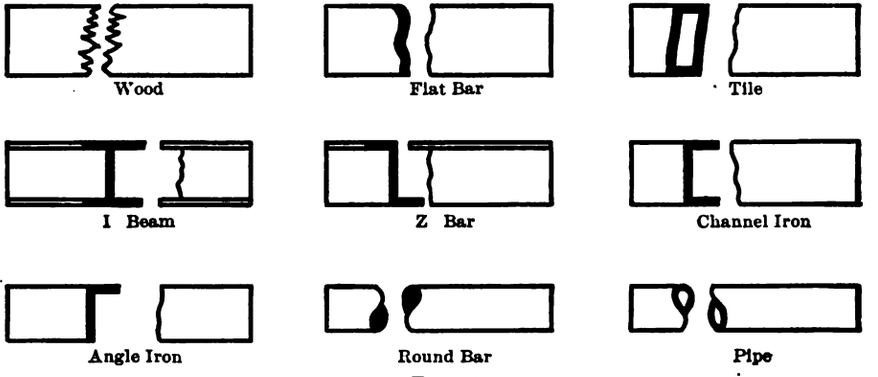


FIG. 35.

219. **Center Lines.**—A center line is used to indicate **symmetry** and any configuration which has a natural axis or axes has a center line or lines to represent it or them. A circle, for instance, should have two center lines at right angles to each other.

Pitch lines of gears should be shown as center lines.

220. When circles are spaced along a circumference on the surface of a disc, as **bolt circles on a flange,** a circular arc and radial lines, passing through the bolt hole centers, are used as the center lines.—**Fig. 36.**

221. A **center line** should be a fine, broken, clean cut line, composed of alternating dashes of one eighth of an inch and three eighths of an inch lengths respectively, evenly spaced and not too close together. A short center line may consist of one dash.—**Plate I.**

222. **Penciled center lines** that are to be inked or traced over should be full lines.

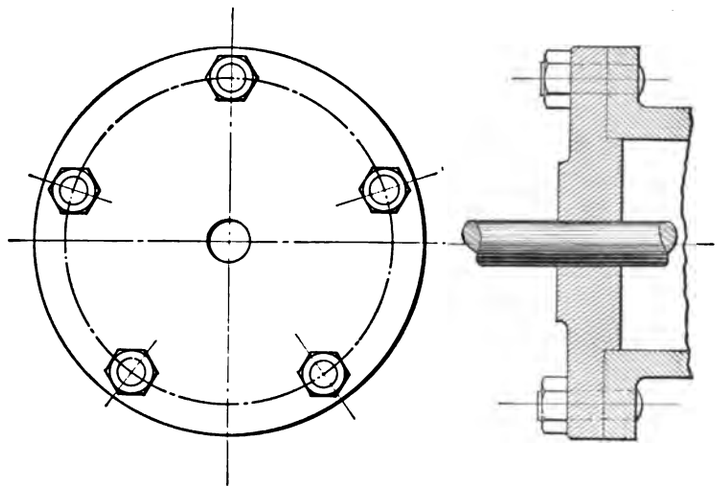


FIG. 36.

223. Visible and invisible lines of an object and surface shade lines have **precedence over center lines** in case there is coincidence.

224. **Dimensions.**—There is **nothing** on the whole drawing **so important as the dimensions.**

225. A **dimension line** is used for **indicating** a dimension between certain limits, and it is broken at some convenient place between its limits (preferably midway) to allow for the dimension.

226. The **character** of a dimension line should be a fine, broken, clean cut line, composed of equal dashes, equally spaced from each other.—**Plate I.**

227. All dimension lines, excepting those representing radii of circular arcs, are **terminated by arrow heads** at both ends. A **dimension line** which indicates a **radius** is terminated by an arrow head at the arc only, and if there are no intersecting center lines at the center from which the arc is struck, a small cross should indicate it. *Rad.* should be placed after the dimension.—**Fig. 37.**

228. The **arrow head** should make a small acute angle with the dimension line, and should be made in short arcs with the same writing pen which is used for the figures and letters on the drawing.

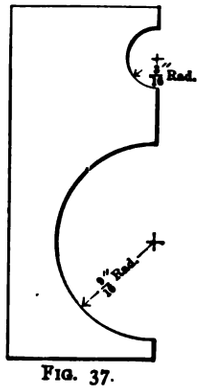


FIG. 37.

229. All **dimensions** should be given **with reference to main lines** or center lines, or both.

230. The position of the **dimension line** is **determined by judgment.** It should be placed on that view which shows the most and in such a manner as to indicate most clearly and directly what the dimension between the extremities of the line stands for.

231. It is well to **distribute** the **dimensions** of a piece over its views, if clearness is gained by so doing.

232. All the dimensions to any **particular** part **of a view;** as, to that of a circle, rib, rectangular surface, etc., should be shown on one view if possible and *not* on several views.

233. A **dimension** is more clear and direct when placed **on the view itself,** provided it does not cause a confusion of lines so as to impair clearness, and, provided there is sufficient space, without crowding, for the figures between.

The **dimension,** however, may be placed **off the view** and a curved witness line drawn from it to the usual place for the figures at the dimension line.

234. **Dimension lines** should **not** be placed so **close to other lines** as to impair clearness.

