T H E S I S

on

A COURSE IN MECHANICAL DRAWING FOR THE O.A.C.

Submitted to the Faculty

of the

O R E G O N A G R I C U L T U R A L C O L L E G E

For the Degree of

M a s t e r of S c i e n c e

in

Electrical Engineering

by

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APPROVED: [redacted]

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+++ PREFACE +++

The title of this thesis indicates the purpose to be the preparation of a new text-book on Mechanical Drawing; however this is hardly the intention, although there is a great demand for a book suited to the instructional work as given in the many technical institutions of the country.

For some years the officers of the department have tried to find a satisfactory text for the work in Drafting, but without success. The difficulty is not that there are no good works on the subject; it is true that for their purposes there are many. Especially to be commended are the splendid courses offered by the American and the International Correspondence Schools, Reinhardt's books, Coolidge and Freeman, and similar works.

An inspection shows that while the above courses are entirely suited to the schools for which they are intended, owing to the disposition of related subjects, they do not fit the curriculum of the O.A.C. Geometric constructions, projective geometry, and other related work is given in other departments, leaving only the practical and commercial phase of the work for this department. Another and very important consideration also is the shortness of

the time which it is possible to devote to the subject; this makes it necessary to eliminate as much as possible of the purely preliminary work and to take up the principles of practical drafting as quickly as may be.

As has been stated this thesis is not written for publication as a text; it is hoped, however, that after such revision as will be dictated by experience, it may serve as a framework or skeleton for a text-book which shall not only exactly fit the needs of institution but those of other schools where conditions are similar. It might be stated in this connection that the course given here has in its making been in use during the past year, and that results have already amply justified the ideas embodied and the effort it has cost.

It was thought well to give an outline of the system of management used in conjunction with the course during the past year; for, although far from perfect, it was very satisfactory considering the unfavorable conditions arising from lack of equipment and instructional force. With this in view the thesis is divided into four parts as follows:

Division I. Tabulation of schedule of credits in Mechanical Drawing. Outline of the proposed course.

Division II. The experience of the past year. The Results attained.

Division III. Notes. A Course in Mechanical Drawing for the O.A.C.

Division IV. Drawing plates to be used with the foregoing.

O.A.C., June 7, 1909. S.H.G.

++++ DIVISION I ++++

Tabulation of Schedule and Outline of the Proposed Course.

It will not be denied that the design and arrangement of a course of study in any subject for maximum efficiency is a task requiring a careful consideration of many factors and as complete as possible an elimination of personal prejudices.

The factors determining the course in drafting as outlined later in this section are:- time available, previous preparation and general maturity of students, nature of the more advanced work, equipment and assistance, and a number of minor factors of various natures.

The time available for the work in Mechanical Drawing will be exhibited by the following extracts from the College Catalog:

Civil Engineering.

Freshman Year.

Studies.	Semester 1	2
Mechanical Drawing I (M E 1)	3	
Descriptive Geometry (M E 2)		3

Electrical Engineering.

Freshman Year.

Mechanical Drawing I (M E 1)	3	
Descriptive Geometry (M E 2)		3

Sophomore Year.

Mechanical Drawing II (M E 3)	4
Mechanism (M E 4)	4

Mechanical Engineering.

(Same as Electrical).

Mining Engineering.

(Same as Civil).

The related subjects, Descriptive Geometry and Mechanism, are given to show their disposition in the general course of study.

A summary of hours devoted to mechanical drawing gives: In Civil and Mining Engineering, one semester, three hours per week credit or a total of 102 hours of work. In Mechanical and Electrical Engineering the course is longer, comprising two semesters separated by one of Descriptive Geometry and followed by one of Mechanism. The two semesters of Mechanical Drawing allow 102 and 144 hours of work respectively.

As to previous preparation not much needs be said; the students are usually from high schools where little or no mechanical drawing is taught, and hence the course must begin with the elements which have to do with the technic of the subject. However, the limited time available, especially in the Civil and Mining courses, makes it necessary to abbreviate the preliminary work perhaps more than is really best. It is quite essential that the students be

taught as much as possible of the principles of practical shop methods, since this work forms the basis of so much of their subsequent work. Again it is important that students understand the principles of projection, exact methods of obtaining the helix, the various gear curves, and other standard constructions which occur so often in drafting. Finally it is of no little importance that as far as possible the course should instill that spirit of artistic taste in arrangement, systematic accuracy, and definitness of action which characterizes the expert.

Owing to the fact that the nature of the advanced work of the students is different in the different courses, a slight variation in the drawing course would be beneficial, both because it would stimulate the interest of the students and because it would more adequately prepare them for their distinctive work.

A course in any subject should be prepared and arranged in such a way that it will cause the student to think independently, and to do this the subject matter must excite questions. Where the instructing force is small the course, as this on in drafting, must as far as possible, answer its own questions. The drawing plates and notes accompanying them should be complete enough to make clear to the average student the purpose of, and method of procedure in drawing the plate. Where one instructor must direct, criticise, and grade the work of over a hundred

students, it is absolutely essential to efficient work that the assignments be made and the records kept systematically. Under these over-crowded conditions too, individual instruction must be reduced as much as possible. Although this is unfortunate good results may be obtained by supplementing the notes and drawing plates by a few general lectures on the subjects suggested later in this outline.

While far from perfect and backed by only one year's experience, it is believed that the course outlined below possessed in a large measure those qualities which have been cited as desirable, and which would lead to the highest efficiency.

The following outline contains the numbers, titles, and brief abstracts of the various plates. The average time required by students, and other useful information is given in connection with each plate.

Tabulation of Plates.....

No.	0	Standard Plate. Specimen Title.
	1	Elementary Practice Sheet.
	2	Second Practice Sheet.
	3	Geometrical Problems. Orthographic Projection.
	°4	Intersections and Developments.
	5	Drawing Room Standards.
	6	Conventional Details.

No. °7 ME Quarter-Turn Belt and Pulley.

°7 CD Section-lining Masonry.

(One of these. ME for Mechanical and Electrical. CD for Civil and Mining).

°8 Plate Cam, Threads, and Springs.

9C Structural Steel Exercise. (Civil)

9D Engineering Details. (Mining)

9E 200 A -250 V - DP - ST Switch. (Elec.)

9M Bench Vise and Details. (Mechanical)

The above concludes the plates for the work in ME 1. The following are Sophomore work, ME 3. (°) Plates so marked may be omitted without destroying the continuity of the course.

10 Mechanical Lettering.

11 Gear Teeth Curves.

12 Involute Gear and Pinion.

°13 Cycloidal Bevel Gears.

°14 Involute Worm Gear.

15E Assembly- Induction Motor.

16E Stator Yoke - Rotor.

17E Heads - Tooth Support.

18E Miscellaneous Details.

Complete Set. Electrical.

15M General Drawing of Engine.

16M Details of Body.

17M Main Moving Parts. + Complete Set-
+ Mechanical.
18M Valve Details. +

°19 Line Shading and Oblique Projection.

Outlines of Plates and other Data.

No. 0 Standard Plate. Specimen Title. This plate which is preliminary to all the others gives the dimensions of the border lines, margins, title space, etc. of all the following ones. A specimen title is also shown. It is not intended as a separate exercise but merely as a help in laying out the regular plates of the course.

No. 1 Elementary Practice Sheet. The figures of this plate are arranged to teach the student the manipulation of T-square, triangles, scale, and ruling pen. A little practice in lettering is also included.

Average time = 14 periods.

Note: The average time as given is so apportioned that the average student may complete about seven of the nine plates designed for the work in M E 1. Six accepted plates should constitute the minimum work for a passing grade. These six should include No.9 in order that the student may get some practice in tracing and blue printing.

No. 2 Second Practice Sheet. This is a continuation of No.1 and gives practice in the use of the compasses,

dividers, and irregular curve. The constructions of the various curves are such as will be useful in the later work of the student.

Average time = 16 periods.

No. 3 Geometrical Problems. Orthographic Projection. Here the subject matter consists of a number of problems in construction and an exercise illustrating the principles of orthographic projection. The geometrical constructions chosen will not only give excellent practice in the use of the instruments but will also be useful throughout.

Average time = 10 periods.

No. 4 Intersections and Developments. Besides giving a good drill in the principles of projection Plate 4 serves as an introduction to sheet metal pattern drafting.

This is one of the plates that may be omitted without destroying the continuity of the course; the average time for its completion is 14 periods.

No. 5 Drawing Room Standards. This is one of the most important plates in the course, since it gives the standard section lining and letter styles to be used throughout the course.

Average time = 20 periods.

No. 6 Conventional Details. This drawing teaches the student the standard conventions used in representing

such details as the various screw threads and springs; a set of bolt and machine screw proportions is also given. This work is instructive and represents actual practice.

Average time = 20 periods.

No. 7CD Section-Lining Masonry. In drafting in connection with Civil and Mining Engineering it is often necessary to show sections of cuts, fills, masonry construction, and such; consequently the standard sections, and examples of constructions involving their use should be of value. No.7CD may be omitted if it is thought advisable.

Average time = 12 periods.

No. 7ME Quarter-Turn Belt. Pulley. This plate comprises a belting layout and a detail drawing of one of the pulleys used. This work would be of value but may be omitted in case the student is backward.

Average time = 12 periods.

No. 8 Plate Cam, Threads, and Springs. Contrary to the purpose of Plate 6 the intention in Plate 8 is to show the exact constructions of screw threads and springs as derived from the helix. A simple plate cam is also given to serve as an introduction to the more extended study of cams taken up in "Mechanism". Plate 8 may be omitted if necessary.

Average time = 14 periods.

Note: The student should without fail draw the Plate 9 corresponding to his course. The drawing is to be pencilled, inked on tracing cloth, and a blue print made; the steps in the process having been explained either in the notes or by the instructor.

No. 9C Structural Steel Exercise. A typical drawing of a built up girder. In addition the "Conventional Signs for Riveting" from the Carnegie Handbook are given, thus making a very instructive exercise.

Average time = Pencil, 12 periods. Tracing, 8.

No. 9D Engineering Details. This plate shows working drawings for a number of typical details, giving in addition the standard proportions of the various forms of rivets.

Average time = Pencil 12 periods. Tracing 8.

No. 9E 2oo A - 25o V - DP - ST Switch. Giving a general drawing and sketches of the details of a typical knife switch. As is the case more or less with all the plates of the course, Plate 9E allows some useful variations; for instance, the general drawing alone might be made the subject of a plate, or it might be left out altogether and the details only drawn. Again, obviously the arrangement used might be copied, and the shade lines might or might not be used. Some variety is good and the instructor should make assignments according to the time available and the needs of the student.

Average time = Pencil 12. Tracing 8.

No. 9M Bench Vise and Details. Similar in arrangemnnt to 9E, and may be modified in the same way. Perhaps the most desirable assignment being an assembly drawing to half size using shade lines.

Average time = Pencil 12. Tracing 8.

The following class lectures are suggested as desirable in connection with the elementary work just outlined:

1. Nomenclature, Use, and Care of Instruments. (Given at the beginning of the course).

2. Lettering and Title Design. (Given early in the course- say before taknig up Plate 5).

3. Blue Printing and other Processes of Reproducing Drawings. (Just before beginning Plate 9).

Students should be required to take notes during the lectures, and to apply in their work the principles set forth.

This concludes the work in M E 1, and following is the outline of work in M E 3. This is taken by the Mechanical and Electrical Sophomores.

No. 10 Mechanical Lettering. Includes Roman and Gothic alphabets and a number of good suggestions along the line of title design.

Average time = 22 periods.

No. 11 Gear Teeth Curves. An introduction to the work on gears. The plate includes the constructions for the cycloid, hypo- and epi-cycloid, and the involute. Single tooth profiles of the various kinds are also given showing the application of the curves to the formation of teeth.

Average time = 12 periods.

No. 12 Involute Gear and Pinion. Shows the gear and pinion in mesh, and well illustrates the method of drawing spur gears.

Average time = 14 periods.

No. 13 Cycloidal Bevel Gears. Two views are shown, a front elevation and a section. With the latter are also given the developments of the tooth profiles.

This plate may be omitted if desirable.

Average time = 16 periods.

No. 14 Involute Worm Gear. Showing two elevations both of which are partly in section to show the construction. The exact method (of Plate 8) is used to construct the worm.

This plate may also be omitted if thought desirable.

Average time = 16 periods.

Nos. (15-16-17-18)E Assembly and Details of 5 H P Induction Motor. This series constitutes a set of drawings of the mechanical features of the above machine. The drawings should be pencilled and tracings and blue prints

made. Any modifications suggesting themselves as desirable may be introduced and either the entire set or only part of it drawn, depending on conditions.

	Plate	Pencil	Tracing
Average time -	15E	14 periods	10
	16E	12	10
	17E	6	4
	18E	10	6

Nos. (15-16-17-18)M Assembly and Details of a 2 H P Steam Engine. A complete set illustrating as near as possible actual practice. The statements concerning tracings, modifications, etc. made in connection with the previous set also apply here.

	Plate	Pencil	Tracing
Average time -	15M	12	8
	16M	14	10
	17M	8	6
	18M	8	6

No. 19 Line Shading and Oblique Projection. Although not especially advanced in character this work is put last; this is because lime shading, isometric, and obliqueprojection are really frills which are little used in practice and would not be a great loss if omitted altogether. It was thought well however to include a plate on the above subjects since these principles are sometimes useful, particularly in connection with patent office work or ornamental drawings intended for exhibition.

Average time = 16 periods.

More latitude is allowed the student in M E 3 than in the elementary work and the work may be considerably modified to suit individual cases. The average student should complete eight plates during the semester and seven should be required as a minimum.

(In the Transitional Courses allowing only three credits per week the minimum should be set at six plates).

Lectures. As with the work in M E 1 some supplemental lectures would be desirable here. The following are suggested:

1. Mechanical Lettering and Advanced Title Design. (With Plate 10).

2. Toothed Gearing. (Given before taking up work on gears).

3. Working Drawings and Bills of Material. (These practical suggestions may be given toward the end of the course).

This completes the outline of the work which is proposed as the future course and which was followed (at least in its important particulars) during the past year. The following division gives a brief outline of the method of administration used and of the results attained.

++++ DIVISION II ++++

The Experience of the Past Year.

The first problem of the year was the question of divising a system of records which would be simple and speedy. During the first semester there were three sections averaging about thirty students each, and during the second there were six sections of the same size. This conjestion was due to the fact that the work in Mechanical Drawing was advanced to the new basis, thus making a suitable system of records even more important.

Although the work of the six sections during the second semester was given in two different buildings and was divided among three instructors it was decided to centralize the records in the Mechanic Arts Building where all the drawings were filed. The sections were designated by letter A,B,C,D,E,and F, the drawing tables being numbered from 1 to 36.

In order to facilitate the keeping of records and assignment of work the students were given "student numbers" at the beginning of each semester. These numbers consisted of the desk number, section letter, and course letter, there being added in the class record for the assistance of the instructor the course number; for example; Student Number 12BE3 designates an electrical student in section B working at desk No.12 and taking the work in M E 3. The names are arranged in the class book in alphabetical order and the desks assigned in numerical sequence. The students are assigned the boards and in-

dividual lockers corresponding to the section letter. The course number (3) is often useful to the instructor, particularly in making out grades at the end of the term.

In order to distribute the work of grading it was found best to grade the drawings at the time they were completed. A drawing just handed in was criticised in the presence of the student and if it merited a grade of 7 (on scale of 10) or more it was accepted, the grade recorded in the class book, the instructor's initials put in the space "Checked By", and the drawing was filed in the proper order on the shelf corresponding to the student number. Upon completion of the term's work the drawings were returned. Although only one filing cabinet was used for nearly 200 students making a total of over 1,000 drawings, it was a matter of but a moment to find any drawing of any student, proper care having been taken to file the drawings correctly.

During the two semesters (1908 - 1909) about 275 students were registered for the work in M E 1 and 3 and a count shows a total of 1400 drawings completed. This gives an average of a little over five plates per student per semester, and justifies the design of the proposed course from that standpoint. With a definite course and system to follow from the beginning it will be

easily possible to raise the average production to six plates as intended.

++++ DIVISION III ++++

Notes. A Course in Mechanical Drawing for the O.A.C.

(The following notes are to accompany the drawing plates of Part IV, and with them constitute the instructions for the execution of the various plates).

Introduction
and
Instructions to the Student.

This course in Mechanical Drawing is arranged primarily to be suited to the curriculum of the engineering courses offered at the Oregon Agricultural College, and will prove most useful when supplemented by some individual instruction in the drafting room. However, the notes and accompanying plates have been made complete enough to omit no essential principle and to cover the entire subject in such a way that the student will be competent to produce a neat, complete, and accurate set of working drawings of any ordinary piece of machinery.

To attain this aim in the allotted time necessitates the omission of nearly all the geometrical constructions, problems in projection, and chapters on ornamental lettering and shading which constitute a large part of many of the text books on mechanical drawing.

To do this is feasible here because the student becomes familiar with the problems in construction in his study of Geometry. Enough of the principles of projection is given in connection with Plate 4 to make their meaning and application practical working drawings intelligible to the student. A complete treatment of Descriptive Geometry is given in another course, and to spend more time on problems in projection would be to the exclusion of matter which is here more important. And lastly, as to the arts of ornamental lettering and shading - while they are a desirable attainment for the expert draftsman their utility in machine drawing is very limited and the great amount of time necessary for their mastery precludes the possibility of extending the treatment beyond the few hints given in the notes on Plates 10 and 19 and in appropriate connections throughout the course.

It is evident that the average student will accomplish far more by learning thoroughly how to make rapidly and well some styles of plain letters than he will accomplish by learning how to make indifferently a few styles of fancy letters, for after all, it is inevitable that in any enterprise economy will be sought, and that, very often to the exclusion of the aesthetic element.

A working shop drawing, commercially considered, may well be defined as being "Complete instruction from

designer to workman issued at minimum expense". The student must not infer from this that he is to hurry through his work, much rather the opposite, but what is meant is that he must learn to husband his time to the best advantage and to direct his efforts with a definite purpose.

It is believed that the following course has been arranged in a way that will keep up the interest of the student and will imbue him with that spirit of accuracy and system which makes rapidity of execution a natural consequence.

General Instructions and Notes on Standard Title and Plate.

The general instructions which follow apply to all the mechanical drawing plates regularly in the course.

From the start the student should remember that it is essential to do neat and accurate work; that all lines, figures, and letters must be clear-cut and distinct; and that there must be no doubt as to the meaning of limits or dimensions. Errors on drawings are serious, as often they would not be detected until the machine is to be assembled. Drawings must be concise, but not needlessly complicated, and when once turned over as complete they should furnish entire and absolute instruction.

Size of Plates. The plates are to be 17" x 19 1/2" with border lines drawn 1/2 inch from the edge except on the left where a one inch margin is left for

binding; this makes the working limits of the drawing 16" x 18". The title is to be placed in the lower right hand corner where a space 4" x 2 1/2" is reserved for it. The lettering is to be a plain vertical Gothic as shown, and guide lines for its construction are to be drawn as indicated.

Laying out the Plate. Place the paper on the board, tack the upper right hand corner, apply the T-square to the left edge of the board and true up the sheet; then hold the lower left hand corner of the paper away from the board and press a tack through it, now lower the tack and paper to the board inserting the tack in a slanting direction so that the paper will be stretched when the tack is pressed into the wood. Put in the other tacks in the same manner. Usually four tacks are sufficient, but if the paper curls too much six or eight may be used. Some draftsmen prefer to use 1 oz. copper or steel tacks as they offer less obstruction to the T-square and triangles.

Preparatory to drawing the border lines draw the two center lines as shown; the one running vertically is 11" from the left edge and the horizontal one is 9" from the lower edge (that is, with the size of paper recommended, viz. 18" x 21"). Draw the trimming lines, and then the border lines at distances such that the working space will be divided into four equal rectangles by the center lines,

and finally rule off the space for the title 4" long by 2 1/2" wide, in the lower right hand corner. Let the border lines extend to the trimming lines except on the left where they end 1/2" from the trimming edge.

Do not ink in the border lines or title before the entire plate is completed in pencil.

Notes on Plate 1.

Pencilling. To draw Plate 1 first lay out the border lines and title space as explained in the notes on Standard Title and Plate using center-lines in so doing. Now measure 2" above and below the horizontal center line and with the T-square draw lines through these points. These lines will form the top and bottom border lines of Figures 4,5, and 6. 1" above and below these draw two other lines to form the respectively the bottom and top border lines of Figures 1,2,& 3 and 7 & 8. Measuring along the vertical center line, 4" above and below these lines draw lines to form the top and bottom borders of these figures; and measuring along the horizontal center line each way from the point where the vertical center line intersects it space off the proper distances for the sides of all the figures.

Figure 1. This is an exercise with the line pen and T-square. Divide the left border accurately into divisions 1/2" long and through these points draw light pencil lines extending to the right border. In drawing these lines be careful to have the pencil point pass exactly through the division marks so that the lines will be the same distance apart. Accuracy and neatness in pencilling insure an accurate drawing and the beginner who thinks that he can correct inaccuracies while inking will soon find by experience that it cannot be done.

Figure 2 is an exercise with the line pen, T-square, and triangle. In general the directions for Fig.1 will apply here as well as in Figures 3 and 7 except that in these greater care is necessary to space the lines accurately. To draw the inclined lines place the proper triangle on the upper edge of the T-square and keeping the square rigid slide the triangle towards the right or left as may be convenient, being careful to have the edge coincide with the division marks in succession.

Figures 4 and 6 are exercises in inclined and vertical freehand lettering respectively. In all cases draw light guide lines in pencil and carefully pencil the letters, making them entirely freehand.

Figure 5 gives the standard lines in most common use and which will be used throughout this course; they should be drawn about the widths indicated.

Figure 8 is an exercise designed to give practice in drawing lines of varying widths. The finer lines (up to 1/32" wide) are to be drawn by properly adjusting the distance between the nibs of the pen, while the wide lines are produced by drawing light limiting lines and filling in (freehand) with the ruling pen or with a common steel pen.

Inking. After all the pencilling on Plate 1 has been completed the exercise should be inked. The pen should be examined and cleaned if necessary. To fill the pen use the quill which forms part of the cork to

the bottle containing the waterproof ink. The pen should not be filled too full as this causes blotting; if the ink fills about 1/4 the distance to the adjusting screw it will usually be sufficient. Any ink adhering to the outside of the pen should be wiped off with a cloth or piece of chamois skin before any drawing is done. The pen should now be tried on the outside margin of the drawing paper or on a separate sheet of paper in order that the width of line may be properly adjusted; this is important, for light lines make the drawing weak and indistinct and heavy lines detract from the artistic appearance and make accuracy almost impossible.

In ruling with the line pen it should be held firmly in the hand almost perpendicular to the paper. If grasped too firmly the width of the line may be varied and the draftsman will soon become fatigued. The pen is usually held so that the adjusting screw is away from the T-square, triangle, etc. Many draftsmen incline the pen slightly in the direction of motion.

If the ink fails to flow freely from the pen it should be tried a couple of times along the grain of a clean portion of the drawing board, or across the fingers of the left hand -- a perhaps objectionable but always effective expedient -- to insure a "starting" of the flow of ink.

The exercises are inked about as they are pencilled except that in the finished drawing there should

be no center lines, construction lines, dimensions, or letters other than those in the exercises, in the title, or those used as figure numbers. The letters should be inked freehand using a steel pen. If the pen is very fine accurate work may be done but the pen is likely to catch in the paper, especially if this is rough, a coarser pen will make broader lines but is on the whole to be preferred. Gillott's 404 is as fine a pen as should be used for letters of the size used on plate 1.

When the plate and title have been completed the student should add his number and the time spent, in the spaces provided.

Notes on Plate 2.

General. Plate 2 is an exercise giving practice in the use of nearly every instrument ordinarily in a draftsman's kit. The first three of the figures involve the use of the line pen, scale, triangles, spacing dividers, bow pen, as well as the large compasses. Accuracy in spacing is absolutely necessary here if the circles are to be tangent where so intended, and if the intersections of the arcs are to be accurate.

Figures 12, 13, 14, and 16 give the methods for constructing the ellipse, hyperbola, parabola, and spiral respectively. These curves give excellent practice in the use of the irregular curve and at the same time are useful, since machine parts sometimes involve them.

The student has no doubt noticed that all corners in casting are rounded; if they are not so rounded the metal will crystallize in such a way on cooling that the casting will be weak. Such a rounded corner is called a fillet, and should always be shown in a drawing. Fig.15 gives the construction for putting in a fillet of given radius. This construction should be memorized as it will be needed constantly in machine drawing.

Pencilling. In pencilling Plate 2, after laying out the plate draw the square borders for the various figures, then draw the two diagonals and find

the center points of the figures.

In Figures 9, 10, and 11 draw a horizontal center line and divide it into spaces 1/4" long, then put in the arcs and circles as shown, finding the centers of the two single circles in Fig.10 by trial. The largest and second largest circles in Fig.11 represent the manner of shading a circular disc and a circular opening respectively. This shading is not attempted with the pencil, but it will be well to draw the dot and dash lines as they are to appear when inked, since this reduces the liability of error. The 35° angle shown in the figure will illustrate the use of the protractor.

In the figures of curves when a sufficient number of points on any curve are found the curve should be drawn through them in pencil by applying the irregular curve so that it will provide a guide for drawing a section of the curve through perhaps three or four points; in this way the entire curve is drawn, a small section at a time.

The purpose of Fig.16 was explained in the general notes, but its construction may not jet be clear. To find the center of the fillet to be drawn, the radius of the curved part is increased by the radius of the fillet, and an arc is struck as shown dotted. A parallel to the straight part is then drawn at a distance equal to the radius of the fillet. The intersection of this parallel and the arc is the center of the arc forming the fillet.

An analogous construction is used when two straight or two curved parts are to be joined.

Inking. Little need be said about inking Figures 9 and 10 except that the student should remember to use a good firm line, yet not so wide as to give the drawing a heavy appearance. The radii for the different circles and arcs must be adjusted with the utmost care or poor figures will result.

In Fig.11 the shading of the circles is effected by shifting centers or in other words by moving the point of the compasses a trifle from the original center, the distance being equal to the width of the desired shade line, and inking in the shading always on the right side of the arc to be shaded. The new center should be taken on the 45° line passing from the upper left hand corner to the lower right hand corner, and if the center is properly taken the shade line will merge perfectly at both ends.

Inking the curves of Figures 12, 13, 14, and 16 will seem a difficult task to the beginner but a little practice will enable him to join perfectly the succeeding sections of the curves as he moves the guide. Care should be taken to wait until the part already drawn is dry before moving the irregular curve to a new position, or a blot will be sure to result. Patience and care are the surest eradicators of blots, but when a blot is made as

much as possible of the ink should be removed with a damp piece of blotting paper and the remainder allowed to dry; when dry it may usually be removed with a soft eraser assisted if necessary by a little scraping with a sharp pen-knife (no ink eraser or gritty eraser of any kind is necessary or desirable).

The title is to be put in as usual and the time and student number inserted in their proper places.

Notes on Plate 3.

In the course of his work a draftsman often encounters problems which are best solved by the use of some geometrical constructions. Plate 3 gives seven such constructions, all of which will be found useful and worth remembering. The student should not draw the problems hastily and thoughtlessly, but should study the principles involved so that he will be able to apply tham in his later work.

Problem 1. To bisect a given straight line.

Solution. With A and B as centers and any convenient radius describe arcs intersecting above and below the line AB. (The radius of the arcs must remain constant and must be greater than half AB). Now draw a line through the intersections; it will cross the line AB at its middle point C.

Proof. Since the two intersections are equidistant from A and B, the line joining them is the perpendicular bisector of AB.

Problem 2. To draw a perpendicular to a line from a point in the line.

First Method. When the point is near the middle of the line. With P as center and any convenient radius draw arcs cutting AB. With these intersections

as centers and a suitable radius draw arcs intersecting at C. Then connect C and P. CP is the perpendicular.

Proof. Points P and C are equally distant from the intersections of the two arcs with AB. Hence CP is the perpendicular bisector of the part of AB limited by the two arcs.

