



The design and construction of a ceramics workshop and the utilization of local clays for ceramic use
by Charles A Stablein

A THESIS Submitted to the Graduate Committee in partial fulfillment of the requirements for the
degree of Master of Arts in Applied Arts
Montana State University
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Abstract:

The material set forth in this thesis is directed to schools, interested groups and individuals who wish to build a ceramics workshop. A workshop was planned that is adequate in operation and complete in equipment for most use. In order to provide a well equipped shop the following items are discussed and, as far as possible, plans for their construction are presented in the thesis.

1. Electric Kilns 4. Dry Boxes, Bats, Damp Boxes 2. Potter's Wheel 5. Miscellaneous Equipment 3. Wedging Boards The sections concerning Low Fire and High Fire Kilns include a full report of the reasons for building electric rather than oil or gas fired kilns, as well as the method of arriving at the final specifications for their construction. This was thought to be necessary in order that persons desiring to work from the plans included in this paper might know the efficiency and capabilities of these kilns.

The Potter's Wheel was designed so that the different heights of students using the wheel would create as little handicap as possible.

The factor of varied heights must be considered wherever groups are using such equipment.

Items 3, 4 and 5 are self-explanatory and are somewhat standard in their requisites. The sizes of these items when listed in the thesis are given as adequate in size for a group of approximately fifteen (the average size group attending ceramics classes at Montana State College at this writing). The amounts or sizes of these items are readily adjusted to fit the need.

A unit on clay and clay bodies has been included to provide an understanding of the requirements of good pottery clays. Such a unit is of especial value when the possible use of local clays comes into consideration. Almost any locality has some clay that is readily adapted for use by the potter. Samples taken from various localities within this state were tested and, with one exception, were found to have possibilities for pottery. In some cases slight changes were necessary to create the best clay body from these local deposits.

Included at the close of the thesis is a list of books and articles of value to ceramists. It will be noted that for the most part these articles are from "The Ceramic Age," a trade type magazine. This magazine will be found to be a good reference in the ceramic workshop.

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AND THE UTILIZATION OF LOCAL CLAYS FOR CERAMICS USE

by

CHARLES A. STABLEIN

A THESIS

Submitted to the Graduate Committee

in

partial fulfillment of the requirements

for the degree of

Master of Arts in Applied Arts

at

Montana State College

Approved:

Cyril H. Conrad
In Charge of Major Work

Cyril H. Conrad
Chairman, Examining Committee

J. A. Nelson
Chairman, Graduate Committee

Bozeman, Montana
June, 1949

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Graduate Committee

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Mr. Robert Seibel of the Electrical Engineering Department has been most helpful in planning the element requirements of the kilns. Without his help this part of the thesis would have been impossible.

Mr. Halver Skinner has made it possible for the author to use the shop equipment in the Rural Engineering Department during the design and construction stages of the Potter's Wheel.

To those persons expressly mentioned above, to all interested individuals who have sent samples of local clays from their communities, and to all others who have in any way contributed to the work of this paper the heartfelt appreciation of the author is expressed.

Special thanks are extended to my wife, Virginia, for her patience during the writing, proof-reading and final typing. Her assistance has been of inestimable value at all times.

ABSTRACT

The material set forth in this thesis is directed to schools, interested groups and individuals who wish to build a ceramics workshop. A workshop was planned that is adequate in operation and complete in equipment for most use. In order to provide a well equipped shop the following items are discussed and, as far as possible, plans for their construction are presented in the thesis.

1. Electric Kilns
2. Potter's Wheel
3. Wedging Boards
4. Dry Boxes, Bats, Damp Boxes
5. Miscellaneous Equipment

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A unit on clay and clay bodies has been included to provide an understanding of the requirements of good pottery clays. Such a unit is of especial value when the possible use of local clays comes into consideration. Almost any locality has some clay that is readily adapted for use by the potter. Samples taken from various localities within this state were tested and, with one exception, were found to have possibilities for pottery. In some cases slight changes were necessary to create the best clay body from these local deposits.

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INTRODUCTION

It is not the aim of this thesis to develop a curriculum or a philosophy for the teaching of ceramics in our schools. The primary purpose is to present plans for the construction of equipment for a ceramic workshop adaptable for use in the average school program. Every effort has been made to present clear, workable plans in order that the average individual with a minimum amount of training in the average industrial arts shop can interpret them and construct the pieces of equipment presented.

The economic construction of the pieces to be set forth will also be taken into consideration. Utilization of existing materials is emphasized in order to further reduce the building costs. This economy will be kept in mind so that schools with limited budgets may still be in a position to have a ceramics shop that will provide adequate opportunity for student expression in the media.

At no point will economy or utilization of material not originally planned for use in ceramics become the controlling factor over good, sound workability. The utmost of efficiency will be sought at all times in order that the expense of repairs and upkeep can be kept to a minimum.

Special emphasis has been placed on the study of local clays and their adaptability to use in ceramics. No effort will be made to estimate the amount of clay in the deposits from which the test samples were taken. The principal intent will be to show that there are many sources from which clays may be locally obtained. The educational aspect of ceramics is greatly enhanced by eliminating the expense and inconvenience of commercial clays.

Group efforts can play an active part in the various phases of digging and preparing local clays for use. The satisfaction of having completed the cycle from digging to finished product as the result of the cooperative effort of a class or group should not be overlooked.