235. When **dimensions** are **grouped in parallel lines,** the shortest dimension is inside and the others are graded to the longest dimension on the outside.—**Fig. 22.**

If one or the two **ends** of a dimension line **terminate** at **two parallel lines** which are close together and there is confusion as to which one of the parallel lines limits the dimension line, and if the dimension is limited by the outside one of the lines, additional short dimension lines should be used with arrow heads just touching the limiting line.—**Fig. 38.**

236. A **short dimension** can be shown by placing the dimension lines with their arrow heads on the outside of the limiting lines and the dimension inside.—**Fig. 39.**

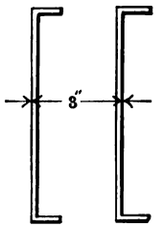


FIG. 38.

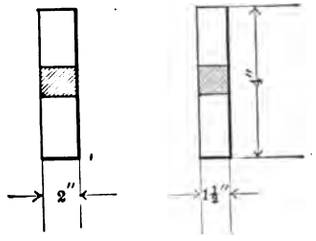


FIG. 39.

237. If **one end** of a **dimension line cannot be shown** the full dimension is given at a break in the line.—**Fig. 40.**

A line of **sub-dimensions** should usually commence at the finished surface, and, if there is an unfinished surface on the opposite side, the

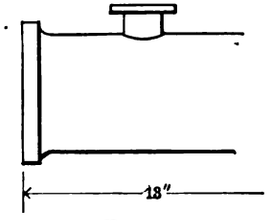


FIG. 40.

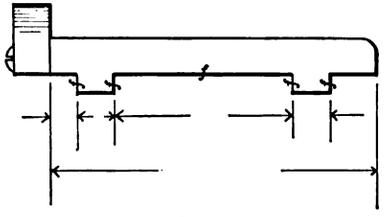


FIG. 41.

last sub-dimension should be omitted, and, also, an **over all dimension** should be given from surface to surface.—**Fig. 41.**

238. The common two-foot rule has undoubtedly been generally adopted for a standard when dimensions are given in feet and inches. Therefore, all **dimensions** must be given in inches including twenty-four inches and below. Dimensions above twenty-four inches must be given **in feet and inches.**

When dimensions are given in feet and inches, a dash one eighth of an inch long should separate them.

Foot and inch marks not less than one sixteneth of an inch long should be used for accents.

If there is a **fractional number less than an inch,** when the dimension is expressed in feet and inches, the **figure zero** should be placed before it.—**Feed Screw, Plate I.**

A fraction must **never have a diagonal division line** and the **figures** must be a little **smaller than the integer** which precedes it.

239. When **dimensions** are given in **decmials,** the inch marks should be placed between the whole number and fraction.

If the **decimal dimension** is **less than an inch,** the figure zero should recede it and the decimal point and the inch marks should be placed as indicated above.

240. If the **outside diameter of a gear** is a fraction, it should be stated in a **common fraction.**

241. All **dimensions** should **read from the bottom and right hand side** of drawing. If **dimensions** are **at an angle** with the edges of the sheet, they should **read from bottom side** of the drawing.

242. If a **dimension** is **not** to the same **scale** as others on the view, indicate it by a dash above the dimension.

243. **Dimensions** on a drawing **should indicate** the **full dimensions** independent of the scale of the drawing.

244. All the **dimensions** given on a piece **indicate** the **final dimensions** of the piece when it is complete and no allowance should be made for the shrinkage of casting, etc.

245. Care and judgment must be exercised as to whether the radii or diameters are the dimensions needed for the mechanic: *e.g.*, a **bolt circle should have** its **radius** given; **a bored hole, its diameter** given; a **turned piece, its diameter** given, etc.

If in a **side view** a round or square shaft or stud, etc., is shown and there is **no circle or square in the end view** to represent them, or if there might be confusion as to which was intended, *dia.* or *sq.*, respectively should **always be placed** after the dimension.—**Feed Screw, Plate I.**

A **dimension** should **never** be **placed on a center line.**

It is an inviolable rule to **never cross a dimension** with a line.

Small rounds on corners, or fillets, are not usually dimensioned.

Circles which do **not** indicate clearly their relation to the piece shown in the view should never be **dimensioned.**

246. If the **end of a screw,** stud, etc., is rounded, the **dimension** should be given **to the corner** and not to the extreme end.—**Stud, Plate II.**

247. If **bolts and screws** are drawn and everything is **standard** except their lengths, only the diameters of their bodies, the length under the heads, and their lengths of thread are shown in the dimensions.

248. **Bolt heads and nuts** (when not standard), and square and hexagonal figures should be **dimensioned across flats** and not across diagonals.—**Fig. 25.**

249. **Rolled structural steel** should be **dimensioned in the commercial sizes** and not in every detail.—**Fig. 42.**

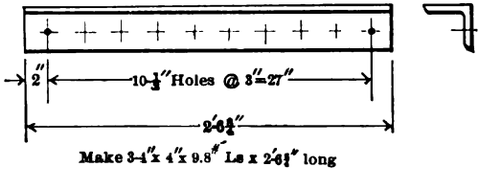


FIG. 42.

250. Where a number of **rivet or small bolt holes** are in a right line, the usual dimensions should be given in a note on the dimension line between the first hole and the last hole. The note should give their number, size, distance apart and the total distance from the first to the last hole. The dimension from one of the end holes to the end of the piece should be regularly given.—**Fig. 42.**

251. The **sizes of pipes** must be stated in their nominal inside diameters.

252. **Pipe tapped holes** must be indicated by the size of pipe tap required and all other data regarding the hole is useless and should not be stated.

253. In giving **board dimensions,** remember that the thicknesses of stock boards are more likely to be in fractional than in even inches; as, a seven eighths of an inch instead of a one inch board and a one and three fourths inch instead of a two inch board, etc. (These are finished board dimensions.)