Second Method. When the point is near the end of the line. Let P be the point in the line; then with any point O as center and a radius OP describe an arc cutting AB at D. Through D and O draw the diameter DC. A line from C to P is the perpendicular to AB at P.

Proof. Angle CPD is inscribed in a semicircle, hende it is a right angle and CP and PD are perpendicular to each other.

Problem 3. To divide a given line into any given number of equal parts.

Solution. Let AB be the given line to be divided into say seven parts. Draw line AC'D' etc. at a convenient angle and lay off along it spaces of say 1/2 inch; from the end of the last space draw a line to B. Then draw parallels to this line through the other points, as DD', CC', etc. and AB will be divided into seven equal parts by them.

Proof. If a series of parallel lines, cutting two straight lines intercept equal distances on one they intercept equal distances on the other also.

Problem 4. To bisect a given angle.

Solution. With O as a center draw an arc intersecting the sides of the angle at A and B. With A and B as centers describe short arcs intersecting at C. Then OC bisects the angle.

Proof. The angles AOC and COB are equal because arc AB is bisected by OC.

Problem 5. To draw through a given point a line parallel to a given line.

Solution. Let P and AB be the given point and line respectively. Draw AC through P making an angle of about 45°. Construct an angle equal to PAB having its vertex at P and one side in PC. The other side PD will be the required parallel.

Proof. If two straight lines are cut by a third making the corresponding angles equal the lines are parallel.

Problem 6. To inscribe a regular hexagon in a given circle.

Solution. Mark off chords equal to the radius.

Proof. Triangle OCB is an equilateral triangle by construction. The angle COB is then 60°. Hence arc BC is one sixth of a circumference and the chord is a side of a regular hexagon.

Problem 7. To draw a line tangent to a circle from a point without.

Solution. Let P be the point outside, draw OP, bisect OP, and draw circle PBOC. Connect O with the intersection of the two circumferences. Then PB and PC are the tangents required.

Proof. Angle PBO is inscribed in a semicircle and is therefore a right angle. Then PB is perpendicular to radius BO at its extremity and hence tangent to the circle.

Inking. In inking these constructions full lines are to be used for the figures, and dotted lines for construction as shown.

Orthographic Projection.

An ordinary perspective drawing is not suitable as a machine drawing to be used for constructive purposes. It represents all angles and surfaces distorted, lines foreshortened and shows only the exterior of the object. For mechanical drawing of the practical kind orthographic projections only are used. These are projections where the rays of light are all parallel for each view of the object and all lines are represented actual length or to scale. Several views may be, and usually are required to represent the object clearly and completely. These views are taken at right angles, and are named as on the instruction print and model, of which the former gives

a drawing.

In mechanical drawing the light is assumed as coming from the upper right hand corner of the plate and the rays of light make an angle of 45° with the plane of the paper. Shade lines improve the appearance of a drawing and often make it clearer; they are used for all edges formed by a light surface intersecting a dark one. That is, conventionally, the right and bottom outlines of an object are shaded, the left and top outlines of an opening in the object are shaded, and circular projections and openings are shaded in accordance with the same principles, and in the manner explained in connection with Plate 2.

Dimension lines should be light, but firm enough to be clear and distinct; the arrow points should be sharp, well formed, heavy enough to be at once apparent, and should touch the limiting lines of the space dimensioned.

Plate 3 will be found easy to draw, but the principles are of utmost importance and the student should work thoughtfully.

Notes on Plate 4.

When a surface cuts another at some angle, an intersection is produced. Either or both of these surfaces may be plane or curved; if both are plane the intersection is a straight line; if one is curved the intersection is in general a curve; and if both are curved the intersection is usually curved and often is not a plane curve. When one of the intersecting surfaces is a plane the line of intersection is always either a plane curve or simply a straight line.

The development of a surface is its true size and shape spread or rolled out on a plane. If the surface to be developed is of such a character that it may be flattened out without tearing or folding, as is the case with all the developments in plate 4, we obtain an exact development. If this cannot be done , as with the sphere, the development will be only approximate.

Figure 1 represents a hexagonal prism intersected by a plane making an angle of 45° with the prism. The side view of the intersection will be a straight line and the plan will have the same shape as the base of the prism. The true size and shape of the figure cut out of the plane by the faces of the prism is shown at B. Its width 1-4 is projected from the elevation and the distances

2-6 and 3-5 are measured on the plan and transferred to B.

The development of the lower section represents the true shape and size of the different faces of the prism. If such a figure is cut from paper or tin and is folded or bent to the proper angle (120°) at each of the lines (representing edges) erected at 1,2,3,etc. a model of the lower section of the prism will be obtained. In fact, these problems of development are of direct practical use to the workers in sheet-metal and are employed by them in laying out the shape of the sheet to form any desired object.

Figure 2 gives the intersection and development of a cone crossed by a plane which cuts all the elements. The figure formed by the intersection in this case is an ellipse; if the cutting plane is parallel to an element of the cone the curve is a parabola, or if parallel to the axis an hyperbola is formed.

To obtain the plan of the intersection divide the circle representing the plan of the cone into twelve equal sectors by drawing radii at 1,2,3,4,etc. These radii will be the horizontal projections or top views of twelve equally spaced elements; next draw these elements in the side view. Now drop perpendiculars from the points where these elements cross the line representing the plane pp. The points in which these perpendiculars cut corresponding radii in the plan will lie on the top view of

the curve of intersection and the latter may be constructed through them by means of the irregular curve. The true size and shape of the intersection (B) is obtained by the method explained in connection with Fig.1.

In drawing the development A' care must be taken to use the true lengths of the intersected elements and not their apparent lengths. As for instance, the true length of element 4 is Or and not the vertical distance from O to the line representing the cutting plane, as might seem at first.

Figure 3 represents a symmetrical three jointed elbow, and it is desired to get the developments of the three joints. Proceed as in Fig.1; lay off the length of the development (B'), equal to 4.70" in this case, and divide it into twelve equal parts. At these divisions erect divisions erect the corresponding elements, as rr' and r"r"', (represented by rr' in B) and through their ends draw smooth curves. The whole represents the development of the middle joint and each half the development of one of the other joints.

Figure 4 gives the intersection and developments of two unequal intersecting cylinders whose axes, making an angle of 60° with each other, do not intersect. A' is the development of the right half of the larger cylinder, and B' is the development of the smaller. The two views of the cylinders are first drawn, leaving out

their curved intersection; this is then found as indicated by the construction lines. Further explanation would be superfluous, as the principles already explained also apply here.

The entire plate should first be accurately drawn in pencil, and then in ink showing as much of the construction lines as is given in the print.

Notes on Plate 5.

General. Plate 5 is intended as an exercise in lettering and as an introduction to elementary machine drawing. It is imperative that a draftsman should know definitely how to represent the different materials in section, and that he should have some simple and effective system to guide him in his lettering. The system illustrated by plate 5 is taken from actual high grade practice and represents the usage of the best commercial drafting offices. The student will later take up other styles of lettering, but it will be best if he confines himself to the plain Gothic until he has thoroughly mastered the principles of proportioning and spacing exemplified in these simple styles.

Pencilling. The manner of arranging the left hand half of the plate is made optional with the student, the only requirement being that he make at least one set of the alphabets in the letter study and at least two sets of the standard alphabets. All the letters are first to be carefully drawn in pencil and spaced so as to look neat and to form an even line. Spaces between words are made about the width of an "n" of the style used, or about twice the normal space between letters of the same word. It will be observed that the spaces between letters vary

according to the letters. A rule for spacing would be too complex to be serviceable and the student must train his eye to tell him when the letters are properly distributed. Two guide lines should always be drawn in lettering. Even expert draftsmen do this in all cases except for small letters used in descriptive notes when the upper guide line is often omitted.

In this work the inclined Gothic letters will be used for dimensions and descriptive matter, and the vertical for titles and headings.

In pencilling the standard cross sections the spacing is purely by eye except in the cases of brick and stone where it is better to space the courses by measurement. Wood, concrete, and earth are drawn freehand. The title should receive the same care as in the original standard plate.

Inking. It will not be necessary to go into details about the inking of the standard cross hatchings, since no new principles are brought into use. It might be well to suggest that in the case of wrought iron where two widths of line are employed it would be economical of time to draw all the lines of one width first and then all the others; by so donig the pen needs to be changed only once.

Inking the "letters and figures" will require a great deal of painstaking care if good work is to result. It is advised that in making the small letters used for

descriptive notes Gillott's 303 pen be used, Gillott's 404 for the standard alphabets, and Soennecken's No.6 for the large letters and figures of the letter study. The arrow heads and small figures numbering the strokes may be put in with Gillott's 303 or with a "crow quill". A lettering pen will not work well when too new or too old. Pens should be "broken in" before being used for lettering a plate. This may be done by stroking the pen for a few minutes on the outer margin of the plate.

The following list gives the names of pens much used for lettering maps and working drawings, and also gives the purpose for which each is best adapted.

Crow Quill. For very fine lettering such as is much used on maps. It is little used by mechanical draftsmen.

Gillott's 303. Used by mechanical draftsmen for small sized Gothic letters and for most Roman letters, for the spurs and serifs of even the large ones are made up of fine lines.

Gillott's 404. Much used by draftsmen for medium sized letters such as most often appear on working drawings.

Soennecken's No.6. Somewhat coarser than Gillott's 404 and a very good pen for general work.

Leonardt's 506EF or 516EF. Both these are ball pointed pens suitable for large letters. Very easy to use.

When the plate is completed the student should not fail to remember to add his number and the number of periods required to produce the plate.

Notes on Plate 6.

General. If the small details of a machine were drawn as they would actually be projected an enormous amount of time would be consumed in making any ordinary working drawing. All common screw threads, bolts, nuts, pipe fittings, etc. are standardized and hence an exact representation is not necessary. To economize time and to facilitate the work of the draftsman is very desirable and to attain this end a number of "conventional" methods of representing various details have been adopted. The most useful of these are given as an exercise in Plate 6.

A great many bolts, cap screws, and set screws are used in machine construction and standard proportions have been adopted for all these. The lower half of the plate gives the dimensions of the various bolts, screws, heads, and nuts in terms of the diameter which is represented by the letter "A".

Pencilling. After the plate is laid out the center lines for the various objects to be drawn should be pencilled in lightly. This is a general principle, and if the student will always first plan the arrangement of his plates and draw center lines for the different objects his work will be more systematic and a neater drawing will result. There should be no large blank spaces unsymetrical-

ly placed, nor should the figures drawn be distributed in such a way that the plate will appear unbalanced.

In drawing the threads lines are first drawn for the tops and bottoms of the threads, after which the line for the tops of the threads is divided into spaces equal to one half the pitch for a single thread and equal to one fourth the pitch for a double thread. The depth of a single square thread is equal to half the pitch and that of a double thread is equal to one fourth the pitch. By pitch is meant the distance the screw thread travels forward during one turn in the nut. Some authorities call this the "lead" and reserve the term "pitch" for the space from the center of one thread to the center of the next convolution whether of the same thread or not.

Multiple threads are used where it is necessary to combine great strength and a large pitch with a small reduction in diameter of the screw. The threads for pipe fittings are made with a taper of 1 in 16 and are finer than screw threads of the same diameter. The print shows a nipple of 1" nominal diameter, an upper quarter being cut out to show the interior and to indicate that the nipple is made of brass.

In drawing long screws, rods, or any long object having the same section throughout it is not necessary to show the entire length. The artifice of "breaking out" a part as employed in the plate may be used to advantage

in all such cases.

As stated by the note on the print the number of threads per inch of common screws has been standardized, and the following table gives the pitch adopted for some of the common sizes of screws:

A =	1/4	5/16	3/8	1/2	
Th'ds. =	20	18	16	13	
A =	5/8	3/4	7/8	1	
Th'ds. =	11	10	9	8	
A =	1 1/8	1 1/4	1 1/2	1 3/4	
Th'ds. =	7	7	6	5	
A =	2	2 1/4	2 1/2	2 3/4	
Th'ds. =	4 1/2	4 1/2	4	4	
A =	3	3 1/4	3 1/2	3 3/4	
Th'ds. =	3 1/2	3 1/2	3 1/4	3	
A =	4	4 1/4	4 1/2	4 3/4	5
Th'ds. =	3	2 7/8	2 3/4	2 5/8	2 1/2

Inking. In the conventional representation of a standard thread as used with the bolts shown in Plate 6 it is not necessary to space the lines representing the threads according to pitch, and these lines may be drawn either all full lines or alternately full and shade, the latter method being preferable.

In drawing the figures made up of both curved and straight lines the former should always be drawn first because it is much easier to join a straight line to a curved one already drawn than vice-versa.

All the lettering on the print except the note in the lower left hand corner is to appear in the finished drawing. The letters should be made of the standard size as given in plate 5 and should be vertical for headings and slanting for descriptive matter and dimensions. It will add to the artistic appearance if the headings are neatly underlined.

Too much stress cannot be laid upon the value of painstaking, neat, and accurate work in these preliminary details. They are the drudgery of mechanical drawing, but at the same time they are the steps by which a student must rise to the more interesting work before him. The student is again warned not to attempt speed in his work; it will come as a matter of course when he is ready for rapid work. At present he should work steadily, deliberately, and with system, making each line carefully. He should not be satisfied with the amount of lettering actually required but he should take Plate 5 home with him and practice lettering during spare minutes. If the student will do this carefully he will be well repaid.

Notes on Plate 7 CD.

Civil and mining engineers are often called upon to design and draw plans for work involving masonry construction, and as an introduction to this Plate 7 CD is given. The plate consists of an extension of the standard cross sections of Plate 5 and includes some typical applications. It hardly seems necessary to give detailed instructions for the execution of this drawing since the plate is practically self-explanatory. A few of the principal points to be observed are:- the quality of the lines, shading, and the manner of drawing cross lines. No very fine lines should be used and the various figures should be neatly shaded. The separate stones and gravel in the concrete should be shown shaded; this can be neatly and quickly done by a continuous stroke and varying pressure on the pen.

In section lining brick and stone the effects of light and shade may be enhanced by leaving open a narrow strip against the lighted sides of the area in section.

As shown in the "Tank Foundation" the relative densities of different materials may be indicated by the weight of the cross sectioning.

In drawing Plate 7 CD the dimensions of the rectangles in the upper part of the plate should be omitted. Also it might be added that the student should pencil the entire plate first (using no shading) and should then trace the lines with ink, adding the proper shading.

Notes on Plate 7 ME.

In general drafting work the drawing of a belting layout is quite a common problem, especially so in mechanical or electrical work. The plate now to be taken up will show how a belt is usually drawn and in addition will give practice in actual shop drawing. It will be noted that the pulley taking up the right hand half of the plate is the same as those used in the layout. In the latter the details of the pulleys are not shown since this is entirely unnecessary in a drawing intended to show merely the locations of the pulleys on the shafts.

The drawing of the pulley consists of two views, a plan and an elevation of a section through the horizontal center line of the plan. Although simple these two views present a few new points. In the plan the elliptical form of the spokes is shown by the cross hatched ellipse drawn in one of the spokes. This convention is often used for showing the section of long uniform parts and saves the labor of an additional view.

Another point to be noted is the letter "f" used as a finish mark. When the letter f appears on an edge it signifies that the surface represented by that edge is to be turned, planed, filed, or otherwise finished; any special finish however is designated by a note also.

The sub-titles used in this plate are typical of actual practice. They state the name of the object, the material, the number desired, and the scale if more than one scale is used on the same drawing.

The belting layout is that of a quarter-turn belt running on two similar pulleys. The problem as it would arise is as follows: Having given two shafts, one above the other, say; and making right angles with each-other; find the location of the pulleys for a given direction of rotation. The diameters of the pulleys are determined by the speed relations of the two shafts and to some extent by the power transmitted. The width of the pulleys should be a little greater than that of the belt. The following formula may be determined to determine the latter: Width of Rim = 9/8 (width of belt + o.4").

After the sizes of pulleys and other details are determined draw the two elevations of the shafts at the given distance apart and indicate the directions of rotation. Start with either pulley, say the upper one, and draw the view in which it appears as a circle (the right hand one), drop a perpendicular, tangent to the side turning downwards; where it cuts the lower shaft will be the center of the lower pulley which will appear as a rectangle.

Now draw the other elevation of the lower pulley (appears as a circle) and draw a vertical tangent

to the side turning upwards; its intersection with the upper shaft is the center of the rectangle representing the upper pulley. The plan may be placed over either elevation and is drawn according to the relative location of the two pulleys by the ordinary principles of projection. The student will also determine the location of the slots which must be cut in the floor for the belt.

It will be observed that the leaving sides of the two pulleys are in the same plumb line, and that the shafts in this arrangement must always turn in the same direction, for if they do not, neither pulley will deliver the belt into the plane of the other, and the belt will run off.

There are many other belting arrangements that might be studied with profit but it is inpossible here.

Shade lines are to be used in drawing the pulley, but would not be worth while in the belting layout, as they would make the drawing but little if any clearer.

Notes on Plate 8.

In Plate 6 the student was made familiar with the different conventional methods of drawing threads and springs; the exact methods of drawing the same, although seldom used in ordinary shop drawings, are shown in the present plate. The exact construction of a thread or spring is an excellent drill in the accurate use of the irregular curve and is well worth while.

Since most coil springs and all screw threads depend upon a curve known as the helix it will be necessary to know what a helix is before taking up the construction of the springs and screws.

The helix is a curve traced on the surface of a cylinder by a point moving at a uniform rate around the circumference and at the same time uniformly in a direction parallel to the axis. The motions are uniform but their rates are independent of each other, and the point may move in the direction of the axis any distance while going once around the circumference. This distance between successive coils is called the pitch. The directions as well as the rates of the two motions are independent of each other and the helix may be either right or left handed.

In Plate 8 the shape of the helix may be seen in any of the threads or springs, the edges of the same

being helices. The construction of the square thread will now be briefly explained, and since the construction of the other thread and of the sprinngs is similar the student should have no great difficulty in drawing them, the construction being indicated for the first turn in each case.

Draw the center lines for all the objects that are to appear. Now construct the rectangle (4x10) representing the side view of the screw; then draw the construction semi-circles for both ends and divide them into 30° sectors. Next divide the first inch from each end of the rectangle into twelve equal spaces and draw light vertical lines through the points marked. Now to draw the helix for the right hand edge of the top of the square thread, say, starting at the lower side of the rectangle project the ends of the radii of the construction simi-circle to the left as shown; the points in which these horizontals intersect corresponding verticals are points on the helix. The back side of the helix might be shown dotted; it is omitted here because it would serve no useful purpose in an actual working drawing. The other helix for the top of the thread is drawn in the same way beginning 1/2" further to the left. Those for the bottom of the thread are similarly executed using the inner semicircle which will have a diameter of three inches.

The U.S. standard thread is a V thread with 1/8 the altitude of the thread cut off and 1/8 the depth of the groove filled. Its construction is similar to that of the square thread.

The best way to draw the round helical spring is to construct the helix representing the center of the wire and then to draw on this helix circles the diameter of which is equal to the diameter of the wire. Curves tangent to these circles will give the convolutions of the spring.

In drawing long threads or springs it will save much labor if a template of a thin strip of hardwood or stiff cardboard is made to fit the curve. The center line should be marked on the template and it should be used like an ordinary curve. The student should not attempt to draw the sharp curves at the vertices with a ruling pen; they are best put in freehand with a lettering pen in small threads, or with a bow-pen in large ones.

Shade lines are to be used in this plate.

Plate 8 also gives a simple cam. A cam is a mechanism which, by means of its rotation about a fixed axis, imparts a back and forth motion to another piece in contact with it. The student has no doubt often seen different cams in operation. Examples may be found in almost any gasoline engine, in the stamp mill, etc.

The drawing shows the construction of the cam under consideration here quite fully. The law of the motion given to the follower will vary according to requirements. More complicated cams are discussed later in the study of Mechanism..

Notes on Plate 9 C.

Plate 9C is a structural steel exercise and includes two parts: the conventional signs for riveting and a single web plate girder.

The first of these shows the standard methods of representing different kinds of rivets. The student should draw the four views to some convenient dimensions and should properly locate them on the plate.

The central part of the plate comprises a shop detail of a simple plate girder of one web. It will be noted that the detail covers only one-half the girder; this is because when a girder (or other object) is exactly symmetrical about the center line, it would be a waste of time to draw both halves. In such cases it is sufficient to mark the center line and note that the other half is the same.

This girder rests on a brick wall at each end and a wall rests on top of the girder, the intermediate stiffeners supporting the flange where the main pier lines come down.

The lower part of the plate gives the bill of material accompanying the girder shown above. With the following abbreviations this bill will be easily understood.

Anch.	= Anchor	R & L	= Right and Left.
L	= Angle	Riv.	= Rivet or Rivets.
Blt.	= Bolt	R	= Radius
C.I.	= Cast Iron	R.W.	= Roadway.
Cor. I.	= Corrugated Iron	o	= Round Rod.
Csk.	= Countersunk	Sepr.	= Separator.
Diam.	= Diameter	S.W.	= Sidewalk.
Fill.	= Filler	Std.	= Standard
Fl.	= Flange	Str.	= Stringer
F.B.	= Floor Beam	T	= Tee
Hex.	= Hexagon	T & G	= Tongued and Grooved also Tar and Gravel
Lat.	= Laterals		
O.H.	= Open Hearth	T.B.	= Turnbuckle
o. to. o.	= Outside to Outside	U.H.	= Underhead.
		W.G.	= Wheel Guard.
Pl.	= Plate	Y.P.	= Yellow Pine

The student will make the pencil drawing of Plate 9C, and will then trace the same on tracing cloth. Shade lines will not be used since they are nearly always omitted in structural work.

....Tracing....

A drawing may be traced on either tracing paper or tracing cloth, the latter being more durable

is usually preferred. The tracing cloth should be stretched smoothly over the original and should be rubbed with chalk dust or talcum powder to remove the slightly greasy coating which prevents the ink from flowing well from the pen. Before beginning to draw the chalk should be carefully removed or it will clog the pen.

The question as to whether the smooth or dull side of the cloth shall be used is not settled. Either side may be used, but the glazed side was originally intended for use and as changes are more easily made on the glazed side it is to be preferred, except when a drawing is pencilled on the cloth when it will be found necessary to use the unglazed side.

Tracing cloth is very susceptible to moisture in the atmosphere even, and will be ruined by water. Care should be taken to keep perspiration from the hands from coming in contact with the surface.

Tracings may be cleaned with gasoline, ether, benzine, or any highly volatile substance. Unless very dirty cleaning with the eraser will suffice.

In inking on tracing cloth especial care should be taken to make the lines clear and firm; if the lines are made light the prints from the tracing will lack contrast and snap.

Notes on Plate 9 D.

Plate 9D is made up of a number of engineering details and will furnish practice in the production of simple working drawings. The plate is to be pencilled, then traced on tracing cloth as explained in connection with Plate 9C.

The general method of procedure to follow in making any working drawing is given in detail in the notes on Plate 9M and should be followed here.

The upper part of the plate shows two views of an ordinary car wheel, and two views of a simple overhung crank. The center of the plate is occupied by the drawings of five standard forms of rivets; the diameter of the rivets is to be taken as 1/2" and the other dimensions expressed in terms of it. The lower part of the drawing gives two views of a cross chopping bit, such as is used in a common air drill. It will be observed that the thread used in the latter is a special rectangular form having a great shearing strength.

Notes on Plate 9 E.

Plate 9E shows a general drawing and sketches of the details of a 200 Ampere, 250 Volt, Double Pole, Single Throw Switch.

The instructor may require either a full size assembly drawing or a detail drawing as shown. In either case the student will make a complete pencil drawing first, being careful to secure a neat and balanced arrangement of the various views; he will then ink in the drawing on tracing cloth as explained in the notes on Plate 9C.

The student should remember to work systematically according to the order of procedure given in the notes on Plate 9M.

The detail sketches furnished the student are rather more fully dimensioned and more carefully drawn than they would be in practice, but they will answer to illustrate the usual practice of working from sketches.

Notes on Plate 9 M.

The present plate gives the general or assembly drawing of a bench vise, and also the details of the same. The purpose of an assembly drawing is to show the relation of the various parts, and to serve as a check on dimensions of details. By details is meant the different elementary parts of which a machine is built up. In the detail drawing care is taken to give all necessary dimensions, while a general drawing gives only a few of the principal or "overall" dimensions.

In this plate the assembly drawing consists of two views: a plan or top view, and the elevation of a longitudinal section through the middle of the vise. In actual practice the general drawing is made first, but here it will be advisable to draw the details first; since nearly all the dimensions are given on them they will help materially in drawing the general views.

In accordance with this plan after laying out the plate and title space the student should draw center lines and leaving space for the two general views should proceed to draw say the two views of the pin D, and the three views of the swinging jaw designated by C in the assembly. The parts marked A, B, and E are circular, thus allowing the rear jaw to swing when the pin D is removed; this makes it possible to hold tapered

pieces firmly with such a vise.

In making any drawing a good plan to follow is to draw first all center lines, thus getting something to work from; then work from the center out, drawing curved lines and circles first; this because it is much easier to join a straight line to a curved one than vice-versa. Each detail should be completely pencilled, dimensioned, and lettered before passing on to the next; however, it is often of advantage to work on two or all three views at the same time because many of the dimensions may be projected from one view to another. The order of drawing the different details is in this case not of much importance and the student may follow his own inclination, always drawing first all the necessary centerlines and building from them until the detail is completed.

Separate views of the handle and screw are not necessary, since the general drawing shows all their dimensions.

It will be noted that the vise to be drawn is fitted with a swivel base which allows the vise to be turned to the angle most convenient to the workman. The swivel base is shown in two views directly to the left of the title, and the pin for holding the vise in the position set is shown in a separate detail near the center of the plate. Owing to the large number of details shown

on the one plate it is necessary that the student exercise especial care in the arrangement; if he does not draw his center lines first and apportion his space properly in the beginning he may find that he does not have room enough or that some parts of the plate will be crowded. Neatness and taste in the arrangement of a plate, perhaps as much as anything, distinguish the good from the poor draftsmen. Mechanical drawing is in the main training of hand and eye, but the student must not imagine that he can accomplish good work if he allows his mind to rove; there is as much need for care and thought is drafting as in any subject.

Reference was made to an order of procedure in pencilling. This is even more important in inking and it is surprising what a saving of time will be effected by systematic work. The following order will be found logical, convenient, and economical of time.

1. Having inked the border, ink all center lines and constructions of the detail.

2. Ink all circles, arcs of circles, and other curved lines, putting on shading where proper.

3. Draw all horizontal full lines.

4. Draw all vertical and inclined full lines.

5. Draw all horizontal shade lines.

6. Draw all vertical and inclined shade lines.

7. Draw all invisible (dotted) lines.

8. Put in cross sectioning if any part is to be shown in section.

9. Put in extension and dimension lines.

10. Put in dimensions, arrow points, and such lettering as is to appear.

This order of procedure should be memorized by the student. It will require the fewest changes of pen setting and will prove easy to learn and apply.

In actual shop drawing the details are often shown on separate plates and to a larger scale than the assembly drawing. However in the case of simple machines the plan used with the present plate is often followed. With the size of plate used it is of course impossible to draw the details to a scale larger than that used in the assembly.

This plate lends itself very well to a number of modifications. As in Plate 9C it may be pencilled and then inked on tracing cloth, either as given or what is perhaps preferable, a general view only may be made to a scale of 6"= 1' or to the special scale 8"= 1'. If the plate is assigned in this way the student should be careful to first locate his center lines in such a way as to secure a pleasing and balanced arrangement.

Detailed instructions for tracing may be found in the notes on Plate 9C.

Notes on Plate 10.

As the student has already learned, all working drawings require more or less lettering, such as titles, dimensions, explanations, etc. In order that the drawing may appear finished the lettering must be well done and a legible style of letters must be used. The small letters which have been used heretofore should be made freehand; the present plate gives some styles of large letters.