For the individual, as well as the group, local clays reduce the expense that is necessarily connected with commercial clays. Shipping charges account for a great percentage of the cost of commercial clays at the present time. With this in mind it seems feasible that a section on preparing and testing of local clays be included with the proposed plan for a ceramic workshop.

LOW FIRE KILN

Before building or buying a ceramics kiln it is necessary that the general requirements of a kiln are known in order that the most suitable design may be chosen. It matters little what method of firing is used; whether it is electricity, gas, or oil the following features must be considered:

1. Economical operation.
2. Adequate muffle volume.
3. Ease of charging.
4. Ease of maintenance.
5. Economical upkeep.
6. Uniform heat rise.
7. Efficiency of operation to allow for proper maturing of ware.
8. Efficient and economical installation.
9. Compliance with local fire and safety ordinances.

It cannot be too strongly stressed that a thorough analysis of the requirements and qualifications of a kiln be made. Before the first kiln was built at Montana State College such a study was made. The result was the design and construction of an electric kiln of a type similar to many of the cone 04 kilns now on the market.

The following reasons determined the choice of such a kiln:

1. Properly built it would have all the features listed above.
2. It would eliminate the necessity of providing the special vent that would have been necessary with a gas or oil fired kiln.
3. Constructed at the college the kiln would be less expensive than if purchased ready built.

4. Being of multi-unit construction the kiln's muffle would be variable, thus allowing for greater economy in firing special tests, where only a small volume is necessary.
5. Electricity would be more convenient than other fuels.

The kiln was planned to be octagonal in shape and constructed of insulating brick. Two manufacturers of such a brick, Armstrong Cork Company, 222 North Bank Drive, Chicago, Illinois, and Robinson Insulation Company, Great Falls, Montana, distributors for Zonolite products, were contacted for information regarding the characteristics of their bricks. Armstrong's A-20 brick proved to be the most suitable. It has the following characteristics:

- | | | |
|---|---|--|
| 1. Temperature Limit | - | 2,000 ^o F. on hot face |
| 2. Thermal Conductivity | - | 2.2 B.t.u./sq. ft./
in. thick/ per hour |
| 3. Size of Brick | - | 4 $\frac{1}{2}$ " x 2 $\frac{1}{2}$ " x 9" |
| 4. Weight of Brick | - | 1.9 lbs. ea. |
| 5. Brick can be easily cut to desired shape by hand or power saw. | | |

After the type of brick had been decided upon and the general plan drawn up, Mr. Robert Seibel, Assistant Professor of Electrical Engineering at Montana State College, was consulted for advice and assistance in regard to the technical details of plotting the size of element wire as well as firing control and voltage requirements.

Listed below are the data arrived at and used as a basis for the construction of the first Low Fire, Cone 04, Multi-Unit, electric kiln built at Montana State College.

Octagonal Area	-	238 sq. in.
----------------	---	-------------

Muffle Volume	-	3220 cu. in. - 1.86 cu. ft.
Outer Surface Area	-	15.1 sq. ft.
Heat Loss Through Walls	-	3.4 Kw. (Est.)
Spec. Heat of Bricks	-	0.22 (Est.)
Brick Weight	-	2.0 lbs. used. Actual weight 1.9 lbs.
Number of Bricks	-	48
B.t.u. to Heat Brick	-	53,000
Furnace Charge	-	5.0 lbs. (Average)
B.t.u. to Heat Charge	-	1930
B.t.u. for Air	-	1730 (Allowing for six complete changes in kiln during firing due to air space between ele- ments.)
TOTAL B.t.u.	-	56,660 for six hour period
B.t.u. per Hour	-	9,443.3
TOTAL Kw.	-	3.4 (Heat Loss) 2.78 Kw. for above plus 8% for regulating margin <u>6.6 Kw. TOTAL</u>

CALCULATIONS FOR ELEMENTS

Power Dissipation	-	Bottom and middle units, 2.5 Kw. ea. Top row, 1.6 Kw.
Voltage Available	-	118V and 236V
Voltage for Peak Fire	-	236V with all units turned on
Ohms at 2,000° F.	-	22.3
Resistance Factor	-	1.078 at 68° F.
Resistance at 68° F.	-	20.7 (Bottom and middle ele- ments)
Mandrel Size	-	3/16"
Element Dia. Wound	-	1/4" due to springing
Element Stretched	-	Approx. 7 turns per inch
Path Length of Element	-	112"
Wire Used	-	Nichrome V
Wire Gauge	-	#18 B&S 0.4062 ohms per ft. at 68° F.
Amount of Wire	-	53 ft. each unit (Bottom and middle only)

TOP ELEMENT

Ohms at 2,000° F.	-	34.8
Resistance Factor	-	1.078 at 68° F.
Resistance at 68° F.	-	32.2 ohms.
Mandrel Size	-	3/16"
Element Dia. Wound	-	1/4" due to springing
Element Stretched	-	Approx. 6 turns per inch
Path Length of Element	-	112"
Wire Used	-	Nichrome V

Wire Gauge	-	#20 E&S 0.6347 ohms per ft. at 68° F. ¹
Amount of Wire	-	51.6 ft.

