AN INVESTIGATION OF UNDERGRADUATE SHOP COURSES AT THE VIRGINIA POLYTECHNIC INSTITUTE

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A Thesis Submitted in Part Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

in

Industrial Engineering

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Virginia Polytechnic Institute
1934

PREFACE

The author does not claim this work to be entirely original. It is hoped, however, that the study will be of aid in making the shop courses at V. P. I. among the best.

The author wishes to take this opportunity to express his appreciation of the help and encouragement rendered by Professor Paul T Norton, Jr., and Dean Earle B. Norris of V. P. I., and to express his appreciation of the assistance rendered by those men who have previously published material on this subject. Credit for many of the suggestions found herein is due the staff of the V. P. I. Shops.

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I. INTRODUCTION

A. Object of the Investigation

To increase the effectiveness of any course requires a study of the course as it exists today and a comparison of other courses of a like nature in similar institutions. Shop courses are no different in this respect except that modern industry must be considered also. Because shop courses involve both theory and practice the problem of increasing their effectiveness is much harder than it is generally thought to be. Recent studies by The Society for the Promotion of Engineering Education[1] and The American Society of Mechanical Engineers[2] show the three main purposes of shop courses to be:

1. To gain a knowledge of materials
2. To gain a knowledge of shop operations and technique
3. To gain a knowledge of production and management methods

With these purposes in mind this investigation was undertaken so that the effectiveness of the undergraduate shop courses at the Virginia Polytechnic Institute could be increased.

B. Need for the Investigation

The investment in machinery and equipment for the teaching of shop work is quite large when compared to the other courses offered in engineering schools. For this reason it is essential that every minute the student is in the shops be productive. That is to say it is necessary that the student be learning every moment. The only way this can be accomplished is to have a definite program of work outlined. This program should be flexible so that new and interesting developments in the manufacturing field can be added and out of date information and processes discarded.

In order to accomplish the best results it is necessary to keep in mind what the student is being taught in his other classes. It is most essential not to duplicate in the shops, work that is being taught in other courses but to so correlate the work that the theory learned in the other courses can be applied in practice. The practical work gotten in the shops, whether actually performed by the student or demonstrated by instructors, is the only chance V. P. I. students have to see the theory put into practice.

For this reason it is believed that shop courses should be a combination lecture and laboratory course. Practical work must be combined with manufacturing methods lectures so the student will get some idea how to apply the theory he has learned and how theory and actual practice in industry are closely connected.

Because of the rapid strides being made by industry it is essential that the Engineering Colleges, training men for these industries, keep in step and progress simultaneously. It is believed that a well formulated plan of instruction and practice will aid in maintaining this progress. Because of these facts it was thought that the shop courses at the Virginia Polytechnic Institute should be redesigned. They should be so arranged that they will keep pace with Industry and turn out graduates more capable of filling the jobs they receive. This is particularly essential at V. P. I.

The majority of engineering students at V. P. I. are not from industrial centers nor are there any large centers of industry near Blacksburg. Students whose homes are in or near industrial cities are usually familiar with manufacturing processes from their associations if not from actual work in industry.

Those institutions located near or in industrial centers can include regular inspection trips in their shop courses. V. P. I. is at a great disadvantage in these respects and must have a good shop course in order to overcome this handicap if its graduates are to continue to compete with the graduates of other Engineering schools.

The courses outlined in this thesis are designed to give a knowledge of terms and processes from the melting and casting through fabrication and assembly until the product is finished and ready for stock or sale. This requires practice in performing the operations and a study of the various processes involved. Thus the courses must consist of a combination of lectures, outside preparation and laboratory practice. The courses are so arranged that they can be expanded or shortened to suit any curriculum. Particular emphasis may be given to those points most pertinent to the curriculum and its objectives. A good shop course will go a long way in developing accuracy and originality in an engineering student.

II. REVIEW OF LITERATURE

A. College Catalogues

In 1930 a study[3] of the catalogues of 109 selected schools was reported by Mr. R. L. Sweigert of the Georgia School of Technology. Table 1 from this study is reproduced on the following page. This table gives some idea of the total time spent on shop work but does not distinguish between lecture hours and hours spent in the laboratory.

Table 2 gives the same data as Table 1 on a quarterly basis. Table 2 gives the information in such a way that it can readily be compared with the shop work as given at V. P. I.

Table 3 is a comparison of the totals taken from Table 2 and the total clock hours spent in the shops by the students here at V. P. I.

It will be noted that some of the courses offered at V. P. I. do not require any shop work at all. This seems unfortunate in view of the fact that V. P. I. is so far removed from industrial centers that the students have no other opportunity to become familiar with the behavior of materials and manufactur-

"Average hours per week for one semester. Represents total shops given, as taken from the catalogues of the 109 schools studied, reduced to a semester basis and clock hours per week.

Table 1

Curriculum	Wood	Pattern	Foundry	Forge	Mach.	Heat Treat.	Weld.	Total
Mechanical Engineering.........	1.1	2.7	2.8	3.1	8.9	.4	.1	19.1
Electrical Engineering.........	1.0	2.5	2.1	2.1	6.2	.1	.1	14.1
Civil Engineering..............	1.1	1.0	.7	1.4	1.1	.1	.07	5.47
Chemical Engineering...........	.6	.8	1.1	1.2	1.6	.03	.0	5.33
Mining Engineering.............	.9	.1	.9	.9	1.2	0	.04	4.04
Industrial Engineering.........	.9	1.2	2.1	1.0	6.8	.5	0	12.5
Arch. Engineering..............	.9	0	.25	.6	.05	.05	0	1.85
Ceramic Engineering............	.4	0	.9	0	0	0	0	1.3
Met. Engineering...............	.7	0	1.0	.8	1.2	.12	0	3.82
Petroleum Engineering..........	.75	0	0	.75	0	0	0	1.5
Textile Engineering............	1.4	0	.3	1.1	5.4	0	0	8.2
Sanitary Engineering...........	.75	0	.75	.75	0	0	0	2.25
Aero. Engineering..............	.4	3.4	2.9	2.7	5.2	.2	0	14.8

"Average hours per week for one quarter. Represents total shop work given, as taken from the catalogues of the 109 schools, reduced to a quarter basis and clock hours per week.

Table 2

Curriculum	Wood	Pattern	Foundry	Forge	Mach.	Treat.	Weld.	Total
Mechanical Engineering.........	1.65	4.05	4.2	4.65	13.35	.6	.15	28.6
Electrical Engineering.........	1.5	3.75	3.15	3.15	9.3	.15	.15	21.1
Civil Engineering..............	1.65	1.5	1.05	2.1	1.65	.15	.10	8.2
Chemical Engineering...........	.9	1.2	1.65	1.8	2.4	.04	0	8.0
Mining Engineering.............	1.35	.15	1.35	1.35	1.8	0	.06	6.06
Industrial Engineering.........	1.35	1.8	3.15	1.5	10.2	.75	0	18.75
Arch. Engineering..............	1.35	0	.37	.9	.07	.07	0	2.78
Ceramic Engineering............	.6	0	1.35	0	0	0	0	1.95
Metallurgical Engineering......	1.05	0	1.5	1.2	1.8	.18	0	5.72
Petroleum Engineering..........	1.12	0	0	1.12	0	0	0	2.25
Textile Engineering............	2.1	0	.45	1.65	8.1	0	0	12.3
Sanitary Engineering...........	1.12	0	1.12	1.12	0	0	0	3.37
Aero. Engineering..............	.6	5.1	4.35	4.05	7.8	.3	0	22.2

"Number of clock hours per week spent on shop work if it were all given in one quarter."

Table 3

Curriculum	Average	V. P. I.
Mechanical Engineering.........	28.6	17
Electrical Engineering.........	21.1	14
Civil Engineering..............	8.2	---
Chemical Engineering...........	8.0	---
Mining Engineering.............	6.06	---
Industrial Engineering.........	18.75	20
Architectural Engineering......	2.78	---
Ceramic Engineering............	1.95	14
Metallurgical Engineering......	5.72	14
Agricultural Engineering.......	Not given	14

ing processes. All engineering students should have some training in and knowledge of the behavior of materials in use. The purpose of shop courses, as has been stated, is not to make trained mechanics out of students but to acquaint the students with the underlying principles and behavior of materials, how and when to use them.

B. Educational and Professional Societies Publications

The following tables and quotations will give a good picture of the general attitude toward shop work among educators and men engaged in actual practice:

"A Summary of Opinions Concerning Engineering Curricula"[4]

Sources of Replies

Number of institutions from which replies were received	115
Response in percent of 137 institutions canvassed	84.7
Number of questionnaires received	534
Response in percent of questionnaires distributed	67.0

Shop Courses

1. Curricula in which Shop Courses should be Required:

Curriculum	Number	Per cent
Mechanical Engineering	205	38.3
Electrical Engineering	171	32.0
Chemical Engineering	50	9.4
Civil Engineering	46	8.6
Mining and Metallurgy	42	7.9
Industrial Engineering	15	2.8
Agricultural Engineering	7	1.3
As an Elective	4	0.8
Other curricula	9	1.8
Considered Uncollegiate	23	4.3
Unclassified	10	1.9
Unstated	282	52.6

2. Summer Employment in Shops should be Required:

	Number	Per cent
In lieu of similar work in college.......	135	25.3
In addition to similar work in college.......	142	26.6
Unclassified.............	30	5.7
Unstated..................	227	42.4

3. If systematic shop instruction is given to students in college, which of the following should be its purposes?

Purposes	Of Primary Importance No.	Of Primary Importance %	Of Secondary Importance No.	Of Secondary Importance %
Knowledge of the technique of shop operations.....	264	49.4	78	14.6
Knowledge of the methods of shop management.....	136	25.4	116	21.7
Knowledge of the economic phases of shop operat'ns	105	19.6	96	18.9
Skill in handling tools and machines...........	73	13.7	79	14.8

	Number	Per cent
Unclassified.................	7	1.3
Unstated.....................	104	19.4

4. Which of the following methods should be employed in organizing shop courses?

	Number	Per cent
Lecture-Laboratory...........	272	50.9
Commercial Production.......	93	17.4
Unclassified.................	17	3.2
Unstated.....................	152	28.5

"Opinions of Professional Engineers Concerning Educational Policies and Practices"[5]

"In response to a specific question, a small majority of the chemical engineers, or 55.1%, favor systematic instruction in shop practice. Opinion is fairly equally divided on the question of substituting for shop instruction in college a requirement that a definite amount and type of shop experience be obtained during vacation periods, with 40.6% favorable, 37.7% opposed and 21.7% non-commital.

"By the ratio of five to three the consensus of opinion among civil engineers is that courses in shop practice should not be required of Civil Engineering students.

"In response to a specific question, a slight majority of the electrical engineers consider it desirable to substitute a definite amount and type of shop experience gained during vacations for systematic shop instruction in college. In rating the relative importance of different aspects of shop instruction, the majority (55.7%) stress the technique of shop operations, a somewhat smaller group (39.2%) the economic phases of shop operations, and much smaller groups manual skill (26.5%) and the technique of management (25.1%). In informal comments many emphasized the desirability of combining vadation experience with shop instruction.

"In view of the diversity of opinion in teaching circles as to the scope and purposes of shop instruction, the following questions were asked of the mechanical engineers:

a. 'What, in your opinion, should be the primary purpose or purposes of such courses -- training in manual operations and acquirement of skill therein, training in management and production methods, training in the economic and business aspects of shop work, etc.?'

Replies:

Management and production methods....	67.5%
Manual operatings and skill..........	18.4%
Omit shop work.......................	7.8%
Economic and business aspects........	6.4%

b. 'In your opinion would it be desirable to require students to acquire shop experience through vacation employment, provided, of course, that practical plans could be devised, or is it desirable to give some shop training in college?'

Replies:

Vacation work........................	42.5%
College instruction..................	25.6%
Both.................................	30.9%
Either...............................	1.0%

"The comment on these questions emphasizes the fact that the college is better organized to do systematic teaching, but that real knowledge of men and methods can be had only through industrial experience. It would seem, however, that mechanical engineers are disposed to give this type of instruction less emphasis than hitherto, and favor more emphasis on the laboratory aspects than on manual training. Many express the view that the latter properly belongs to the high school period and to vacation experience."

The following table was prepared from Curriculum Revision in the Light of the Board's Recommendations.[6] As can be seen, Table 4 gives the suggested quarter credit hours for shop work as compared with that actually given in the schools shown.

Table 4

Suggested quarter credit hours compared with the quarter credit hours actually given in the schools shown:

Curriculum	Suggested	M. I. T.	Cornell	Penn. State	Purdue	Wisconsin	V. P. I.
Civil Engineering....	3	---	3	---	---	---	---
Electrical "	3-6	4.05	9	7.5	12	6	8
Mechanical "	12	9.5	10.5	9	12	15	9
Chemical "	6	---	---	---	6	6	---
Mining "	3	1.05	---	---	6	---	---
Industrial "*	---	---	10.5	9	9	---	11

*Added by author from 1934-1935 catalogues

Table 5 gives a summary of replies by a number of typical engineering schools to the question "What are the general purposes of shop courses?"[1]

Table 5

College	General purposes of Shop Courses
CORNELL	To illustrate economic methods of production. To acquaint students with materials and equipment by actual contact, and the operation of as many standard machines as possible, demonstration of labor saving devices and specialized machines and automatics.
MICHIGAN	Principles underlying the working and treating of materials; teshnique of processes; Relation between processes, materials and designs, acquaintance with equipment and economic factors in production.
MINNESOTA	Materials, equipment and processes. Some operation.
MISSOURI	Acquaintance with tools, machines, materials. Little stress on skill owing to shortness of time.
WISCONSIN	To develop what skill can be developed, and all the above.
OHIO STATE	To acquaint the student with what can be done; how it can be done; the machines, tools, and methods used in the doing; and the nomenclature of the subject. This, of course, applies to the shaping of wood and metals to some useful purpose.

(Table 5 concl'd)

PENN. STATE	Teach Production Methods.
IOWA UNIV.	To acquaint students with materials, equipment and processes.