254. **Brick dimensions** should be given in multiples of four except for height.

255. **Windows** in brick walls should be **dimensioned to their centers,** and **doors** should be **dimensioned for the width of opening.**—**Plate XI.**

256. When **angles** are given **in degrees and minutes,** the usual degree and minute accents should be used and a curved dimension line should replace the usual right line. Otherwise the dimension line conforms to the same rules as are observed for all dimension lines.

257. **Dimensions of angles** on a drawing intended for pattern-makers, are often more convenient when given **in coordinates** from a given reference line or point than when given in degrees and minutes.—**Fig. 43.**

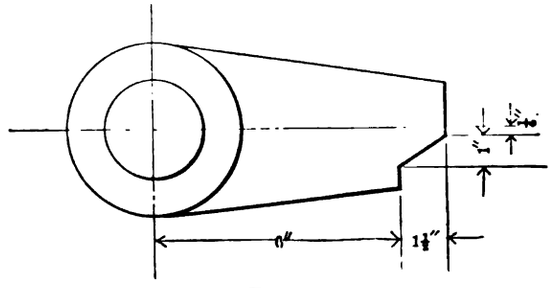


FIG. 43.

As a rule, the **dimension figures** should be put in with as **wide a line as the lines of the object.**

258. **Extension lines are limiting lines** that are used when a dimension is placed off the view and must have the included distance between them equal to the same distance as referred to on the view. They should be fine, broken, parallel lines composed of equal dashes spaced at equal distances, and no extension line should join a projection line.—**Plate I.**

Short extension lines of one dash only can sometimes be used.

259. **Notes.**—Notes should be placed on a drawing so that they can be read easily and quickly.

If convenience admits of it, and there are several **words** in the note, they are more quickly read when placed **in a horizontal line.**

260. **All letters** used in notes on drawings must be of the **most simple type,** plain, of uniform height, and composed of lines of uniform width to match the projection lines of the object.

The **initial letter** of every word, excepting prepositions, should be taller than the others.

All the **letters in a word should be close together** and not less than one sixteenth of an inch nor more than one eighth of an inch in height.

261. **Draw parallel guide lines** in pencil before printing words. All words should be sufficiently separated for clearness.

262. **All notes** should be **written** on **pencil drawings** which are to be traced, and **printed on inked or finished** pencil drawings.

263. **Notes** must not be too **abbreviated.**

All notes must be in **short sentences, explicit and concise.**

264. **Castings** and **rough forgings** are occasionally not finished all over; as a consequence, the custom in practice is to note the surfaces on each piece which are finished.

When a surface is machined or finished, an *f* **mark** should be placed on that line of the view which represents it and not on the view where the blank surface only is shown.—**Plate V.**

If a **casting** is **finished all over** the several *f* marks should be left off and the words *fin. all over* should be printed under or near the views.

265. When there are **two** lines **close together** representing the edges of surfaces, and one or both of them represent finished surfaces, the *f* mark should be placed outside with a witness line drawn to the finished surface.—**Fig. 44.**

266. It is sometimes clearer, or necessary, to **state** the **kind of finish** or machining a piece should have, as *file finish, grind, plane, bore,* etc.

Pieces which are **made from rolled** or wrought steel bars, as spindles, shafts, studs, etc., are usually finished all over; and it is the custom to omit the finish notes.

267. If a **steel casting** is wanted do not confound it with cast steel but call it a *steel casting* everywhere on the drawing.

268. A plane surface that is **partially finished** should be indicated with a dimension. If it is **counterbored** to furnish a **seat** for washer, etc., only the note *spot face* is necessary.—**Fig. 45.**

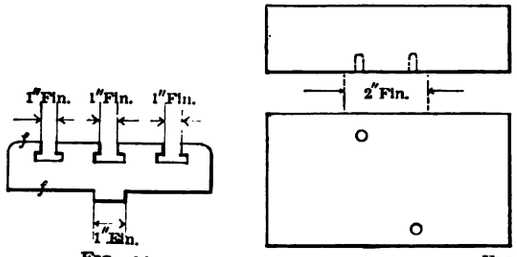


FIG. 44.

FIG. 45.

269. If in machining a **fixture or jig** is used for any interchangeable part in a machine, it should be indicated on or near the view of the piece.

270. **Threads** should be **noted in number per inch,** unless they are U. S. standard; in which case, they should be indicated as such.

271. **Tapers** on shafts should be given in inches per foot on diameter.

272. **Springs** are described in detail by giving gage size of wire in a coil, the number of free coils to the inch, and the inside or outside dimensions of the body of the spring.

273. The **mesh of wire** in screens is indicated by the size of wire to gage used, and the number per inch or the amount of opening between the wires.

274. **Forced fits** should be indicated by the total pressure required per unit area.

275. The **inclination of a pipe or roof** should be described as the pitch or slope and given in the ratio of the unit rise or fall to the horizontal distance; as, 1 in 6 pitch or one sixth pitch, etc.

276. **Every piece** shown on a drawing must **have** an **identifying letter** which should be a capital letter somewhat larger than the initial letter in the other notes on the drawing and must be the same letter as used in the bill of material for the same piece. The letters "**I**" and "**J**" **must not be used,** and, when the letters in the alphabet are exhausted,

small capitals should be used along with and at the side of the large capitals.—**Plate I.**

277. **Shading.**—Shade lines for outline shading are sometimes used on edges and surfaces of views which conventionally cast shadows. They should not be used too freely, for they are a convention which adds to the work of the draftsman, but, occasionally, they make clearer the configuration ot an intricate piece which is shown on a drawing, provided that the mechanic understands the convention as well as the draftsman who uses it. They are occasionally used for the purpose of display, which, at its best in detail drawing, is very much out of place. If, however, they are used on the views of one piece, they should be used on all the views of all the pieces which are shown on that one drawing in order to conform to that fundamental rule of uniformity which should obtain on all drawings.