Rapid heat rise is a disadvantage rather than an advantage when firing a kiln. It is first necessary to pass off any remaining moisture in the green ware during the initial stages of heat rise or explosion of pieces is likely to take place.² In order to assure a slow heat rise with greater efficiency the top unit was wired with a smaller gauge wire for initial heating on 118V. Following the initial firing of the top unit the bottom and middle elements were then turned on according to a set firing plan plotted by use of a pyrometer in order to consume no less than six hours.³ The wiring had to be fused with 30 amp. fuses to accommodate the use of all three elements on 236V during the final stages of firing.⁴

From the outset it was found that the efficiency of the first kiln was far above expectations. Heat loss was not as great as was estimated and the change of air through the muffle was negligible. At the peak of operation it is possible to touch the outer brick surfaces of the kiln. The kiln is placed upon a star pattern of eight ordinary bricks to allow for air space underneath. These bricks in turn are placed upon $\frac{1}{4}$ " sheet asbestos covering a wooden table. Such a method of placing the kiln was approved by the fire chief of the city of Bozeman, Montana, and the col-

1. See Nichrome and Other High Nickel Electrical Alloys, Catalogue R-46, Driver Harris Co., Harrison, N. J., PP. 17-19, for ohm rating of #18 and #20 E&S gauge wire.
2. Binns, C. F., Lectures on Ceramics, 1946, PP. 45-47.
3. See Figure 13, P. 45.
4. Ibid.

lege plant supervisor. No venting over the kiln was required by them at the time of inspection.

Two kilns have been built by the Art Department at Montana State College using the above specifications and constructed from the plan as set forth in a subsequent chapter. Both kilns have been highly satisfactory in performance. Two changes have been made in the second kiln and these changes have been incorporated in the plans. One change is in the method of holding the element in the grooves. In the first kiln this was accomplished by use of staples made of #30 Nichrome V wire which were hand formed, then driven into the walls of the kiln. The staples had a tendency to pull free as the element expanded due to the heat. It was necessary to replace these staples frequently. In order to overcome the disadvantages of staples, strips of insulating brick have since been fastened to the kiln wall with Airset Cement or Latite.

The second change was to wind all three elements alike using 55 feet of Nichrome V #18 B&S wound on a 3/16" mandrel. This change was made in order that only one size of wire would need to be stocked and also to distribute the heat more evenly. So that a reasonable degree of heat would be available during the warm-up period the ohm rating was increased by the addition of two feet of wire to each element, thereby providing greater heat potential on 118V. This change necessitated heavier fuses inasmuch as the amperage at full heat now reached 31.5 amps. whereas with the smaller element the amperage rating was 30.0.

The first kiln has been in use since March, 1948, and to date has been fired about one hundred times on the original set of elements.

As of May, 1949, there is no indication of immediate element failure. Records show that this kiln has been fired as many as 18 days in succession with time allowed only for cooling, unloading and restacking.

The second kiln was built in September, 1948, and indications are that it will give equal service. Changing the method of fastening the elements has been a decided improvement in ease of maintenance.

Basic construction of the college kilns was accomplished through the cooperative efforts of Mr. Cyril Conrad, Head of the Art Department, Miss Frances Senska, Ceramics Instructor, Mr. Robert Story, and the author.

HIGH FIRE KILN

Nichrome V wire will give good results in kilns operating in the cone 04 range but due to the characteristics of the wire it has an operating ceiling of 2150° F. for best life expectancy. The temperature of the element is greater than the temperature of the muffle at the peak of firing. Taking this fact into consideration, it is necessary to set the maturing point of the kiln below 2150° F.¹

In order to fire electrically above cone 04 another type of wire must be used. For cone 4-5 ranges such a wire as produced under the trade name of Kanthal is satisfactory. Gobar elements are necessary for heat above the range of Kanthal. Gobar units would be too complicated and expensive for most schools, clay clubs, adult education activities or individuals. As ceramics work has progressed at Montana State College it has been desirable to do some work in the stoneware range, or around cone 5.² With the success of Armstrong Insulation Brick for the first kilns there seemed to be no indication that a high fire kiln could not be designed to fire satisfactorily using Armstrong brick and Kanthal.

As in building the first kiln, the qualifications and advantages of this new kiln were analysed.

1. Economy of construction.
2. Ease of construction with a minimum amount of tools and equipment.
3. No special firing mechanisms or constructions needed such as air vents, flues and firing rooms.

1. Op cit Driver Harris Co. P. 13.

2. See Cone-Temperature Chart, P. 80.

4. Uniform heat rise.
5. Multi-unit firing allowing for a change of muffle volume.
6. Ease of charging.
7. Compliance with local fire regulations.

A series of tests were run on the first kiln to determine its heating characteristics and the peak efficiency of the elements. These figures were then interpolated to verify what might be expected with a similar kiln operating at 2350° F.

Figure 1 indicates the heat rise at intervals of fifteen minutes with kilowatt ratings varying from 1.6 kilowatts to 6.6 kilowatts being tested.

Figure 2 graphs the correlation between the kilowatts per square foot of kiln and the heat obtained.

Figure 3 indicates the rate of heat rise as the kilowatt rating was increased. As the heat from the first element reached its peak, the second element was connected, then, as that peak was reached, the third element was turned on.

In order to more fully understand the facts gained from these tests it is necessary to set up the specifications for a kiln to fire at 2300° F.