The Roman and Gothic letters are perhaps the most used for titles, and being of larger size, are generally made mechanically, that is, the drawing instruments are used in their construction. It will be noted that in order to make the letters appear of the same height, some of them, owing to the shape, must be made a little higher than others. This is the case with the letters curved at top and bottom, such as C,O,S, etc. The letter A should extend a little above and V a little below the guide lines, because if made of the same height as the others they will appear shorter. This is true of both Roman and Gothic capitals.

There is no absolute size or proportion of letters, as the dimensions are regulated by the size of drawing, effect desired, space available, etc. In some cases letters are made so that the height is greater than

the width, and sometimes the reverse. The most common proportion is that where the height and width are the same. In any line of lettering certain relations of width must be observed. Thus , no matter what the style of alphabet used, W should be the widest letter; J the narrowest next to I; M and T next widest to W: and then A and B. The other letters are of about the same width.

In the vertical Gothic alphabet the average height is that ob B,D,E,F, etc. and the additional height of the curved letters and A and V is very slight. The horizontal cross lines of E,F,H, etc. are slightly above the center; those of A,G, and P slightly below.

The angle chosen for inclined letters is usually about 70°.

The Roman letters are quite ornamental in effect when well made, the inclined Roman being particularly attractive although rather difficult to make.

For small letters, called lower case letters, the height may be made about two-thirds that of the capitals. The proportion however varies.

One of the most important points to be remembered in lettering is the spacing. To space correctly and rapidly requires considerable experience, and rules are of little value. A few directions however will be found useful. For instance in the word "Agricultural";

if all the spaces were made equal, the distance between L and T would appear too great, and the same would apply to A and G. The spaces between U and L, and U and R would be too small. Hence we may say that in general, the spacing should be such that a uniform appearance will be obtained. The distance between words depends upon the effect desired and may be about one and one-half the width of the average letter used.

In drawing Plate 10 after laying out the border lines the student should draw light pencil lines dividing the plate into one-eighth inch squares as shown. These will serve as guide lines and should be entirely erased after inking.

Notes on Plate 11.

Gear wheels of all kinds are used to a great extent in a great variety of machinery, and a draftsman must know how to make, not only the drawings as usually made for shop use, but he must be able to draw the exact profiles of the teeth as well.

Plate 11 is intended as an introduction to t the gear plates which follow. In will be found the constructions for the curves ordinarily used for gear profiles, and their application to a single tooth of each kind is also shown. The discussion of the reason why these curves are used belongs properly to the study of Mechanism and will not be taken up here.

The first gear curve in the plate is the cycloid, which is the curve generated by a point on the circumference of a circle rolling on a line. Its construction is almost evident from the figure. Draw the middle position of the generating circle as shown in full line; draw a horizontal line tangent to it at its lowest point; divide the circle into twelve equal sectors as shown; divide into six equal parts a portion of the base line equal to half the circumference of the generating circle; erect perpendiculars at the dividing points; draw the successive positions of the generating circle (shown dotted) with centers on the perpendiculars just drawn; and draw horizon-

tal lines through the points 1,2,3,etc. on the generating circle. The points of intersection of these horizontals and the dotted arcs determine the cycloid.

The epi- and hypo-cycloid are similarly drawn, substituting an arc for base line and arcs for the horizontals used before.

The involute of a circle is the curve generated by a point in a line as the line unwinds from the circle. The construction is very simple; the points P_1 P_2 etc. being the ends of tangents at 1,2,3,etc.; the lengths of these tangents being equal to the arcs thus far unwound. These lengths may be gotten exactly by calculation or approximately by means of the dividers; that is, by taking the first one equal to the chord P1, the second one twice this length, etc.

In these constructions the generating circles have been divided into twelve parts; this is entirely arbitrary: the greater the number of divisions the more accurate the work. In the gear tooth profifes below it will be noted that a greater nimber of divisions is used.

Before going further the following definitions will be in order:

The circle upon which the generating circles roll and upon which the teeth are constructed is called the pitch circle. The diameter of a gear is always

understood to be the diameter of the pitch circle.

The pitch is the length of arc measured on the pitch circle between the centers of two consecutive teeth. When the gears are cut in a milling machine the widths of tooth and space (on pitch circle) are equal; when cast the spaces are a little wider than the teeth; the difference is called the "backlash" and usually equals 4% of the pitch.

The part of the tooth outside the pitch circle is called the addendum; the part inside, the root.

Addendum usually equals 0.3 pitch and the root equals 0.4 pitch.

The face of a tooth is the part outside the pitch circle extending the whole width of the tooth; the part within extending the whole width is called the flank.

The width of the gear depends on the power transmitted and is a matter to be determined by the designer.

Let A = Addendum

R = Root

P = Circular Pitch

N = Number of Teeth

D = Diameter of Pitch Circle.

Then $D = PN / \pi$

or $P = D\pi / N$

or $N = D\pi / P.$

For cycloidal gears the following empirical formula for the diameter of the describing circle has been found to work well;

$$d = 6P / \pi$$

Also as already stated:

$$A = 0.3\ P$$

$$R = 0.4\ P$$

Backlash = 0.04 P for cast gears and zero for cut gears.

The method of applying the curves to the teeth as shown should be clear from a careful inspection. Note also the method of obtaining the base circle for the involute tooth; it is drawn tangent to the 75° line drawn as shown.

The root of an involute tooth is radial below the base circle.

A rack is a gear with an infinite radius, or what amounts to the same thing, a gear with a straight line for a pitch circle.

The involute rack is a special case and is very easy to draw.

When one side of a tooth has been found the other side may be easily laid off by drawing a center line

through the tooth and transferring point by point by means of the dividers, the curve already found.

Notes on Plate 12.

This plate shows an involute gear in mesh with a smaller gear, usually called a pinion. The student should find no difficulty in drawing these gears after completing Plate 11. The mechanical details are also quite simple.

The following order of procedure for pencilling will indicate the most dires way of executing the work:

Lay out border lines and title space.

Draw all center lines.

Draw the two pitch circles.

Mark off the pitch, thus locating the teeth.

Make construction for and draw the two base circles.

Construct one tooth on each gear by the exact method of Plate 11.

Make a template for each gear by means of these.

Pivot each template in turn at center of gear and pencil all the tooth profiles.

Put in all mechanical details, dimensions, sectioning, etc.

Ink the plate according to the order of procedure previously given for inking.

This plate as well as the two succeeding ones, is capable of a very neat and artistic finish; shade lines are to be used, and the student should be careful to make his curves smooth and the fillets at the roots of the teeth exact.

Notes on Plate 13.

This plate shows two cycloidal bevel gears in mesh. Such gears are used in connecting two shafts at right angles, and may be made in a variety of forms as to mechanical details. Also, involute teeth might be used.

The following order of procedure will outline the method, and should be sufficient if the problems of Plate 11 were solved and understood.

Lay out the border lines and title space.

Draw all center lines, following dimensions, and locating the views properly.

Draw the lines radiating from O as shown.

Draw JK perpendicular to the line from O which intersects it.

Put in the mechanical details of the elevation which is shown in section.

According to the principles of Plate 11 construct the developments of the single teeth at A,B, C, and D.

From the last construct the view E, which is the horizontal projection of the smaller gear.

Draw the pitch circles of the elevation at the left.

Draw the mechanical details of the same.

Now having the widths of the teeth on the pitch circle (1/2") and top and bottom from the developments at A and B, put in the curves for the larger gear.

It must be noted that none of the tooth profiles in E nor in the front elevation are shown in their true size. Those of the larger gear and of E are shown in true width but shortened, and some of those of the smaller gear are both shortened and reduced in width.

The curves in the front elevation cannot be very exact having only three points given, but this does not matter since this view is only put in to satisfy the eye, and to show the mechanical details. A template may be used to advantage here.

The teeth of the smaller gear are obtained by projecting from E and from the right elevation as shown.

Ink as before using shade lines.

Notes on Plate 14.

The present plate shows an involute worm gear. Although not as often used as the other gears already drawn, it forms a very instructive exercise and will well be worth the time spent on it.

The mechanical details of the gear blank are very simple and need no comment. The method of constructing the teeth will be indicated by the following order of procedure:

Lay out border lines and title space.

Put in all center lines, following the dimensions given.

Draw as per dimensions the upper half of the left elevation.

In Plate 11 it was noted that the sides of involute rack teeth were straight, hence the worm in this plate is a simple screw with threads 11/16" high and making an angle of 15° with the vertical. It may be drawn by the helix construction explained in Plate 8.

Draw the pitch circle for the front elevation and construct the teeth shown in section. (Plate 11).

The wheel advances one tooth or one inch on the pitch circle for each turn of the worm, hence for 60°, the angle of the worm wheel teeth, the wheel advances 1/6". This explains why the part of the tooth

faces visible is dimensioned 1/6".

Although it is not exactly correct the same template may be used for drawing the outside profiles of the teeth as is used for drawing the section profiles.

The curves in the lower part of the left elevation are obtained by projection from the teeth in the front elevation.

The small curves forming the tops of the teeth in the front elevation are best put in freehand.

The student should be careful to do neat and clear-cut work, even though such extreme accuracy in the curves is not necessary. In practice the separate teeth of a gear are usually not shown, the top, bottom, and pitch circles being indicated by three dot and dash circles. Where it is necessary to furnish the pattern maker with a template it is usual to draw two or three of the teeth, but in cut gears even this is omitted.

In the case of a worm gear it is in practice only necessary to show the exact form of the threads on the worm. This is because to make a worm wheel a steel screw of the same size as that finally to be used is notched to make a cutter, then hardened, tempered, and used for cutting the teeth of the wheel.

Notes on Plates (15,16,17,18)E.

These plates constitute a set of the most important mechanical parts of a 5 H.P. Induction Motor.

The plates are arranged as follows:

A	Assembly
B	Stator Yoke Rotor
C	Heads Tooth Support
D	Miscellaneous Details

This set allows many modifications in assig n-ment, and the student will draw such plates as the instructor may determine.

In any drawing of the set the order of procedure given in the notes of Plate 9M will be applicable, and if tracings are to be made the student should read the instructions for doing so. These instructions may be found in the notes on Plate 9C.

On these plates will be noticed lists of parts giving in the first column the material, in the second the name , in the third the pattern number, and in the fourth the estimated weight. Another example of such lists or material bills will be found in Plates (16,17,18)M.

The prints for plates 17E and 18E are made to represent freehand sketches. They are however more com-

plete than would be usual in practice. They are fully dimensioned and the student is expected to make finished drawings from them.

Notes on Plates (15,16,17,18)M.

These plates constitute a complete set of drawings for a 2 H.P. Simple Slide Valve Engine. The titles of the four plates are as follows:

A General Drawing.

B Details of Body.

C Main Moving Parts.

D Valve Details.

The set allows many modifications in assignment and the student will draw such plates as the instructor may determine.

In any case the student will follow the order of procedure set down in the notes on Plate 9M, and if tracings are made instructions for doing so may be found in the notes on Plate 9C.

A feature often used in actual drafting is the "bill of material" on each plate of details, and the student should particularly note the arrangement. The first column gives the number of the various parts required, the second column the name, the third the number, the fourth the material, and the last the pattern number.

It will be noted that the prints for the plates No.17M and No.18M are made to represent freehand sketches. They are however more complete than would usually be the case and are fully dimensioned. The student will make make finished drawings from them.

Notes on Plate 19.

Plate 19 gives some exercises in line shading and in isometric and oblique projection. The line shading is seldom used in shop drawings, but in finely finished work it is frequently desirable to make the various parts more readily seen by showing the gradations of light and shade on the curved surfaces. This is especially true of such surfaces as cylinders, cones, spheres, and such shapes as are shown in the plate. The effect is obtained by drawing a series of parallel or converging lines on the surface at varying distances. The widths of the lines themselves are usually also varied. The lines are farther apart on the lighter portion of the surface, and closer together and heavier on the darker part.

In the elements of the cone Fig.14 the shade lines should diminish in width as they approach the apex. If this is not done a blot will be likely to result.

Further detailed directions on shading are hardly necessary, and the other figures will not be considered.

The purpose sought in isometric and oblique projection is the same: a more or less complete representation in one view of any object.

An isometrical drawing of an object shows in one view the three dimensions, length, breadth, and thickness; it is called for short the isometric of the object.

Figure 20 shows the isometric of a cube in which the top and the two sides are visible; it also shows an approximate method of drawing the isometric of a circle in various positions.

In Figure 19 is shown the manner in which the isometric projection of a cube may be derived from its orthographic projections. Beginning with the simple position of the left hand figure the cube is swung around to the second position, where the diagonal is parallel to the vertical plane and slopes downward to the left. In the third view the cube has been revolved about an axis through the lower right hand corner until the diagonal is parallel to the horizontal plane, becoming then parallel to both planes. The plan of this position is found by the principles of projection from the elevation and the preceding plan. The final position is attained by revolution about a vertical axis until the original diagonal is perpendicular to the vertical plane. From the new plan of this position the elevation is constructed and gives the isometrical projection of the cube. It will be noted that the length of the cube has become shortened ; this is disregarded and the edges are all made the same

or true length.

The rays of light are parallel to that diagonal of the cube which runs from the upper left hand corner to the lower right hand - hence the shade lines as shown.

In oblique projection one face of the object is represented as if parallel to the vertical plane of projection, the others inclined to it. Also, oblique projection cannot be deduced from orthographic, as is isometric.

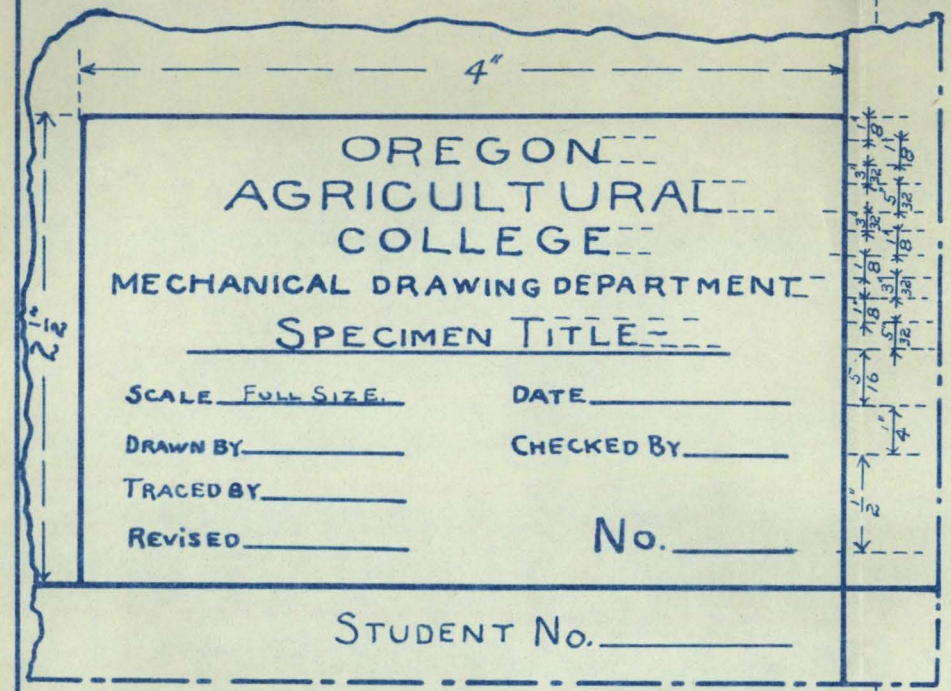
The lower part of the plate shows an ordinary working drawing or orthographic projection of a model. To the right are the oblique projection and isometric of the same.

Finis.

++++ DIVISION IV ++++

Drawing Plates.

Margin 1/2" wide.



- NOTE -

Use style of title given here except when specially instructed otherwise.

Border - Trim here

Margin 1" wide here for binding.

Margin 1/2" wide.

- NOTE -

The dotted lines shown are to be used in laying out the plate and title but do not appear in finished drawing.

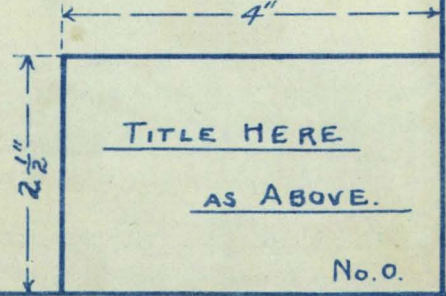
STANDARD PLATE - SCALE - 6" = 1ft.

This size and style of plate is to be used in all cases except when special work is assigned and another size specified.

Size - Original Sheet --- 18" x 21".

Size - Trimmed Plate --- 17" x 19 1/2"

Size - Within Border --- 16" x 18".



TIME

Margin 1/2" wide.

STUDENT No.

FIG. 1

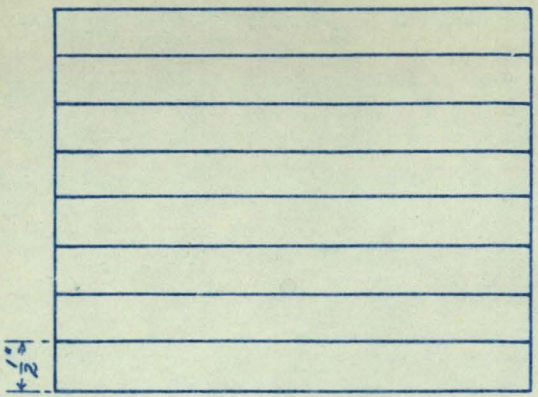


FIG. 2

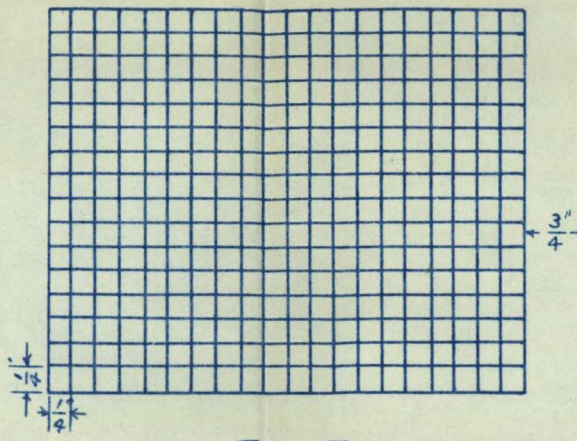


FIG. 3

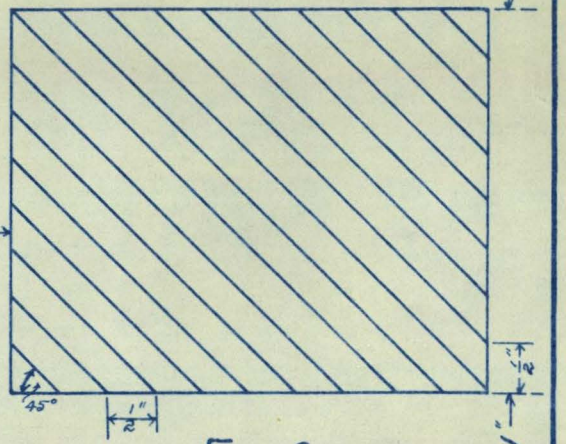


FIG. 4

((These letters are full-size))

ABCDEFGHIJKL

MNOPQRSTUVW

XYZ & 123456789

abcdefghijklmno

pqrstuvwxyz

Use this Style for Dimensions and Descriptions.

((Make four Sets)).

FIG. 5

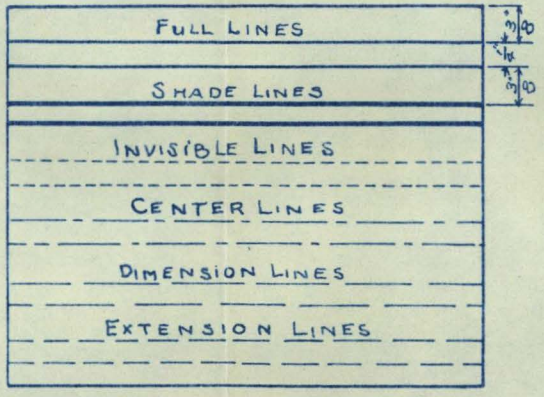


FIG. 6

((These letters are full size))

A B C D E F G H I J K

L M N O P Q R S T U V W

X Y Z & 1 2 3 4 5 6 7 8 9

a b c d e f g h i j k l m n o

p q r s t u v w x y z

Use this Style for Titles - and Captions.

((Make four Sets)).

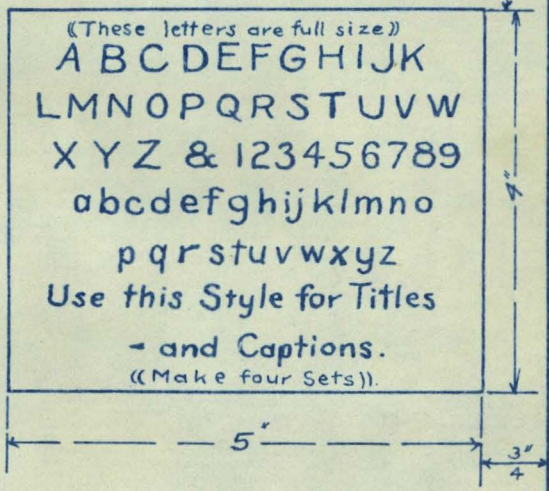


FIG. 7

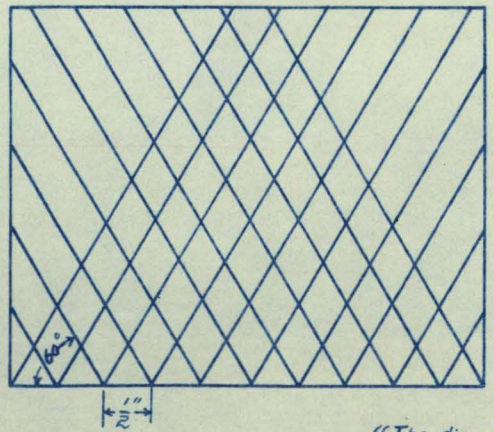
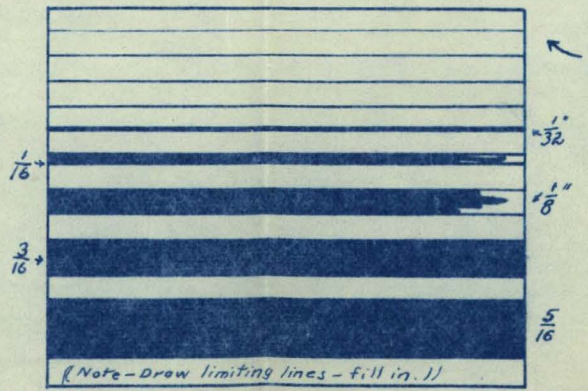


FIG. 8



((Spaces between lines are 1/4" - Widths of lines are to be double those shown)).

((The dimensions on this print are merely to guide the student - none are to appear on finished plate)).

OREGON AGRICULTURAL COLLEGE

MECHANICAL DRAWING DEPARTMENT

ELEM. PRACTICE SHEET.

SCALE - 6" = 1 ft. DATE

DRAWN BY CHECKED BY

TRACED BY

REVISED BY

No. - 1.

TIME

STUDENT NO.

FIG. 9.

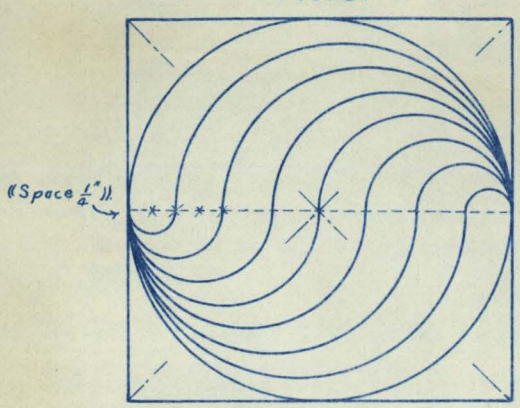


FIG. 10.

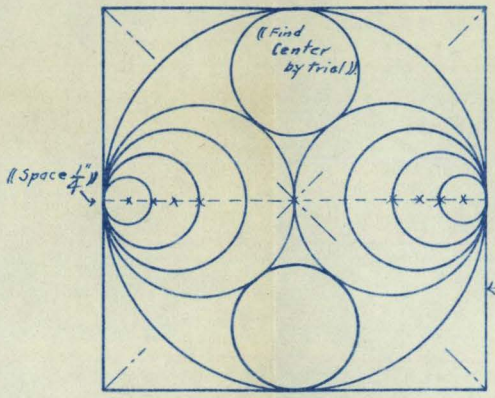


FIG. 11.

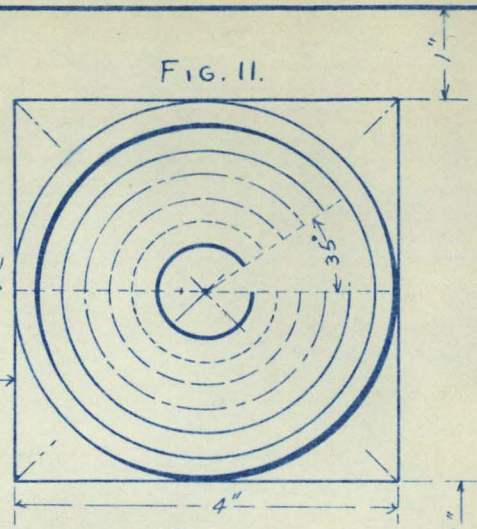
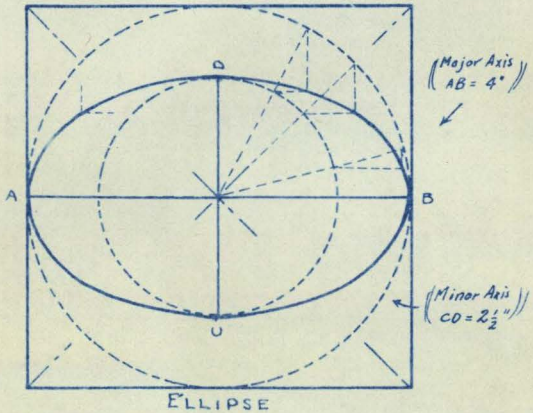
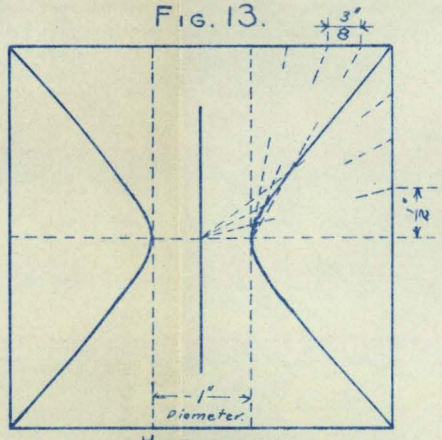


FIG. 12.



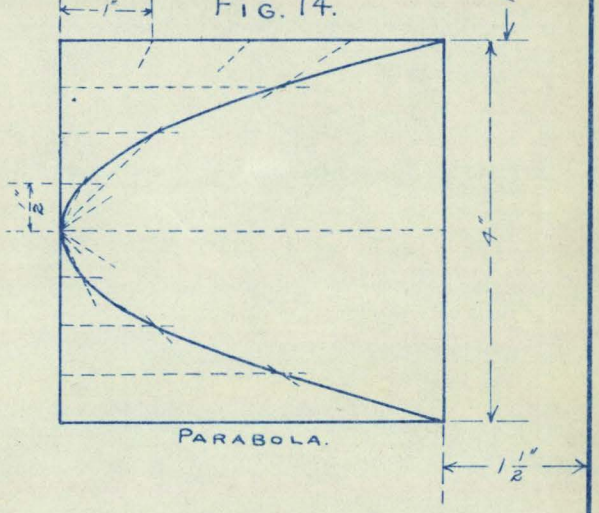
ELLIPSE

FIG. 13.