Table 6 is the summary of replies to the question "What required shop courses should be offered?"[1]

Table 6

"Required Shop Courses Offered by Various Schools, Showing the Students Taking Them, the Year the Course is Regularly Taken, and the Hours of the Course Expressed as a Function of the Total Hours or Units Required for Graduation:

College	Course	Students	Year offered	Units over Total
CORNELL	Pattern Making	M, E, C	1	2/140
	Introductory Lab.	M, E, C	1	2/140
	Foundry	M, E	2	2/140
	Machine work	E	3	2/140
	Machine work	M	3	3/140
ILLINOIS	Foundry and Pattern Lab.	M, E, General	2	3/142
	Machine Lab.	M, E, General	3	3/142
	Machine Lab.	M.	3	3/142
	Heat Treatment of Metals	M.	4	3/142

(Table 6 cont'd)

College	Course	Students	Year offered	Units over Total
MICHIGAN	Metal working & Treating	All	1	2/140
	Foundry	M.	3 or 4	4/140
	Machine Shop	M. & A.E.	3 or 4	4/140
MINNESOTA	Pattern	M, C, E, P, D.	1	2/204
	Foundry	M, C, E, P.D., Ch.	1	2/204
	Forge	M, C, E, P.D., Ch.	1	2/204
	Machine	Ch., C.	1	2/204
	Machine	E.	2	2/204
	Machine	M.	2	3/204
	Machine	M.	2	3/204
MISSOURI	Pattern Making	M, E, C.	1	2/120
	Forge and Machine Shop	M, E, C, Ch.	1	2/120
	Foundry Practice....	M.	4	4/120
OHIO STATE	Foundry	M, I	2	3/235
	Advance Foundry	I.	3	2/235
	Metal Bench Work........	M, I.	2	2/235
	Millwrighting	M, I.	2	2/235
	Pattern Making Ch..........	M, I, E, Ch.	1	3/235
	Forge & Heat	M, I.	1	3/235
	Forge & Sheet Metal Work..	E, Ch.	1	3/235
	Elementary Machine Work	M, I, E.	2	3/235
	Advanced Machine Work	I.	3	3/235
	Advanced Machine Work	M, I, E.	2	3/235

(Table 6 concl'd)

College	Course	Students	Year offered	Units over Total
WISCONSIN	Pattern Making, Welding, Forge and Bench.......	M, E, Ch.	1	2/140
	Machine Work	M, E, Ch.	1 & 2	2/140
	Tool Making	M.	2	2/140
	Shop Projects	M.	3	2/140
	Problems......	M.	4	1/140
	Foundry.......	M.	3	1/140
IOWA UNIV.	Mfg. Processes	M.	2	5/138
	Mfg. Processes	E.	2	3/138
	Mfg. Processes	Ch.	2	3/138
	Prod. Methods	M.	4	2/138
PENN. STATE	Joining.......	Archit.	1	1/152
	Production....	M, I, E, E, C.	1 & 2	1/152
	Foundry.......	M, I, E, E. C.	1 & 2	1/152
	Pattern Making	M, I, E.	1 & 2	1/152
	Forging.......	M, I, E. C.	1	1/152
	Mach. Tool Work........	M, I, E.	2 & 3	1/152
	Mach. Construction	I.	3	1/152

M = Mechanical I = Industrial

E = Electrical P. D. = Pre-dental

C = Civil E. C. = Electo-Chemistry

Ch = Chemical A. E. = Aero.

Table 7 is a summary of opinions as to the best time to give shop work.

Replies to the question, "Should shop courses be Given During the First, Second, Third or Fourth Year and Why?"

College	Replies
CORNELL	During the first three or all four years. Better curriculum arrangement; more satisfactory results; and better for the student.
IOWA UNIV.	Never the first bear because greater investmenktin equipment is necessary for a larger number of students. Prefer second year because of better relation with drawing and design work. Fourth year preferred for production because students are accustomed to make accurate reports and generally are more interested.
MICHIGAN	Some work should be given early to acquaint students with materials. Work in the latter part of the curriculum is desirable that technique of operations and methods of manufacture may be studied and that better correlation may be obtained between courses, such as design, economics, metallurgy, etc.
MINNESOTA	First and second preferable. It leaves more time for advanced technical work.

(Table 7 concl'd)

College	Replies
MISSOURI	Courses given in the first year are largely due to established curriculum and program. Courses are given in the fourth year to mature students, introductory to their early entrance in the field of production.
OHIO STATE	Shop work should be given during the second and third years. Freshmen are too young and seniors are too ripe for best results.

C. Conclusions

A. The objectives of shop courses are:

(1) To gain a knowledge of materials
(2) To gain a knowledge of shop operations and technique
(3) To gain a knowledge of production and management methods

B. The aim of shop courses is not to develop manual skill but is to enable students to better understand how to apply theory

C. Shop courses should come under four main headings:

(1) Melting and casting of metals
(2) Forging and related treatments
(3) Machining
(4) Design and economics of manufacturing

D. Shop courses should be closely coordinated with other courses

E. Shop courses should be a combination of lectures and laboratory demonstration and practice

F. Where possible it is desirable to have a short introductory shop course in the freshman year, with actual shop practice in the second and third years, followed by the economic and production phases in the senior year

G. Some shop work should be required in the following curricula at V. P. I.:

(1) Mechanical Engineering
(2) Electrical Engineering
(3) Industrial Engineering
(4) Chemical Engineering
(5) Civil Engineering
(6) Mining Engineering
(7) Agricultural Engineering
(8) Ceramic Engineering
(9) General Engineering

III. THE INVESTIGATION

A. Method of Procedure

A study of the shop courses as they now exist at V. P. I. was made after reviewing the literature on the subject of shop work in engineering curricula. This involved a close study of the available equipment, shop layout, exercises or practical work given, lectures and manner of instructing and demonstrating the work. As the writer had more shop work, as an undergraduate, than is now given at V. P. I., additional work being taken only last year, it was comparatively easy to study the present set up.

After becoming familiar with existing practices the next step was to make motion and time studies of the work as now given. This was no simple matter because of the intangibles, such as indecision on the part of students as to the proper sequence of operations, which tools to use and inability to properly read blueprints. Instructors are not available at all times because of the repair and maintenance work done in the V. P. I. shops. Where it was impossible to get a complete study of an exercise, the synthetic method was used. By the use of job analysis and past performances a comparatively accurate study could be made. An example of this is in milling the teeth on a pinion. If one pinion on which a study had been made had 20 teeth and the time for cutting each tooth was 0.90 minutes and the time for indexing to the next tooth was 0.10 minutes, then the total time per tooth was 1.00 minutes or 20 minutes for milling the pinion. Another pinion of 40 teeth would take twice as long, or 40 minutes.

These studies were used for determining the time lost by the student due to the causes mentioned. By a careful analysis of the time studies simple and positive means of increasing the amount of work done in a given period of time were found. It might be added that the amount of work done this year has been increased to some extent over that done last year. The psychological effect of this study being made probably had something to do with this.

The next step was to study methods of increasing the effectiveness of instruction, demonstration and the shop courses as a whole. This was accomplished by comparing methods used at V. P. I.

with those used at other colleges, always keeping in mind the type of student, the location, equipment and purposes of the courses at the various engineering colleges and at V. P. I. This information was obtained from the college catalogues, from information published in the various magazines and from interviews with graduates of other colleges.

In general a shop course of the production type would not be practical at V. P. I. It is impossible to accommodate all the students in the foundry in one quarter, in the forge shop the next and in the machine shop the third quarter. Some of the students must start in the machine shop and some in the forge shop. It was thought best to have definite exercises which demonstrated the basic principles rather than have the students make some object such as a vise, motor or screw jack, because in making such an article too much emphasis is likely to be put on producing the article itself rather than on the underlying principles.

The castings for all the exercises made from cast iron are cast in the foundry. It is hoped in time to have suitable dies to make small forgings which can be finished in the machine shop. This will increase the similarity to the work of a production shop.

Incentive to do good work is obtained through the students' knowing that the finished articles are to be used by other students in the case of castings and that the machined exercises are to be graded and in some cases stored for sale or for use in maintenance work.

B. Results and Discussion of Results

Machine Shop

Thirty-five percent of the time of each student in sophomore shop work and twenty percent in junior shop work is lost due to the students not knowing the sequence of operations and the tools to be used for each exercise. This was found to be due mainly to not having sufficient instruction, proper demonstration and proper drawing and operation sheets. Under the present set up it is nearly impossible to give proper demonstrations. Under present conditions about fifteen students gather around an instructor at a lathe or other machine out in the shop, and try to see and absorb what the instructor does or says. In some instances only four or five students are given demonstrations at one time. This is a waste of the instructor's time, and each student does not receive the same instruction. If there is any noise or commotion it disturbs the instructor and attracts the student's attention. This is continually happening because of the repair work done by the shop instructors.

The best way to overcome this is to have a combined lecture and demonstration room. This room should have tiered seats so all students could see what is being done and at the same time could take notes. This room should be used for all demonstrations and laboratory instructions. Where possible the room could be used for lectures as well.

This change would be made for approximately $600.00, not including chairs, by removing the balcony from room A-2 to the store room, thus allowing all materials to be kept in the one room. Then remove the partition from between rooms A-2 and A-3. This would give plenty of light from the skylights and these skylights could be made movable to allow ventilation. All the demonstration could be done in the northwest end and the tiered seats placed in the southeast end of the new room. The room should be equipped with electric outlets so machines could be moved into it and plugged in. Installation of a small projection machine and screen will increase the effectiveness of lectures and demonstrations. All equipment, other than large machines, such as gages, straight edges, surface plates, etc., could be kept in this room in cabinets and used during demonstrations and lectures. A display rack containing all exercises in rough, semi-finished and finished conditions would be of aid to the students also. This would eliminate all confusion during lectures and demonstrations and all students would get the same amount of demonstration under much more favorable conditions. Another result would be that of having all stores and materials in one place, which would save time and avoid confusion.

The work sheets, shown in Appendix 2, will eliminate the time lost by the students due to indecision as to the correct sequence of operations and as to what tools to use. These sheets seem to be incomplete but they are left this way for several reasons. The operations column has no explanation or detailed information because the student should do some thinking for himself in applying what he sees and hears during the demonstrations. The tool column is complete so far as the names of the tools to be used are concerned. The speed and feed columns are left vacant because it is thought best to have the student calculate his own speeds and feeds for the machine, kind of tool and kind of material used. The time column is left vacant because there has been no opportunity to study the exercises under the new set up. It is suggested that this column be filled in when suitable studies have been made so the students will know the time required to do each job.

It will be noted that the student will know at the beginning of the period just what tools he will need and can obtain these tools when he gets his tool box. This will eliminate the necessity of a man staying in the store room during the laboratory period as is now done. It will be best to have the students given their tools at the beginning of the period; the assistant can then go out into the laboratory to help in the instruction. At the end of the period the assistant can return to the store room and receive the tools as they are returned. In this way there will be need for a man in the store room only the first and last fifteen minutes of each laboratory period. If special tools are needed they may be obtained by any of the instructors.

Some inattention to the work and the resulting lost time is due to the repair work which is constantly being done in the machine shop. To overcome this it is suggested that the two northwest bays of the shop be partitioned off and that one of the milling machines, a small lathe, the gas welding equipment and necessary tools be moved to this part of the shop. There will in all probability be someone in this part at all times. In case there is no one there a bell could be installed to call one of the shop men. This would eliminate most of the noise and confusion which inevitably attracts the attention of the students. At the same time it will facilitate the repair work because the necessary tools will be close at hand and not scattered as they now are.

The equipment could be arranged to better advantage by having the lathes staggered and in a more compact group, instead of in two long rows as they now are. This would necessitate the installation of individual motor drives on all lathes. Installing individual motor drives would decrease the power consumption and would eliminate the expensive shaft and belting system now in use. This would allow the benches to be grouped and not scattered over the entire shop. Danger from flying pieces of iron from the chipping operations would not be so great. This would take up less room and would make it possible for the instructors to get around to each student more often. Another advantage of this change would be that the students would not be facing the glare and heat of the afternoon sun through the southwest windows.

If the present shop layout is to be kept a traveling ladder with a small platform and running between the two rows of lathes as they now stand would save forty percent of the time it now takes to oil and grease this equipment. This time is now consumed in moving, ascending and descending the hand ladder. This traveling ladder would also make it possible for each student to oil his own machinery and would facilitate making repairs to the equipment.

Under the present layout it is suggested that the southwest windows be either painted or furnished with shades so that the heat and glare from the afternoon sun will be eliminated. This would not be necessary if the layout were changed as previously suggested.

Other suggestions which would increase the effectiveness of the machine work under the present or suggested shop layout are:

1. Equip every student with high speed steel round nose and threading tools. The present carbon steel tools could be used for special tools as they are needed.

2. Put small shop built shaper in condition to relieve pressure on existing shapers and to be used in demonstrations.

3. Fix skylights so they can be readily opened and shut to secure proper ventilation.

4. Place automatic switch on air compressor so compressed air will be available at all times.

It is recommended that a course of the millwrighting nature be given either the summer between the sophomore and junior years or during the junior year. The students should be allowed to dismantle, clean, repair and assemble machinery. The course should also include pipe fitting, babbeting, scraping and fitting bearings and other simple maintenance and repair operations. This would furnish a rounding-out course and should be given to the mechanical and industrial engineers only. Such a course would furnish a good background for the jig and fixture design, production planning and motion and time study courses.

The course for the machine shop as outlined presupposes that the lecture and demonstration room has been obtained. With this in mind it can easily be seen how such a course would be a big improvement over the present one. The course as outlined can be shortened or lengthened to suit the needs of the curriculum and needs no further explanation.

<u>Outline of Machine Shop Course</u>:

Period #1.

Lecture on machine shop development and the use of the machine shop today.

Period #2.

Lecture on the care of machines and cleanliness in a machine shop (emphasizing rejections due to dirty machines.

Period #3.

Lecture on laying out work--
- A. Tools used
- B. Correct procedure
- C. When used

Period #4.

Lecture on chipping, filing and scraping--
- A. Tools used
- B. Correct procedure
- C. When used

Period #5.

Lecture on kinds of cutting tools--

A. Carbon steel
B. High speed steel
C. Stellite
D. Tungsten and tantalum carbide
E. Carborundum

Period #6.

Lecture on care and sharpening of cutting tools--

A. For cast iron
B. For steel
C. For brass and bronze
D. For aluminum alloys
E. For other alloys

Period #7.

Lecture on measuring devices and their uses--

A. Calipers
B. 1. Inside
   2. Outside
   3. Thread

B. Micrometers
   1. Inside
   2. Outside
   3. Thread

C. Special measuring devices and gages

Period #8.

Lecture on Lathes--

A. Speed lathes
   1. Operation
   2. Uses

B. Engine lathes
   1. Mechanism
   2. Operation
   3. Tools
   4. Uses

Period #9.

Lecture on turning and fitting--
- A. Outside turning
- B. Inside turning or boring
- C. Facing
- D. Correct procedure and sequence of operations

Period #10

Quiz.

Period #11

Lecture on threading--
- A. Forms of threads
- B. Uses of threads
- C. Strength of threads
- D. Calculations for threads

Period #12

Lecture on threading--
- A. How to set machine
- B. Compound gearing
- C. How to set tools
- D. Methods of threading

Period #13

Lecture on turning and threading--
- A. Speeds
- B. Feeds
- C. Depths of cut

Period #14

Lecture on shaping, planning and slotting--

A. Shapers
   1. Kinds
   2. Mechanism
   3. Uses
   4. Procedure

B. Planers
   1. Kinds
   2. Mechanism
   3. Uses
   4. Procedure

C. Slotters
   1. Kinds
   2. Uses
   3. Procedure

Period #15

Lecture on milling machines--

A. Types of milling machines
B. Uses of milling machines
C. Cutters
   1. Types
   2. Uses of various cutters

Period #16

Lecture on milling--

A. Speeds and feeds for various metals
B. Lubricant
C. Setting up machines

Period #17

Lecture on gears and gear cutting--

A. Kinds of gears
   1. Uses
   2. Calculations

B. Cutting gears
   1. Formed-tooth method
   2. Form-generating method

Period #18

Lecture on drills and drilling--
- A. Kinds of drills
- B. Speeeds and feeds
- C. When to use drills

Period #19

Quiz.