278. **Outline shading** should be done by drawing a second adjoining projection line on and not outside that part of the view which represents the surface of the material. By drawing a shade line then, on the surface of the piece, it **cannot be considered** as **a line in the shadow** which is cast by an edge of an object as it is often interpreted.

By considering a **shade line** as a line in the shade of the piece and **not** as a **shadow** cast by it, the actual dimensions from edge to edge are kept to scale; and it follows, that the **lower** and **right hand outside edges** of a piece and the **upper** and **left hand edges** of holes would have shade lines.

279. When a **circle is shaded,** the set of the compass which strikes the circle should not be changed, but another center should be taken up and along a line which makes 45° with the horizontal. The eccentric arc which is then struck with the new center to represent the shade line should just join the original circle at the end of the 45° line and should continue until it just merges with the original circle.

280. In the side view of a **round piece** there is theoretically no outline **shade line on the round edge but, by convention, a shade line should be used.**

281. An **unsectioned round piece in a bushing that is sectioned** by a meridian plane has conventionally an outline shade line.

282. In a **V-thread screw,** by convention, **the short** conventional thread line is shown as a shade line.

283. In a sectional **V-thread nut,** by convention, **the long** conventional thread line is shown as a shade line.

284. **Pencil drawings** that are to be inked or traced over should **never be outline shaded.**

285. **Surfaces** of pieces, which are in the shade, are occasionally **shade lined.** Surface shading should be done to a very limited extent on commercial mechanical drawings and only when it is quite necessary to make clear or stand out some surface which would otherwise be wholly confused in the view of an intricate piece.

As a rule, **no surface shading** should be used **on any detail drawing.** The exception to this rule might be the round base on a casting.

286. **Penciled Drawings.**—When penciling a drawing, each piece, with all its views, should be completed before another is begun and the penciling should be done in the following order:

1. Draw **border lines.**
2. Draw **match lines.**
3. Block out **space for titles.**
4. Block out **space for bill of material** if there is one.
5. Draw **main center lines** of object in all its views.
6. Draw **main lines of object.**
7. Draw **small** and **inside lines of object,** commencing with that view which shows the most essential feature if there is a choice.
8. Put in **dimensions** and necessary **notes.**

As large **arcs** as possible should be put in **free-hand.**

It is an art to **make** a finished pencil **drawing neatly, quickly and properly.** With some draftsmen it appears to be a gift, but with others it must be acquired.

287. A **drawing,** which is to be traced or inked, should usually be **completely penciled.** It is an undesirable habit to form and an unneces-

sary tax on the mind, when a draftsman leaves a large share of the details in his mind for inking, instead of penciling them on the drawing paper.

288. **Inked Drawings.**—All drawings must be **inked** in with **black waterproof drawing ink.**

289. The different parts of a **drawing** should be **inked** in the following order: first, all the lines of the object, which are represented by the **small arcs,** the **large arcs,** and **right lines** taken in their respective order—and if there is any outline shading it should be done at the same time; second, all **auxiliary lines excepting hatch lines;** third, **dimension lines, arrow heads** and **notes;** fourth, **hatch lines;** fifth, **surface shade lines,** if there are any; sixth, **bill of material;** seventh, **title;** eighth, **border lines.**

290. It is sometimes well to **ink** only a **section** of a drawing at a time, particularly if the drawing is not to be finished the same day that it is begun.

It is rather imperative that **tracing cloth** should be **inked** in sections, as change of atmospheric conditions has a marked effect on the tracing cloth.

291. Always **commence** the **inking at the top and left-hand side** and **work across and down** the sheet.

292. **Any line** which is over one thirty-second of an inch **wide,** and drawn with a medium size ruling pen, should be made with more than one stroke of the pen.

293. When **inking** in the sections of **very narrow walls** in building plan or like sections, draw heavy parallel lines to represent their outlines and fill in with the writing pen or, preferably, a large ruling pen.

294. **Hatch lines** which are **three sixteenths of an inch long** or less, should be put in with the writing pen.

295. That which makes an inked drawing look well is **uniformity in every detail,** to wit: All figures, letters, lines, etc., that are used for like purposes should be of the same height, same width of line and same style.

296. **Checking Drawings.**—Everything on a drawing must be thoroughly checked by at least two persons before it is allowed to pass into the shops.

A draftsman should **check** his drawing **by** methodical **steps** and should not try to check it by taking a bird's-eye view of what he has done.

The following steps are to be observed in checking a detail drawing:

1. **Identify every piece** in its relation to the machine and note if it is of proper form and that none are missing.

2. Check every view for **correct** and **complete lines of object.**

3. Note if there are any required **dimensions or** working **notes missing.**

4. **Scale every dimension,** and note if they agree with the one given on the drawing.

5. **Check** the **main dimensions** of the pieces in detail and assembly and note if they agree.

6. **Check** the **arrow heads** to see if there are any missing.

7. **Check** the **accents** to figures as inch marks, foot marks, and degree marks.

8. **Check** the **center lines.**

9. **Check** the supplementary **notes** and **marks** to see if they are correct and none missing.

297. **Assembly Drawings.**—The function of an assembly drawing is to show the arrangement of its principal parts in the most simple, direct and comprehensive manner.