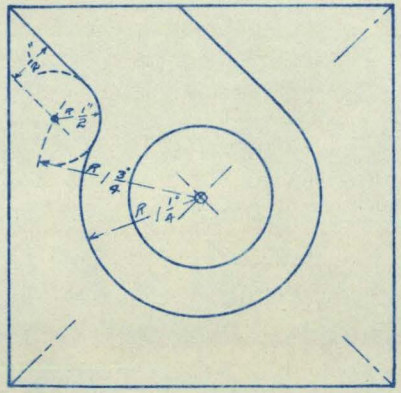
HYPERBOLA

FIG. 14.



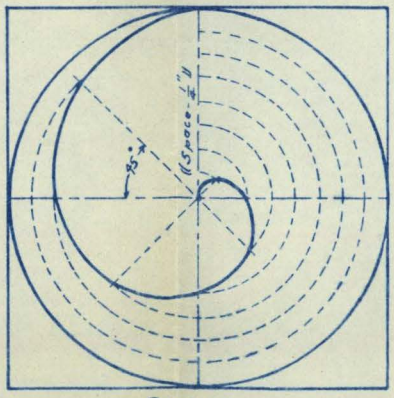
PARABOLA.

FIG. 15.



CONSTRUCTION FOR FILLET.

FIG. 16.



SPIRAL

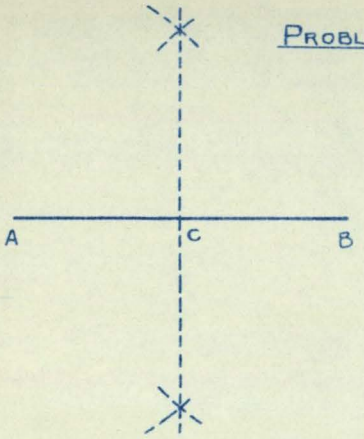
(Note - Read notes on each figure carefully before beginning to draw).

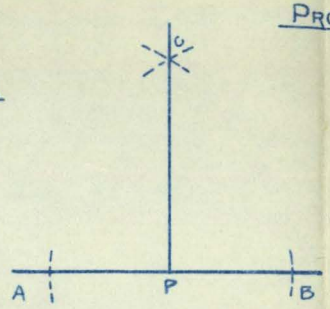
OREGON AGRICULTURAL COLLEGE
MECHANICAL DRAWING DEPARTMENT
SECOND PRACTICE SHEET.
SCALE - 6" = 1ft. DATE _____
DRAWN BY _____ CHECKED BY _____
TRACED BY _____
REVISED BY _____
No.-2.

TIME _____

STUDENT NO. _____

Problem 1.





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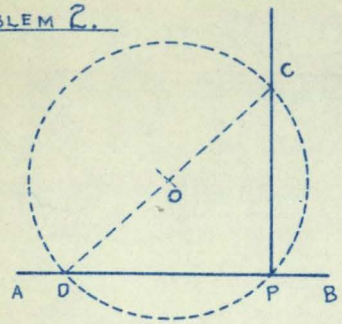
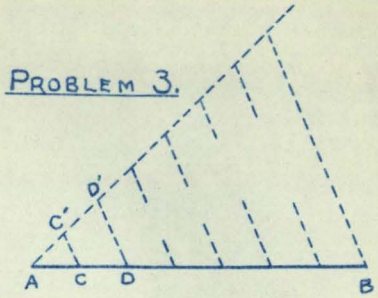


Problem 3.



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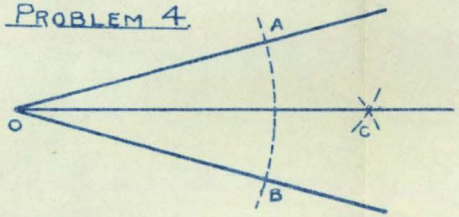
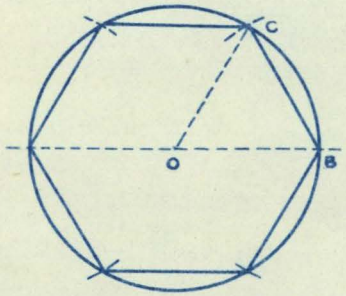
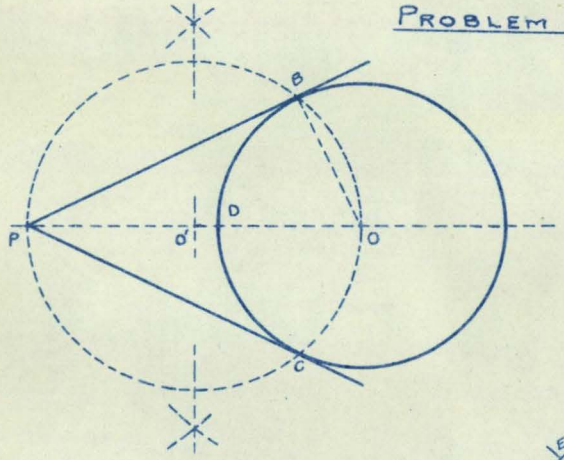


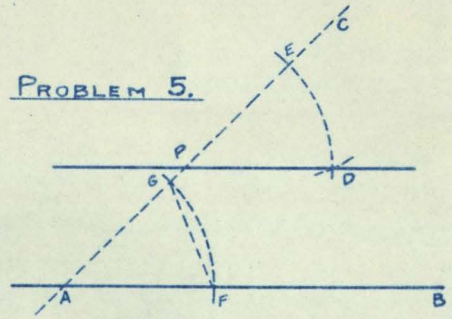
Problem 6.



Problem 7.

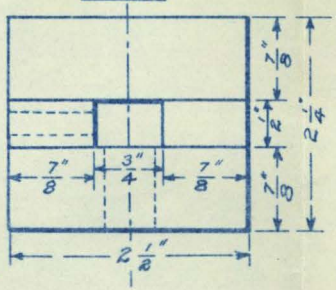


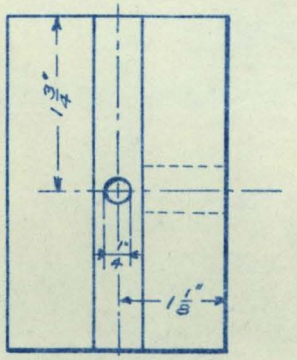
Problem 5.



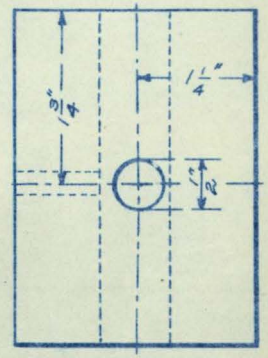
Model Illustrating Orthographic Projection.

Plan.

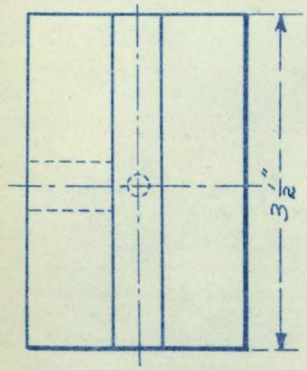




Left Elevation.



Front View.



Right Elevation.

OREGON AGRICULTURAL COLLEGE
MECHANICAL DRAWING DEPARTMENT
GEOMETRICAL PROBLEMS—
ORTHOGRAPHIC PROJECTION.
SCALE 6" = 1 ft. DATE _____
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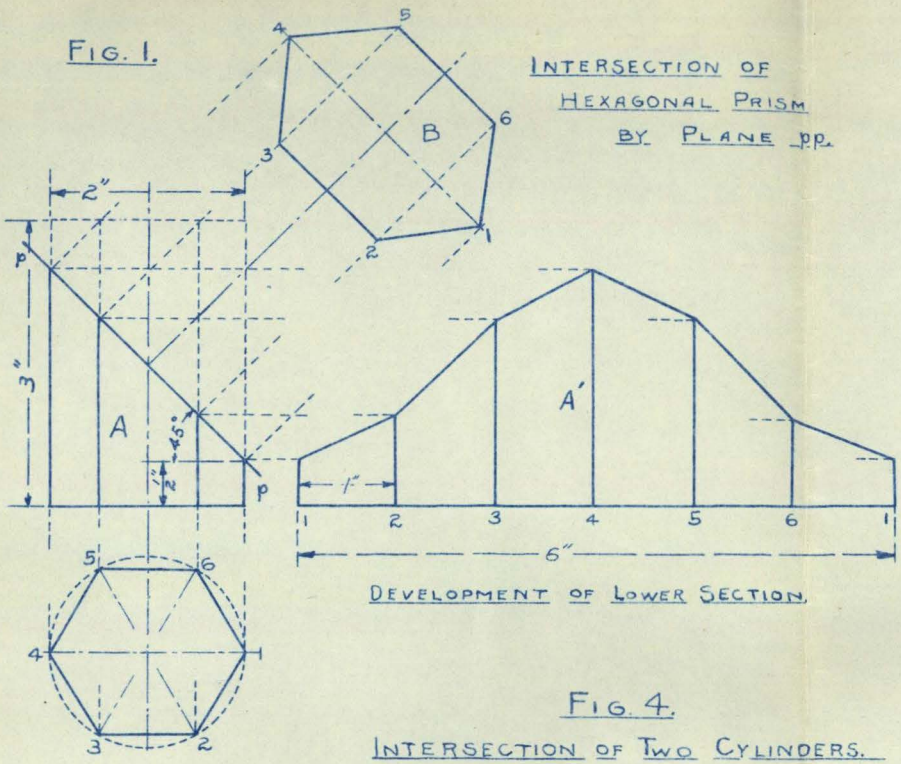
CHECKED BY _____
No.- 3.

TIME _____

STUDENT NO. _____

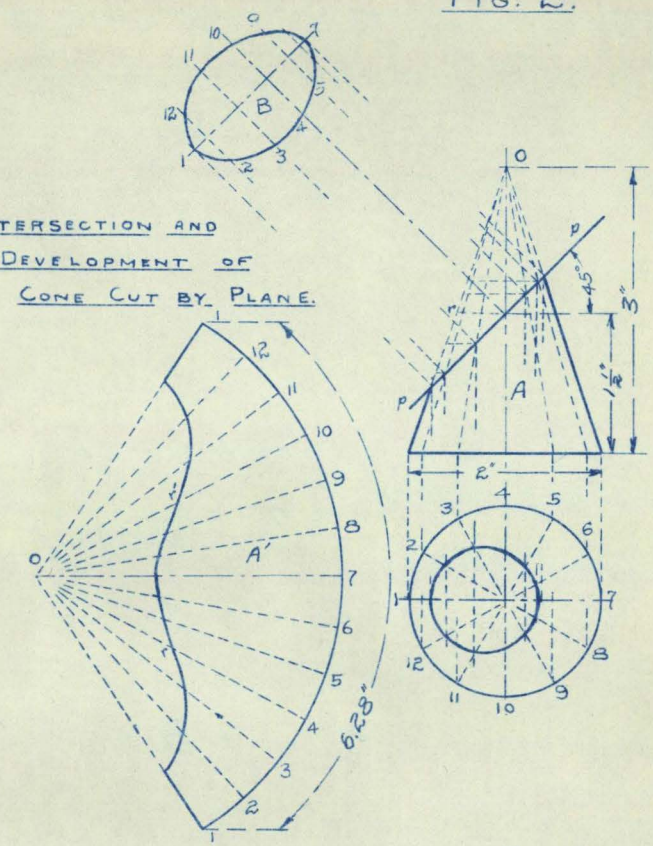
FIG. 1.



INTERSECTION OF HEXAGONAL PRISM BY PLANE pp.

DEVELOPMENT OF LOWER SECTION.

FIG. 2.



INTERSECTION AND DEVELOPMENT OF CONE CUT BY PLANE.

FIG. 4.

INTERSECTION OF TWO CYLINDERS.

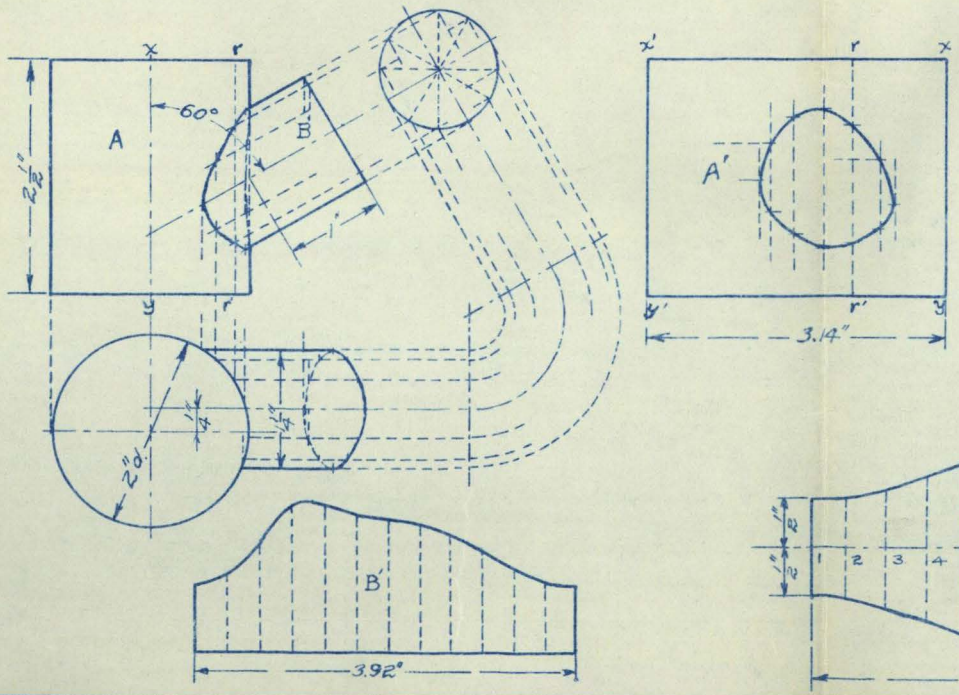
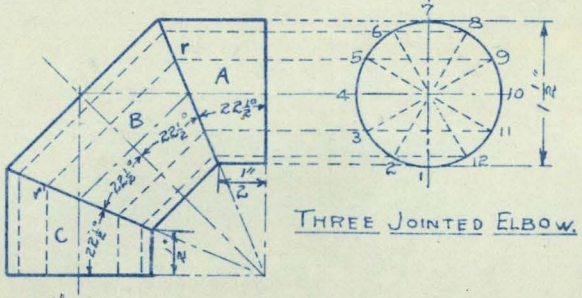
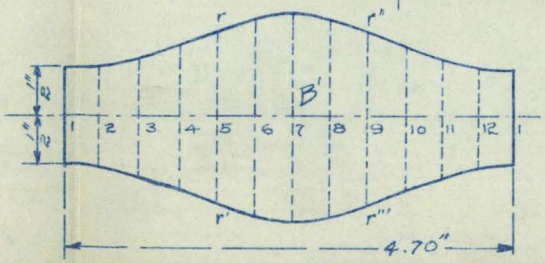


FIG. 3.



THREE JOINTED ELBOW.



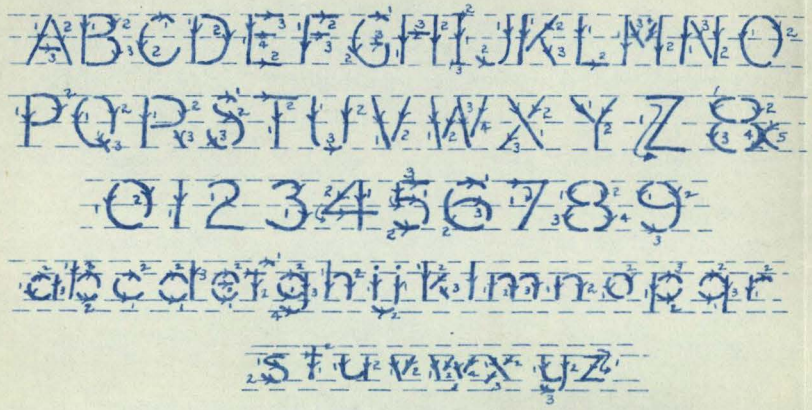
OREGON AGRICULTURAL COLLEGE
MECHANICAL DRAWING DEPARTMENT
INTERSECTIONS & DEVELOPMENTS.
SCALE - 6" = 1 ft. DATE
DRAWN BY CHECKED BY
TRACED BY
REVISED BY
No. - 4.

TIME

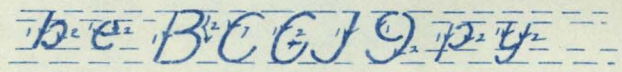
STUDENT NO.

Letters and Figures.

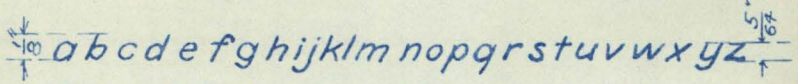
The following letter study illustrates the sequence of strokes used in the construction of the standard alphabets below.



The following of the inclined letters may be more easily drawn as shown herewith—



The standard alphabets below are full-size; i.e., as the letters are to appear on working drawings.
((On full-size plate make two sets; side-by-side))



ABCDEFGHIJKLMNOPQRSTU
VWXYZ

$1\frac{5}{8}$"; 1234567890 & IIIIIIVVIIIIXX etc.

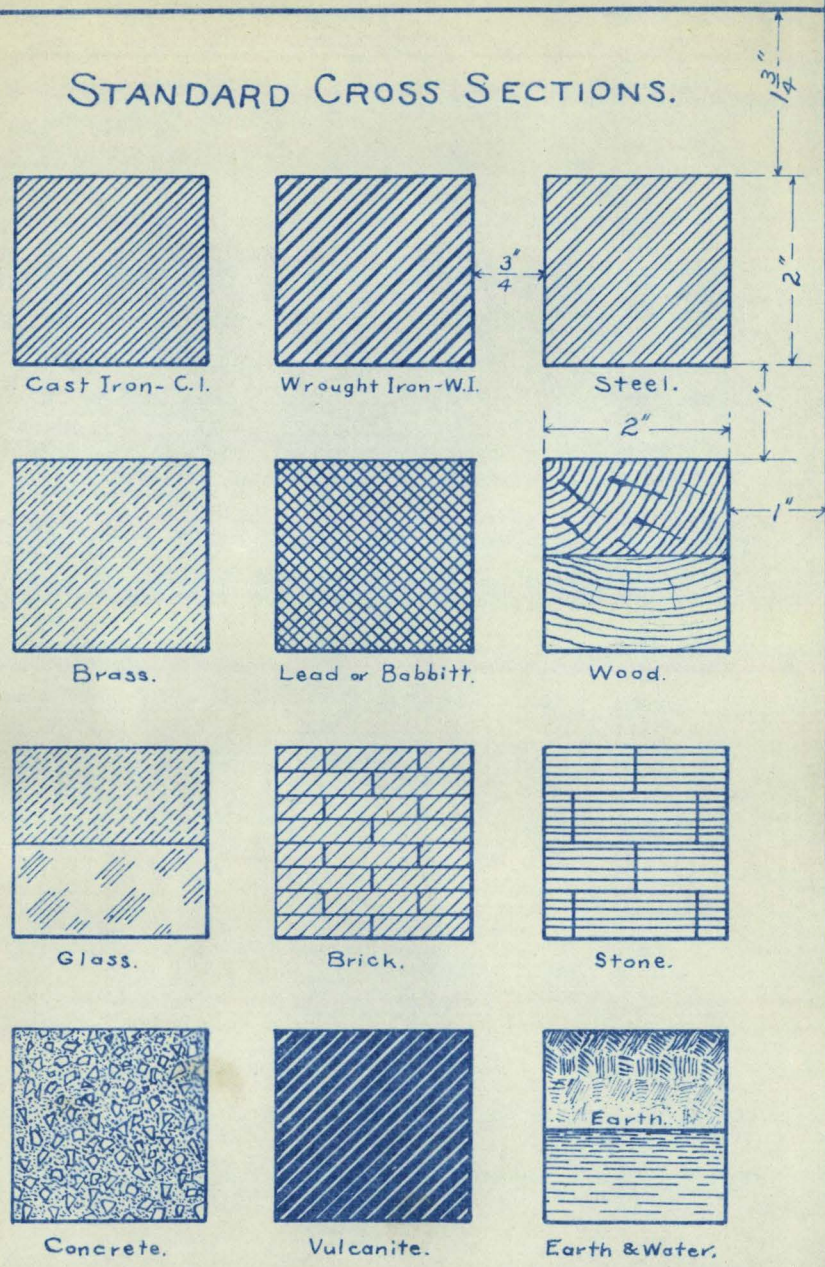
Inclined lettering used for descriptive matter.

abcdefghijklmnopqrstuvwxyz
ABCDEFGHIJKLMNOPQRSTUVW
~XYZ~

Condensed Style & 1234567890. Extended.

Upright Lettering, Suitable for Captions.

Standard Cross Sections.



((Note- The titles above are full size.))

OREGON AGRICULTURAL COLLEGE.
MECHANICAL DRAWING DEPARTMENT
DRAWING ROOM STANDARDS
SCALE- 6" = 1 ft. DATE
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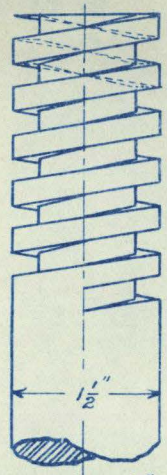
REVISED BY
No.- 5.

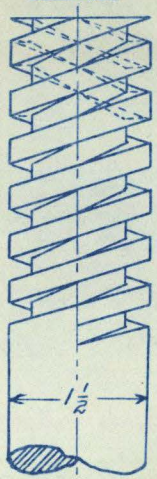
TIME STUDENT NO.

SQUARE THREAD
SINGLE



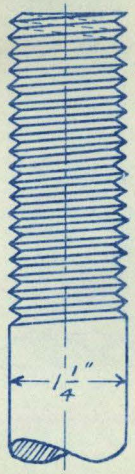
Pitch = ½".

SQUARE THREAD
DOUBLE.



Pitch = 1".

R.H. V-TH'D.
SINGLE

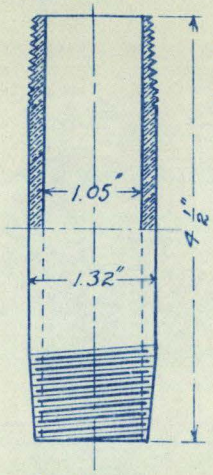


6 th'ds per in.

L.H. V-TH'D.
SINGLE

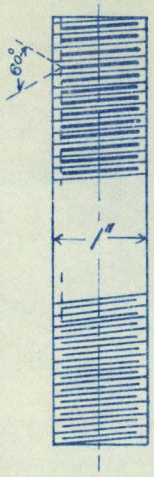
6 th'ds per in.

1" BRASS
NIPPLE.



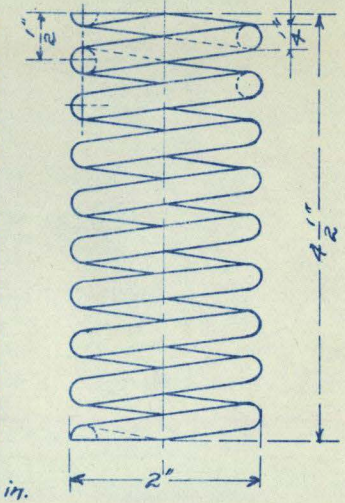
11½ th'ds per in.

R.H. V-TH'D.
St'd.

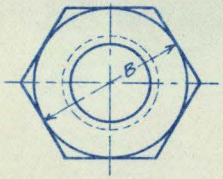


8 th'ds per in.

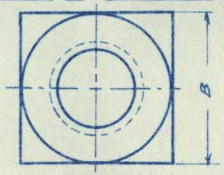
STEEL SPRING
Pitch = ½".

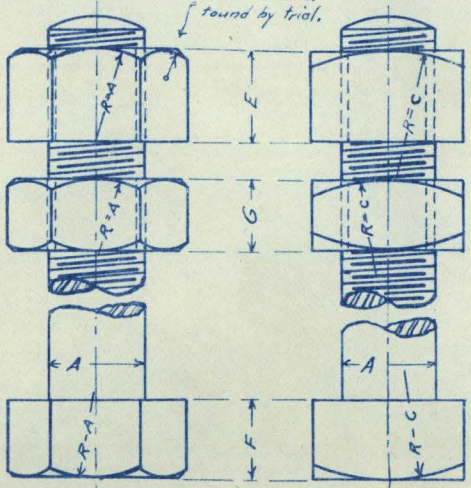


BOLT WITH
HEXAGON HEAD,
NUT, & CHECK NUT.



BOLT
SQUARE HEAD,
NUT & CHECK NUT.

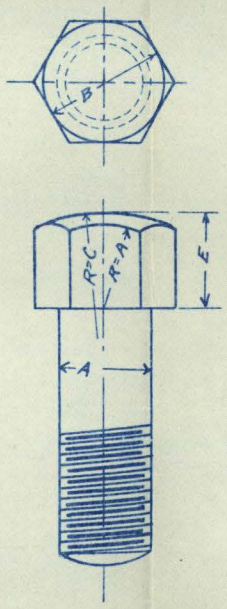




Make A = 1" in all cases given on this plate.

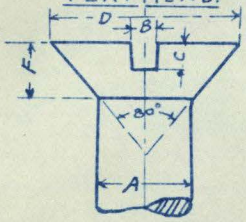
E=A, B = 1½ A + ⅛",
C=2A, F = ¾ A + 1/16",
G = ¾ A.

CAP SCREW.



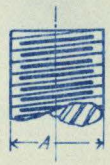
E=A, C=2A,
B = { A + 3/16" until A exceeds ½".
    { A + ¼" when A exceeds ½".

FLAT HEAD.

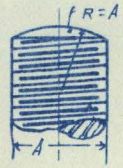


B = ¼ A, C = 9/32 A,
D = 2A, F = 9/16 A, about.

ENDS OF
MACHINE SCREWS.

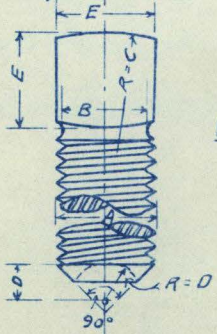


BOLTS, CAP
SCREWS, & STUDS.

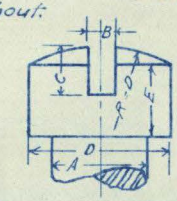


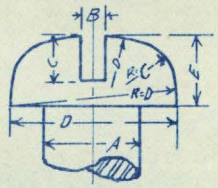
Note: Number of threads per inch of common screws of given diameter is standardized.

SET SCREW.



E=A, B = 7/8 A,
C=2A, D = ⅜ A.





FILISTER HEAD.
D = 1½ A,
E = ¾ A, B = ¼ A, C = ½ A.

ROUND HEAD.
D = 1¾ A,

OREGON
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MECHANICAL DRAWING DEPARTMENT
CONVENTIONAL DETAILS.
SCALE = 6" = 1ft. DATE _____
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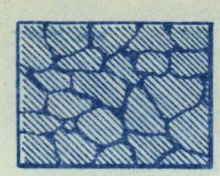
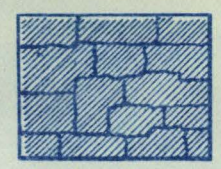
TRACED BY _____
REVISED BY _____
No.-6.

TIME _____

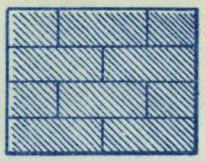
STUDENT NO. _____



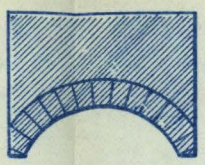
Rubble, Uncoursed.



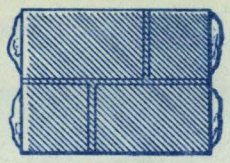
Rubble-Coursed.



Brick.



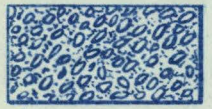
Brick.



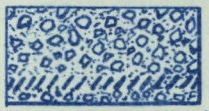
Ashlar.

Riprap.

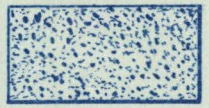
½ Concrete, ½ Rubble.



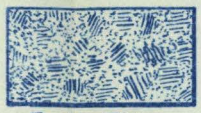
Gravel Concrete.



Expanded Metal Reinf.



Cement, Mortar, or Plaster.