Period #20

Lecture on boring and boring machines--
- A. Kinds of boring machines
- B. When to use
- C. Speeds and feeds
- D. Auxiliary equipment

Period #21

Lecture on grinders--
- A. Universal grinders
- B. Plain grinders
- C. Centerless grinders
- D. Cutter grinders
- E. Special grinders
- F. Honing machines

Period #22

Lecture on grinding--
- A. Grinding wheels
  1. Abrasives
  2. Binders
  3. Uses

B. Selecting correct wheel
C. Setting and adjusting machine
D. Speeds and rate of grinding
E. Lubricants

Period #23

Lecture on reaming and broaching
A. Machines
B. Tools
C. Uses

Period #24

Lecture on safety and safety devices used in the machine shop.

Period #25

Lecture on automatic machines--
A. Automatic and turret lathes
B. Automatic and multimatic millers
C. Automatic grinders
D. Screw cutting machines
E. Other automatic machines

Period #26

Lecture on special operations--
A. Eccentric and taper turning
B. Knurling
C. Polishing
D. Use of taps and dies

Period #27

Lecture on the uses of special tools and fixtures--
A. Magnetic chucks
B. Jigs
C. Surface plates and straight edges
D. Gages and gage blocks

Period #28

Quiz.

Laboratory Period #1

General inspection of machine shop
- A. Lay out
- B. Uses and names of the various machines

Laboratory Period #2

Demonstration and practice in lay out work

Laboratory Period #3

Demonstration and practice in chipping, filing and scraping.

Laboratory Period #4

Demonstration of lathe work, including construction of lathe, how to turn and thread.

Laboratory Period #5

Demonstration of planing, shaping and slotting

Laboratory Period #6

Demonstration of milling.

Laboratory Period #7

Practice in chipping (cast iron blocks).

Laboratory Period #8

Practice in filing (cast iron block).

Laboratory Period #9

Practice in scraping (cast iron block).

Laboratory Period #10

Practice in lathe work.

Laboratory Period #11

Practice in lathe work

Laboratory Period #12

Demonstration of turret lathe. Practice in lathe work.

Laboratory Period #13

Demonstration of automatic lathe. Practice in lathe work.

Laboratory Period #14

Practice in general machine work. (Shaping, milling or slotting and lathe).

Laboratory Period #15

Practice in general machine work.

Laboratory Period #16

Demonstration of Bilgram gear shaper. Practice in general machine work.

Laboratory Period #17

Practice in general machine work.

Laboratory Period #18

Inspection of products of machine work and study of causes of defects and rejections.

The Foundry

All of the moulding now being done in the foundry is done on the floor. The student has to do a lot of bending, stooping and kneeling in order to make the molds. This is tiresome and slow. As most of the patterns and flasks are small this work could be done on a moulding table. Such a table has been designed. The plans for the table are in the hands of Professor Norton.

The table is double, to allow of students working on both sides. The work benches are 30 inches high by 18 inches deep and the table is 30 feet long, which provides room for from sixteen to twenty students. Separating the two work bench parts is a small shelf, 12 inches deep and 20 inches above the working level, running the entire length of the table. This shelf is to support the tool boxes of the students. The front and back of the work benches are open so the sand can be brushed or "struck off" and then removed from under the table. The table is to be made of steel angles welded together, with wood tops. The estimated cost is $125.00. This bench will save from fifteen to twenty-five percent of the time now consumed in moulding and the work will not be so tiring. This will allow the students time to make larger floor moulds, which is not now done.

Another phase which is not sufficiently considered at this institution is that of cleaning, inspecting and studying the causes of defects in castings. It is better to prevent defects rather than to correct them after they occur. In order to prevent the causes of rejections in castings a study of defects is necessary. The two laboratory periods following the iron cast should be spent in cleaning, inspecting and studying the defects in the castings. As most of the castings are to be used, this will be an easy and inexpensive way of having them cleaned and will also familiarize the students with defects and their causes.

As all foundry men know, the kind and condition of the sand plays a very important part in the production of good castings. This is as important as moulding and pattern design and should be studied as far as is possible in the limited time available. At least one whole laboratory period should be spent in tempering and preparing the sand so that the effect of too much or too little moisture or too much or too little clay can be seen. Other things such as the proper clay and size and shape of sand grain play a large part in the production of good castings and should be studied.

No pattern design or pattern making is taught at V. P. I. now. This is as important a phase of foundry work as is the making of moulds and should be taught in one of two ways.

Pattern making can be taught in the wood shop by having the students actually build or make patterns. This is a long, costly process requiring a first class pattern maker and costly tools and equipment. If there were a lot of time which could be allotted to this work, this would be the best way to give the course. Because there is no large amount of time available in the foundry too much time would be consumed in making joints, sawing, hammering and general carpenter work. Very little of the theory of pattern design would be learned.

The ideal way to teach pattern design in such a short time is to have the work done in a drawing room on paper. No time would be lost in having the students learn to use tools. The theory of pattern design could more easily be presented because it would be a combination lecture and laboratory course given in the same room. This would be a far less expensive and better way of teaching pattern design than having the students actually construct the patterns. At the same time more technical knowledge such as shrinkage and finish allowances, number of castings and other economic phases of design in relation to moulding and casting could be taught.

The outline of the foundry course, to be given the sophomore year, needs no further explanation. This course can easily be shortened, lengthened, or changed to meet changing conditions in actual foundry practice.

<u>Outline of Foundry Course (Lectures)</u>:

Period #1.

Lecture on the history of founding and the use of castings.

Period #2.

Lecture on founding equipment and tools
- A. Patterns
  1. One piece
  2. Split
  3. Parting line
  4. Draft
  5. Core print
  6. Match plates and gated patterns

- B. Flasks
  1. Drag
  2. Cope
  3. Cheek
  4. Snap

- C. Miscellaneous tools

Period #3.

Lecture on moulding--
- A. Kinds of moulding
  1. Bench
  2. Floor
  3. Pit
  4. Loam
  5. Machine

- B. Process of moulding

Period #4.

Lecture on moulding sands--
- A. Composition of natural and synthetic sands
  1. Sand grain
  2. Clay
  3. Water

B. Properties of moulding sands
   1. Bond strength
   2. Permeability
   3. Effect of moisture

C. Preparation and care of moulding sands

Period #5.

Lecture on cores and core sands
   A. Core boxes
   B. Kinds of cores
      1. Oil sand
      2. Green sand
      3. Dry sand
      4. Loam cores
      5. Special mixtures

Period #6.

Lecture on machine moulding equipment
   A. Squeezer type machine
   B. Stripper plate machine
   C. Jolt machine
   D. Permanent molds
   E. Die casting machines
   F. Sand slinger
   G. Foundry conveyor systems

Period #7.

Lecture on safety and safety appliances used in foundries.

Period #8.

Lecture on non-ferrous founding
   A. Brass
      1. Composition
      2. Manufacture
      3. Properties and uses

B. Bronze
   1. Composition
   2. Manufacture
   3. Properties and uses

C. Aluminum alloys
   1. Composition
   2. Manufacture
   3. Properties and uses

D. Other non-ferrous casting alloys

Period #9.

Lecture on non-ferrous melting furnaces
A. Crucible
B. Non-crucible
C. Electric
D. Gas, oil and coke

Period #10

Quiz. (Including laboratory work)

Period #11

Lecture on iron founding
A. Pig iron
   1. Composition
   2. Manufacture
   3. Classification

B. Gray cast iron
   1. Composition
   2. Manufacture
   3. Properties and uses

C. Malleable cast iron (cast as white iron)
   1. Composition
   2. Manufacture
   3. Properties and uses

Period #12

Lecture on steel founding

A. Composition
B. Manufacture
    1. Bessemer
    2. Open hearth
    3. Electric
    4. Crucible
    5. Duplexing

Period #13

Lecture on melting

A. Cupola
    1. Use
    2. Advantages and disadvantages

B. Air furnaces
    1. Use
    2. Advantages and disadvantages

C. Electric furnaces
    1. Use
    2. Advantages and disadvantages

D. Open hearth furnaces
    1. Use
    2. Advantages and disadvantages

E. Rotary furnaces

Period #14

Lecture on refractories used in founding

A. Kinds and composition
    1. Acid
    2. Basic
    3. Neutral

B. Properties and uses
    1. Expansion
    2. Porosity
    3. Strength

C. Cost

Period #15

Lecture on pouring and casting practices

A. Non-ferrous
   1. Brass
   2. Bronze
   3. Aluminum alloys
   4. Others

B. Ferrous
   1. Cast irons
   2. Steels

Period #16

Lecture on defects and weaknesses of castings

A. Incorrect moulding
   1. Non-ferrous
   2. Ferrous

B. Improper pouring practices
   1. Non-ferrous
   2. Ferrous

Period #17

Lecture on defects and weaknesses of castings

A. Due to cores
   1. Non-ferrous
   2. Ferrous

B. Other causes
   1. Non-ferrous
   2. Ferrous

Period #18

Lecture on cleaning and inspecting castings

A. Equipment

B. Cost

Period #19

Lecture on physical properties of cast metals
- A. Strength
- B. Weight
- C. Resistance to shock
- D. Elongation
- E. Hardness
- F. Wear resistance
- G. Corrosion resistance
- H. Electrical properties
- I. Cost

Period #20

Quiz. (Including laboratory work)

Period #21

Lecture on importance of patterns to economic production of castings.

Period #22

Lecture on pattern design
- A. Draft
- B. Fillets
- C. Shrinkage
  1. Brass
  2. Bronze
  3. Aluminum
  4. Cast iron
  5. Steel
- D. Allowance for finish

Period #23

Lecture on patterns
- A. Types of patterns
  1. Solid
     - (a) Requiring 2 part flask
     - (b) Requiring 3 or more part flask

A. (cont'd)

2. Split patterns
3. Skeleton patterns
4. Match plates and gated patterns

Period #24

Lecture on woods and construction of wooden patterns.

A. Woods
   1. Kind
   2. Seasoning and grain

B. Construction
   1. Glued up stock
   2. Disk construction
   3. Ring work
   4. Conical work
   5. Core box construction

Period #25

Lecture on metal pattern equipment

A. When to use metal patterns
B. Materials used
C. Design of permanent molds

Period #26

Lecture on pattern finish and storage

A. Finishes
   1. Shellac
   2. Lacquers
   3. Paint

B. Storage
   1. Order and system
   2. Humidity and temperature

Period #27

Lecture on economy
- A. Redesign of parts
- B. Wood vs. metal patterns
- C. Quantity of castings

Period #28

Quiz. (Including laboratory work)

Laboratory Period #1

Inspection of laboratory and demonstration of the use of the equipment and tools.

Laboratory Period #2

Practice in ramming and molding small bench mold.

Laboratory Period #3

Demonstration and practice in tempering sands. Make small bench mold illustrating various methods of gating.

Laboratory Period #4

Demonstration of core making. Practice in the making of cores.

Laboratory Period #5

Demonstration of moulding machine. Practice in moulding with split patterns.

Laboratory Period #6

Small brass cast. Making bench mold with parting line pattern.

Laboratory Period #7

Small aluminum cast. Making bench mold with a split parting line pattern.

Laboratory Period #8

Making a bench mold with a complicated pattern involving cores.

Laboratory Period #9

Floor moulding practice with large flasks and patterns.

Laboratory Period #10

Floor and bench moulding. Making moulds for iron cast.

Laboratory Period #11

Floor and bench moulding for iron cast.

Laboratory Period #12

Melting and pouring iron cast.

Laboratory Period #13

Cleaning and inspection of iron castings.

Laboratory Period #14

Assignment of simple pattern and design factors study such as number of castings to be made, type of metal, etc.

Laboratory Period #15

Start design. Drafting room.

Laboratory Period #16

Design. Drafting room.

Laboratory Period #17

Design. Drafting room.

Laboratory Period #18

Design. Drafting room.

Forge Shop

The forge work now given at V. P. I. is out of date in so far as too much hand work with anvil and hammer is given. The main reason for this is the lack of adequate equipment to demonstrate machine forging. It is advisable to have the power hammers and presses put in condition as soon as possible and to have suitable dies made. With this equipment in commission, power forging can be demonstrated and some little practice may be had. This will necessitate the purchase of a preheating furnace with adequate temperature control apparatus. The control of temperature in forging operations is very important and automatic controls are necessary for good results in demonstrations.

There is very little hand forging done these days. The disappearance of the village blacksmith will attest to this fact. Why, then, instruct students, who are in training to become engineers, in nothing but hand forging? It is true that some of the theory of forging can be gained from hand forging operations. Many of the tools used in hand forging are used in power forging. For this reason it is best to have students begin on hand forging operations.

Not all forging operations are done when the metal is hot. This is especially true of many small parts for different types of machinery, as well as small bolts, nuts and rivets. If it is at all possible it is recommended that a small cold forging machine, on the order of the national forging machine, be obtained.

Another subject which should be included in the forge courses and which is only touched on at V. P. I. is welding. This process is being used more every day, and is of the utmost importance to engineering students if they are to be well trained when they graduate. There is plenty of room in the west corner of the forge shop to install several welding tables for instructional purposes. These tables should be so arranged that the flames will not be seen by other students working in the shop. It is much better to have a central acetylene generator with pipe lines running to each table than to use tanks of acetylene. The same generator could be used to supply acetylene for maintenance and repair work. An oxygen tank would be placed at each welding table.

Electric arc welding should be demonstrated and compared with gas welding. The equipment for this type of welding is expensive and it is not advisable to have students do much arc welding. The theory and technique should be taught and demonstrated.

There are other types of welding which should be taught. The theory of these other types such as spot welding and thermit welding, is of value, to an engineer. This theory could be taught by lectures, and demonstrations could be given where possible.

Other methods of hot and cold forming of metal should be touched upon. The theory involved and equipment used in extrusion, drawing and such forming processes should be explained, and where possible slides should be used to supplement the lectures.

The following outline will furnish a basis for starting such a forge course. As in the cases of the machine shop and foundry, the course may be changed to suit varying conditions.

Outline of Forge Course:

Period #1.

Lecture on the history of forging and the use of forgings.

Period #2.

Lecture on correct usage of hand forging equipment

A. Forge
B. Anvil
C. Sledges
D. Hammer
E. Tongs
F. Chisel
G. Miscellaneous tools

Period #3.

Lecture on forge fires
- A. Building fire
- B. Size of fires
- C. Temperatures
- D. Kind of fire
    - 1. Oxidizing
    - 2. Reducing
    - 3. Neutral

Period #4.

Lecture on forging operations
- A. Drawing out
- B. Upsetting
- C. Bending
- D. Forming
- E. Offsetting
- F. Punching
- G. Riveting

Period #5.

Lecture on metals used in forging.
- A. Ferrous
- B. Non-ferrous

Period #6.

Lecture on forging procedure
- A. Calculation of stock
- B. Sequence of operations
- C. Tools to be used

Period #7.

Lecture on forge welding
- A. Welding temperatures
- B. Effect of temperatures on structure of metal
- C. Fluxes and tools

Period #8.

Lecture on forge welding
- A. Kinds
  1. Link
  2. Lap
  3. Jump or butt

Period #9.

Quiz.