298. An arrangement of parts is sometimes clearer when the **main part** has its outline **fringed** with a **dotted section line.** That scheme however is not common at the present time.—**Stub end of connecting rod, fourth grade.**

299. On a small scale, it sometimes happens that several **lines** in true projection would be **close together** and even merge if inked in. If such is the case, the lines should be spaced a little farther apart or now and then one left out.—**Fig. 24.**

300. In assembly drawings show **elevations in a line,** if possible.

301. **Minor details,** as nuts, keys, set-screws, etc., can be **left off** of the assembly drawing when they are evident without drawing.

302. **Over all and important main dimensions** are the most that are needed in an assembly drawing.—**Fig. 24.**

303. **Structural steel parts,** when they are shown on such a **reduced scale** as to make a section one eighth of an inch or less in width, should be blacked in.—**Fig. 35.**

304. When there are four or more **bolts** in a piece, two should generally be shown, in a side view, at their true scale distance from the center, as measured each side of the center line.—**Fig. 36.**

305. Show only **pitch circles** in **end views of gears.**—**Fig. 46.**

306. **Diagram Drawings.**—If merely an outline of a machine is desired, a diagram drawing is made, which is composed of the main lines of the machine with the usual center lines.—**Fig. 47.** If the **relation of** some of the **moving parts** of a machine is desired, they may be represented by connected heavy lines passing through the center line of the members, as a Corliss valve gear, etc.—**Fig. 48.**

In some **intricate types** of machinery, as shoe machinery, textile machinery, etc., and especially in textile machinery, it is often quite impossible to show, for an assembly drawing, anything more than a diagram drawing.

307. **Patent Office Drawings.**—A patent office drawing must be made to certain specifications which are given verbatim as published in the official "Rules of Practice" in the United States Patent Office:

When the **invention** consists of an **improvement on an old machine** the drawing must exhibit, in one or more views, the invention itself disconnected from the old structure, and also, in another view, so much only of the old structure as will suffice to show the connection of the invention therewith.

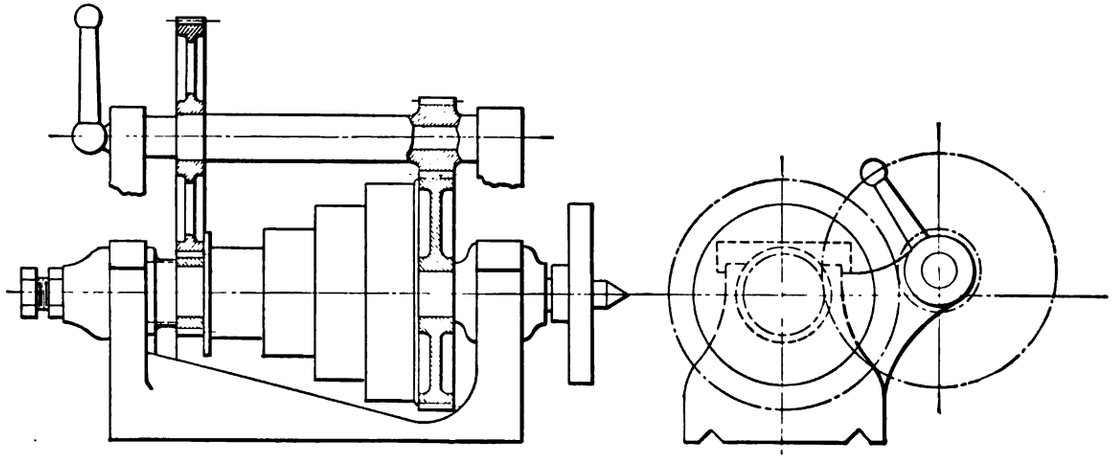


FIG. 46.

Drawings must be **made upon** pure white paper of a thickness corresponding to three sheet **Bristol board.** The surface of the paper must be calendered and smooth. India ink alone must be used to secure perfectly black and solid lines. (Two sheet bristol board and Higgins' drawing ink is used a great deal by Patent Office draftsmen.—Author.)

The **size of a sheet** on which a drawing is made must be exactly 10×15 inches. One inch from its edges a single **marginal** line is to be drawn, leaving the "sight" precisely 8×13 inches. Within this margin all work and signatures must be included. One of the shorter sides of

the sheet is regarded as its top, and, measuring downwardly from the marginal line, a **space of not less than 1¼ inches** is to be left blank for the heading of title, name, number, and date.