Brick Used	-	Armstrong A-26 - 2600° F.
		Face Heat
Octagonal Area	-	238 Sq. In.
Muffle Volume	-	3220 Cu. In. - 1.86 Cu. Ft.
Outer Surface Area	-	15.1 Sq. Ft.
Spec. Heat of Bricks	-	0.22 (Est.)
Brick Weight	-	3.0 Lbs. used - Actual Weight
		2.8 Lbs.
Number of Bricks	-	48
B.t.u. to Heat Brick	-	73,814
Furnace Charge	-	20 Lbs. (Average)

B.t.u. to Heat Charge	-	9320
Heat Loss B.t.u.	-	10,570 (Est.) Per Hour ¹
Heat Loss Kw.	-	3.1 Kw. Per Hour of Firing
TOTAL B.t.u.	-	111,790 for 8 Hour Period
B.t.u. Per Hour	-	20,961.8
TOTAL Kw. Per Hour	-	6.13 Plus 10% for Operating Margin
		<u>6.8 Kw. Per Hour</u>

Reference to figure 1 will show that 2,000° F. is reached when 5 Kw. are used as the power source. The direction of the curve indicates that the peak heat obtainable would be in the area of 2,100° F. The curve based upon the use of 6.6 Kw. has not begun to level off when the 2,000° F. point is reached. Extending this curve indicates a peak of 2,350 - 2,400° F. could be obtained. Facts gained from figure 1 substantiate the projected kilowatt rating as listed above.

Figure 2 reveals that from the tests and extension of the curve, 0.43 Kw. per sq. ft. are necessary to reach a heat of 2,300° F. Comparing this with the specifications above show a close relationship between the 0.43 Kw. per sq. ft. by test and 0.45 Kw. per sq. ft. in specifications which were arrived at mathematically.

Figure 3 indicates the rate of heat rise as the power is increased. It shows the necessity of a set firing pattern to allow for proper maturing of ceramic ware.

All tests graphed on figures 1, 2 and 3 were made at 236V. On the basis of the specifications previously set forth and the findings of the tests graphed in figures 1 and 2, Kanthal A-1 B&S gauge #17 wire was selected as the element material. The principal reason for using

1. Specification Chart, Universal Zonolite Insulation Co., Chicago, Illinois, Copyright 1942.

this size wire was that it would simplify the turning of the element inasmuch as the same mandrel used for turning the elements for the low fire kiln could be used for the Kanthal A-1 wire. Using #17 wire for proper resistance would necessitate turning the elements on a 3/16" mandrel from 55 feet of wire.

Two hundred and forty feet of #17 Kanthal A-1 were ordered from the Jelliff Co. of Southport, Connecticut. Some changes had been made in the type of wire being produced by that concern since their catalogue had been received. A-1 wire is no longer drawn in smaller sizes than #15. The correspondence carried on between the author and Jelliff Co. is significant enough to warrant reproduction at the end of this chapter inasmuch as it was due to the interest of the Jelliff Co. in ascertaining that the best use be made of their product that the final wire size was chosen.

Eighty-five feet of Kanthal A-1 B&S gauge #15, diameter .057, with a resistance of .272 ohms per foot was used for each element. Two changes were made from the suggested plans set forth in the letter from Jelliff Co. dated April 6, 1949. The element was turned on a 3/8" mandrel to reduce the close wound length and make it possible to turn the element on a lathe rather than by hand. No indication of free silicate has been evident in the previous two kilns. Therefore, the element track was not painted with resistor cement.

It will be necessary to operate the high fire kiln for several firings to determine its full capabilities. On the basis of tests upon existing kilns, specifications of the brick, and the verification of the element requirements by the Jelliff Co., manufacturers of Kan-

that, there is every reason to believe that the kiln will prove successful.

THE C. O. JELLIFF MFG. CORPORATION

Southport, Conn.

C O P Y

March 29, 1949

Associated Students Store
Montana State College
Bozeman, Montana

ATT: Mr. Edwin Howard, Mgr.

Gentlemen:

Thank you very much for your order #5194.

We would like to point out to you that this seems to be the initial order we have received from you for KANTHAL wire, and in line with our customary procedure we would deeply appreciate your giving us complete information as to your proposed method of installation on this KANTHAL so that our engineers may satisfy themselves that your intended use will be a suitable one for KANTHAL. The electrical and mechanical properties of KANTHAL vary so much from those of other resistance wires that this is a precaution we must take in order to assure that KANTHAL is properly installed for long wear and complete operating satisfaction.

Therefore, if you will be kind enough to give us this data, we will be very happy to enter your order.

Incidentally, the #17 gauge we can furnish in KANTHAL "A" only. Number 16 represents the smallest size that can be furnished in KANTHAL "A-1"; all sizes smaller than that are furnished of KANTHAL "A".

We hope you will send us along complete data as to your installa-

tion so that it may have the immediate attention of our engineering department.

Very truly yours,

THE C. O. JELLIFF MFG. CORP.

(s) J. F. Kelly, Asst. Secy.

JFK:RC

Bozeman, Montana
April 2, 1949

C O P Y

The C. O. Jelliff Mfg. Corporation
Southport, Connecticut

Att: Mr. J. F. Kelly, Asst. Secy.

Gentlemen:

Your letter of March 29, 1949 to the attention of Mr. Edwin Howard has been forwarded to me inasmuch as the material ordered by the Associated Students Store is for my use.

The KANTHAL ordered is to be used in a ceramics kiln which I am designing in connection with work for a Master's Degree. I have worked in close cooperation with the Electrical Engineering Department here at Montana State College in the designing of this kiln and submit the following data for your approval.