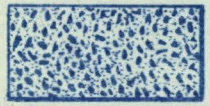


Earth-Filling.

Undefined.

Brick Paving.

Wood Paving.



Cinder Concrete

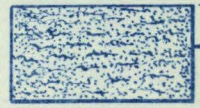
Wire Reinforcement.

Asphalt on Concrete.

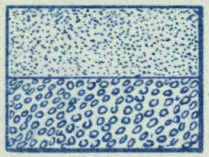
Hardpan.

Mud.

Block Paving.

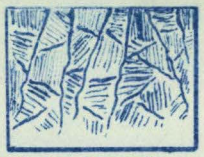


Quicksand.

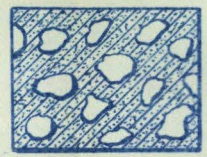


Sand and Gravel.

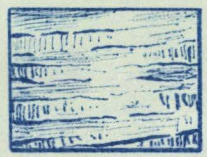
Puddle and Loam.



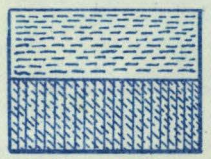
Rock - Amorphous.



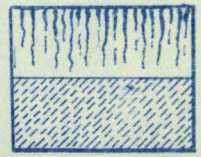
Boulders in Sandy Loam.



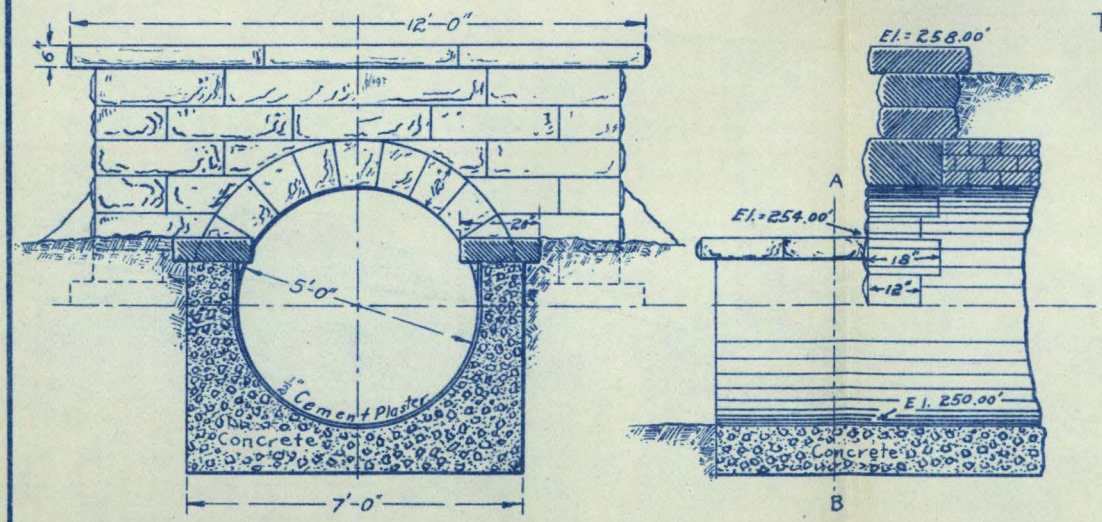
Rock - Stratified



Silt and Marl.



Soapstone and Clay.



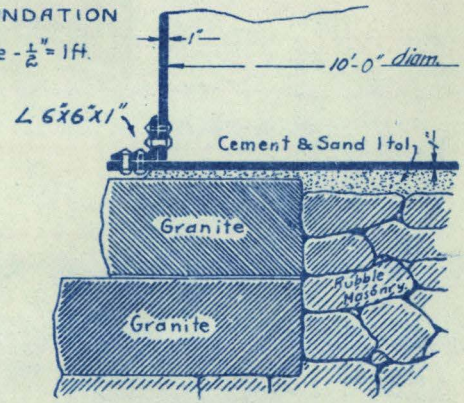
Section A-B.

CHANNEL AND PORTAL OF SEWER

Scale - ¼" = 1 ft.

TANK FOUNDATION

Scale - ½" = 1 ft.



OREGON AGRICULTURAL COLLEGE.

MECHANICAL DRAWING DEPARTMENT

SECTION LINING MASONRY

Scale - ¼" = ½" = 1 ft. DATE _____

DRAWN BY _____ CHECKED BY _____

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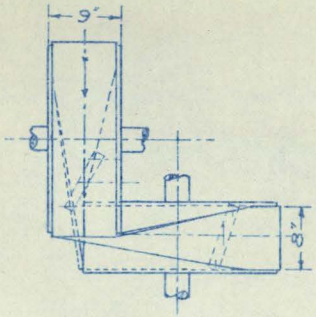
REVISED BY _____

No. 7-C0.

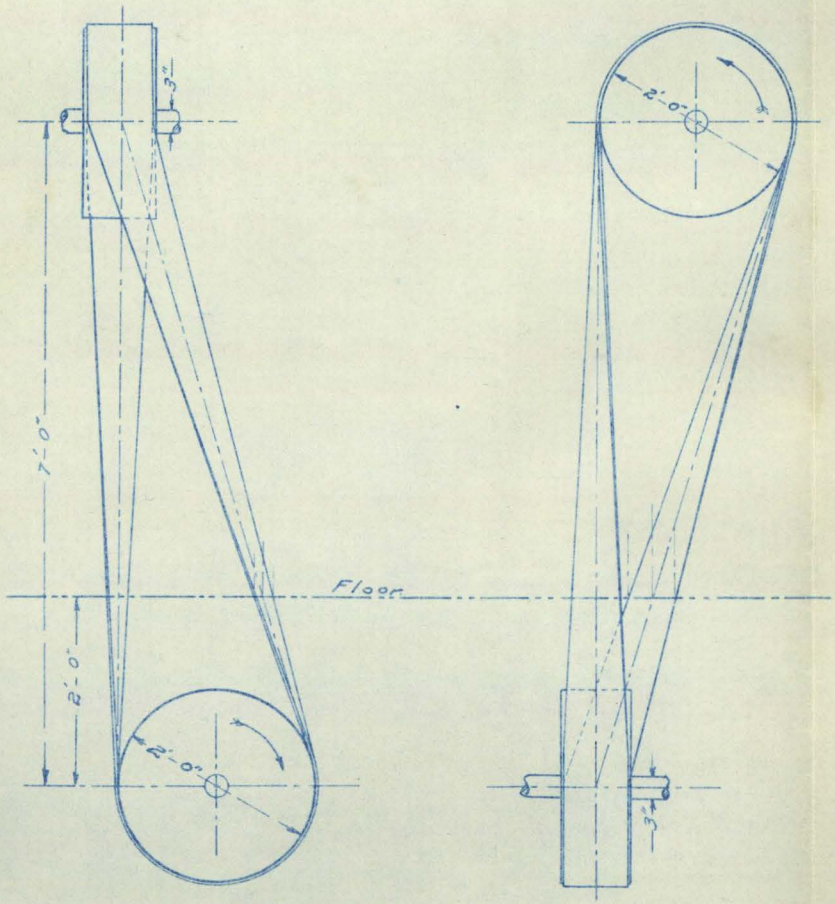
TIME _____

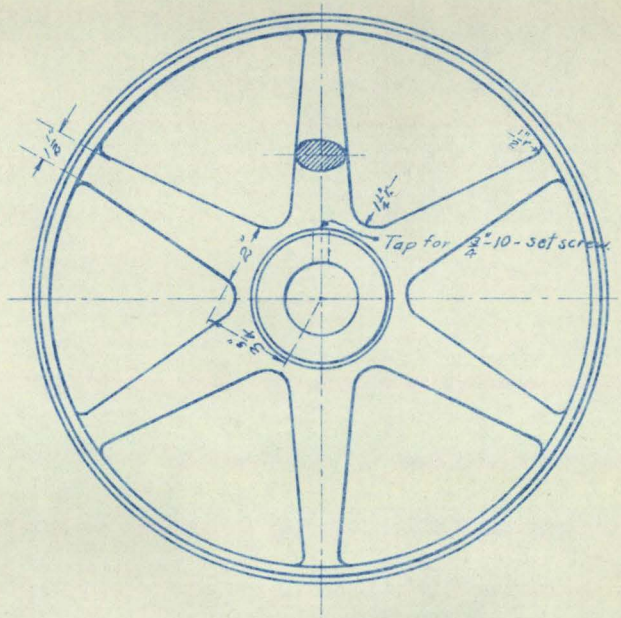
STUDENT NO. _____

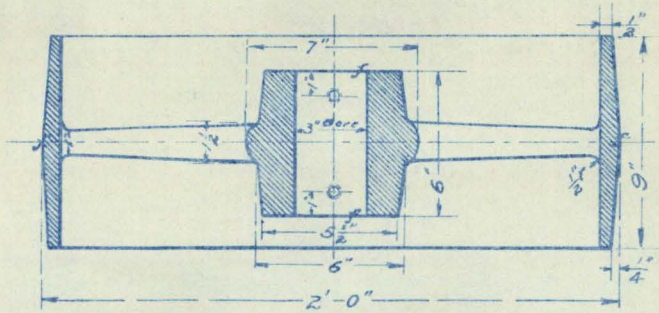


QUARTER TURN BELT LAY-OUT.

Scale - $\frac{1}{2}$" = 1ft.







f means finish.

24"x 9" PULLEY.

Cast Iron Make Two.

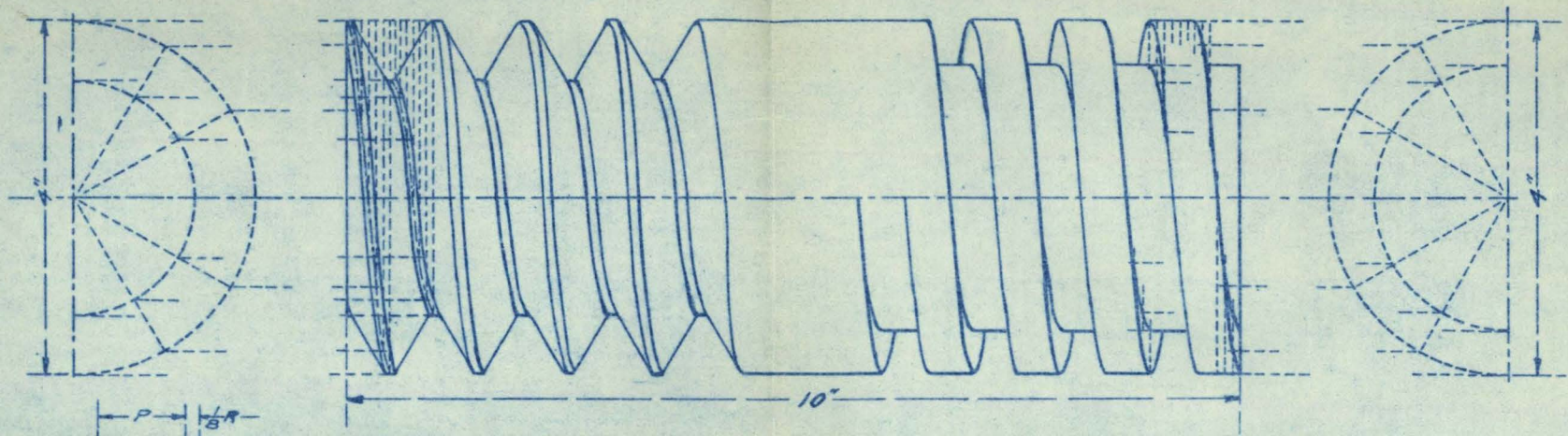
Scale - $1\frac{1}{2}$" = 1ft.

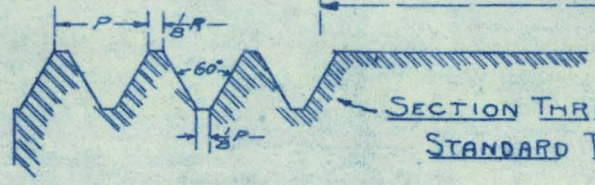
OREGON AGRICULTURAL COLLEGE.
MECHANICAL DRAWING DEPARTMENT
QUARTER-TURN BELT & PULLEY.
SCALE- $\frac{1}{2}$"-$1\frac{1}{2}$"=1ft. DATE _____
DRAWN BY _____ CHECKED BY _____
TRACED BY _____
REVISED BY _____
No. 7-ME.

TIME _____ STUDENT NO. _____

U. S. STANDARD THREAD - PITCH = 1".

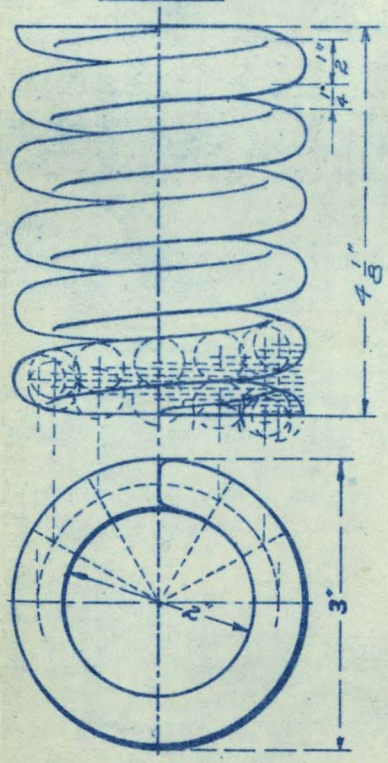
SQUARE THREAD - PITCH = 1".





SECTION THROUGH STANDARD THREAD.

HELICAL SPRING -ROUND.-



HELICAL SPRING -SQUARE-

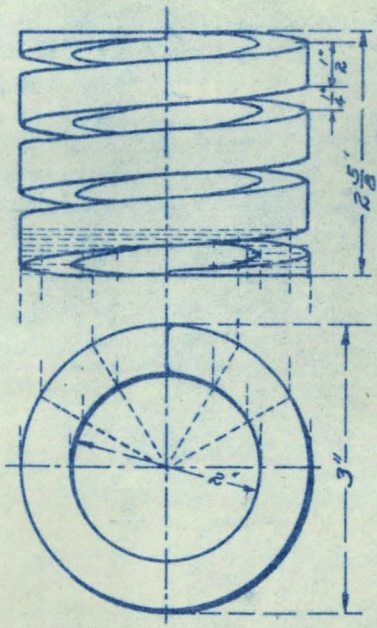
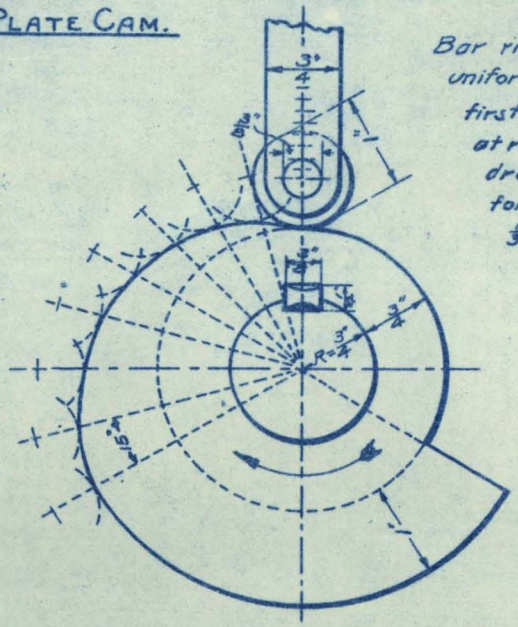


PLATE CAM.



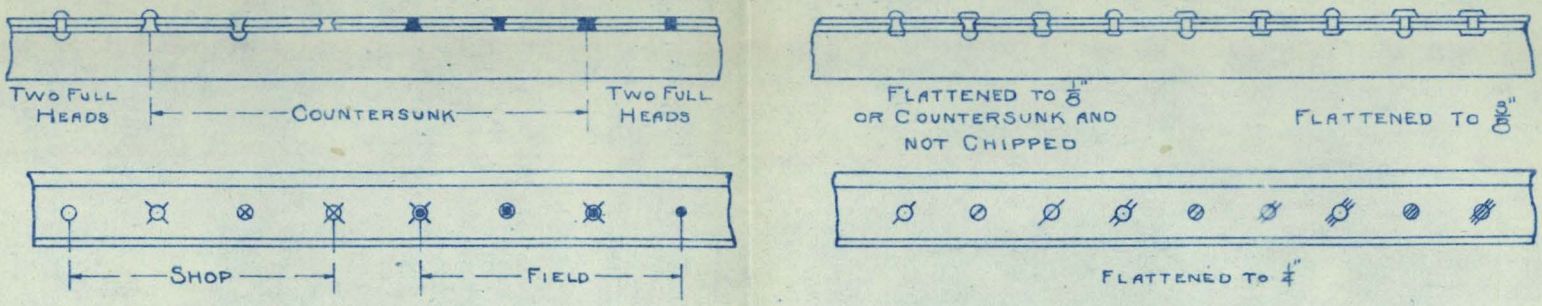
Bar rises 1" with uniform motion in first ⅓ revolution - at rest ⅓ revolution - drops 1" - at rest for the remaining ⅓ revolution.

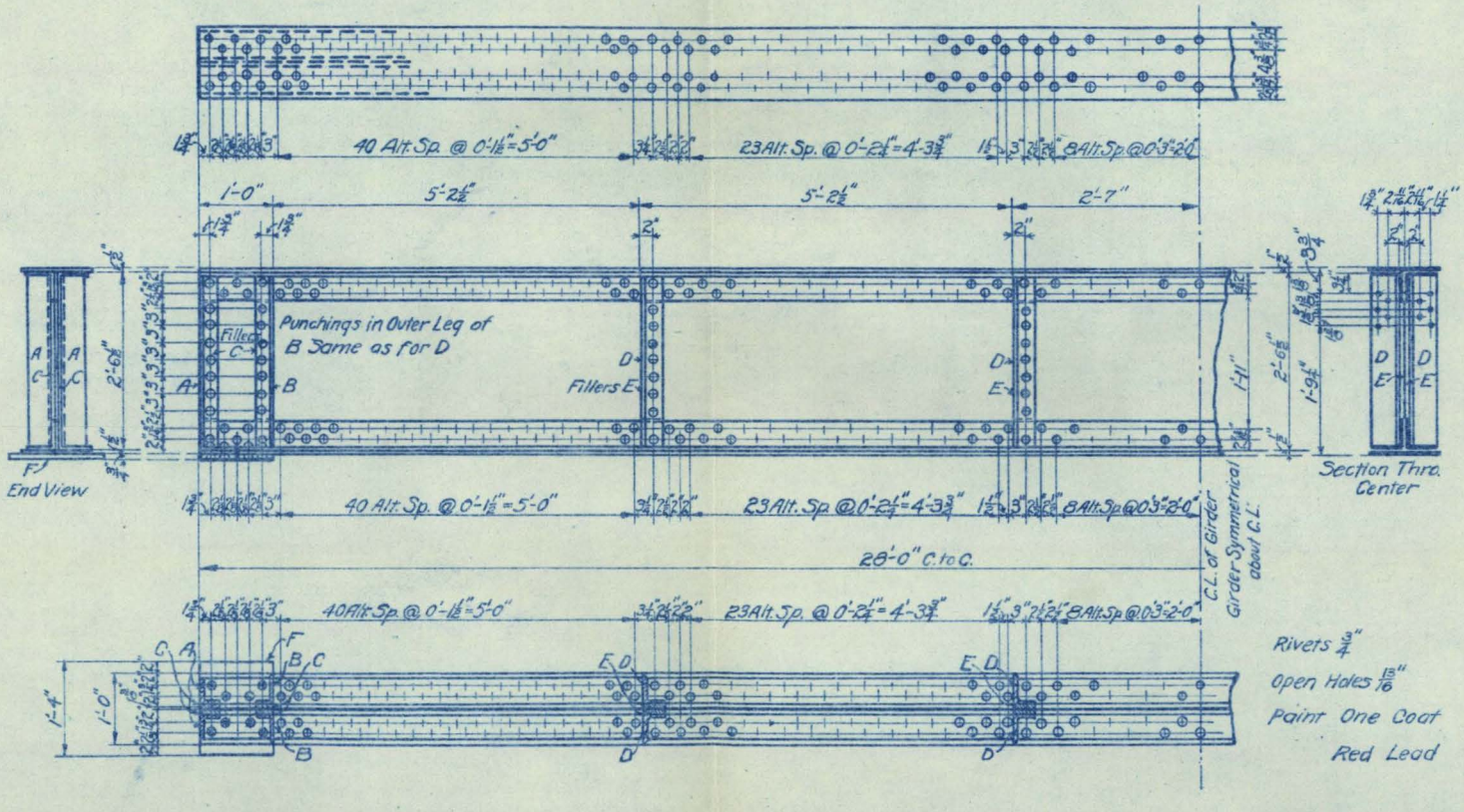
OREGON AGRICULTURAL COLLEGE.
MECHANICAL DRAWING DEPARTMENT
PLATE CAM, THREADS & SPRINGS.
SCALE - 6" = 1ft. DATE
DRAWN BY CHECKED BY
TRACED BY
REVISED BY
No.-8.

TIME

STUDENT NO.

CONVENTIONAL SIGNS FOR RIVETING





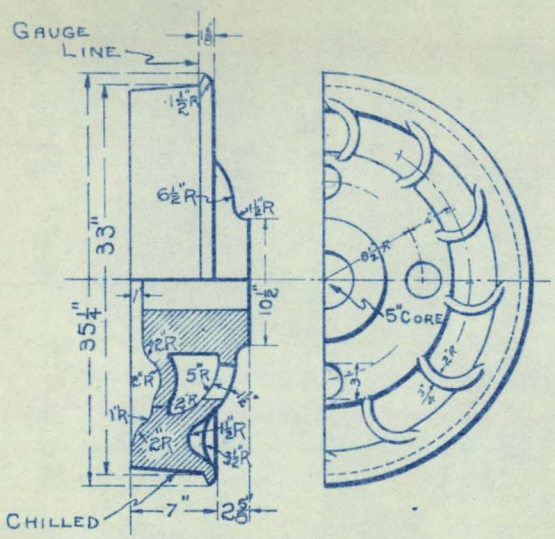
BILL OF MATERIAL FOR 3 GIRDERS. 3 GIRDERS LIKE THIS. MARK A1. A2. A3.

ITEM	No. of PCS.	KIND	SIZE	LENGTH FEET	LENGTH IN'S.	WORK
	3	Web Pls.	30" x 3/8"	28	0	
	12	Flge. Ls.	5" x 5" x 1/2"	28	0	
	6	Flge. Pls.	12" x 1/2"	28	0	
A	12	Stiff'r. Ls.	4" x 3" x 3/8"	2	5 1/2	Fitted Top & Bottom
B	12	Stiff'r. Ls.	5" x 3" x 3/8"	2	5 1/2	Fitted Top & Bottom
C	24	Fills.	3" x 1/2"	1	8	
D	24	Stiff'r. Ls.	5" x 3 1/2" x 7/16"	2	5 1/2	Fitted Top & Bottom
E	24	Fills.	3 1/2" x 1/2"	1	8	
F	6	Bed Pls.	12" x 3/4"	1	4	Countersunk

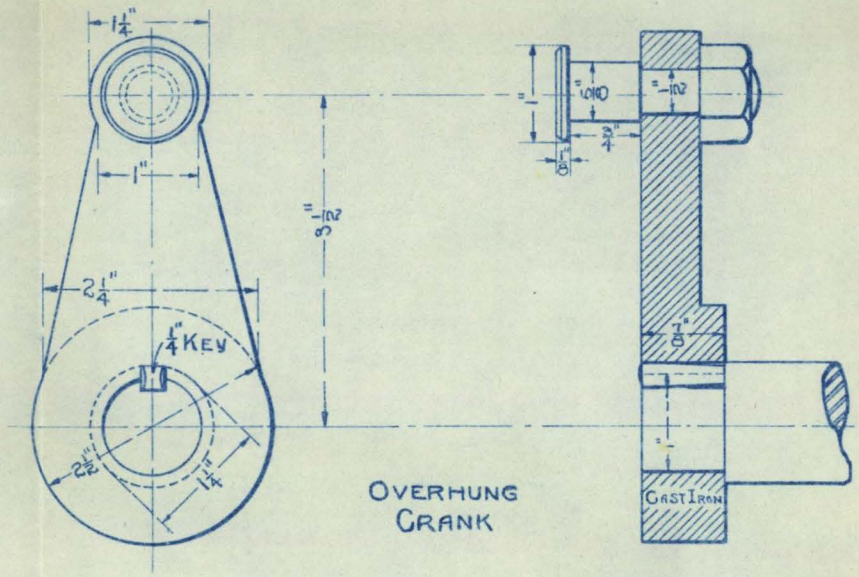
OREGON AGRICULTURAL COLLEGE
MECHANICAL DRAWING DEPARTMENT
STRUCTURAL STEEL EXERCISE
SCALE = 3/8" = 1 ft. DATE
DRAWN BY — CHECKED BY
TRACED BY
REVISED BY
No. 9C

TIME =

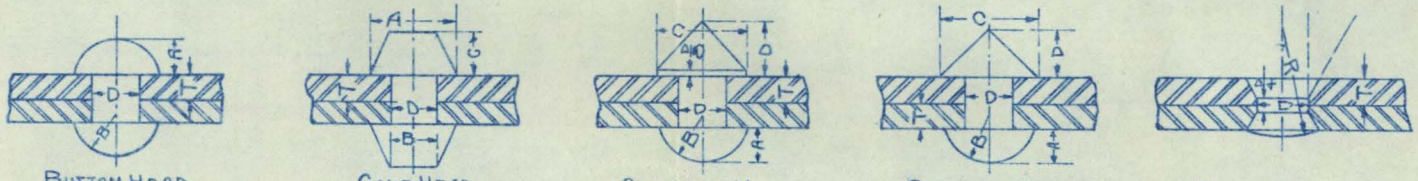
STUDENT NO. =



33" CAR WHEEL
CAST IRON MAKE 8



OVERHUNG CRANK



BUTTON HEAD
$A=\frac{3}{4}D$, $B=\frac{7}{8}D$

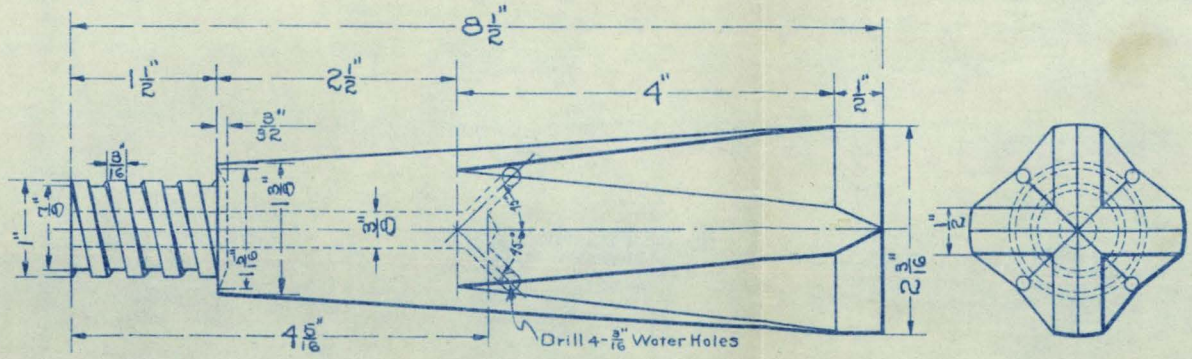
CONE HEAD
$B=D$, $A=1\frac{3}{4}D$, $C=\frac{3}{4}D$.

STEEPLE HEAD
$A=\frac{3}{4}D$, $B=\frac{7}{8}D$, $C=1\frac{3}{4}D$.

STEEPLE HEAD
$C=2D$, $A=\frac{3}{4}D$, $B=\frac{7}{8}D$.

COUNTERSUNK
$R=2\frac{1}{2}D$.