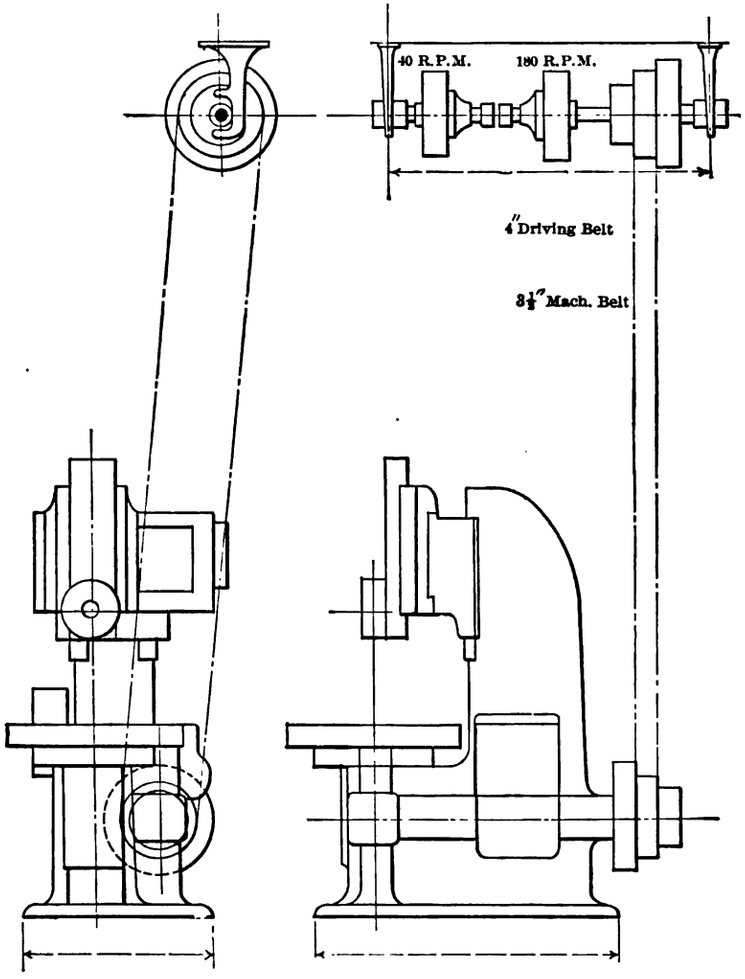


FIG. 47.

All drawings must be made **with the pen** only. Every line and letter (signatures included) must be absolutely black. This direction applies to all lines, however fine, to shading, and to lines representing cut surfaces in sectional views. All **lines must be clean, sharp, and solid,** and they **must not be too fine or crowded. Surface shading** when used, **should be open. Sectional shading** should be made by oblique parallel lines, which may be **about one twentieth of an inch apart. Solid black should not be used** for sectional or surface shading.

Drawings should be made with the fewest lines possible consistent with clearness. (This means no center lines, dimension lines, etc.—

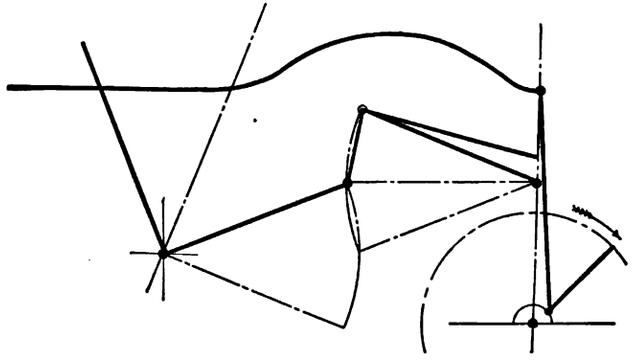


FIG. 48.

Author.) By the observance of this rule the effectiveness of the work after reduction will be much increased.

Shading (except on sectional views) should be used **only on convex and concave surfaces,** where it should be used sparingly, and may be even there dispensed with if the drawing is otherwise well executed. The plane upon which a sectional view is taken should be indicated on the general view by a broken or dotted line. **Heavy lines on the shade sides of objects should be used,** except when they tend to thicken the work and obscure letters of reference. The light is always supposed to come from the upper left-hand corner at an angle of 45°. **Imitations of wood** or surface graining **should not be attempted.**

The **scale** to which a drawing is made ought to be large enough to show the mechanism without crowding, and two or more sheets should

be used if one does not give sufficient room to accomplish this end; but the number of sheets must never be more than is absolutely necessary.

The **different views** should be **consecutively numbered. Letters and figures of reference** must be carefully formed. They should, if possible, measure at least one-eighth of an inch in height, so that they may bear reduction to one twenty-fourth of an inch, and they may be much larger when there is sufficient room. They must be so placed in the close and complex parts of drawings as not to interfere with a thorough comprehension of the same, and therefore should rarely cross or mingle with the lines. When necessarily grouped around a certain part, they should be placed at a little distance where there is available space, and connected by short broken lines with the parts to which they refer. They **must never appear upon shaded surfaces,** and when it is difficult to avoid this a blank space must be left in the shading where the letter occurs, so that it shall appear perfectly distinct and separate from the work. If the same part of an invention **appears in more than one view** of the drawing it must always **be represented by the same character;** and the same character must never be used to designate different parts.

The **signature of the inventor** should be placed at the lower right-hand corner of each sheet, and the signatures of the witnesses at the lower left-hand corner, all within the marginal line, but in no instance should they trespass upon the drawings. The **title should be written with pencil on the back of the sheet.** The permanent names and title will be supplied subsequently by the office in uniform style.

When **views are longer than the width of the sheet,** the sheet should be turned on its side, and the heading will be placed at the right and the signatures at the left, occupying the same space and position as in upright views, and being horizontal when the sheet is held in an upright position; and all views on the same sheet must stand in the same direction.

As a rule, **one view only of each invention can be shown in the Gazette illustrations.** The selection of that portion of a drawing best calculated to explain the nature of the specific improvement would be facilitated and the final result improved by the judicious **execution of a figure with express reference to the Gazette,** but which might at the same time serve as one of the figures referred to in the specification. For this purpose the figure **may be a plan, elevation, section, or perspective view,** according to the judgment of the draftsman. (An **axometric drawing** is often a good substitute **for** the true **perspective.** It is based on the principle of establishing three axes which theoretically can make **any** angle with each other; of drawing lines parallel to the axes when they are parallel in the object; and of making them either full length or foreshortened. When an **axometric** drawing is used for a **working drawing,** the lines in the drawing should be to a full or some convenient scale, but, if the **picture effect** is desired, certain **lines** may be slightly **converged** and **foreshortened.**

The **arrangement** of the **axes** is practically based on the convenience obtained in drawing the lines of the object with the instruments. **Three** convenient **arrangements** may be made which are known technically; as, **Isometric, Cavalier,** and **Cabinet projection. Isometric projection** is drawn with axes making 120° with each other, one axis vertical and the other two making 30° with the horizontal. **Cavalier projection** is drawn with one of the axes making any angle with the horizontal, the other two being vertical and horizontal. **Cabinet projection** is drawn with one of the axes 45° with the horizontal, the other two being horizontal and vertical. Isometric projection is the one most commonly used and cabinet projection usually gives the best picture effect.