Period #10

Lecture on gas welding
- A. Kinds of gas used
  1. Oxygen
  2. Acetylene
  3. Hydrogen

- B. Gas containers and regulators

Period #11

Lecture on gas welding
- A. Setting up equipment
- B. Bluw pipe construction
- C. Tips to be used

Period #12

Lecture on gas welding
- A. Technique of welding
- B.
  1. Handling torch
  2. Handling welding rod and flux

- B. Technique of cutting
- C. Comparison of forge and gas welds

Period #13

Lecture on electric arc welding equipment
- A. Types of current used
- B. Adjustment of motor-generators
- C. Types of welds

Period #14

Lecture on arc welding
- A. Technique of arc welding
- B. Comparison of gas and arc welds
- C. Where to use arc welds

Period #15

Lecture on other welding processes
- A. Spot welding
- B. Thermit welding

Period #16

Lecture on annealing
- A. Purpose
- B. Kinds
    1. Full annealing
    2. Shop annealing
    3. Normalizing
    4. Patenting
    5. Spheroidizing

Period #17

Lecture on hardening and tempering
- A. Hardening
    1. Definition
    2. How accomplished
    3. Purpose

- B. Tempering or drawing
    1. Definition
    2. How accomplished
    3. Purpose

Period #18

Lecture on heat treating equipment

A. Furnaces and fuels
   1. Muffle
   2. Semi-muffle
   3. Direct flame
   4. Bath furnaces
      a. Salt
      b. Metal

B. Quenching media
   1. Air
   2. Water
   3. Oil
   4. Other

C. Temperature recording instruments
   1. Automatic
   2. Non-automatic

Period #19

Lecture on other methods of hardening

A. Carborizing
B. Case hardening
C. Cyaniding
D. Nitriding

Period #20

Quiz.

Period #21

Lecture on safety and safety appliances used in forge shops.

Period #22

Lecture on mechanical forging equipment
- A. Hammers and cleaning presses
  1. Board drop hammer
  2. Steam hammer
  3. Mechanical hammer

- B. Punches and shears

Period #23

Lecture on mechanical forging equipment
- A. Presses
  1. Cold forming
  2. Hot forming

- B. Grinders
- C. Slacking presses

Period #24

Lecture on auxiliary equipment used with power forging.
- A. Tools and dies
- B. Furnaces
- C. Handling equipment

Period #25

Lecture on national forging machine.

Period #26

Lecture on dies
- A. Materials
- B. Kind of forging
- C. Heat treatment

Period #27

Lecture on other methods of forming
- A. Extrusion
- B. Drawing
- C. Rolling

Period #28

Quiz.

Laboratory Period #1

Inspection of laboratory and demonstration of tools.

Laboratory Period #2

Demonstration and practice in building and maintaining correct forge fires.

Laboratory Period #3

Demonstration and practice in bending and forming.

Laboratory Period #4

Demonstration and practice in drawing out, upsetting and offsetting.

Laboratory Period #5

Demonstration and practice in punching and riveting.

Laboratory Period #6

Demonstration and practice in forge welding.

Laboratory Period #7

Practice in forging simple shape.

Laboratory Period #8

Practice in forging shape involving forge welding.

Laboratory Period #9

Demonstration and practice in gas welding.

Laboratory Period #10

Demonstration and practice in gas welding and cutting.

Laboratory Period #11

Demonstration and practice in arc welding.

Laboratory Period #12

Practice in arc welding.

Laboratory Period #13

Demonstration of annealing, hardening and drawing. Practice in making cold chisel.

Laboratory Period #14

Demonstration and practice in other methods of hardening.

Laboratory Period #15

Demonstration of steam and mechanical hammer in forging.

Laboratory Period #16

Demonstration of board drop hammer and cleaning press.

Laboratory Period #17

Demonstration and inspection of auxiliary equipment, furnaces, tools and dies, etc.

Laboratory Period #18

Inspection and cleaning forgings.

IV. GENERAL DISCUSSION

One of the first problems a young engineer faces when he goes to work is that of safety. Some colleges have regular safety courses. There is no such course offered at V. P. I. nor is the subject touched on in the other courses. Every industrial concern has its safety department and safety engineers. Because safety is important, one lecture period in each of the three courses is devoted to safety and safety devices. This will bring the subject before the student and he can be thinking along these lines the rest of his college career and will not be astounded when he is confronted with the subject after he gets a job.

It is recommended that ten minute quizes be given at intervals on the work which has preceded. The quizes combined with tests will serve as a guide of what a student is learning. They will keep him thinking and on his toes, thus he will be more apt to learn the theory to be applied. The quizes and tests should cover the practical as well as the theoretical work.

While it is realized that the civil, mining, chemical, metallurgical and ceramic engineering curricula are not as closely allied to industry as are the mechanical, industrial and electrical engineering curricula, they should have some shop work included. Many of the graduates of civil, mining, chemical, metallurgical and ceramic engineering curricula find their way into industrial organizations. Shop courses would prove of great value to such men.

V. FINAL SUMMARY

A. General Conclusions

1. The objectives of shop courses are:
   - (a) To gain a knowledge of materials
   - (b) To gain a knowledge of shop operations and technique
   - (c) To gain a knowledge of production and management methods

2. The aim of shop courses is not to develop manual skill but is to enable students to better understand how to apply theory.

3. Shop courses should come under four main headings:
   - (a) Melting and casting metals
   - (b) Forging and related treatments
   - (c) Machining
   - (d) Design and economics of manufacturing

4. Shop courses should be closely coordinated with other courses.

5. Shop courses should be a combination of lectures and laboratory demonstration and practice.

6. Where possible it is desirable to have a short introductory shop course in the freshman year, with actual shop practice in the second and third years, followed by the economic and production phases the senior year.

7. Some shop work should be required in the following curricula at V. P. I.:

   (a) Mechanical Engineering
   (b) Electrical Engineering
   (c) Industrial Engineering
   (d) Chemical Engineering
   (e) Civil Engineering
   (f) Mining Engineering
   (g) Ceramic Engineering
   (h) Agricultural Engineering
   (i) General Engineering

B. Machine Shop

1. Equipment of lecture and demonstration room would increase the effectiveness of the course.

2. The use of the operation sheets would save time for the students and allow more work to be given.

3. It will be unnecessary to keep a man in the store room all of the laboratory period.

4. Partition off two bays of shop; would increase work done by students and aid in repair work.

5. Rearrange equipment; would aid in increasing the effectiveness of the machine shop course.

6. Install travelling ladder in lathe line to facilitate oiling and repairs, and paint or furnish shades for southwest windows if present layout is to be kept.

7. Equip every student with high speed steel round nose and threading tools and holder.

8. Put small shop built shaper in condition.

9. Make sky lights movable.

10. Equip air compressor with automatic switch.

11. Install millwrighting course to be given, in the summer between sophomore and junior years or in the junior year.

12. Follow course as outlined or some definite plan of attack.

C. Foundry

1. Build moulding table to increase practical work done in moulding.

2. Have students clean, inspect and study defects of castings.

3. Have students study moulding sands.

4. Install course in pattern design, to be held in drawing room.

5. Follow course as outlined, or some definite plan.

D. Forge Shop

1. Decrease amount of hand forging done.

2. Put power forging equipment in operating condition.

3. Purchase preheating furnace.

4. Purchase national forging machine.

5. Install gas welding equipment.

6. Demonstrate and lecture on arc, spot and thermit welding.

7. Follow course as outlined.

APPENDIX I.

A. Literature Cited

1. "Purpose and Scope of Shop Courses". By O. W. Boston, J. Eng. Educ. 20:248-67. February 1930.

2. "Mechanical Engineering Curriculum, Summary of Replies to a Questionnaire Sent to Five Hundred Members of the A. S. M. E." By J. T. Harrington. Mechanical Engineering, 48 : 201 - 204, March 1926.

3. "Summarized Report of Shop Study." By R. L. Sweigert, Georgia School of Technology, November 1930.

4. "A Summary of Opinions Concerning Engineering Curricula." J. Eng. Educ. 17 : 380, 390 - 391, December 1926. (Original, Bulletin #9 of the Investigation of Engineering Education, not seen).

5. "Opinions of Professional Engineers Concerning Educational Policies and Practices." J. Eng. Educ. 18 : 248, 252, 258, 265 - 266. (Original, Bulletin #13 of the Investigation of Engineering Education, not seen.)

6. "Curriculum Revision in The Light of the Board's Recommendations." By W. E. Wickenden, J. Eng. Educ. 17 : 800 - 801, April 1927.

B. Other Literature Reviewed

Journal of Engineering Education:

Vol. 17:	pages	551 - 85,	February 1927
Vol. 18:	"	907-- 39,	June 1928
Vol. 20:	"	757 - 74,	March 1930
Vol. 20:	"	830 - 40,	April 1930
Vol. 20:	"	448-- 60,	June 1930
Vol. 21:	"	504 - 06,	March 1931
Vol. 22:	"	806 - 39,	June 1932
Vol. 23:	"	309 - 21,	January 1933
Vol. 23:	"	427 - 37,	February 1933
Vol. 23:	"	442 - 57,	February 1933
Vol. 23:	"	753 - 61,	June 1933

"Recommended Course in Foundry Practice for Engineering Schools." American Foundrymen's Association.

"Course and Equipment Organization for Welding." By George B. Cox. Oregon State College of Engineering.

Books

Richards, Wm. H. -- "Principles of Pattern and Foundry Practice." McGraw-Hill Book Co., New York. 1930.

Bacon, J. L. -- "Forge Practice and Heat Treatment of Steel." John Wiley and Sons, Inc., New York. 1919.

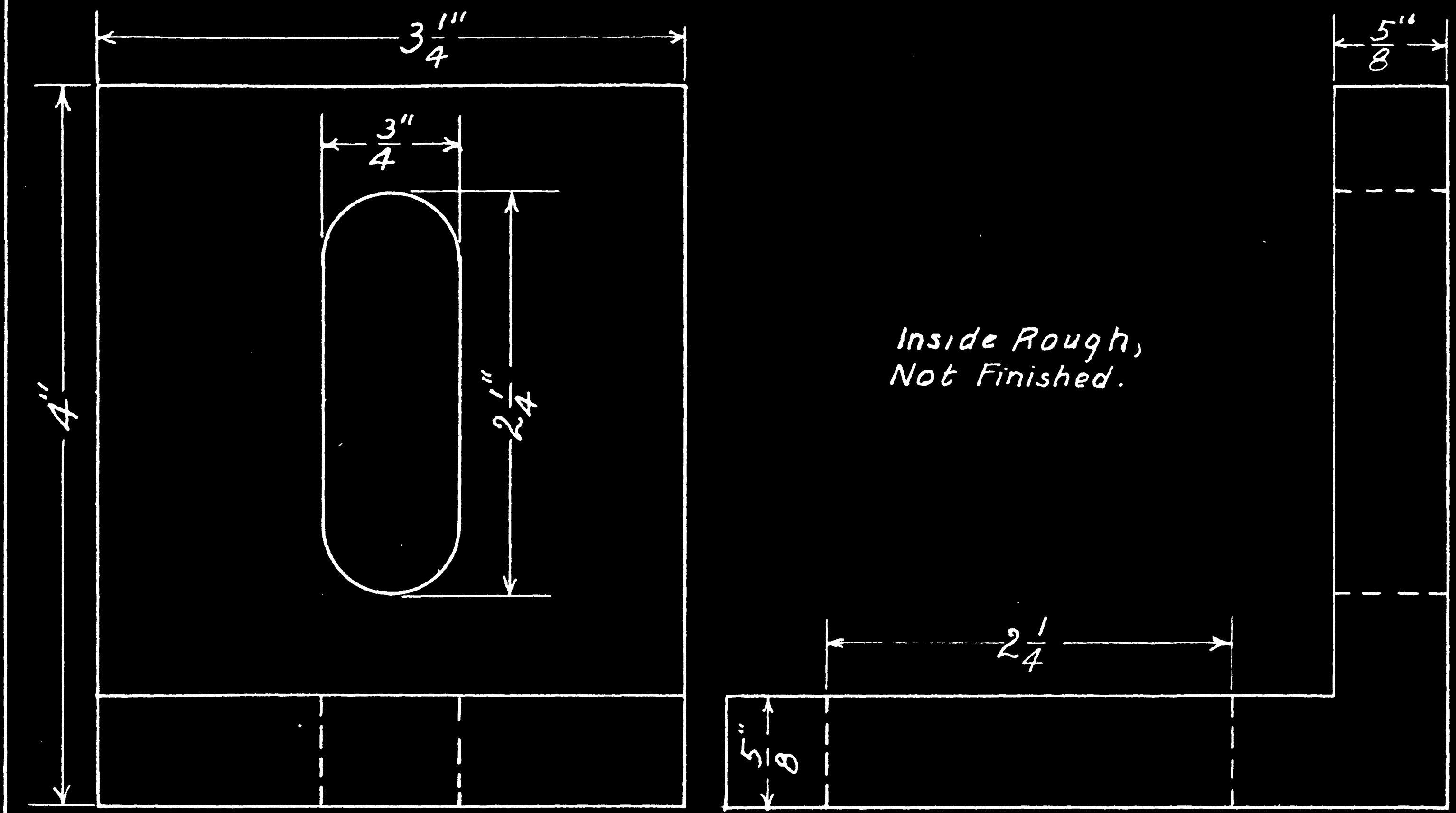
Roe, Joseph W. -- "The Mechanical Equipment." Industrial Extension Institute, Inc., New York. 1932.

Smith, Robert H. -- "Advanced Machine Work." Industrial Education Book Co., Boston. 1915.

APPENDIX 2.

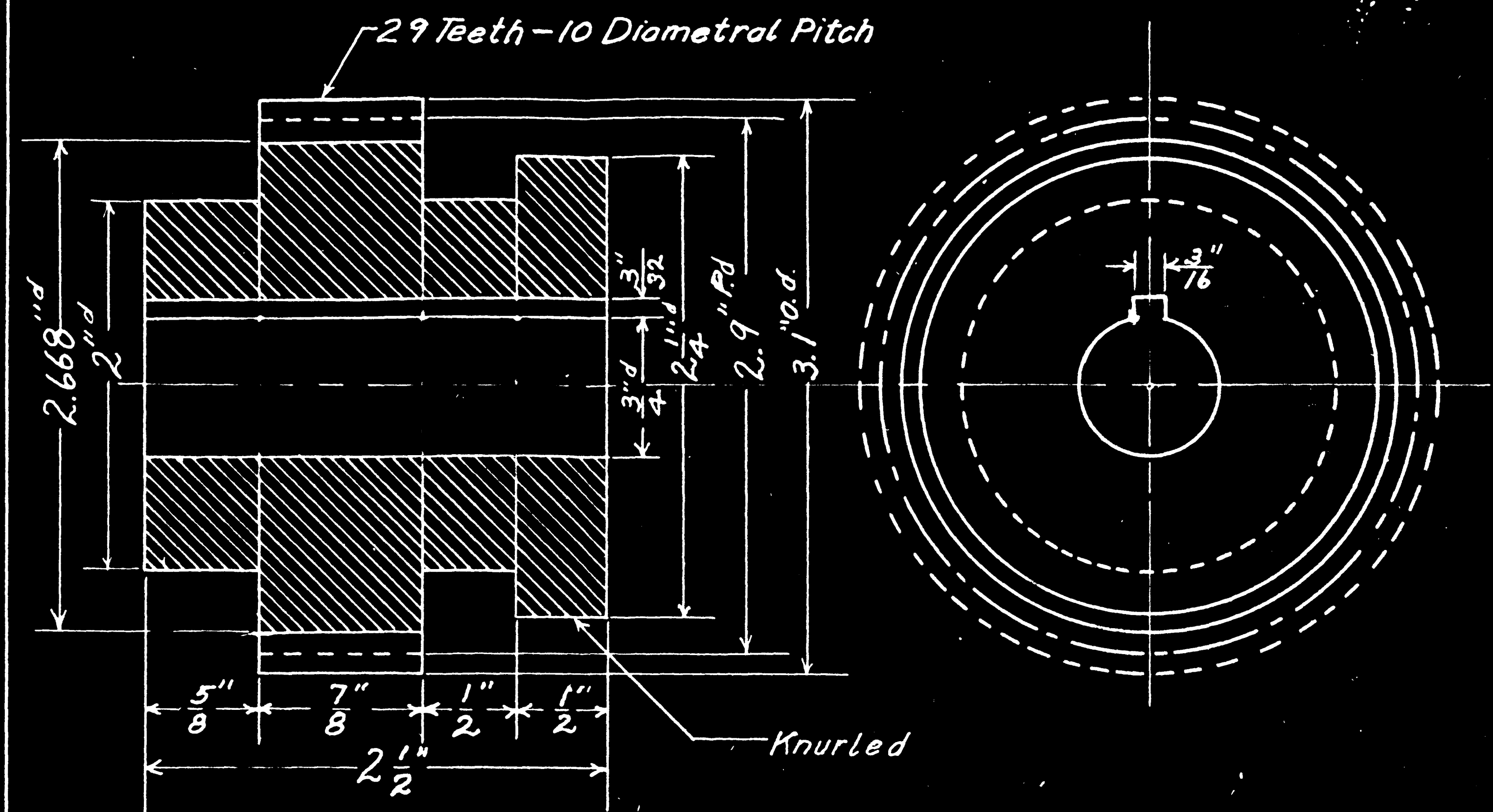
Work sheets to be used in the Machine Shop Course.