NOTE—ON FULL SIZE PLATE
MAKE $T=\frac{1}{4}$", $D=\frac{1}{2}$"

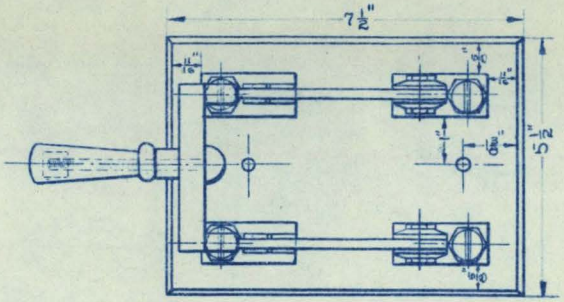


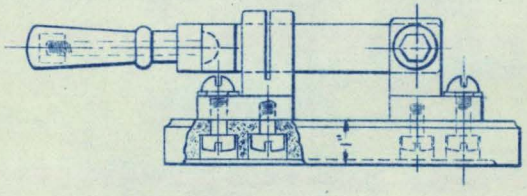
CROSS CHOPPING BIT
MACH. STEEL MAKE 2.

OREGON AGRICULTURAL COLLEGE
MECHANICAL DRAWING DEPARTMENT
ENGINEERING DETAILS
SCALE 1½"-6"=1ft. DATE
DRAWN BY CHECKED BY
TRACED BY
REVISED BY
No. 9D

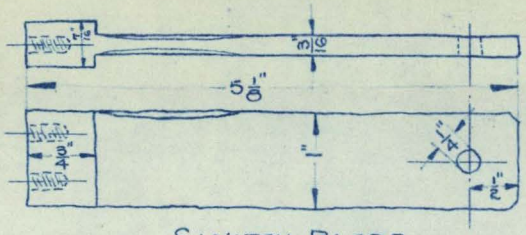
TIME =

STUDENT NO.=

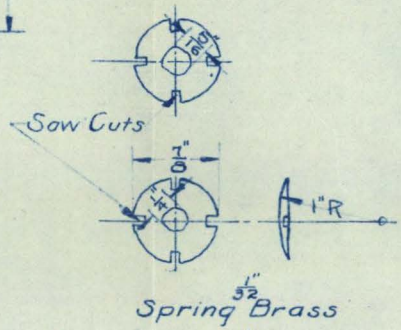




ASSEMBLY OF SWITCH
PORCELAIN BASE

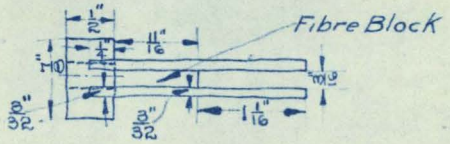


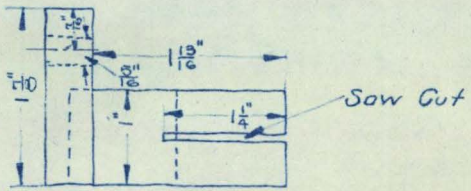
SWITCH BLADE
COPPER 2 REQ'D



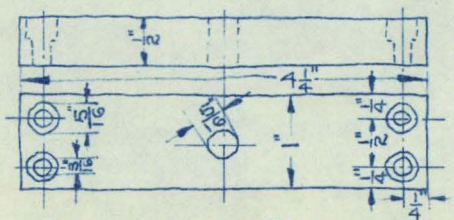
Spring Brass

SPRING WASHERS
SPRING BRASS 2 REQ'D

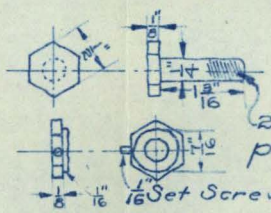




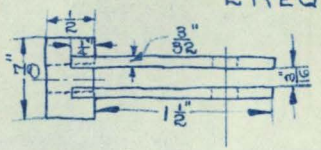
SPRING TERMINAL CLIP
COPPER 2 REQ'D

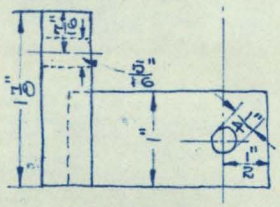


INSULATING BRIDGE
BLACK FIBRE 1 REQ'D

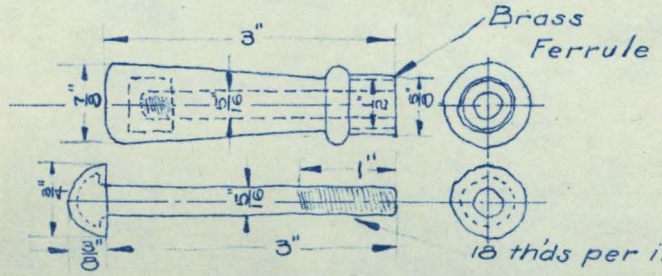


PIVOT BOLT
BRASS 2 REQ'D

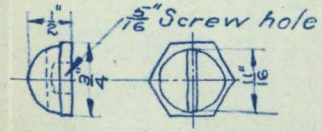




PIVOT TERMINAL CLIP
COPPER 2 REQ'D



SWITCH HANDLE
HARD RUBBER 1 REQ'D



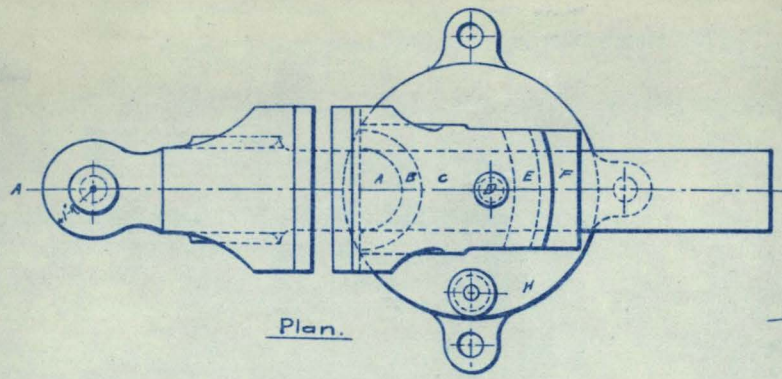
TERMINAL NUTS
BRASS 4 REQ'D

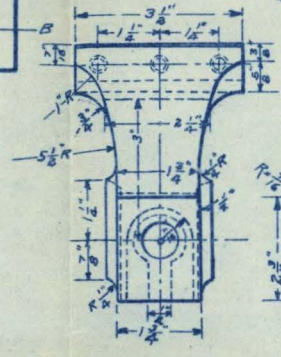
Note—Make pencil Drawing, Tracing, and Blue Print.

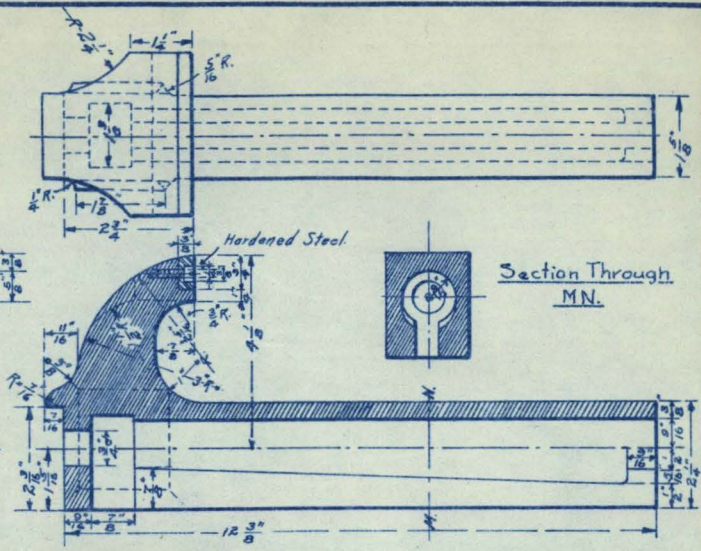
OREGON AGRICULTURAL COLLEGE
MECHANICAL DRAWING DEPARTMENT
200 A-250V-D.P.-S.T.- SWITCH.
SCALE 3"-6"=1 ft. DATE
DRAWN BY CHECKED BY
TRACED BY
REVISED BY
No. 9E

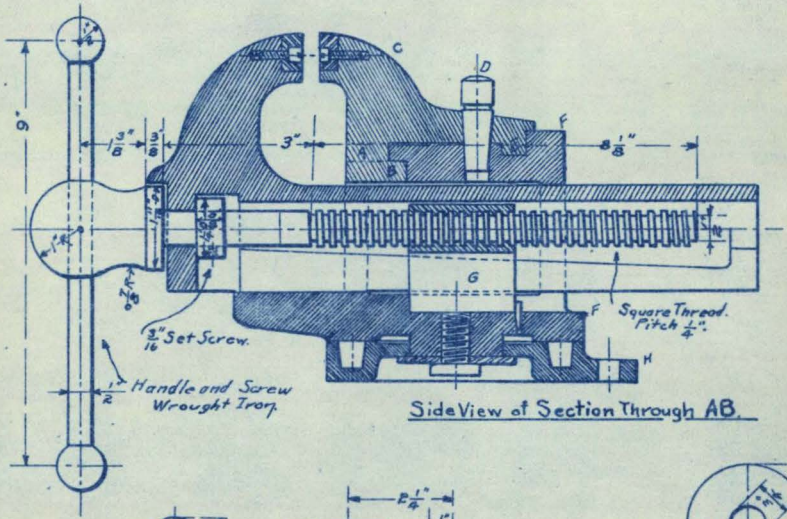
TIME

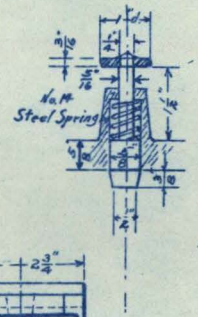
STUDENT NO.

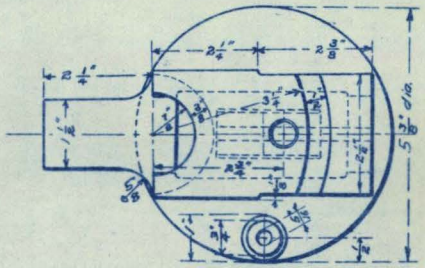


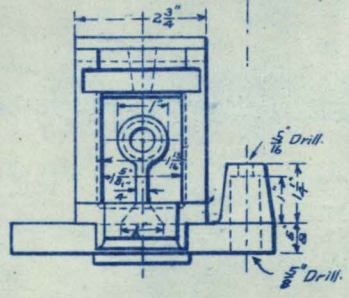


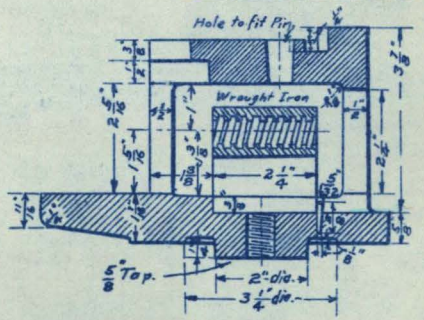


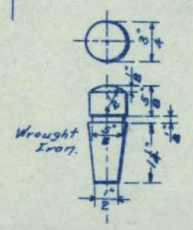


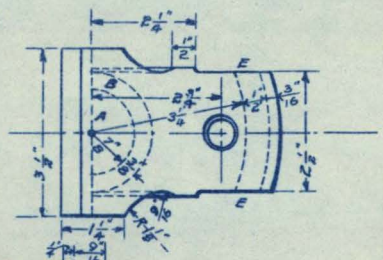


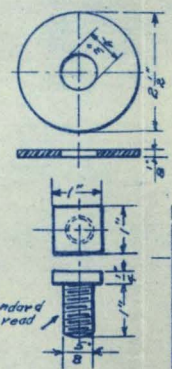


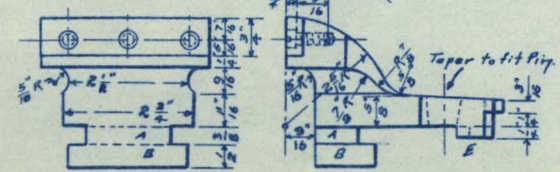


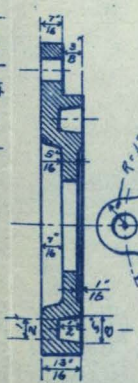


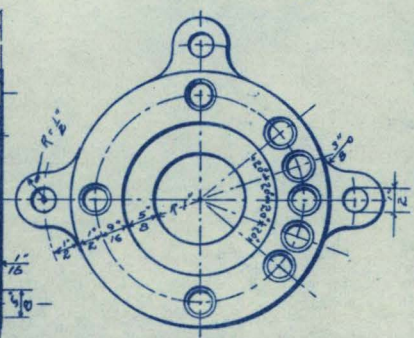












OREGON AGRICULTURAL COLLEGE
MECHANICAL DRAWING DEPARTMENT
BENCH VISE AND DETAILS.
SCALE - 3" = 1ft. DATE
DRAWN BY CHECKED BY
TRACED BY
REVISED BY
No.-9-M.

TIME

STUDENT NO.

COURSE
IN
MECHANICAL DRAWING
OREGON AGRICULTURAL COLLEGE

~ ROMAN ~

ABCDEFGHIJKLMNOPQRSTUVWXYZ

1234567890

abcdefghijklmnopqrstuvwxyz

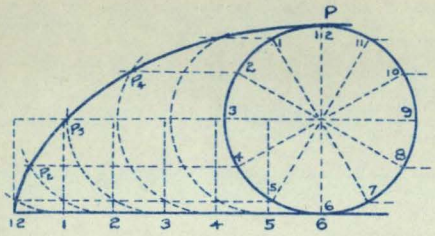
- GOTHIC -

ABCDEFGHIJKLMNOPQRSTUVWXYZ

1234567890

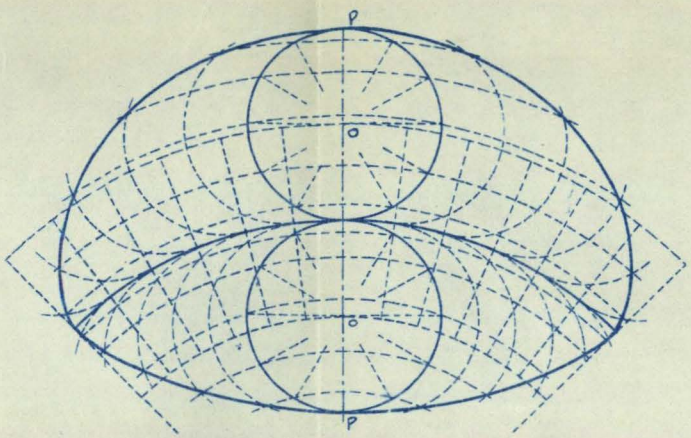
abcdefghijklmnopqrstuvwxyz

DATE=_____ TIME=_____ NAME=_____ STUDENT No.=_____



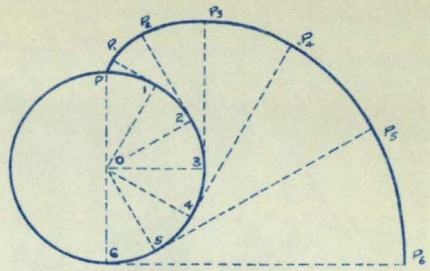
CYCLOID

Generating Circle d = 2".



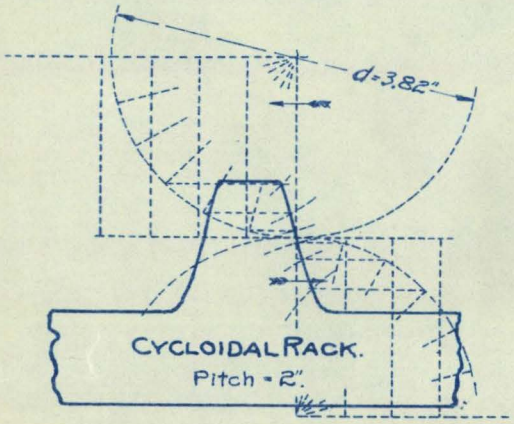
EPICYCLOID & HYPOCYCLOID

Gen. Circles: d = 2" Arc: r = 4".



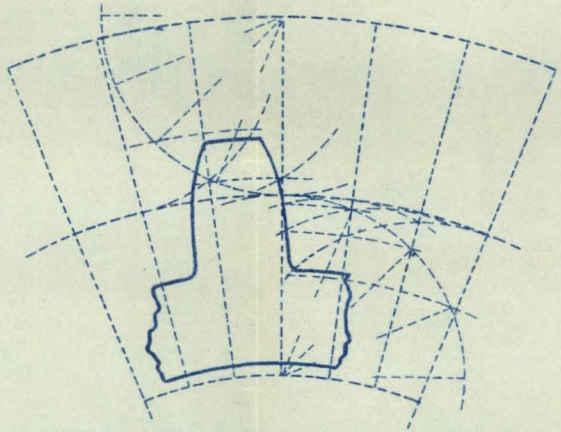
INVOLUTE

Base Circle: d = 2"



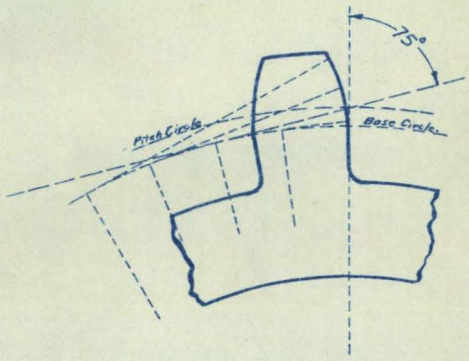
CYCLOIDAL RACK.

Pitch = 2".



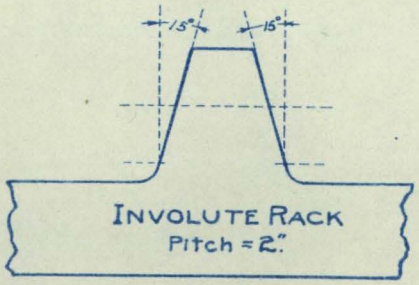
SINGLE CYCLOIDAL TOOTH.

For Spur Gear - 18 Teeth - Pitch - 2".



SINGLE INVOLUTE TOOTH.

For 18 Tooth - p = 2" - Spur Gear.



INVOLUTE RACK

Pitch = 2".

OREGON AGRICULTURAL COLLEGE

MECHANICAL DRAWING DEPARTMENT

GEAR TEETH CURVES

Scale - 6" = 1ft. Date

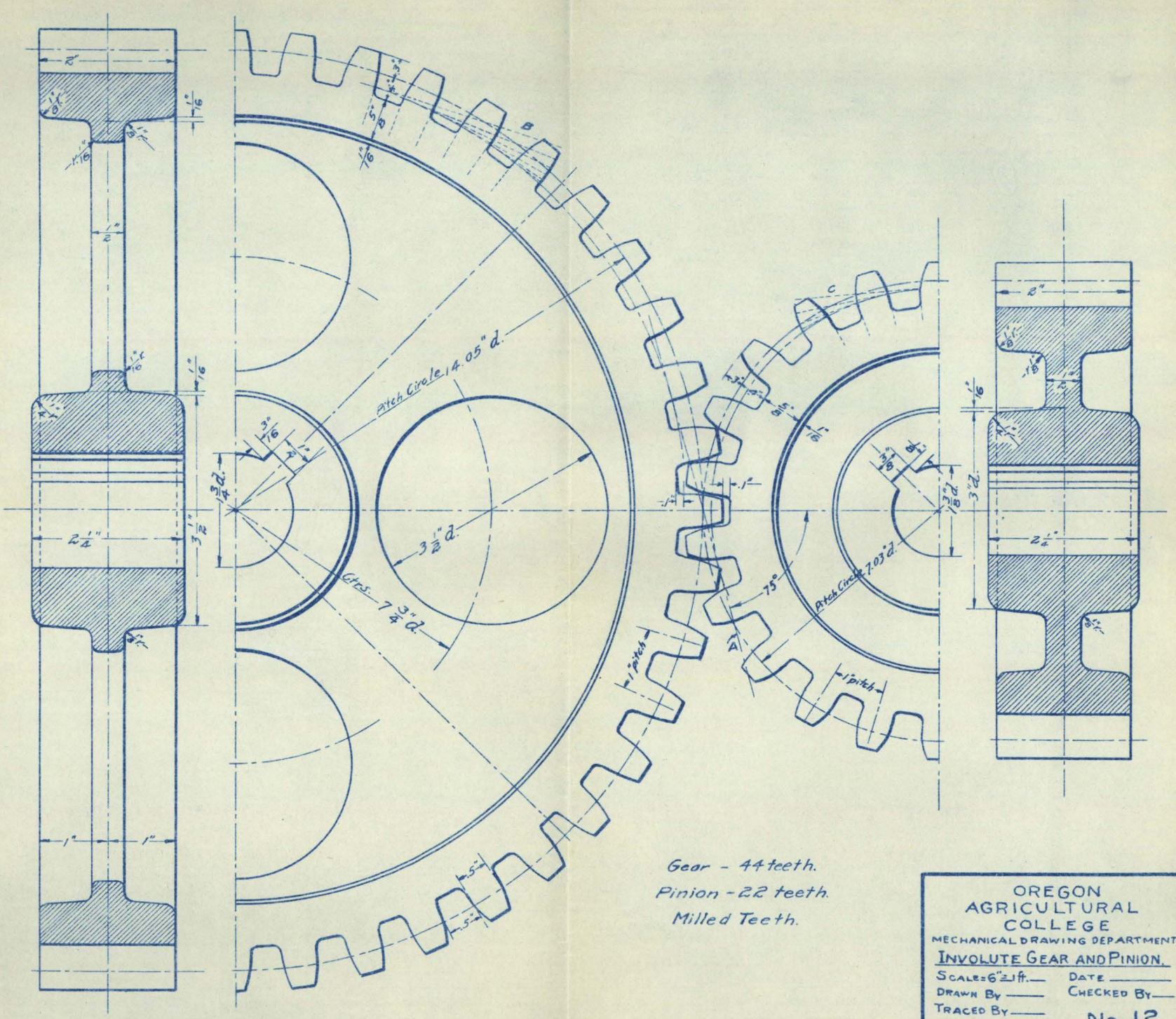
Drawn By Checked By

Traced By

Revised By No. 11

Time

Student No.

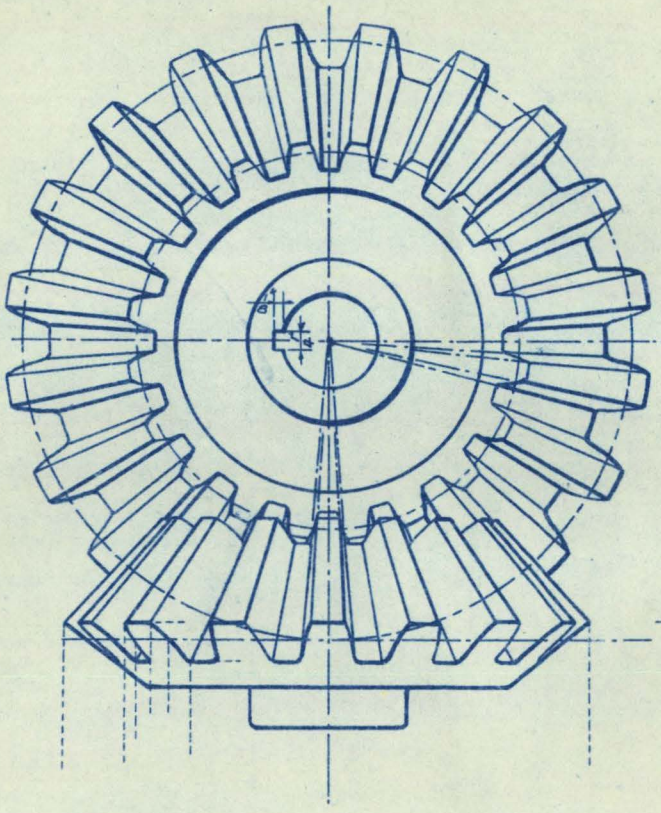


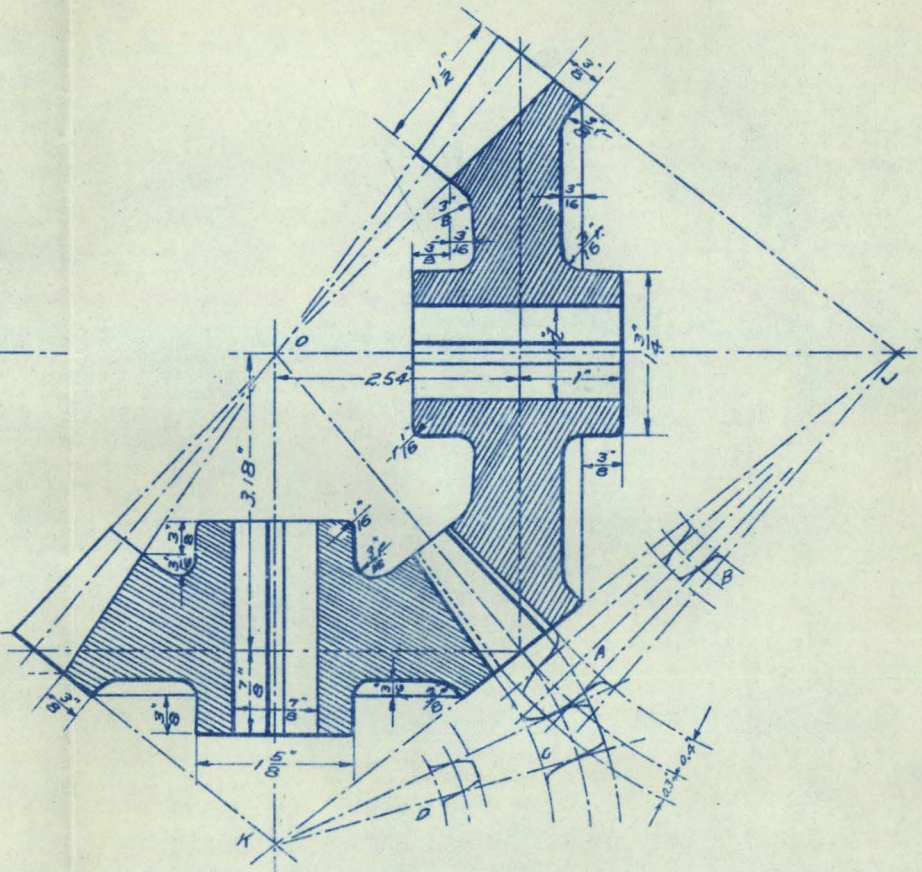
Gear - 44 teeth.
Pinion - 22 teeth.
Milled Teeth.

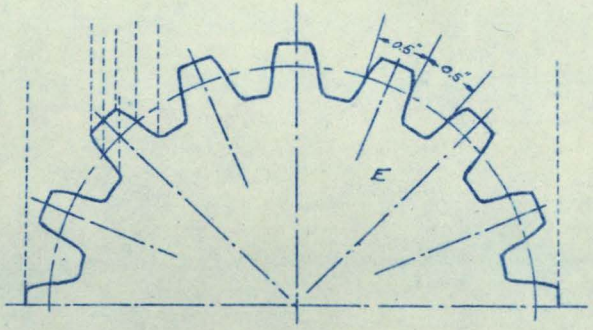
OREGON AGRICULTURAL COLLEGE
MECHANICAL DRAWING DEPARTMENT
INVOLUTE GEAR AND PINION.
SCALE=6"=1ft. DATE
DRAWN BY CHECKED BY
TRACED BY
REVISED BY
No. 12

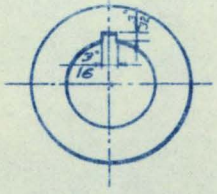
TIME=

STUDENT NO.









Gears to be cut from Cast Iron Blanks - Large wheel - 20 teeth - Pinion - 16 teeth. — Pitch = 1."