In making an **axometric projection** it is well to **consider:** that the drawing may be facilitated by drawing first an enveloping square prism around plan and elevation of object for reference; that, if it is isometric, the vertical and 30° axes correspond respectively to the vertical edge of the enveloping prism and to the two right angle edges in its horizontal base; that, if it is cavalier, the vertical and angular and horizontal axes correspond respectively to the vertical edge of the enveloping prism and to the two right angle edges in its horizontal base; that, if it is cabinet, the vertical and horizontal and 45° axes correspond respectively to the vertical edge of the enveloping prism and to the two right angle edges in its horizontal base; and also that lines in the object which are parallel to the 45° axis are shortened to one half their actual length; that, since it is a species

of orthographic projection, lines which are parallel in the object will be parallel in the drawing; and that all irregular lines may be drawn if their connecting points are first formed. Isometric, cavalier and cabinet cubes are shown in **Fig. 49**.—Author.)

It must **not cover a space exceeding 16 square inches.** All its **parts** should be **open and distinct,** with very **little or no shading,** and it must **illustrate** the invention claimed only, to the exclusion of all other details. When well executed, it will be used without curtailment or change, but **any** excessive fineness, or crowding, or unnecessary elaborateness of **detail** will necessitate its exclusion from the Gazette.

An agent's or attorney's stamp, or advertisement, or written address will not be permitted upon the face of a drawing, within or without the marginal line.—**Plate XXI.**

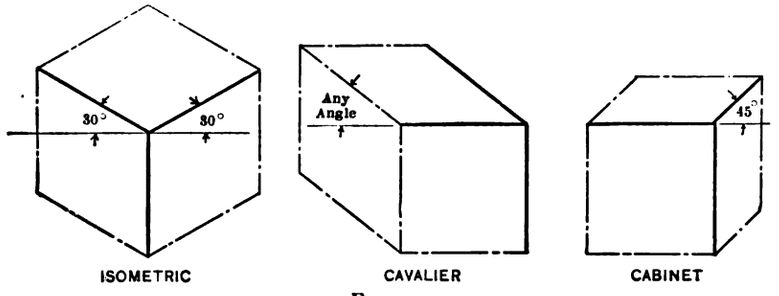


FIG. 49.

INDEX.

PLATE I

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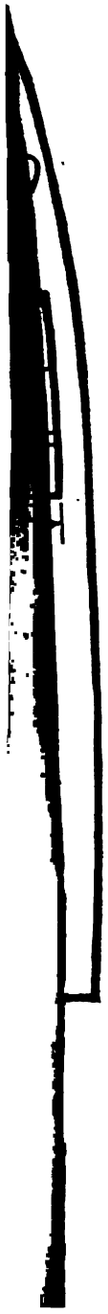

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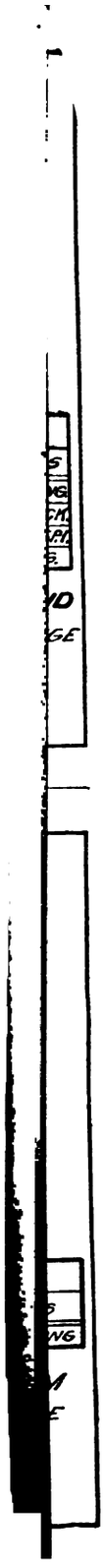

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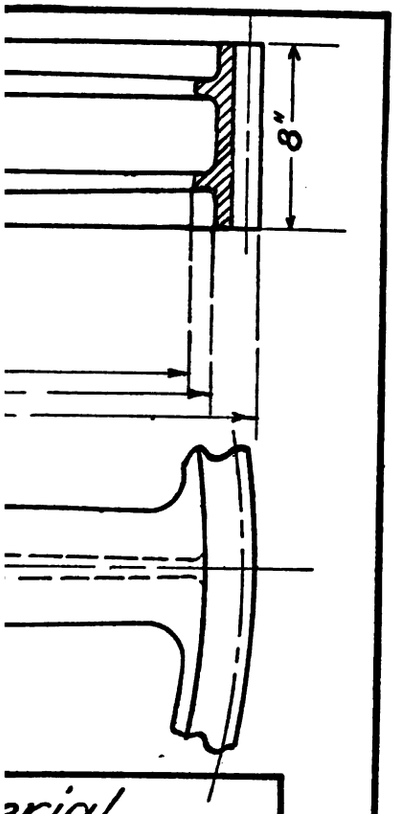