V.P.I. Ind. Eng. Dept.
Shop Exercise No.-
Name- Angle.
Material- Cast Iron.



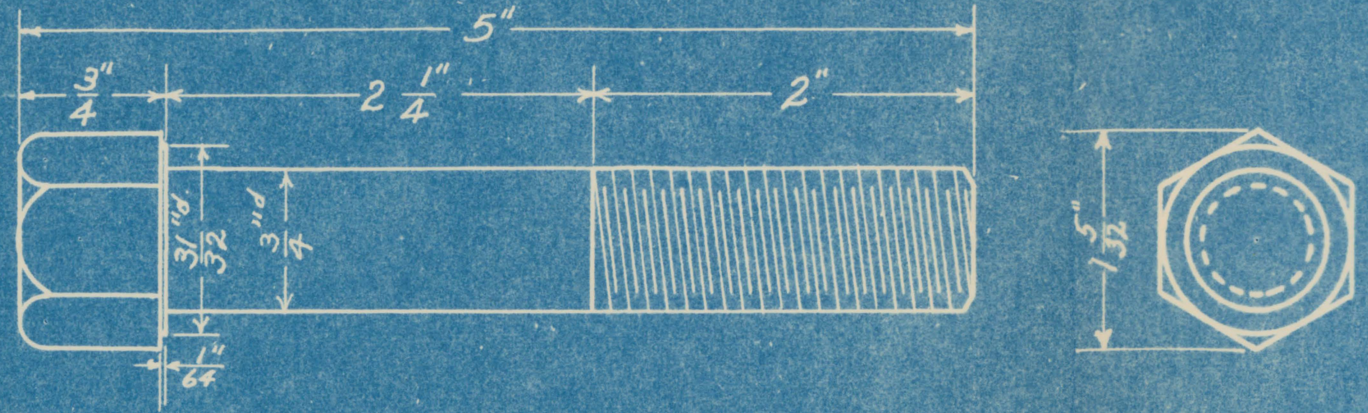
Operation	Tools	Speed	Feed	Time
No.1. Shape Outside Dimensions	Shaper, Square, Scale, Chalk + Scriber.			
No.2. Layout Slots, Centered In Each Leg.	Chalk, Scale, Square + Scriber.			
No.3. Drill Three - 3/4" Holes For Each Slot	Drill Press, 1/4" + 3/4" Drills.			
No.4. Chip Slots	Hammer + Cold Chisel + Vice.			
No.5. File Slots.	Vice + Files.			

V.P.I. Ind. Eng. Dept.
Shop Exercise No.-
Name- Planer Slip Gear.
Material- Cast Iron.



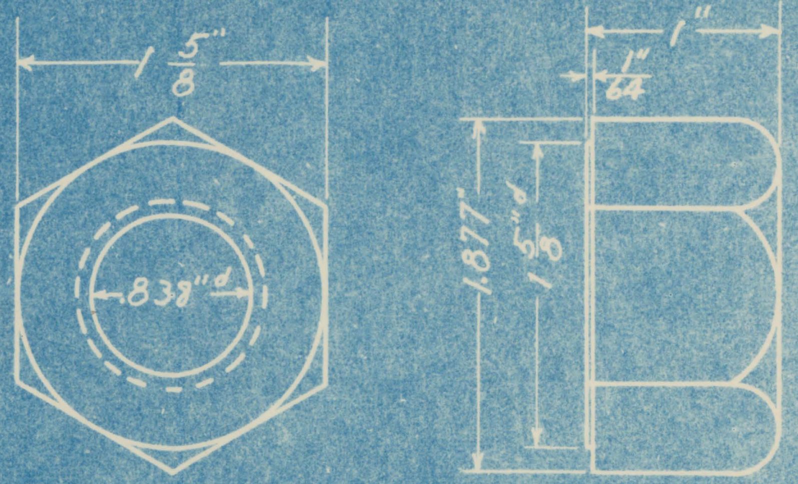
Operation	Tools	Speed	Feed	Time
No.1. Chuck + Face End	Lathe, Chuck + Rd. Nose Tool.			
No.2. Center + Drill	Lathe, Centering Tool + 11/16" Drill.			
No.3. Bore Hole to 3/4"	Lathe, Boring Tool, Scale + Inside Calipers.			
No. 4. Turn Outside to Size.	Lathe, Mandrel, Dog, Rd. Nose Tool, Outside Calipers + Scale.			
No. 5. Face Sides.	Lathe, Mandrel, Dog, Facing Tool + Scale.			
No. 6. Knurl Grip.	Lathe, Knurling Tool.			
No. 7 Layout Keyway	Scale, Scriber, Copper Sulfate			
No. 8 Cut Keyway	Slotter + Jig.			

V.P.I. Ind. Eng. Dept.
Shop Exercise No.-
Name - Cap Screw
Material - Machine Steel.



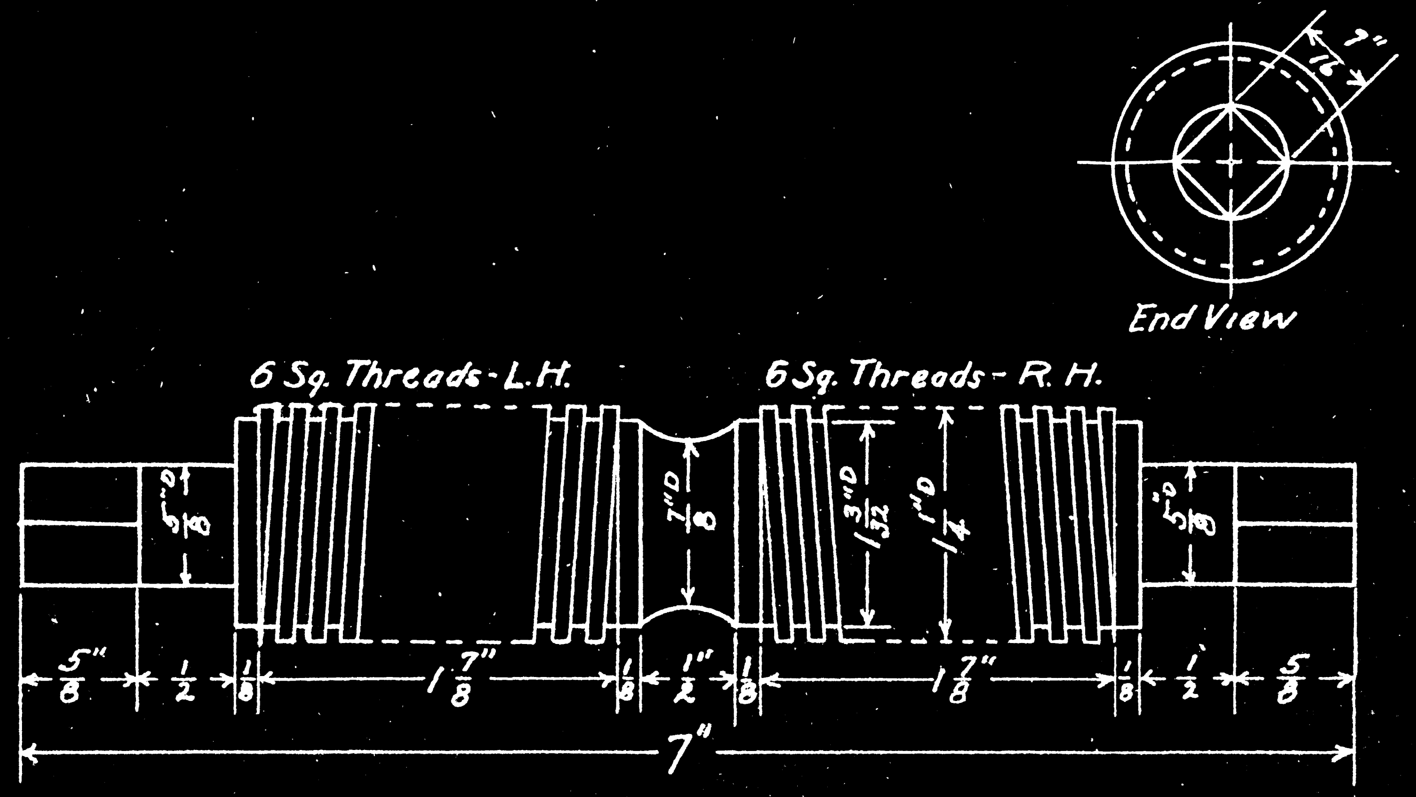
Operation	Tools	Speed	Feed	Time
No. 1. Center	Hammer, Center Punch, Speed Lathe, Drill + Counter-Sink			
No. 2. Face To Length	Lathe, Dog, Facing Tool + Scale.			
No. 3. Turn Outside Dimensions	Lathe, Dog, Rd. Nose + Facing Tools, Outside Calipers + Scale.			
No. 4. Thread-U.S. Standard 10 Per Inch.	Lathe, Dog, Thread Tool + Gage + Nut.			
No. 5. Mill Hex Head	Milling Machine + End Mill			
No. 6. Curve Head + Turn Shoulder 1/64"	Lathe, Dog, Thread + Facing Tools, Outside Calipers + Scale.			

V.P.I. Ind. Eng. Dept.
Shop Exercise No.-
Name - Nut.
Material - Brass.



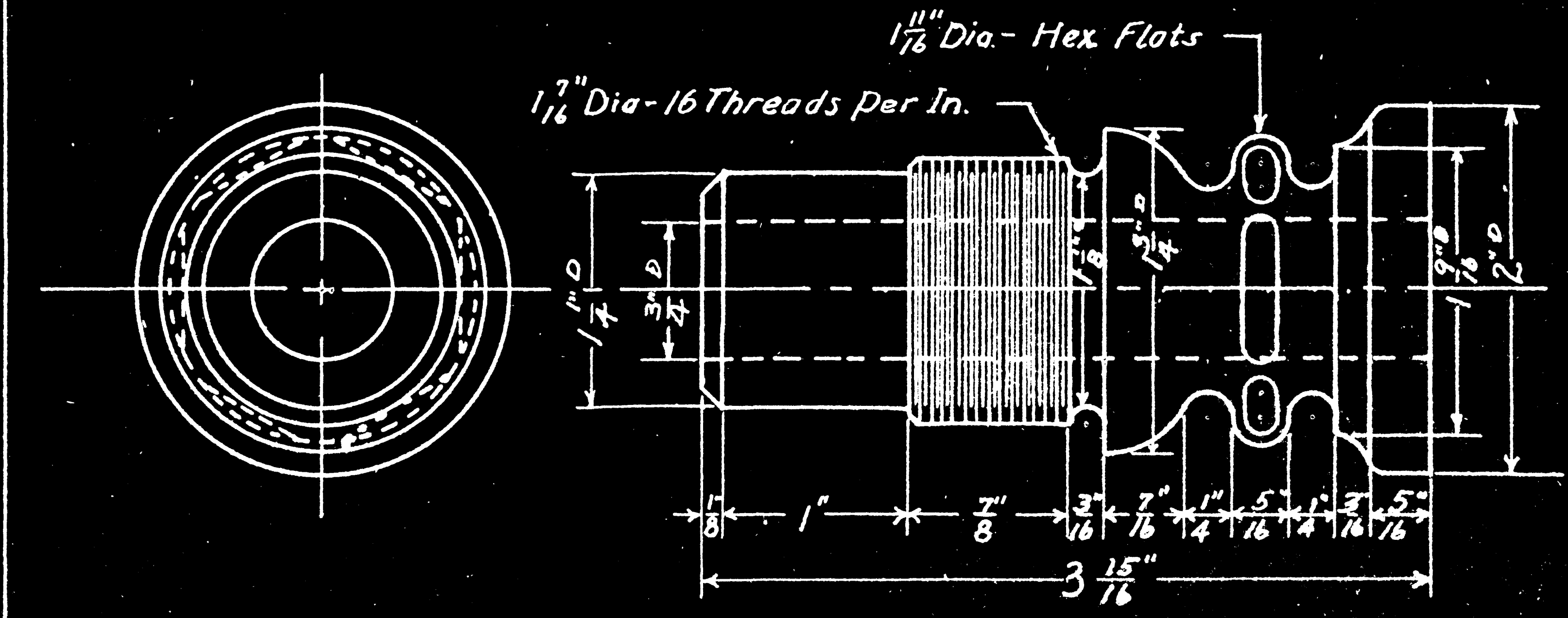
Operation	Tools	Speed	Feed	Time
No. 1. Chuck + Face End	Lathe, Chuck + Rd. Nose Tool			
No. 2. Center + Drill	Lathe Centering Tool + 3/4 Drill			
No. 3. Bore Hole	Lathe, Boring Tool, Inside Calipers + Scale.			
No. 4. Thread-U.S. Standard 8 Per Inch.	Lathe, Inside Thread Tool + Gage, Threaded Mandrel.			
No. 5. Turn Outside.	Lathe, Threaded Mandrel, Dog, Rd. Nose Tool, Scale + Outside Calipers.			
No. 6. Mill Hex. Flats	Milling Machine + End Mill			
No. 7. Curve Top + Turn 1/64" Shoulder.	Lathe, Threaded Mandrel, Dog, Thread + Facing Tools + Scale			

V.P.I. Ind. Eng. Dept.
Shop Exercise No.-
Name- Chuck Screw.
Material-Cast Iron.