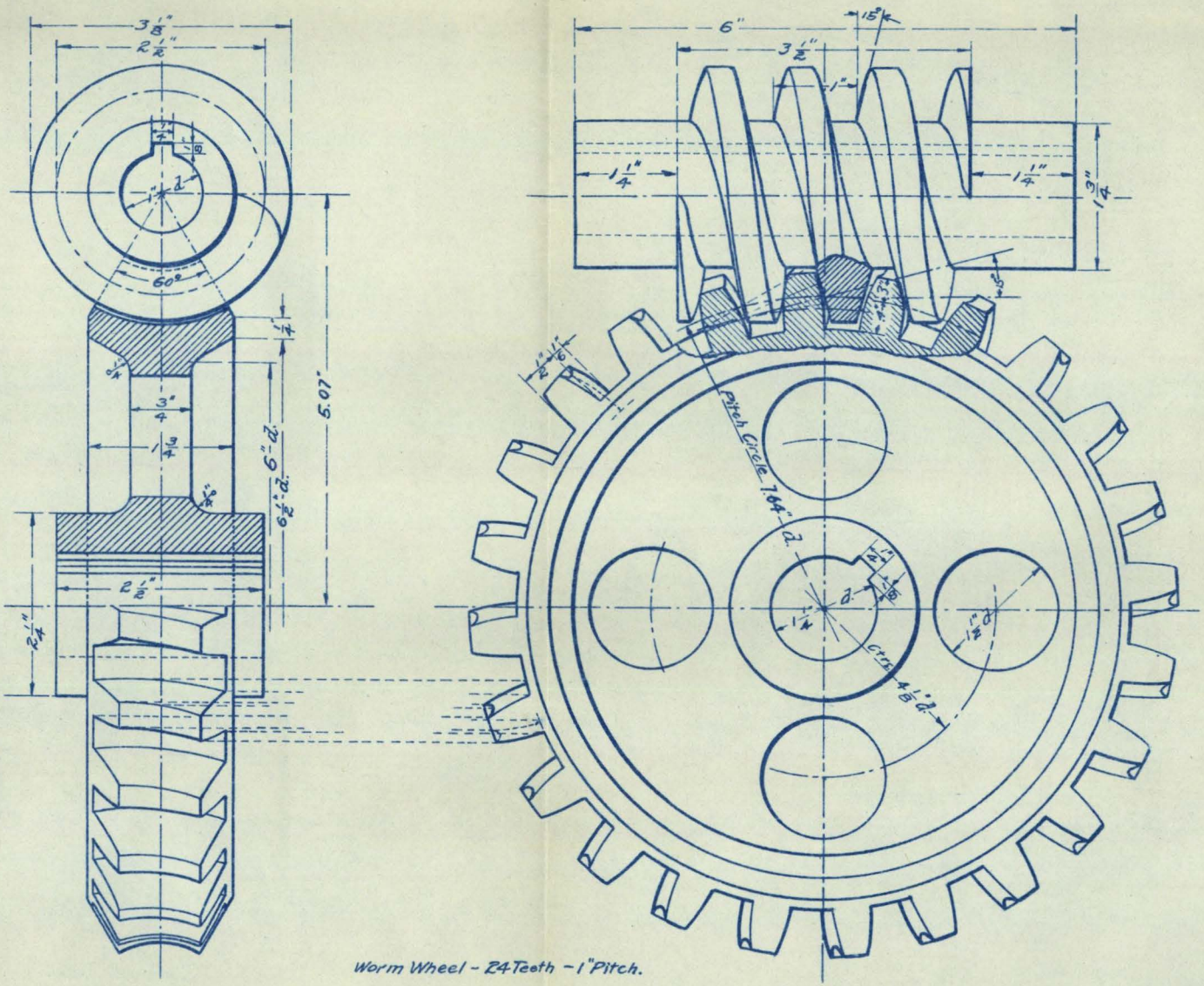
OREGON AGRICULTURAL COLLEGE
MECHANICAL DRAWING DEPARTMENT
CYCLOIDAL BEVEL GEARS.

SCALE - 6" = 1 ft. ___ DATE ___
DRAWN BY ___ CHECKED BY ___
TRACED BY ___
REVISED BY ___

No. 13.

TIME: ___

STUDENT No. ___



Worm Wheel - 24 Teeth - 1" Pitch.

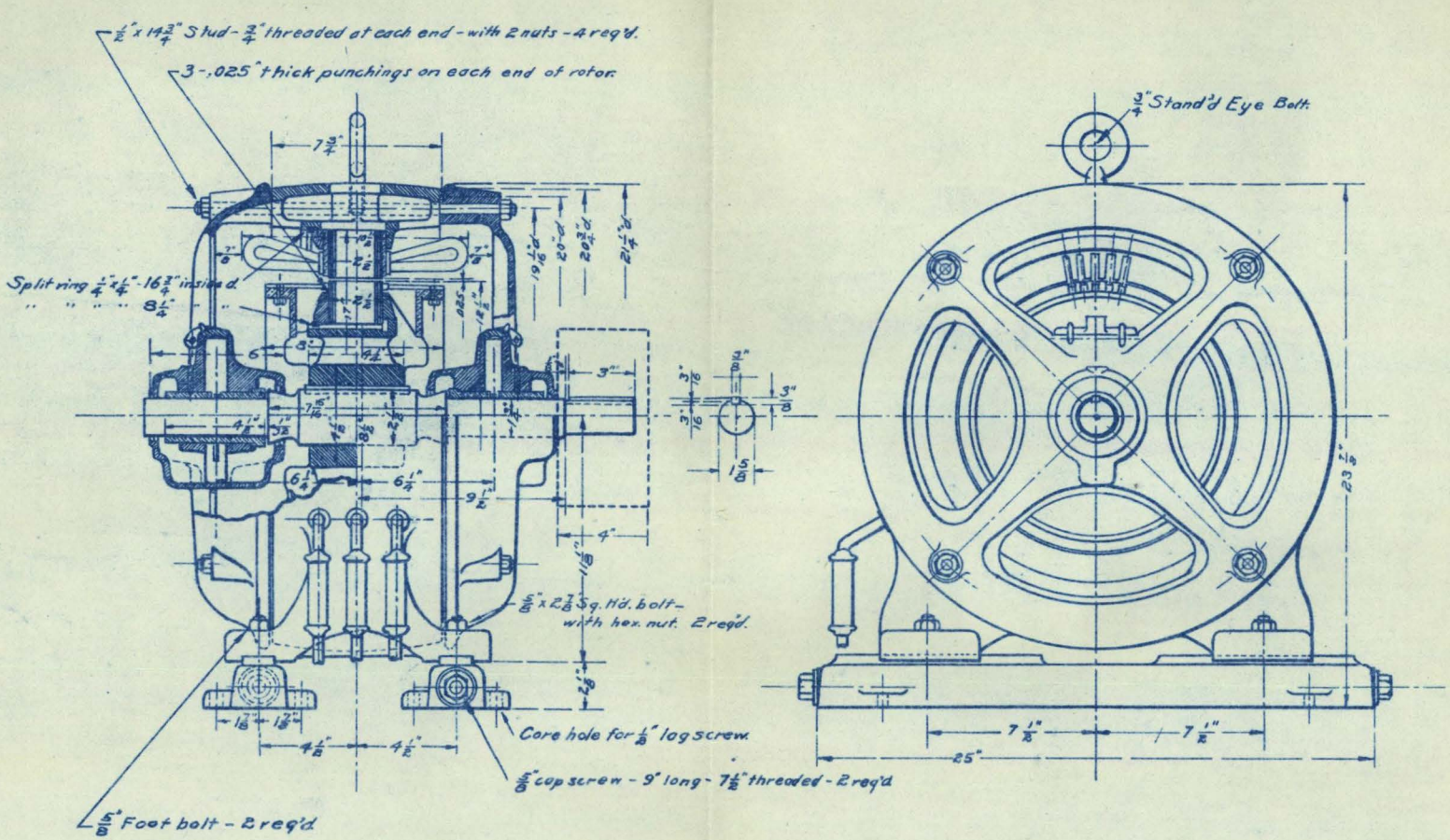
OREGON AGRICULTURAL COLLEGE
MECHANICAL DRAWING DEPARTMENT

INVOLUTE WORM GEAR

SCALE = 6" = 1ft. DATE _____
DRAWN BY _____ CHECKED BY _____
TRACED BY _____
REVISED BY _____ No. 14.

TIME: _____

STUDENT NO.: _____



DRAWING LIST	
No.	TITLE
A	ASSEMBLY.
B	STATOR YOKE - ROTOR.
C+D	MISC. DETAILS.

ASSEMBLY - INDUCTION MOTOR

5 HP 440 VOLTS 3PH 60 CYCLES 1200 RPM

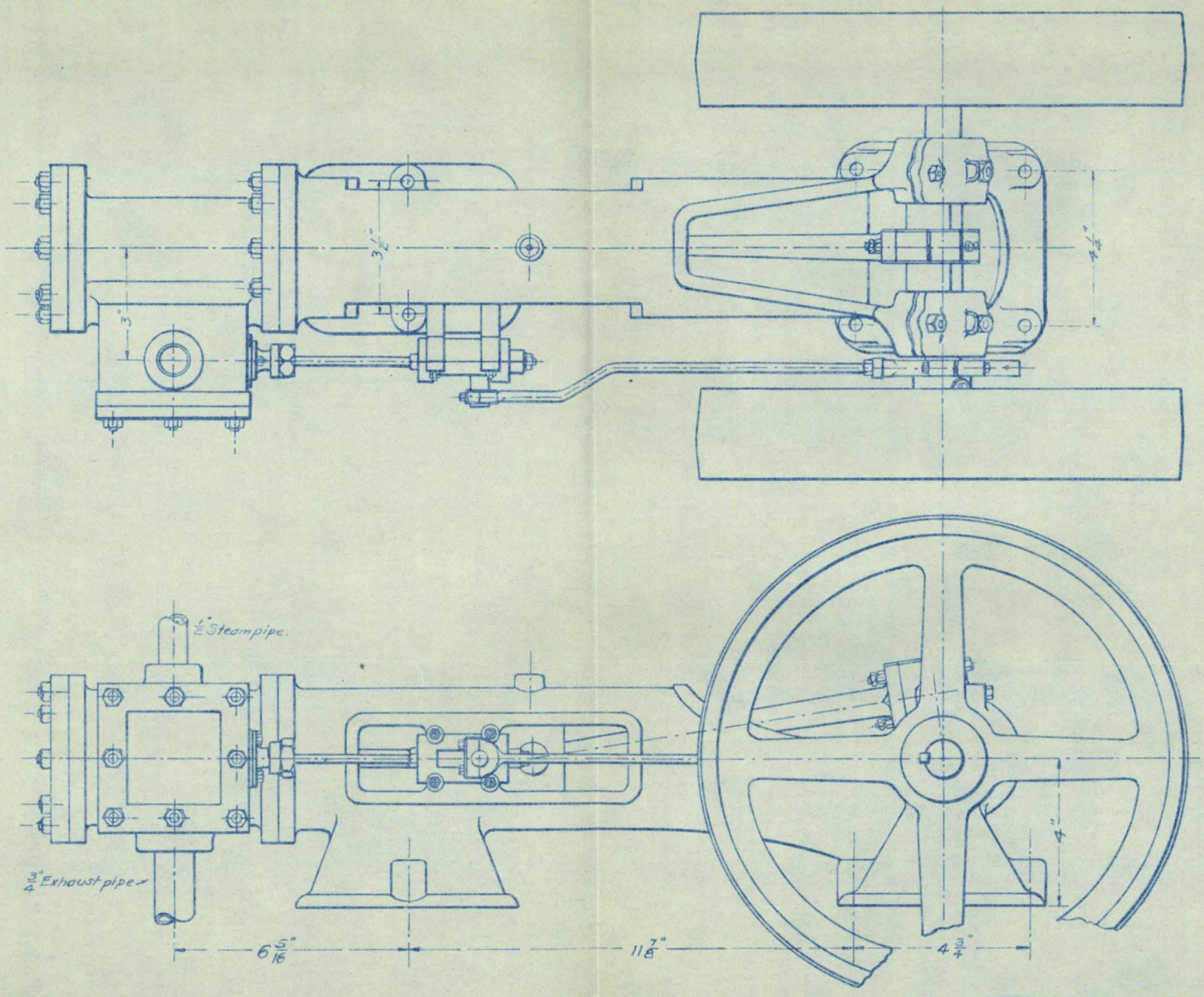
THE OREGON AGRICULTURAL COLLEGE

CORVALLIS OREGON

SCALE - 1 1/2" = 1 FT. DATE - _____

(A)

TIME = _____ CHECKED BY = _____ NAME = _____ STUDENT NO. = _____



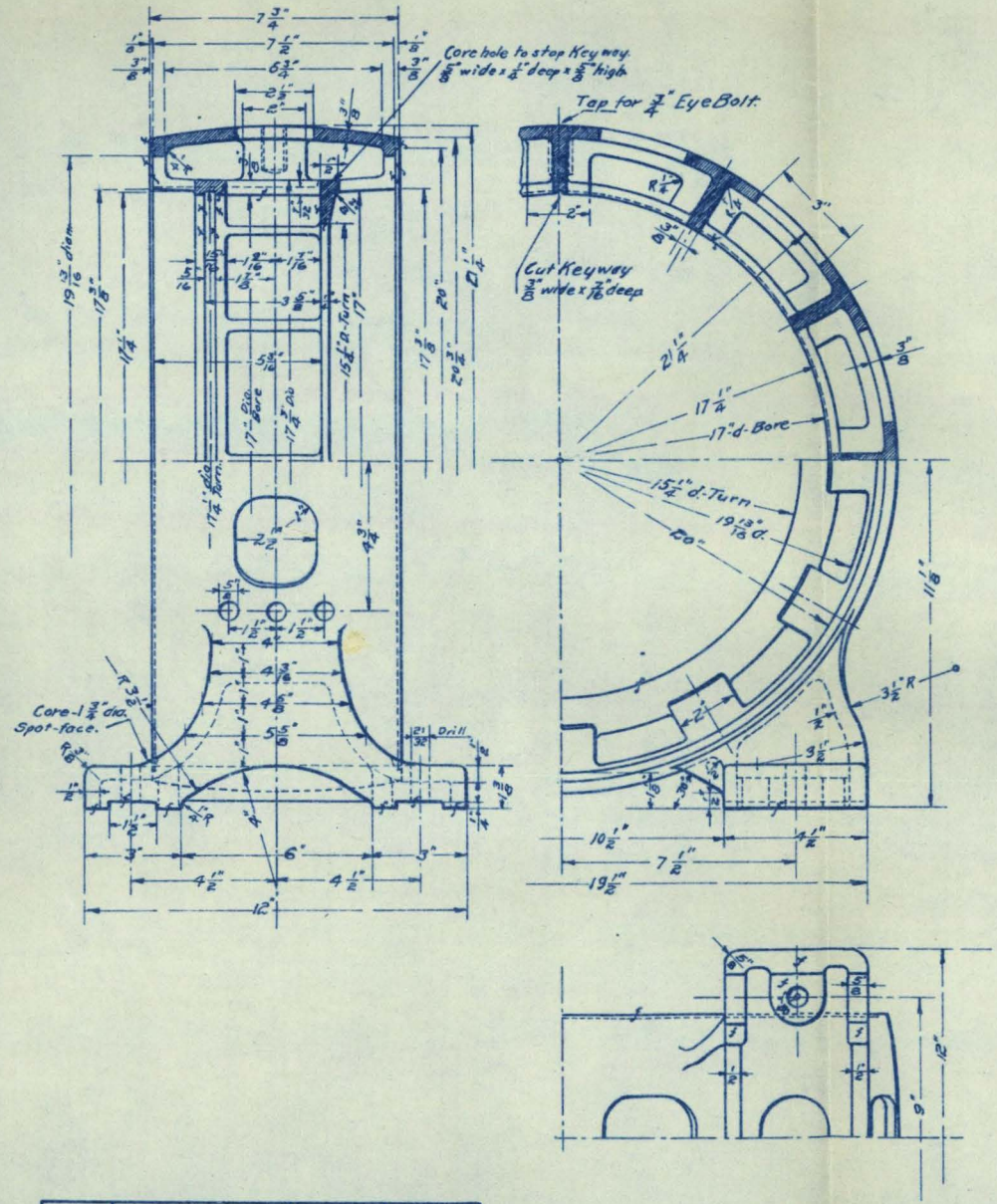
THE
OREGON AGRICULTURAL COLLEGE.

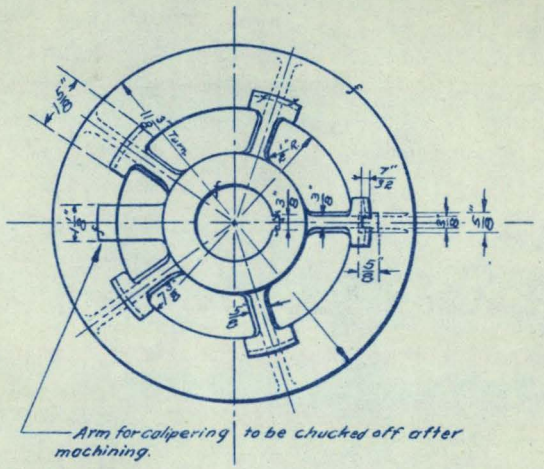
GENERAL DRAWING
2 H.P SIMPLE SLIDE VALVE ENGINE

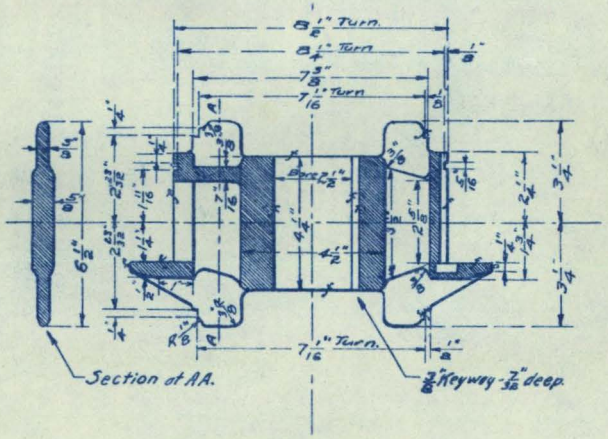
DRAWN BY——— DATE ———
TRACED BY ———
CHECKED BY———

TIME:———

STUDENT NO.———







MAT.	NAME	PATT.	EST. WT.
C. I.	STATOR YOKE.	E 2574	135#
C. I.	ROTOR.	E 1453	31#

STATOR YOKE - ROTOR

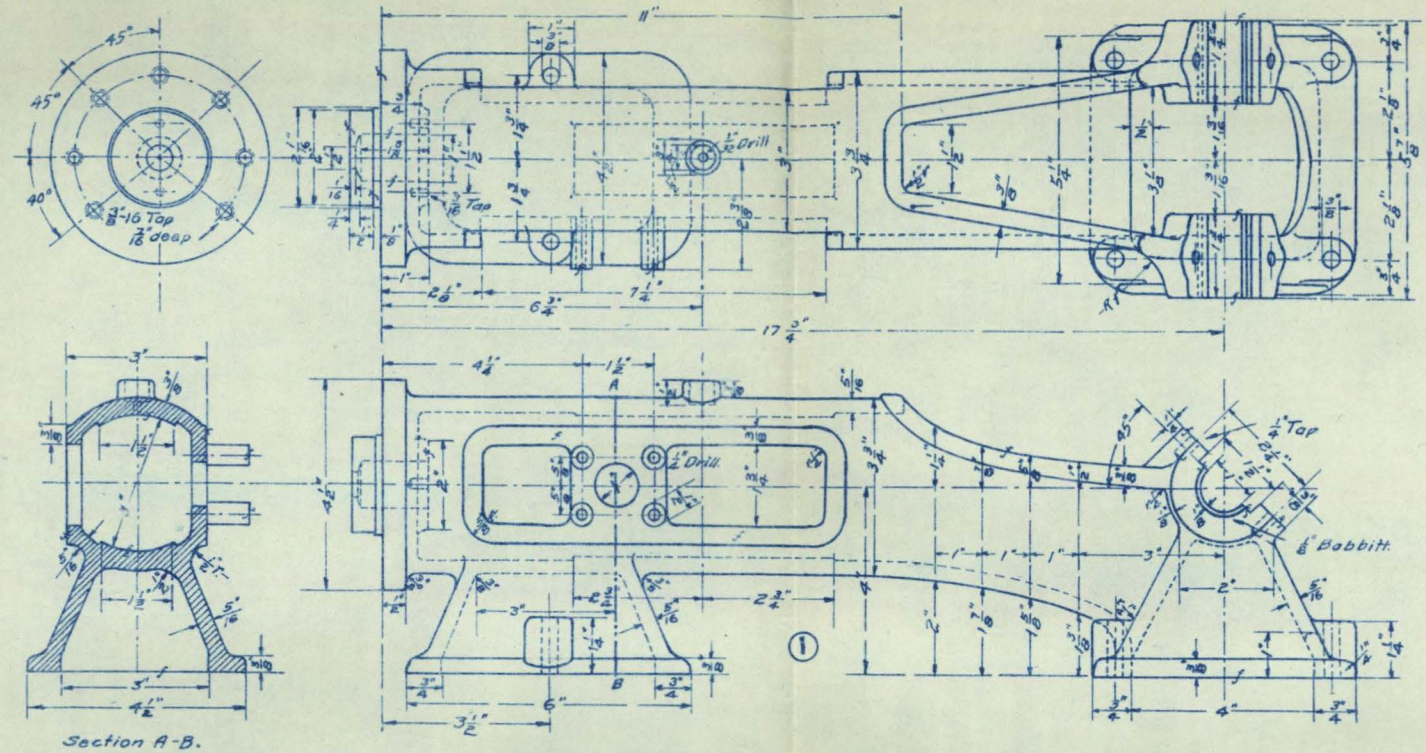
5HP 440V 3PH 60~ 1200RPM INDUCTION MOTOR

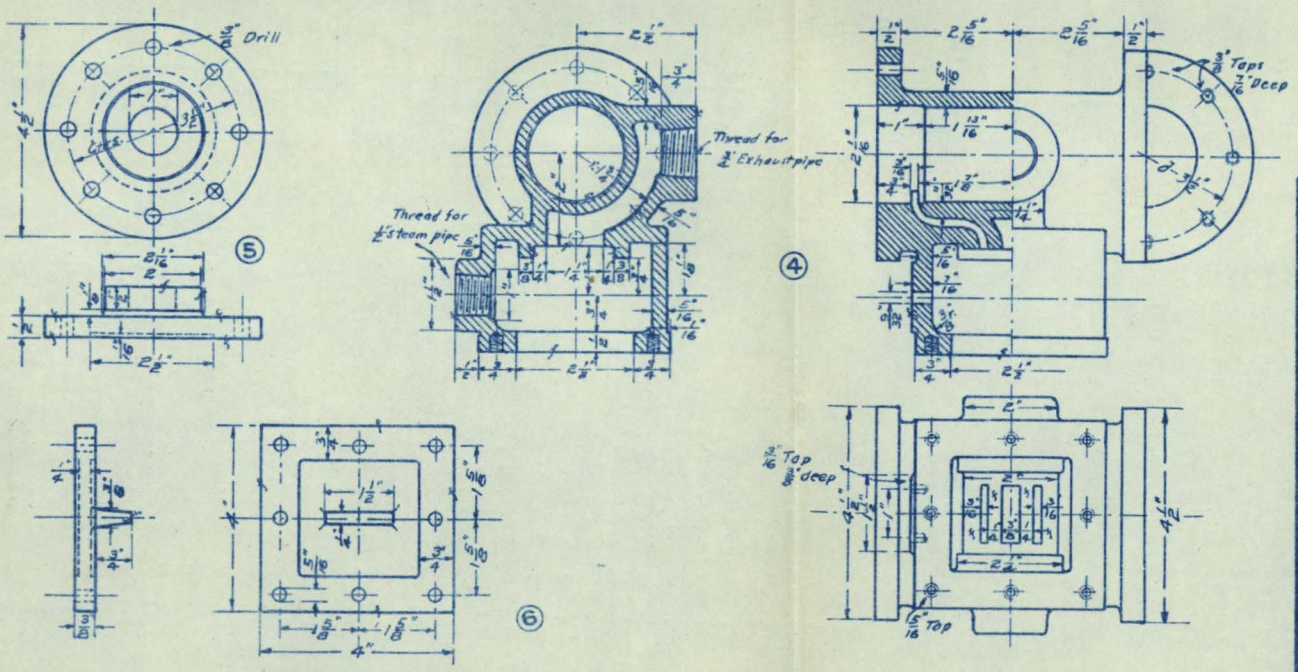
THE OREGON AGRICULTURAL COLLEGE
CORVALLIS OREGON

SCALE - 2" = 1 FT. DATE - _____

B

TIME - _____ CHECKED BY - _____ NAME _____ STUDENT NO. - _____





BILL OF MATERIAL

1	Engine frame	1	C.I.	Patt. A.
2	Bearing cap	2	C.I.	Patt. B.
1	Main gland	3	Brass	Patt. C.
1	Cylinder	4	C.I.	Patt. D.
1	Cylinder head	5	C.I.	Patt. E.
1	Steam chest cover	6	C.I.	Patt. F.
2	3/16" Stud-1 1/2" long-thread 3/16" & 5/16"-Nut & Ck. nut.	7	M.S.	
7	5/16" Stud 1 1/2" long-thd 1/2" & 1/2"-Nut.	8	M.S.	
4	1/4" Stud-1 1/8" long-thd 1/2" & 1/2"-Nut.	9	M.S.	
4	1/4" Hex. Hd. bolts 2 1/2" long-Nut.	10	M.S.	
8	5/16" Stud-1 1/8" long-thd 3/8" & 3/8" Nut.	11	M.S.	
8	3/8" Stud-1 1/2" long-thd 1/2" & 1/2" Nut.	12	M.S.	

THE
OREGON AGRICULTURAL COLLEGE

DETAILS OF BODY
2 H.P. SIMPLE SLIDE VALVE ENGINE.