Kiln Shape	-	Octagonal
Number of Elements	-	3
Outlets	-	3 - 220 Volt 2 - 110 Volt (110 for Warm-up)
Firing Time	-	6 Hours
Capacity	-	1.86 Cu. Ft.
Kw./Unit	-	1.93
Ohms/Unit	-	23.2 Cold
Temperature Desired	-	2300° F.
Element Path Length	-	112"
Brick	-	Armstrong A-26 A-26 Face Heat Permissible 2600° F.

Elements are drawn through the brick and connected outside the kiln proper to brass contacts set in asbestos.

The method of setting the element in the brick is illustrated on the attached sheet.

This kiln is similar to two kilns which we have built here at the college for Nichrome V wire and have proven satisfactory within the operating limits of Nichrome. At this time, however, it is desired to attain the higher heat and also to do away with the reduction in glaze ware due to the nickel wire. These two kilns have over a year's service and have proven satisfactory in every way. With the construction of the new one we have changed the brick to 2600° F. face heat and planned to set the element in in a more protected manner to compensate for the brittle quality of KANTHAL after it has reached its heat.

We had planned to use KANTHAL A-1 because of its higher capacity which would allow us a greater operating margin, but if you feel that KANTHAL A is all right, we can adapt it to our use. If, however, it would be more practical to use Number 16 KANTHAL A-1, we can adapt that. The order originally placed by us was enough wire for four complete elements when turned on a 3/16" mandrel and stretched to approximately five turns per inch. Therefore, I would appreciate it if you would make any proportionate change in the order to accomplish this.

I believe this information will be sufficient to establish our correct use of KANTHAL in our kiln but I will be glad to forward any additional information you may need.

Thank you for the trouble you have taken to make sure we can

get the most out of KANTHAL.

Very truly yours,

(s) Charles A. Stablein

THE C. O. JELLIFF MFG. CORPORATION

Southport, Conn.
April 6, 1949

C O P Y

Mr. Charles A. Stablein
95 Cedar Avenue
Bozeman, Montana

Dear Mr. Stablein:

Thank you for your letter of the 2nd in which you furnished data on the experimental ceramic kiln which you are designing.

We regret that we cannot recommend No. 17 KANTHAL "A" wire for your kiln. It would undoubtedly be an improvement over the nickel chromium wire you are now using but would not permit you to reach the high temperature which KANTHAL makes possible, because the surface loading would be approximately 20 watts per square inch. This means that the wire would run considerably hotter than the work in the kiln.

We would recommend that you use 85 ft. of No. 15 (.057" dia.) KANTHAL "A-1" wire for each element. If this wire is coiled on a 9/32" diameter mandrel and stretched to twice the close wound length, it will be approximately 112" long. However, since it will be about 4/10 of an inch in diameter, it will be necessary to use 7/16" grooves for supporting.

When stretching coils of wire this large we would recommend that you heat them to about 1200 degrees F. by means of an electric current while slowly stretching them to the desired length. This results in a more uniform coil with considerably less effort than

stretching cold.

The method of supporting the element shown in your sketch is very satisfactory for KANTHAL elements. However, we would suggest that you paint the grooves before installing the elements with either No. 78 electric resistor cement made by the Sauereisen Cement Co. in Pittsburgh, Pa., or with No. 1161 Alundum Cement made by the Norton Company in Worcester, Mass. These cements have no effect on KANTHAL and would prevent possible attack at high temperatures by the free silica and impurities in the insulating brick.

We would appreciate your consideration of the remarks above and will hold your order, pending your decision on the larger size of wire which we recommended.

Very truly yours,

THE C. O. JELLIFF MFG. CORP.

(s) C. W. Armstrong,
Wire Division

CWA/dbf

P.S. A KANTHAL Handbook is being forwarded to you under separate cover. C.W.A.

Bozeman, Montana
April 8, 1949

C O P Y

The C. O. Jelliff Mfg. Corp.
Southport, Conn.

Att: Mr. C. W. Armstrong, Wire Division

Gentlemen:

Thank you very much for your letter of April 6th and the interest you have shown in making sure that I receive the proper KANTHAL for my ceramics kiln. I can assure you that your advice has been well received because, as you say, you are in a better position to see that the "KANTHAL" is put to its proper use.

I can cut my grooves to 7/16" for proper support of No. 15 KANTHAL A-1 with no trouble at all. Therefore, I would like to use the No. 15 KANTHAL A-1, as you suggested.

Do you prefabricate KANTHAL elements to order? If this is the case, will you please coil this as you suggested in your letter of April 6th. If not, please send at your earliest possible convenience 340 feet of No. 15 KANTHAL A-1, our order No. 5194, The Associated Students Book Store, Montana State College, Bozeman, Montana, Attention Mr. Edwin Howard, Mgr.

Thank you again for every attention you have afforded me in this matter.

Very truly yours,

(s) Charles A. Stablein

THE C. O. JELLIFF MFG. CORPORATION

Southport, Conn.
April 21, 1949

C O P Y

Mr. Charles A. Stablein
95 Cedar Avenue
Bozeman, Montana

Dear Mr. Stablein:

The material covered by your recent order for KANTHAL was shipped to you on the date of April 13th.

In this connection we sincerely hope when using KANTHAL that you follow our Mr. Armstrong's suggestions contained in his letter of April 6th.

If you have any questions about this, won't you please write to us so we can help you before you start using the material.