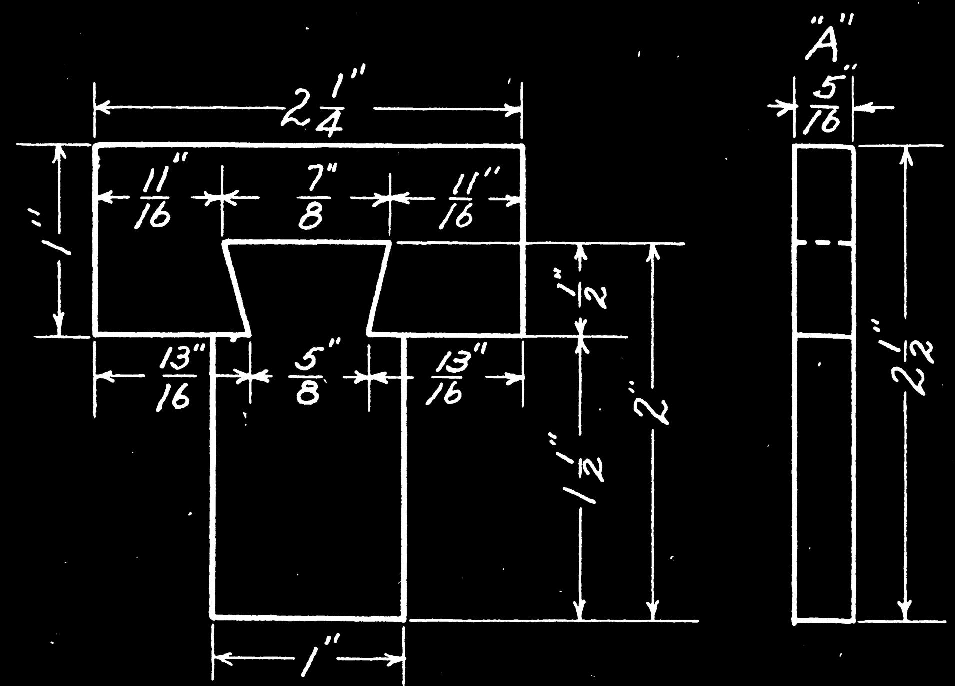
Operation	Tools	Speed	Feed	Time
No.1. Center	Center Punch, Hammer Speed Lathe, Drill + Counter-Sink			
No.2. Face to Length	Lathe, Dog, Facing Tool + Scale.			
No.3. Turn to Size.	Lathe, Dog Rd. Nose + Facing Tools, Scale + Outside Calipers			
No.4. Thread As Shown.	Lathe, Dog, Square Thread Tool + Scale.			
No.5. Mill Ends	Milling Machine, End Cutter.			

V.P.I. Ind. Eng. Dept.
Shop Exercise No.-
Name- Cross Feed Screw Bearing.
Material- Cast Iron.



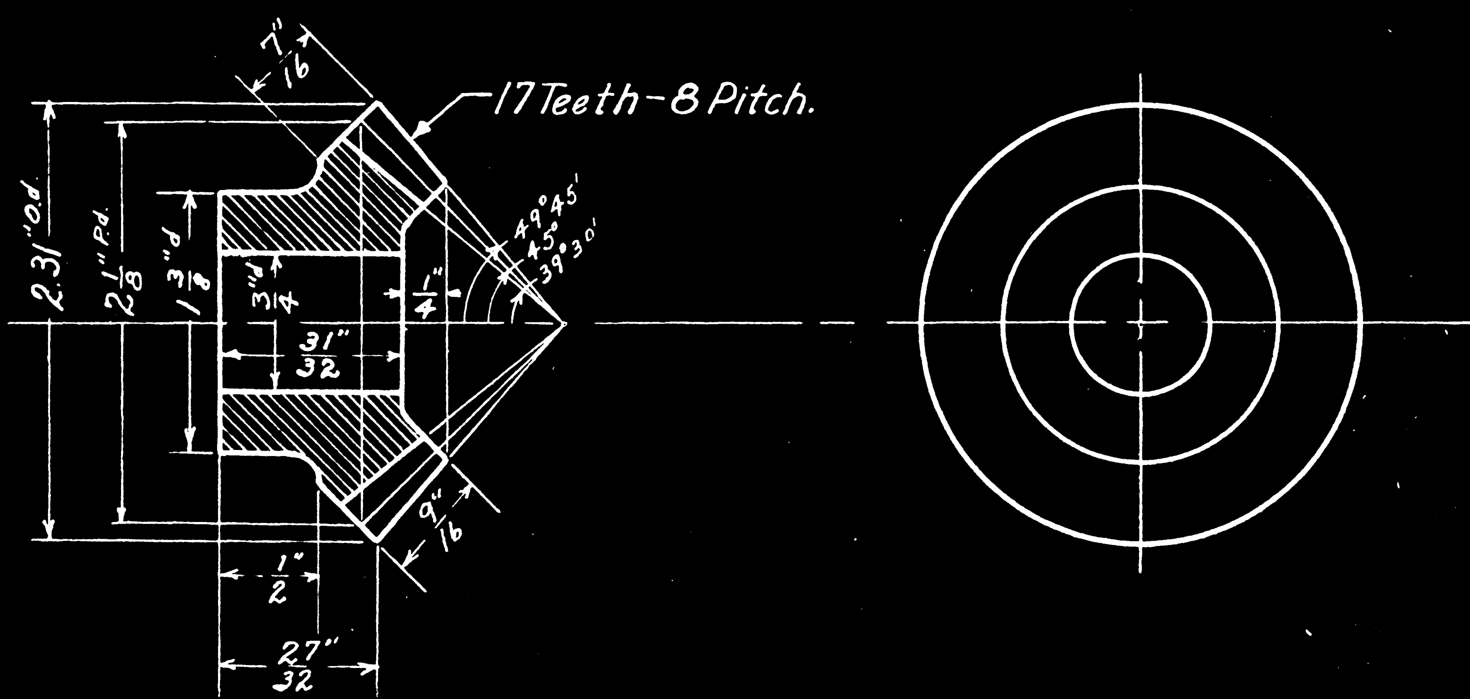
Operation	Tools	Speed	Feed	Time
No.1. Chuck + Face End.	Lathe, Chuck + Rd. Nose Tool.			
No.2. Center + Drill	Centering Tool + $\frac{11}{16}$" Drill			
No.3. Bore Hole	Lathe, Boring Tool, Inside Calipers + Scale, Mandrel.			
No.4. Turn Outside.	Lathe, Mandrel, Dog, Rd. Nose + Facing Tools, Outside Calipers. Scale.			
No.5. Thread-16 per Inch.	Lathe, Mandrel, Dog, Thread (V) Tool + Gage, Scale.			
No.6. Face to Length.	Lathe, Mandrel, Dog, Facing Tool + Scale.			
No.7. Mill Hex. Flats	Milling Machine, End Cutter.			

V.P.I. Ind. Eng. Dept.
Shop Exercise No.-
Name- Dove Tail.
Material- Cast Iron.



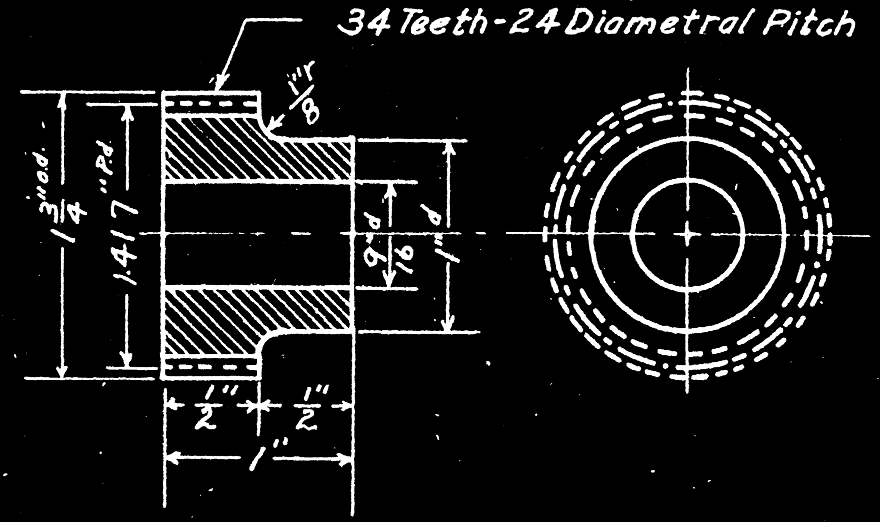
Operation	Tools	Speed	Feed	Time
No. 1. Shape Outside. Leave "A" 1/32" Oversize For Grinding.	Shaper, Chalk, Scale, Square, Scriber.			
No. 2. Lay Out.	Copper Sulfate, Square, Scale, Scriber.			
No. 3. File Fit.	Vice, Copper Jaws + Files.			
No. 4. Grind.	Grinder + Magnetic Chuck.			

V.P.I. Ind. Eng. Dept.
Shop Exercise No.-
Name.- Bevel Gear.
Material- Cast Iron.



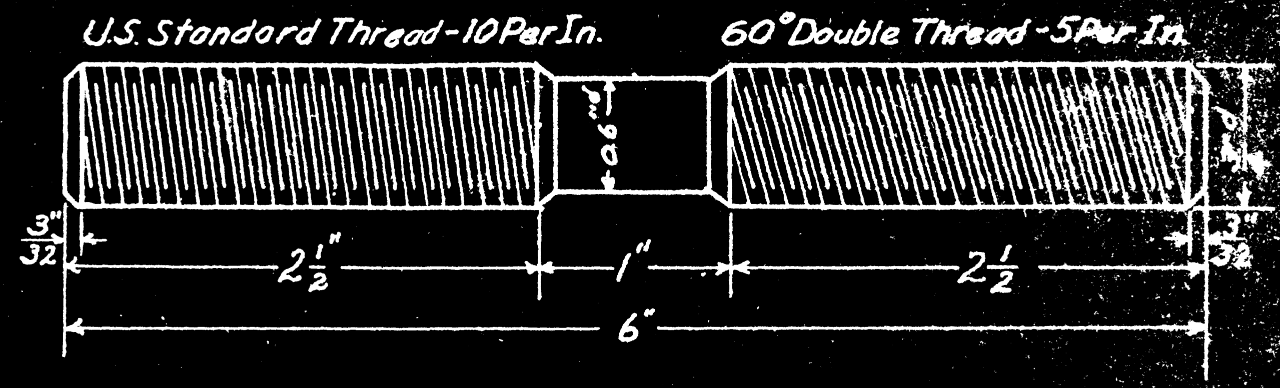
Operation	Tools	Speed	Feed	Time
No. 1. Chuck + Face End	Lathe, Chuck + Rd. Nose Tool			
No. 2. Drill Hole.	Lathe, Centering Tool + 11/16" Drill			
No. 3. Bore Hole.	Lathe, Boring Tool, Scale + Inside Calipers			
No. 4. Turn To Size.	Lathe, Mandrel, Dog, Rd. Nose + Facing Tools Scale, Outside Calipers.			
No. 5. Cut Teeth - 17-8P.	Bilgram Gear Shaper.			

V.P.I. Ind. Eng. Dept.
Shop Exercise No.-
Name- Pinion
Material - Cast Iron



Operation	Tools	Speed	Feed	Time
No. 1. Chuck + Face End. (Big End In Chuck)	Lathe, Chuck + Rd Nose Tool.			
No. 2. Center + Drill.	Lathe, Centering Tool + 1/2" Drill.			
No. 3. Bore Hole.	Lathe, Boring Tool, Scale + Inside Calipers.			
No. 4. Face Ends.	Lathe, Mandrel, Dog, Facing Tool + Scale.			
No. 5. Turn To Size.	Lathe, Mandrel, Dog, Rd. Nose Tool, Outside Calipers + Scale.			
No. 6. Cut Teeth	Milling Machine + Cutter.			

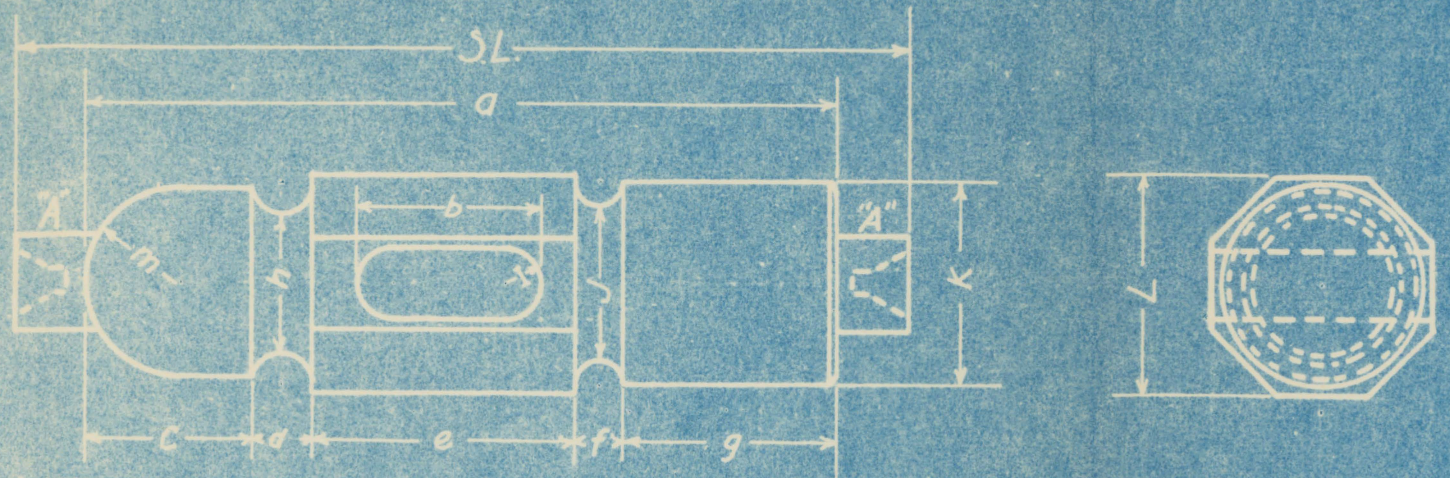
V.P.I. Ind. Eng. Dept.
Shop Exercise No.-
Name- Stud Bolt
Material- Machine Steel.



Operation	Tools	Speed	Feed	Time
No. 1. Center.	Hammer, Center Punch, Speed Lathe, Drill + Counter-sink.			
No. 2. Face Ends.	Lathe, Dog, Scale + Facing Tool.			
No. 3. Turn To Size	Lathe, Dog, Rd. Nose Tool, Scale + Outside Calipers.			
No. 4. Thread-U.S. Standard.	Lathe, Dog, U.S. Stand. Tool.			
No. 5. Thread-60° Double	Lathe, Dog, 60° Tool + Gage.			

V.P.I. Ind. Eng. Dept.