DRAWN BY____ DATE ____

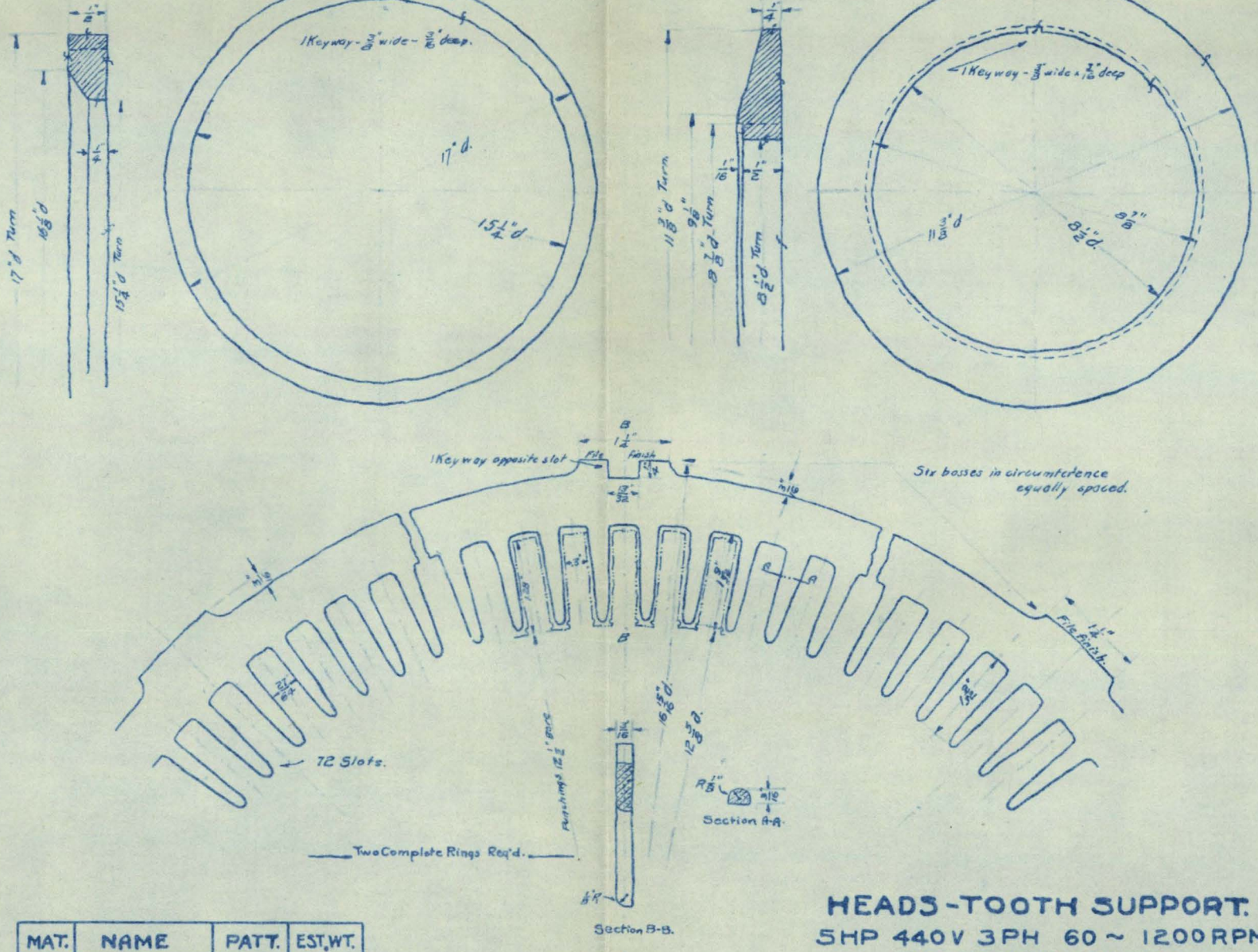
TRACED BY____

CHECKED BY____

B

TIME=_____

STUDENT NO.=_____



MAT.	NAME	PATT.	EST. WT.
C.I.	STATOR HEAD	E.1086	5.6*
C.I.	ROTOR HEAD	E.1087	3.5*
C.B.	TOOTH SUPPORT	E.6019	3.2*

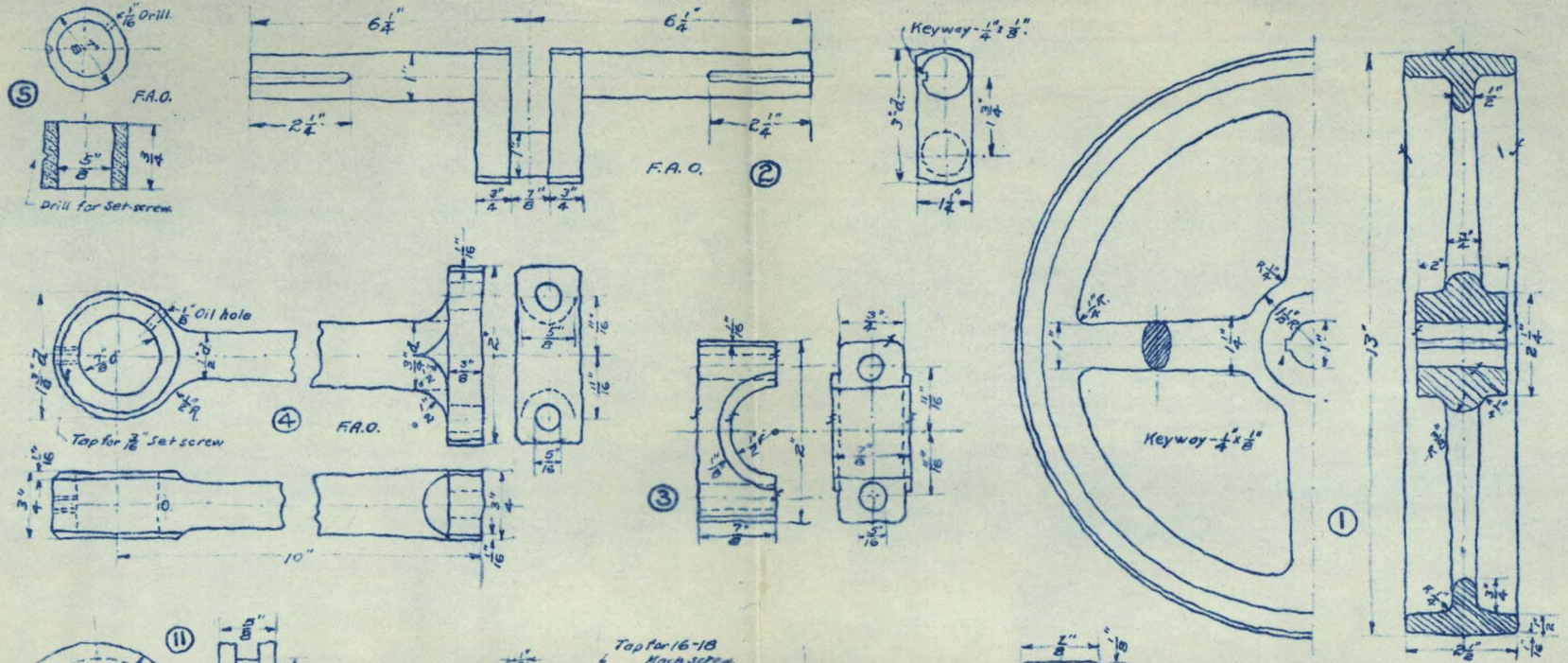
HEADS - TOOTH SUPPORT.

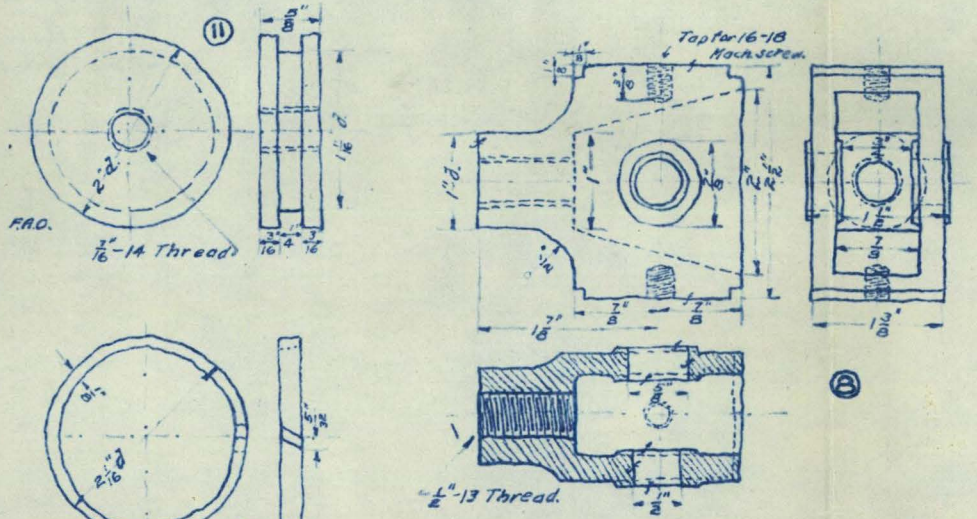
5HP 440V 3PH 60 ~ 1200RPM INDUCTION MOTOR

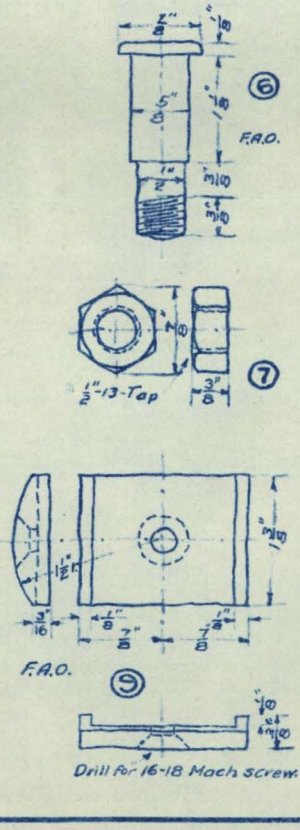
THE OREGON AGRICULTURAL COLLEGE
CORVALLIS OREGON

SCALE = 2"-3"-6" = 1' DATE = _____

TIME = _____ CHECKED BY = _____ NAME = _____ STUDENT NO. = _____







BILL OF MATERIAL				
2	Fly wheel	1	C.I.	Patt. G.
1	Crank shaft.	2	F.S.	
2	Connecting rod bearing	3	Brass	Patt. H.
1	Connecting rod.	4	M.S.	
1	Connecting rod bearing	5	Brass	Patt. I.
1	Cross-head pin.	6	M.S.	
1	Nut for 6	7	M.S.	
1	Cross head.	8	C.I.	Patt. J.
2	Bearing strips	9	Brass	Patt. K.
1	Piston rod	10	M.S.	
1	Piston	11	C.I.	Patt. L.
1	Piston ring	12	C.I.	Patt. M.
2	Keys 2 1/2" long - 1/4" x 1/4"	13	M.S.	
1	3/16" set screw - 5/16" long.	14	M.S.	
2	5/16"-18 bolts - 2 5/8" long with nut & ck. nut.	15	M.S.	
2	16-18 - F.H. Mach. screw	16	M.S.	
1	7/16" Hex. nut	17	M.S.	
1	1/2" Hex. check nut	18	M.S.	
1	1/8" Split cotter pin.	19	M.S.	

THE
OREGON AGRICULTURAL COLLEGE.

MAIN MOVING PARTS

E.H.P. SIMPLE SLIDE VALVE ENGINE.

DRAWN BY____ DATE ____

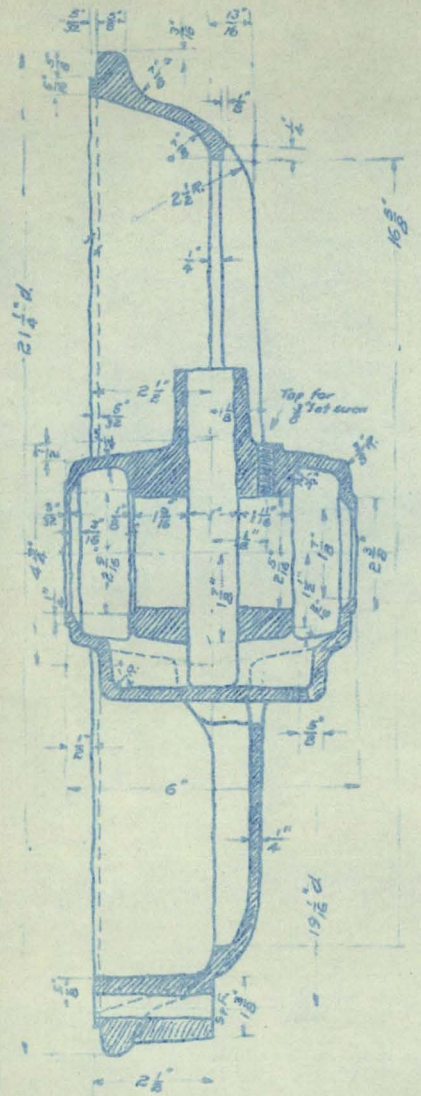
TRACED BY____

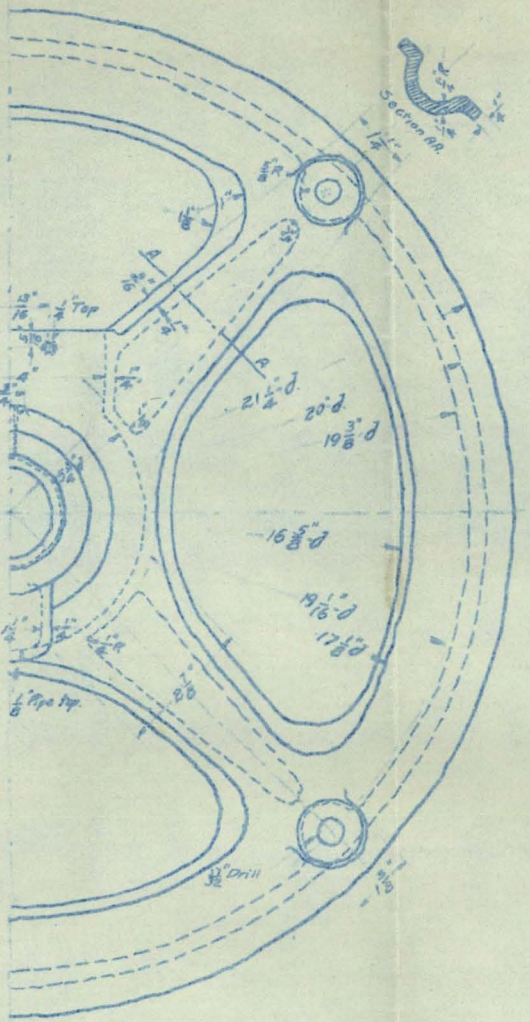
CHECKED BY____

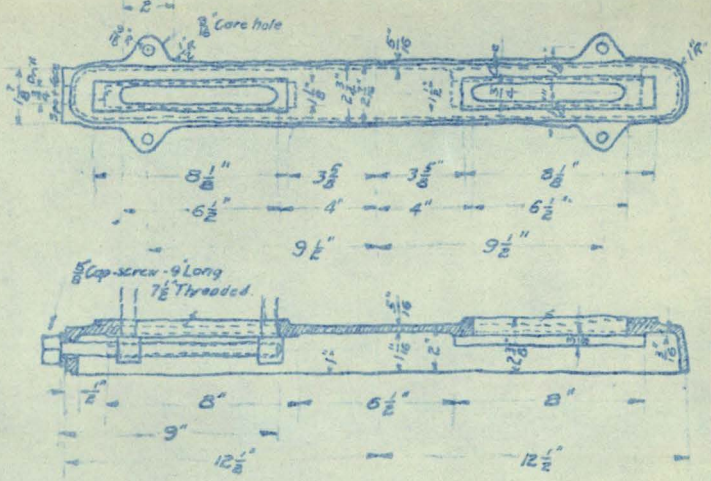
C

TIME = ____

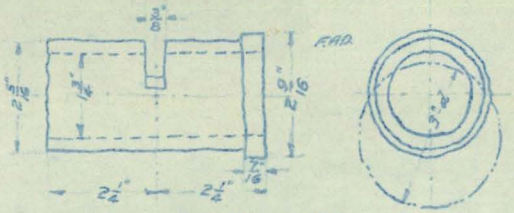
STUDENT NO.- ____



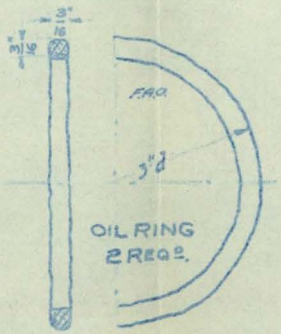




SLIDE RAIL
2- REQ'D.



BEARING LINER
2 REQ'D.



OIL RING
2 REQ'D.

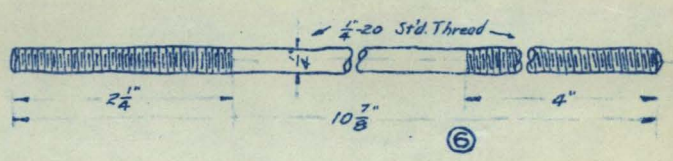
MAT.	NAME	PATT.	EST. WT.
C.I.	BEARING HOUSING	E.2907	22#
C.I.	SLIDE RAIL	E.1105	17#
BRASS	BEARING LINER	E.3122	2.5#
BRASS	OIL RING	E.3301	

MISCELLANEOUS DETAILS
5HP 440V 3PH 60~ 1200RPM
INDUCTION MOTOR
THE OREGON AGRICULTURAL COLLEGE
CORVALLIS OREGON

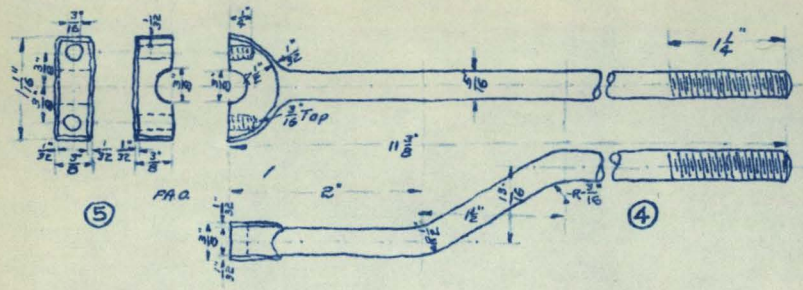
SCALE - 1 1/2" - 3" - 6" = 1' DATE = _____

D

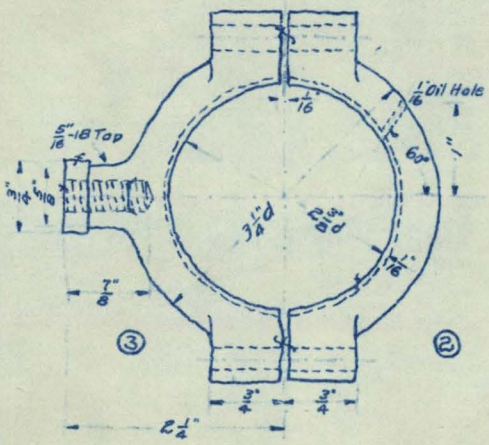
TIME = _____ CHECKED BY = _____ NAME = _____ STUDENT NO. = _____



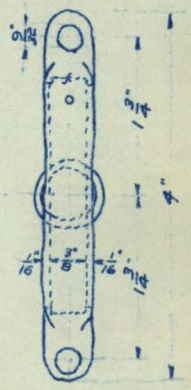
⑥

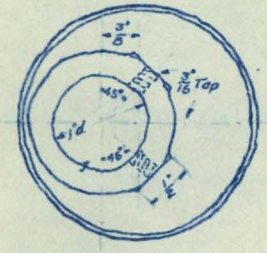


⑤ ④



③ ②





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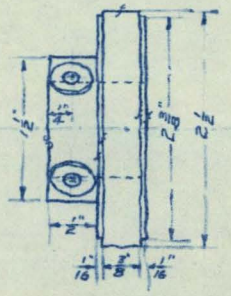

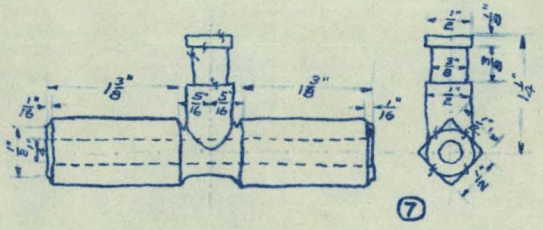

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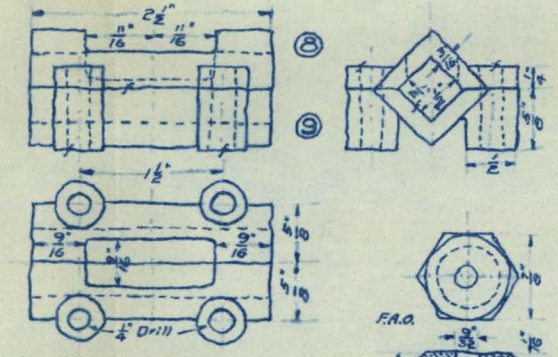
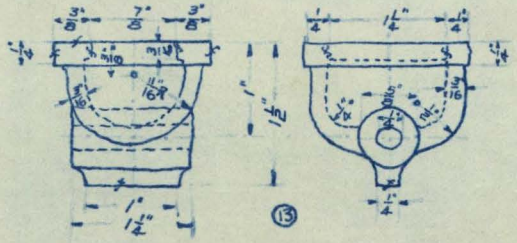


⑧ ⑨

⑫



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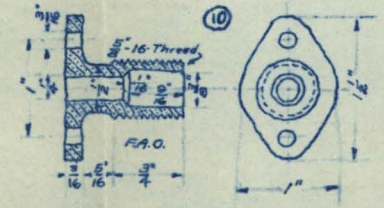

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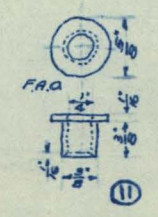


⑪

BILL OF MATERIAL.

1	Eccentric	1	C.I.	Patt. N.
1	Half of ecc. strap	2	C.I.	Patt. O.
1	Half of ecc. strap	3	C.I.	Patt. P.
1	Eccentric rod	4	F.S.	
1	Ecc. rod strap	5	F.S.	
1	Valve stem	6	M.S.	
1	Valve stem slide	7	Brass	Patt. Q.
1	Top V. stem guide	8	Brass	Patt. R.
1	Bott. V. stem guide	9	Brass	Patt. S.
1	Valve stem stuffing box	10	Brass	Patt. T.
1	Stuffing box gland	11	Brass	Patt. U.
1	Nut for stuffing box	12	Brass	Patt. V.
1	Valve	13	C.I.	Patt. W.
2	3/16" Set screw - ⅜" long.	14	M.S.	
2	¼" Hex. hd. bolt - 2" long - nut - cotter	15	M.S.	
1	⅝" Hex. nut.	16	M.S.	
2	3/16" Hex. hd. mach. screw - ⅝" long	17	M.S.	
4	¼" Hex. hd. bolts - 2½" long - nut	18	M.S.	
4	¼" Hex. nuts.	19	M.S.	
2	¼" Hex. check nuts	20	M.S.	
2	3/16" Rd. hd. mach. screw - ½" long	21	M.S.	

THE
OREGON AGRICULTURAL COLLEGE.

VALVE DETAILS

2 H.P. SIMPLE SLIDE VALVE ENGINE.

DRAWN BY _____ DATE _____

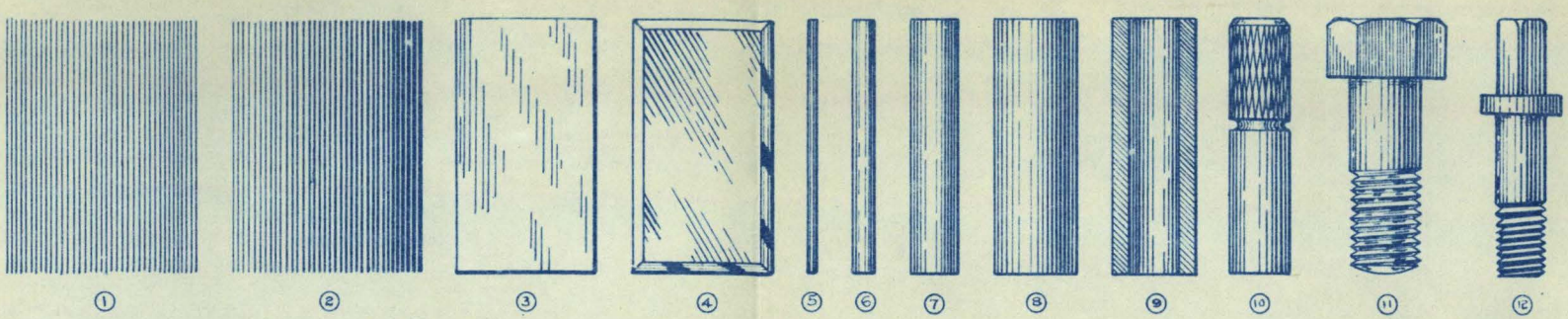
TRACED BY _____

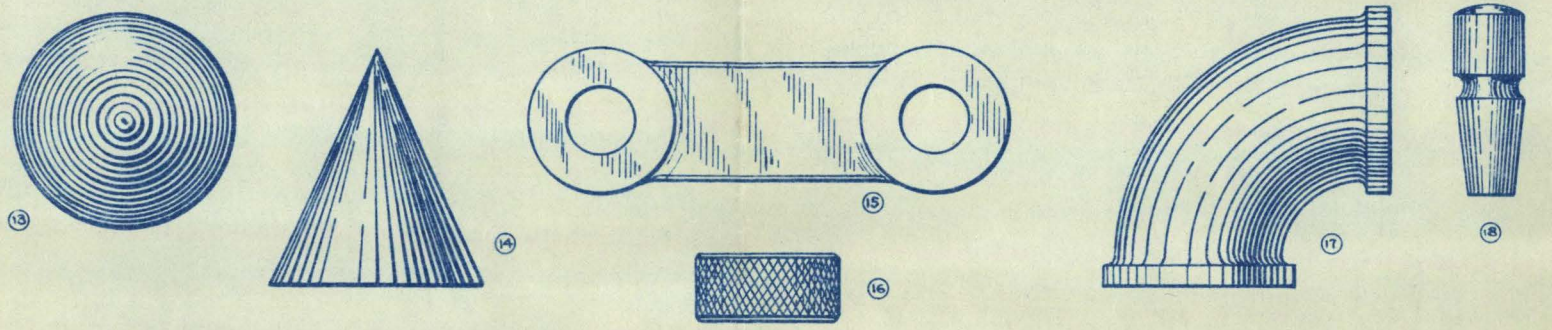
CHECKED BY _____

D

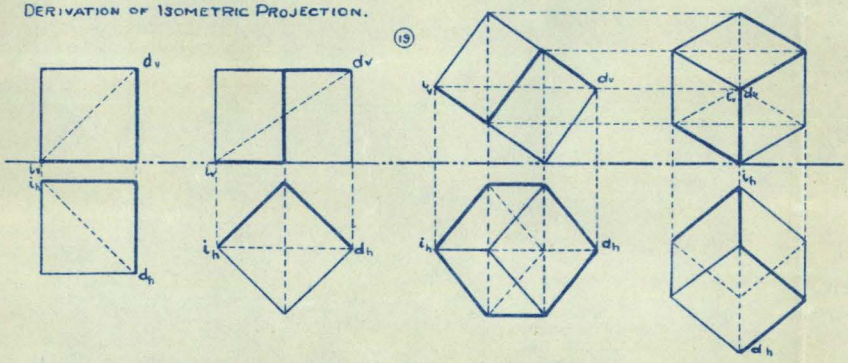
TIME - _____

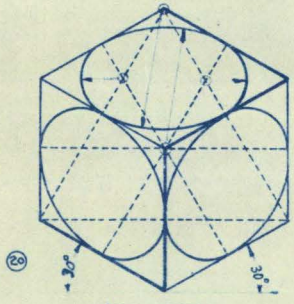
STUDENT NO. - _____



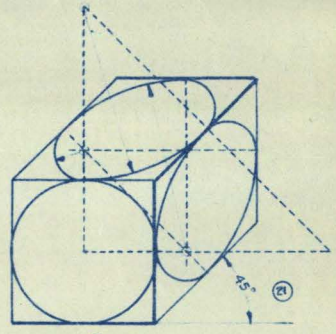


DERIVATION OF ISOMETRIC PROJECTION.



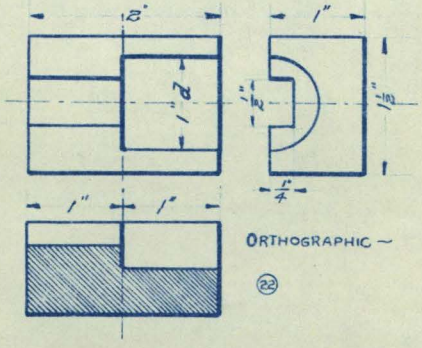


ISOMETRIC

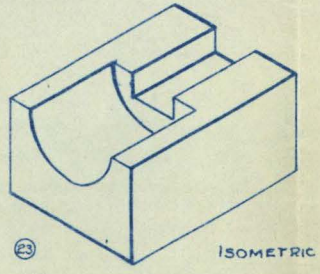


OBLIQUE

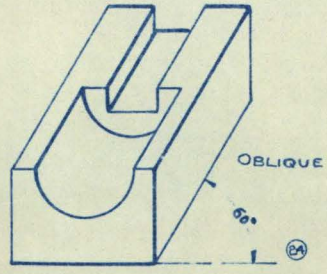
20 and 21 show isometric and oblique cubes with circles inscribed in faces. The circles appear as ellipses which may be drawn by the above approximate constructions.



ORTHOGRAPHIC



ISOMETRIC



OREGON AGRICULTURAL COLLEGE
MECHANICAL DRAWING DEPARTMENT

LINE SHADING & OBLIQUE PROJECTION

SCALE - 6" = 1 ft. — DATE ——
DRAWN BY —— CHECKED BY ——
TRACED BY ——
REVISED BY ——

No. 19.

TIME ——

STUDENT NO. ——