Very truly yours,

THE C. O. JELLIFF MFG. CORP.

(s) J. F. Kavanaugh,
Wire Division

JFK/dbf

KILN CONSTRUCTION

The two kilns (High Fire and Low Fire) previously described were designed with the average school shop in mind.

While it is a help, a power saw is not absolutely necessary to cut the bricks of the kiln. If a hand saw is to be used, a cutting guide should be constructed so that all cutting will be accurate. In the event that a power saw is used, it is advisable that an old blade be employed as the grit of the brick will dull a blade quite rapidly. Five sets of kiln brick seem to be the maximum possible to cut with an eight inch blade. After that many kilns had been cut no tooth was left on the blade.

General hand tools for metal work are all that are necessary in fabricating the bands and corner plates.

A lathe simplifies turning the elements but is not a necessity. A hand operated turning jig is easily constructed.

Bill of Materials - Low Fire Kiln¹

Armstrong A-20 Insulating Brick	-	50 (25 Per Box)
Airset Cement	-	16 Lbs.
.024 Gauge Sheet Metal 1" x 76"	-	8 Bands
.024 Gauge Sheet Metal 3" x 4"	-	24 Corner Plates
.024 Gauge Sheet Metal 2" x 3"	-	16 Corner Plates
3/16D x 1/4" Tinner's Rivets	-	16
1" x 1" x 1/8" Angle Iron	-	16
1/4" x 3" Roundhead Stove Bolts	-	8

1. See List of Supply Houses P. 81.

Nichrome V #18B&S Gauge	-	165 Ft. (3 Elements)
Nichrome V #20B&S Gauge	-	53 Ft. (Top Element Optional)
3" x 3" Hard Faced Asbestos Sheet	-	3 Element Plate
10/32 Brass Bolts	-	6 Element Connection
Brass Washers for Above	-	12
Brass Nuts for Bolts (Above)	-	18
Lead-in Wire to Suit Needs (Must be at Least 10 Amp.)	-	3 Lengths

Bill of Materials - High Fire Kiln¹

Armstrong A-26 Insulating Brick	-	50 (25 Per Box)
Airset Cement	-	16 Lbs.
.024 Gauge Sheet Metal 1" x 76"	-	8 Bands
.024 Gauge Sheet Metal 3" x 4"	-	24 Corner Plates
.024 Gauge Sheet Metal 2" x 3"	-	16 Corner Plates
3/16D x 1/2" Tinner's Rivets	-	16
1" x 1" x 1/8" Angle Iron	-	16
1/4" x 3" Roundhead Stove Bolts	-	8
Kanthal A-1 #15B&S Gauge	-	255 Ft. (3 Elements)
3" x 3" Hard Faced Asbestos Sheet-	-	3 Element Plate
10/32 Brass Bolts	-	6 Element Connection
Brass Washers for Above	-	12
Brass Nuts for Bolts (Above)	-	18
Lead-in Wire to Suit Needs (Must be at Least 10 Amp.)	-	3 Lengths

1. See List of Supply Houses, P. 81

Cut Sheet for Kiln. (Makes one kiln.)
Use for either high fire or low fire kiln.)

Pattern A	-	Ea. 16
Pattern B	-	Ea. 4
Pattern C	-	Ea. 4
Pattern D	-	Ea. 24

Patterns A, B, C and the two full bricks make up the parts for the bottom and lid. Pattern D makes the parts for the element units.¹

Two alternatives are possible in cutting the element grooves. If Nichrome wire is to be used, the groove may be cut at a 90° angle to the inside face of the brick. Kanthal requires a greater support due to its characteristic of becoming quite brittle after being fired. The element groove for Kanthal wire is cut at a 22° angle to the face of the brick. Figures 8 and 9 should be noted before cutting the brick.

Assembly of Bottom and Lid

The bottom and lid are identical in construction and should be assembled first.

The bricks are cemented together with Airset cement for greater strength. Only enough cement is used to provide a good bond between the bricks. Due to the porous quality it has been found advisable to dip the brick first in order that the moisture may not be drawn too rapidly from the cement.

Guard plates are set at each corner and held in place by one clamping band as indicated in figure 5.

1. See Figure 8, P. 40.

Clamping Bands

It is suggested that as soon as the first set of bricks is assembled all of the bands be made to fit it. For best results about 2" is left between the ends of the bands when they are first clamped. This will allow for room to tighten them if they stretch as a result of the heat. One kiln was made with aluminum bands. These bands have given good service but tend to stretch more than galvanized iron. Stainless steel makes a good band but increases cost with no increase in efficiency.

Unit Assembly

All but three of the unit bricks previously cut to Pattern D are grooved by either method of grooving, as in figure 8 depending upon which type of element is to be used. The three bricks not previously grooved will be cut as in figure 8 in the same style groove as used in the other 21 unit bricks. Three of the regular bricks must have observation holes cut in them and will be used one to each unit. The shape of the observation hole is dependant upon the style groove chosen. See figure 8. Actual assembly can be started after the grooves have been cut in the bricks. The element retainer bars are cut from scrap brick or the two remaining bricks. These retainer bars are attached to the kiln wall with Airset cement in the same manner as the lid and bottom were cemented. After placing the elements in the grooves, use ample cement for cementing the bars in place and allow to dry well before firing the units. It will be necessary to re-cement these bars from time to time because the high degree of heat acting upon

them causes some cracking.