Shop Exercise No-
Name- Hammer
Material- Tool Steel

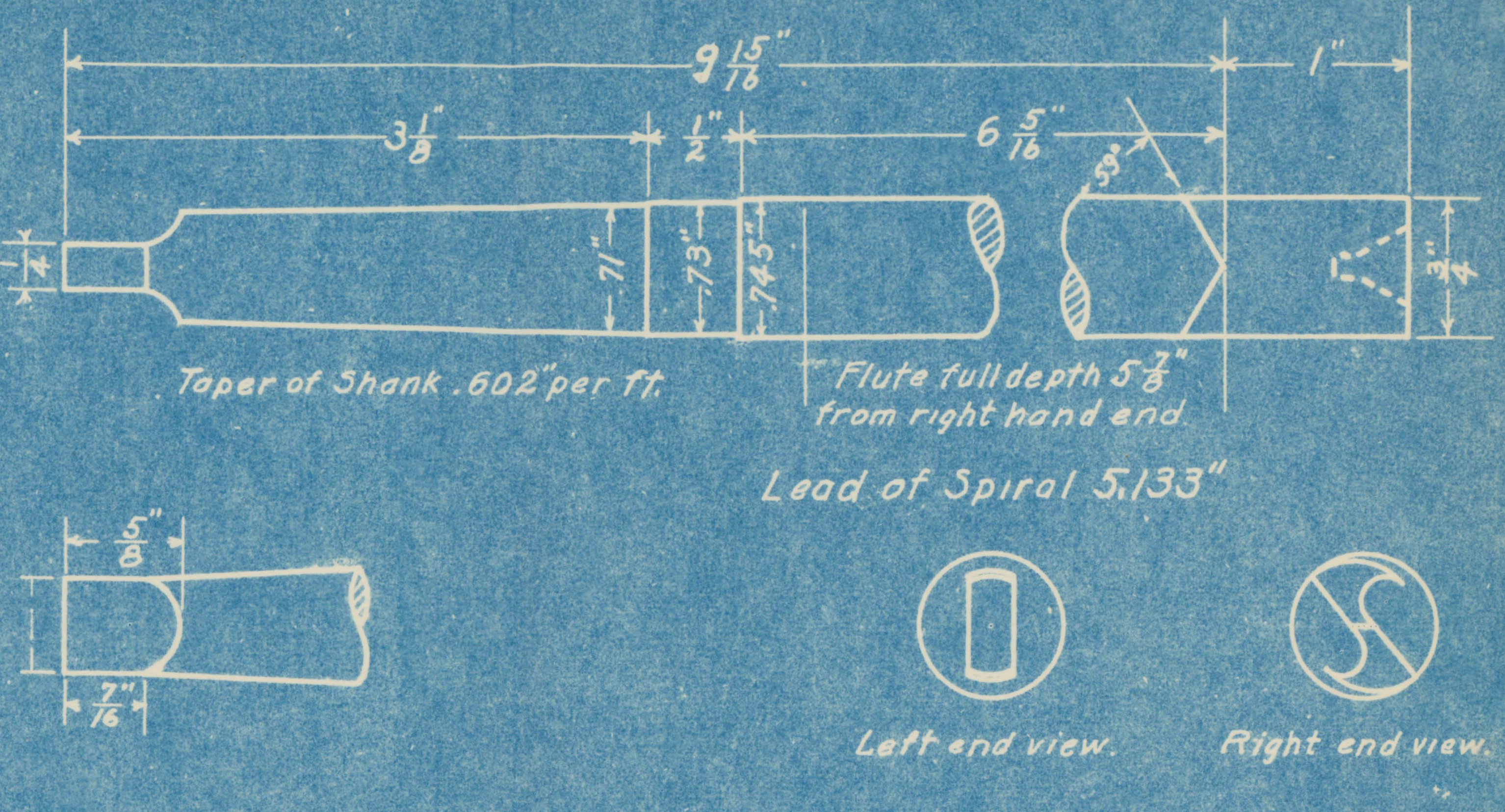


Dimensions														
Size	S.L	a	b	c	d	e	f	g	h	I	J	K	L	m
1	5"	$4\frac{1}{8}$"	1"	$\frac{15}{16}$"	$\frac{5}{16}$"	$1\frac{7}{16}$"	$\frac{5}{16}$"	$1\frac{1}{8}$"	$\frac{13}{16}$"	$\frac{7}{32}$"r	1"	$1\frac{5}{16}$"	$1\frac{7}{16}$"	Variab.
2	$4\frac{3}{4}$"	4"	$\frac{7}{8}$"	$\frac{7}{8}$"	$\frac{5}{16}$"	$1\frac{3}{8}$"	$\frac{1}{4}$"	$1\frac{1}{8}$"	$\frac{23}{32}$"	$\frac{3}{16}$"r	$\frac{27}{32}$"	$1\frac{1}{16}$"	$1\frac{5}{32}$"	"
3	$3\frac{7}{8}$"	$3\frac{5}{8}$"	$\frac{3}{4}$"	$\frac{11}{16}$"	$\frac{1}{4}$"	$1\frac{1}{16}$"	$\frac{1}{4}$"	$\frac{11}{16}$"	$\frac{1}{2}$"	$\frac{5}{32}$"r	$\frac{5}{8}$"	$\frac{13}{16}$"	$\frac{7}{8}$"	"

Operation	Tools	Speed	Feed	Time
No.1 Center	Hammer, Center Punch, Speed Lathe, Drill + Center Punch + Counter-Sink			
No.2 Face Ends Leaving "A" $\frac{3}{8}$" Dia.	Lathe, Dog, Facing Tool + Scale.			
No.3 Turn Outside Dia. of c, d, f + g.	Lathe, Dog, Rd. Nose Tool, Outside Calipers + Scale.			
No. 4 Mill Octagon	Milling Machine + End Cutter.			
No.5 Cut Off "A"	Hack Saw			
No.6 Lay Out Eye	Copper Sulfate, Dividers, Scale, Scriber, Hammer + C.P.			
No.7 Drill Eye	Drill Press, Small + Large Drills + Plug			
No.8 File Eye	Files			
No.9 Polish	Speed Lathe, Files + Emery Cloth			
No.10 Harden + Temper	Furnace + Quenching Tank.			

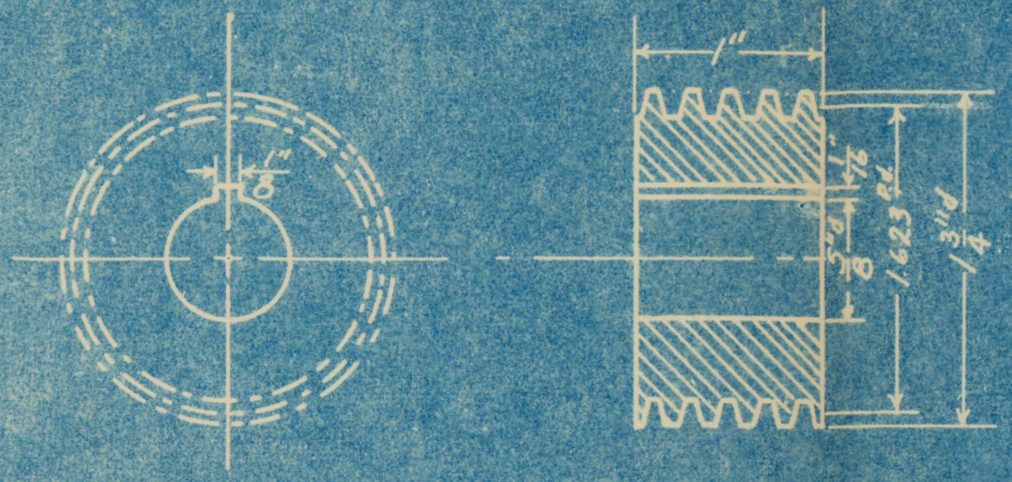
V.P.I. Ind. Eng. Dept.

Shop Exercise No.-
Name- Twist Drill
Material- Tool Steel



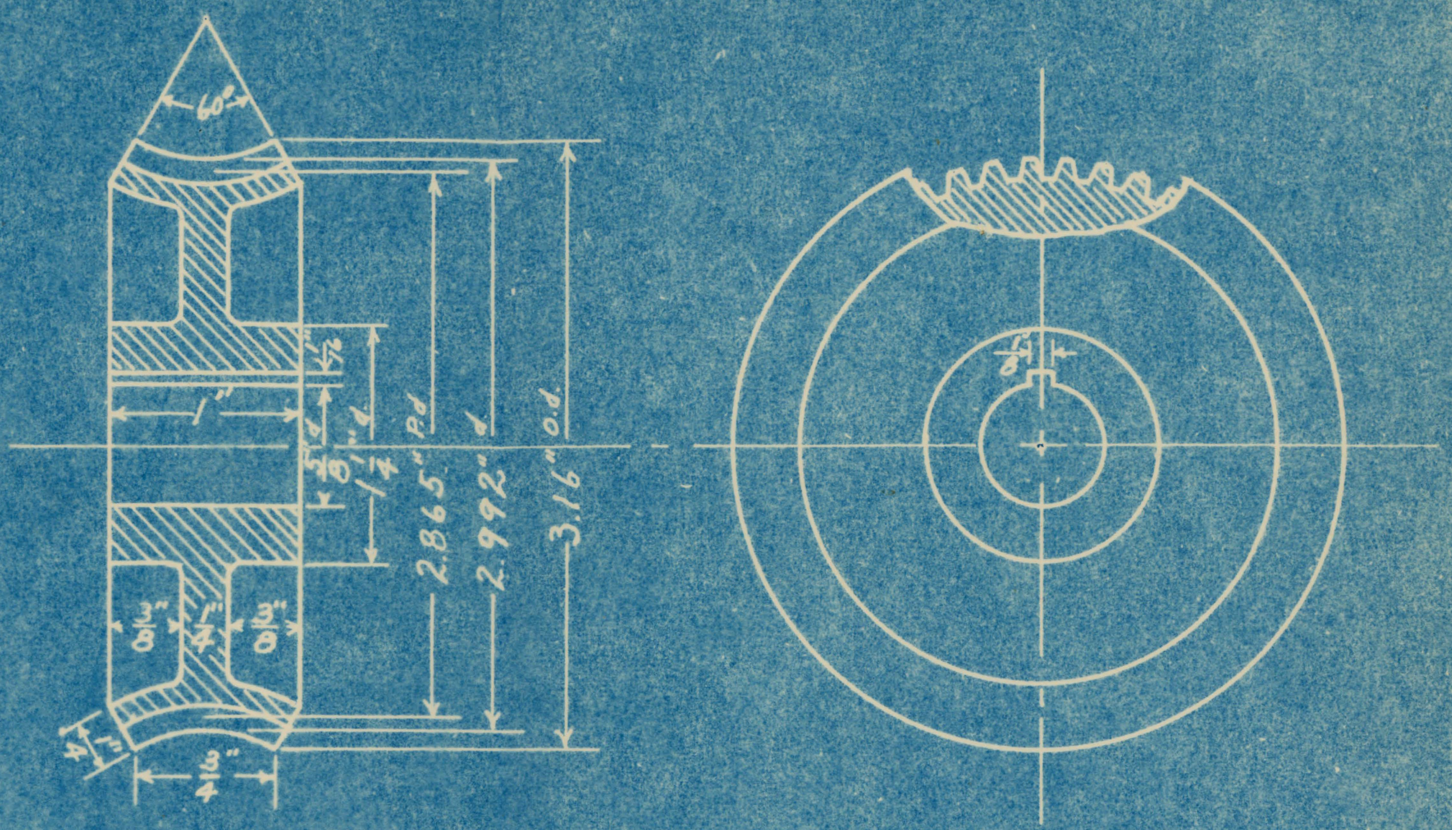
Operation	Tools	Speed	Feed	Time
No.1. Center.	Hammer, Center Punch, Speed Lathe, Drill + Counter Sink			
No.2. Face Both Ends	Lathe, Dog + Facing Tool			
No.3. Turn to 3" O.D.	Lathe, Dog, Rd. Nose Tool, Scale, + Outside Calipers.			
No.4. Taper Shank.	Same Tools as Operation #3			
No.5. Turn $\frac{1}{2}$" Recess	Lathe, Dog, Rd. Nose + Facing Tools, Scale + Outside Calipers.			
No.6. Polish	Speed Lathe, File + Emery Cloth			
No.7. Cut Flutes + Clearence.	Milling Machine, End Mill + Drill Cutter			
No.8. Mill Shank.	Milling Machine + End Mill.			
No.9. Cut to Length	Hack Saw + Scale.			
No.10. Point	Drill Grinder.			

V.P.I. Ind Eng. Dept.
Shop Exercise No-
Name- Worm.
Material- Cast Iron.



Operation	Tools	Speed	Feed	Time
No.1. Chuck + Face End	Lath. Chuck + Rd. Nose Tool.			
No.2. Drill Hole	Lathe, Center Tool + 9/16" Drill			
No.3. Bore Hole to 5/8"	Lathe, Boring Tool, Inside Calipers + Scale			
No. 4. Turn to Size.	Lathe, Mandrel, Dog, Rd. Nose + Facing Tools, Calipers + Scale			
No. 5 Thread- 5 per In	Lathe, 29° Thread Tool.			
[illegible]	[illegible]			
No. 7 Lay Out	Scale, Scriber, Copper Sulfate			
No. 8 Cut Keyway	Slotter + Jig.			

V.P.I. Ind. Eng. Dept.
Shop Exercise No-
Name- Worm Wheel.
Material- Cast Iron.



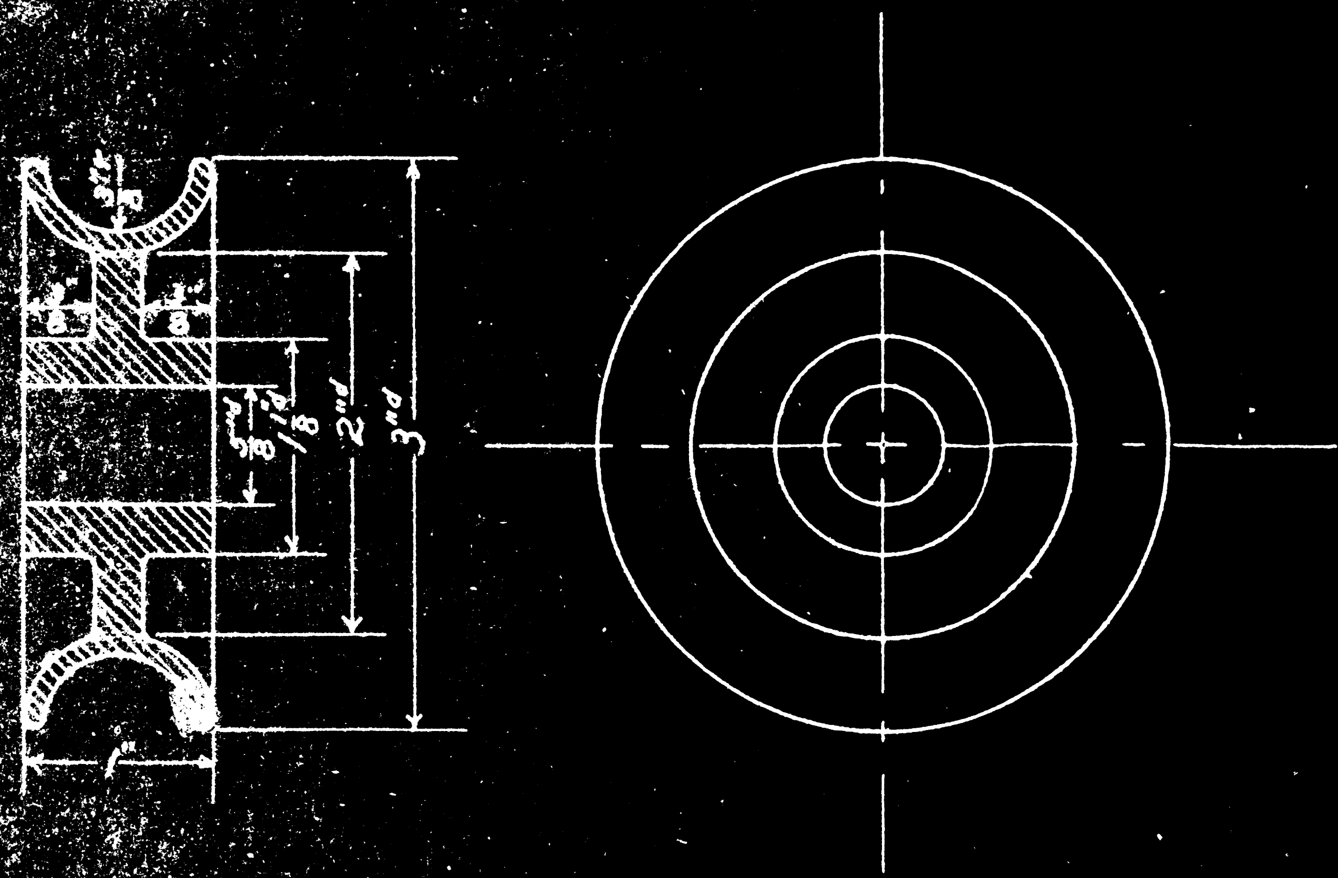
Operation	Tools	Speed	Feed	Time
No.1. Chuck + Face End	Lathe, Chuck + Rd. Nose Tool			
No.2. Drill Hole	Lathe, Centering Tool + 9/16" Drill			
No.3. Bore Hole.	Lathe, Boring Tool, Inside Calipers + Scale.			
No.4. Turn to Size.	Lathe, Dog, Mandrel, Rd. Nose Tool, Facing Tool, Outside Calipers + Scale.			
No.5. Turn Throat.	Lathe, Forming Tool, Outside Calipers + Scale.			
No.6. Turn 3/8 Recess	Lathe, Forming Tool, Outside Calipers + Scale.			
No.7. Cut Teeth, 45-15 Circular Pitch	Milling Machine + Cutter.			
No.8. Hob Teeth.	Milling Machine + Hob			
No.9. Layout Keyway.	Scale, Scriber + Copper Sulfate			
No. 10. Cut Keyway.	Slotter + Jig.			