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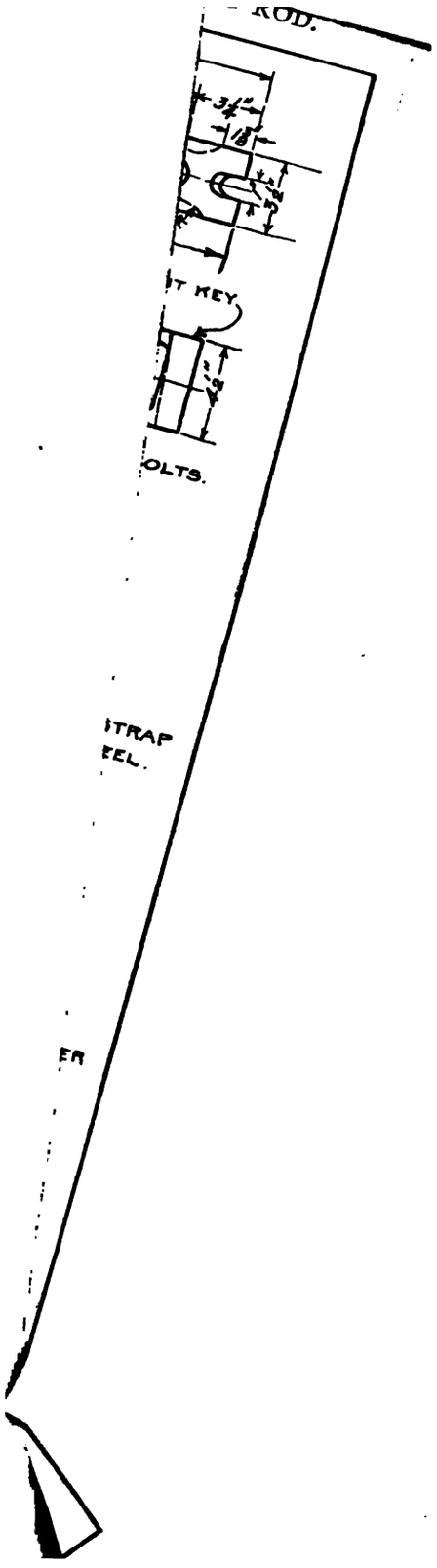

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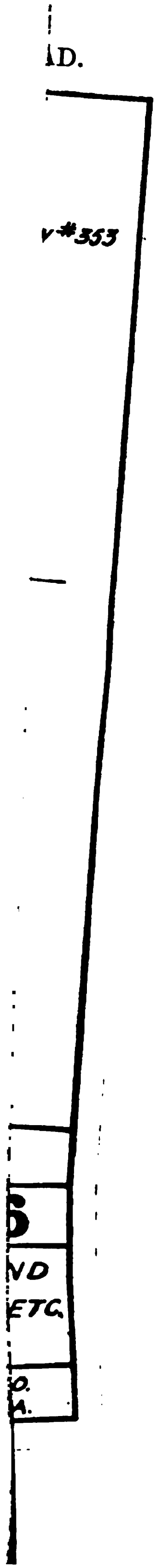
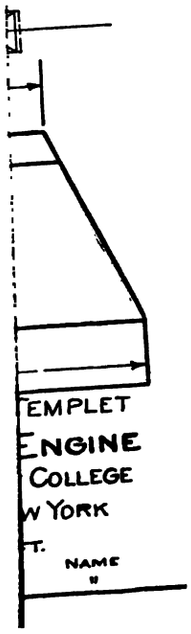


TION.

PLATE I

FOUNDAT



PLATE

AIR COMPR

PLATE X

FLOOR PL

PLATE XI

15" PILLAR SH

PLATE

15" PILLAR

PLATE XIV

15" COLLAR SHA

PLATE XV

15" PILLAR SHA

PLATE XV

15" PILLAR SH

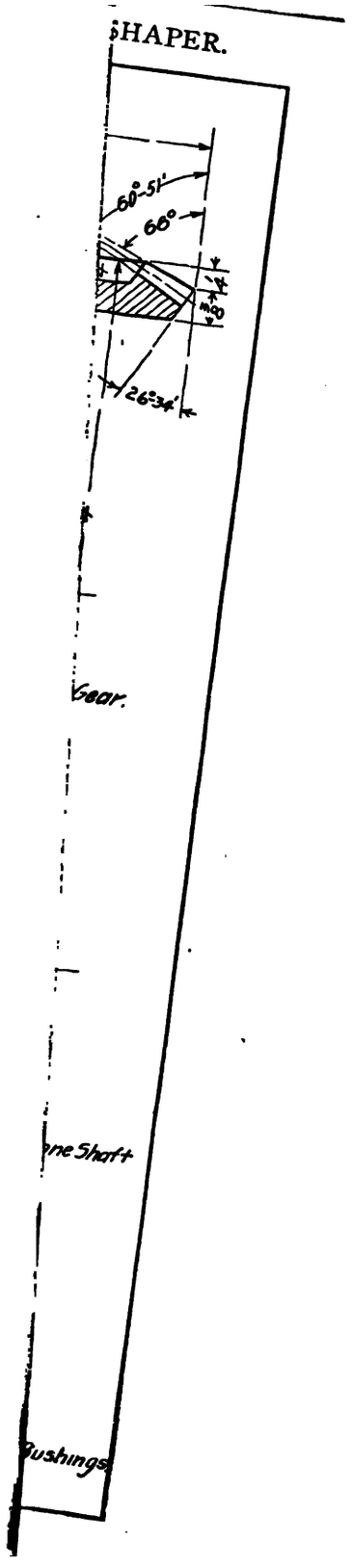


PLATE X

15" PILLAR S1

PLATE XV

15" PILLAR SH

PLATE X

15" PILLAR SI

PLATE X

ISOMETRI

PLATE XXI.

PATENT OFFICE DRAWI

Coolidge
Elements of Drafting .C