The element units are not cemented and are only clamped snugly to allow for expansion during heating. The wear surfaces of the units are painted with a thin coat of cement to prevent wear or chipping when the units are removed to clean the kiln or to change the muffle area. See figure 6. The position of the brick incorporating the observation hole and the brick used as the element outlet have no fixed position in each element and may be placed to the best advantage of the operator. The plans, however, indicate their position on the constructed kilns.

Element Assembly

For the low fire kiln three 55 foot lengths of Nichrome wire of the size listed in the bill of materials are turned on a mandrel $\frac{3}{16}$ " in diameter. A length of welding rod serves as a good mandrel. After the element has been turned it will spring to about $\frac{1}{4}$ " in diameter. The elements are close wound and stretched to a length of 112" before being set in the units. Enough wire is left at each end of the element to extend out of the brick where the outlet attachment is made. This is necessary because the temperature in the muffle is high enough to melt the brass connections if they were inside. The element is attached to a hard faced asbestos plate $\frac{1}{4}$ " x 3" x 3" with $\frac{3}{16}$ " brass bolts. Figure 11 indicates the method of attaching the element and outlet plugs. Offset wall plugs are used inasmuch as the wiring is 230V as indicated and this will eliminate the possibility of inadvertently plugging in lights or fixtures made for regular 115V outlets. Such a method is a precautionary measure of especial value in schools or where groups are working.

The Kanthal or high fire elements are turned in the same manner as the Nichrome. The diameter of the mandrel has been changed to 3/8" in the kiln constructed rather than the 9/32" as suggested by the Jelliff Co. inasmuch as this size is more readily available. Turning the element on a larger diameter indicates that the element will be stretched greater than twice the coiled length. The element is stretched hot to help the wire hold its length. Warm the wire just past the glow point and while it is still hot stretch the element to 112". The element and outlet wire are attached in the same manner as listed above for the low fire kiln except that the brass bolt used is 1/4" in diameter.

Relative Cost of the Kilns

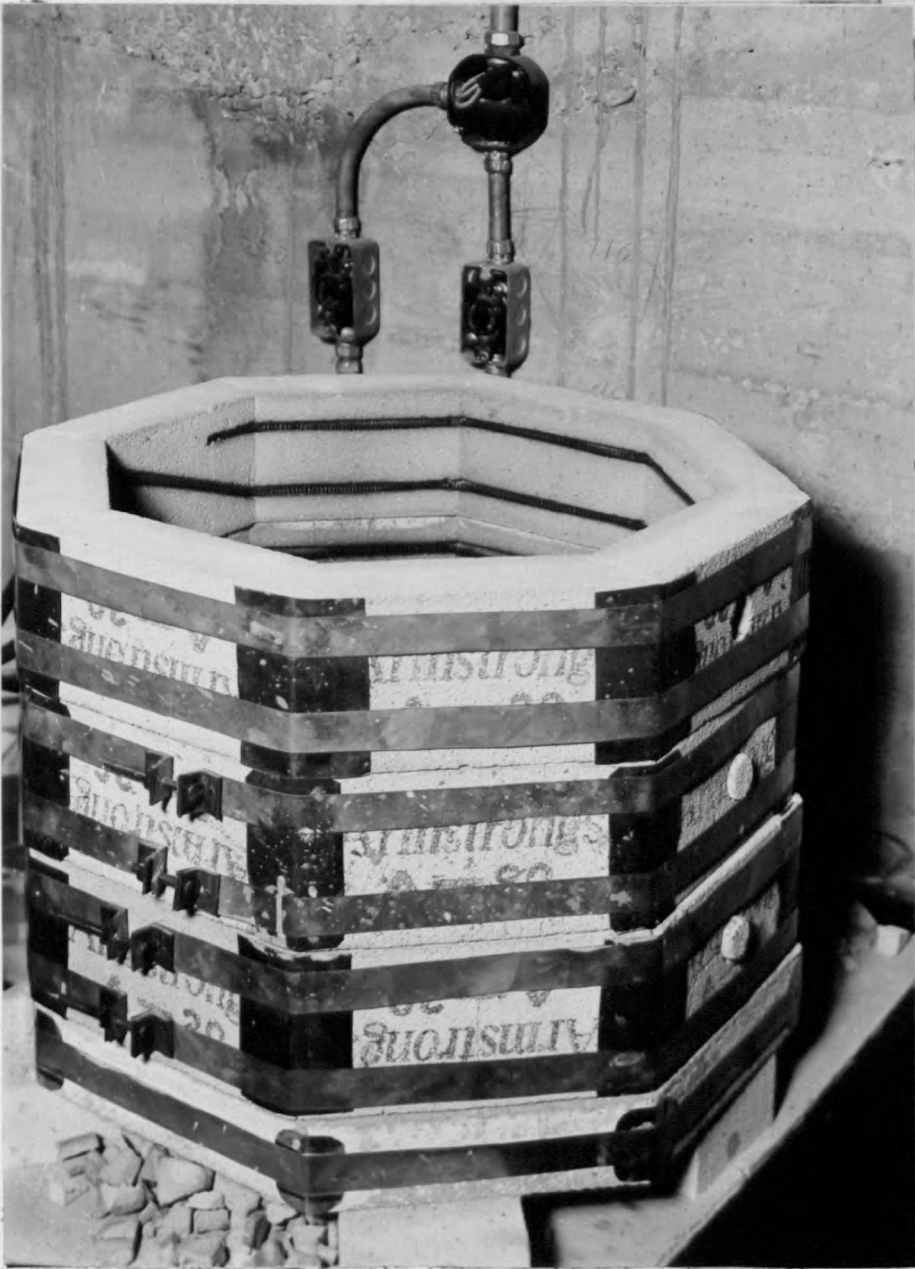
Due to present day in changes in costs, availability of the required materials in the locality, and the adaptability of scrap tin, etc. usually available at tin shops, no attempt has been made to set an actual cost price for the kilns. The cone 04 kiln was built at a total cost of about \$25.00, not including the stacking shelves and the stand for the kiln itself. Listed below is an itemized cost sheet for the high fire kiln.