V.P.I. Ind. Eng. Dept.

Shop Exercise No.-

Name- Rope Pulley.

Material- Cast Iron.



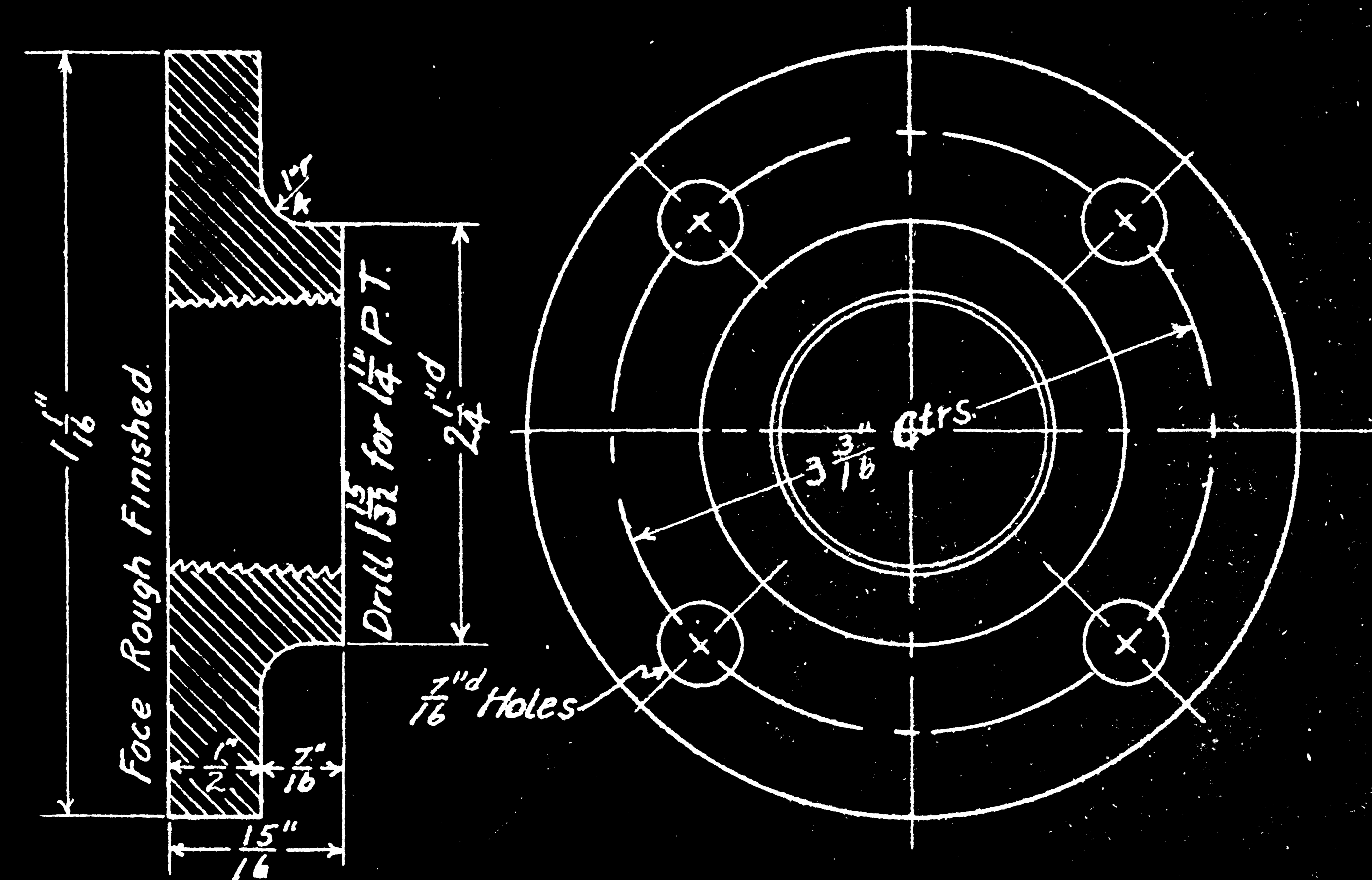
Operation	Tools	Speed	Feed	Time
No.1- Chuck + Face Side	Lathe, Chuck + Rd. Nose Tool.			
No.2- Drill	Lathe, Chuck + 9/16" Drill.			
No.3- Bore 5/8" Dia.	Lathe, Chuck, Boreing Tool, Inside Calipers + Scale.			
No.4- Turn to Size	Lathe, Mandrel, Dog, Rd. Nose Tool, Calipers + Scale.			
No.5- Turn 3/16" r Groove	Lathe, Special Forming Tool, Calipers + Scale.			
No.6- Turn 3/16" Recesses On Each Side.	Lathe, Special Right + Left Hand Forming Tools, Scale, Calipers.			
No.7- Polish	Speed Lathe, File + Emery Cloth.			

V.P.I. Ind. Eng. Dept.

Shop Exercise No.-

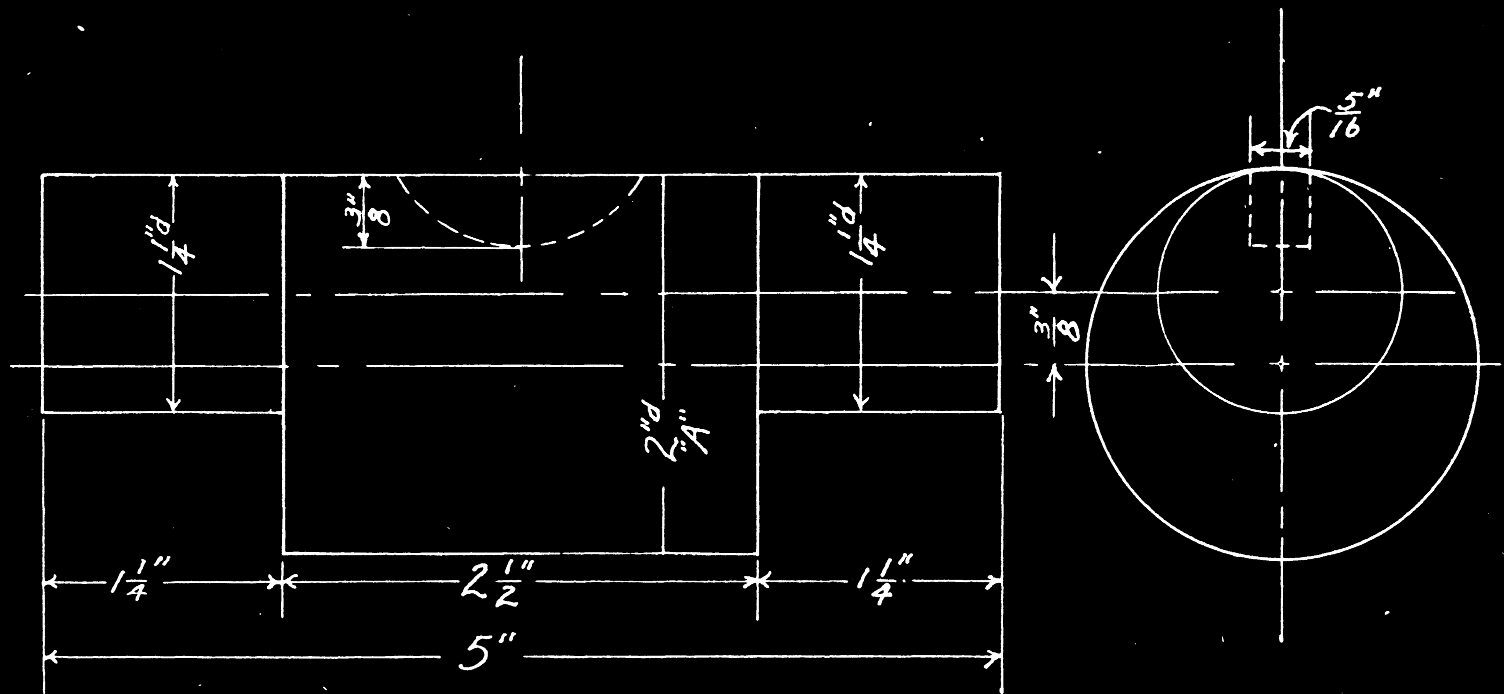
Name- Flange.

Material- Cast Iron.



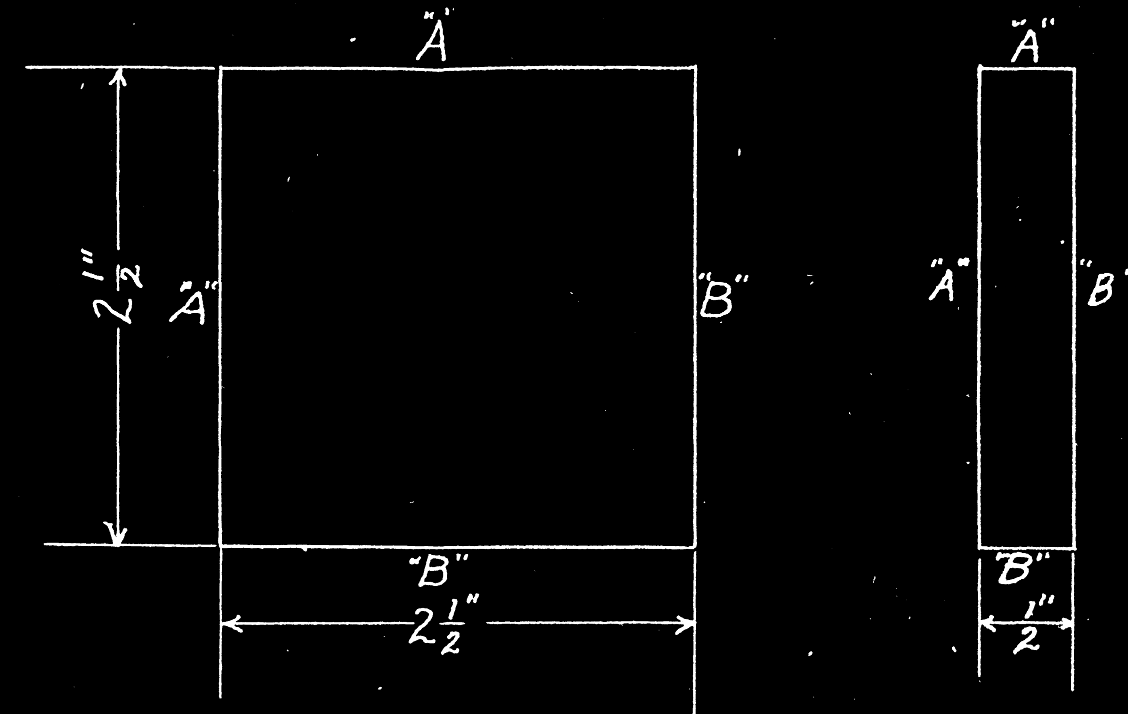
Operation	Tools	Speed	Feed	Time
No.1- Chuck + Face Side.	Lathe, Chuck, Rd. Nose Tool.			
No.2- Drill.	Lathe, 1 15/32" Drill.			
No.3- Bore Inside.	Lathe, Boring Tool, Scale, Inside Calipers.			
No.4- Thread.	Lathe, Inside Threading Tool, Thread Gage + Special Mandrel.			
No.5- Tap.	Standard Pipe Tap + Wrench.			
No.6.- Finish Turning	Lathe, Special Mandrel, Rd. Nose + Facing Tools, Scale + Calipers.			
No.7- Lay Out.	Copper Sulphate, Scale + Scriber.			
No.8.- Drill 7/16" Holes.	Drill Press, Special Jig, + 7/16" Drill.			

V.P.I. Ind. Eng. Dept.
Shop Exercise No.- 6
Name- Eccentric.
Material-Cast Iron.



Operation	Tools	Speed	Feed	Time
No. 1. Chuck + Face Ends 1/32" Long.	Lathe with Chuck, Scale, Round Nose Tool.			
No. 2. Center.	Scale, Scriber, Surface Gage, Center Punch, Hammer, Speed Lathe, Drill + Counter-Sink.			
No. 3. Turn Outside Dia. Leaving "A" 1/32" Oversize For Grinding.	Lathe, Dog, Rd. Nose Tool, Scale + Outside Calipers.			
No. 4. Grind "A" to Size.	Grinder.			
No. 5. Lay Off Keyway.	Scale, Scriber, Surface Gage.			
No. 6. Cut Keyway.	Milling Machine, 1½" Dia. Woodruff Cutter.			

V.P.I. Ind. Eng. Dept.
Shop Exercise No.- 5
Name- Block.
Material- Cast Iron.



Operation	Tools	Speed	Feed	Time
No. 1. Lay Out and Chamfer Corners 3/32"	Chalk, Scale, Square, Scriber, File.			
No. 2. Chip Sides "A", Cut ½" Groove With Cape Chisel First.	Vice, Hammer, Cape Chisel + Cold Chisel.			
No. 3. File Sides "A"	Vice, Copper Jaws, 12 in. Bastard File.			
No. 4. Lay Out	Copper Sulphate, Scale, Square + Scriber.			
No. 5. Shape Sides "B"	Shaper, Tool.			
No. 6. Scrape Sides "A"	Vice, Copper Jaws, Surface Plate, Persian Blue + Scraper.			