Insulation Bricks, Airset Cement, and Transportation	\$ 21.58
Clamping Bands and Angle Iron, 3/16" Tinner's Rivets	1.20
Brass Bolts and Nuts	.40
Kanthal A-1 Wire and Postage	15.21
Outlet Cord #12	1.00
1/4" Stove Bolts	.15

Plug Bodies	3.00
Corner Plates Cut from Scrap	<u>****</u>
TOTAL	\$ 42.54

The increased cost of the high fire kiln is due to the cost of the Kanthal wire and the A-26 brick which run a little higher in cost than the Nichrome V wire and the A-20 brick used in the cone 04 kiln.

Enough wire for one low fire kiln costs about \$1.50.



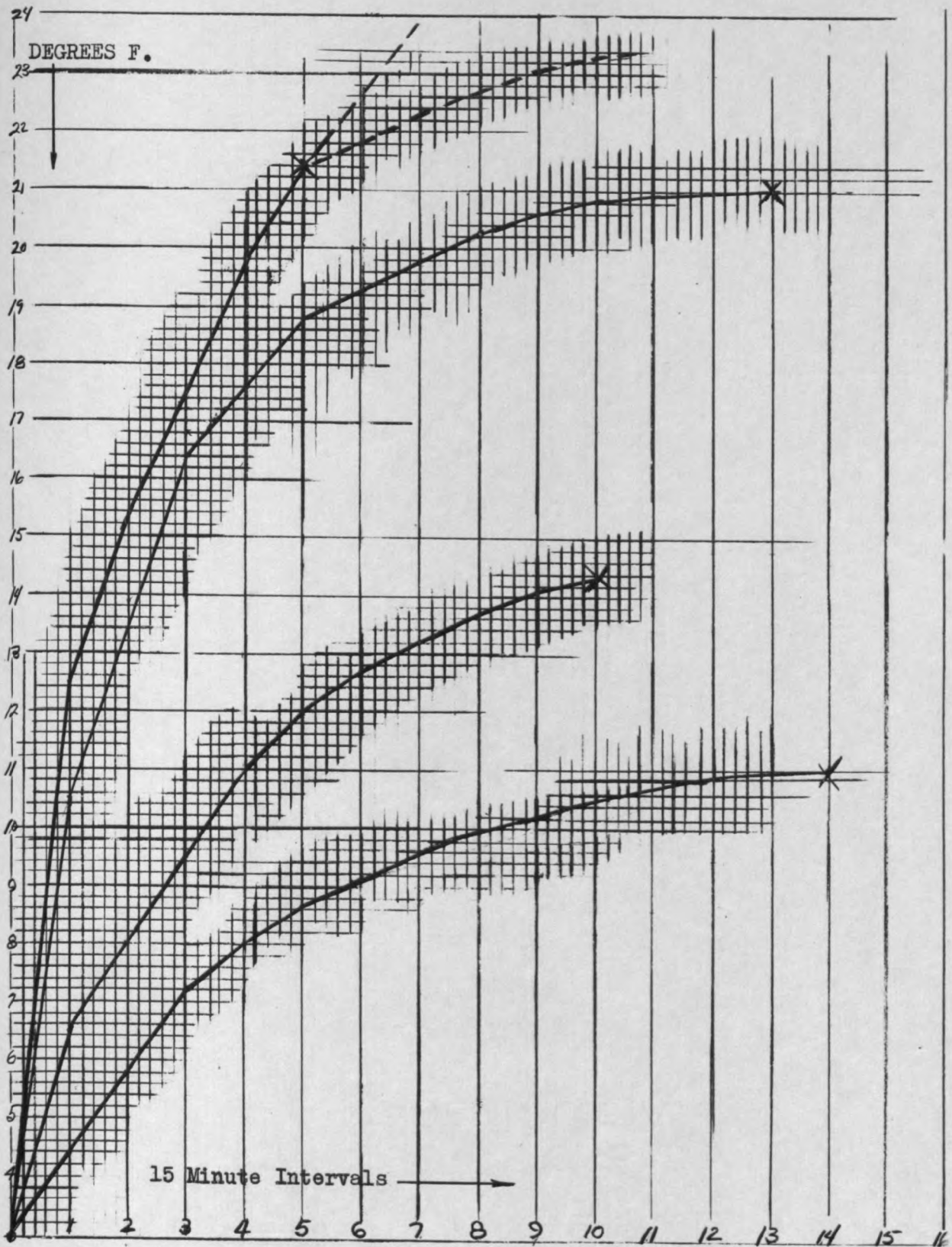


Figure 1

25 15 Minute Intervals

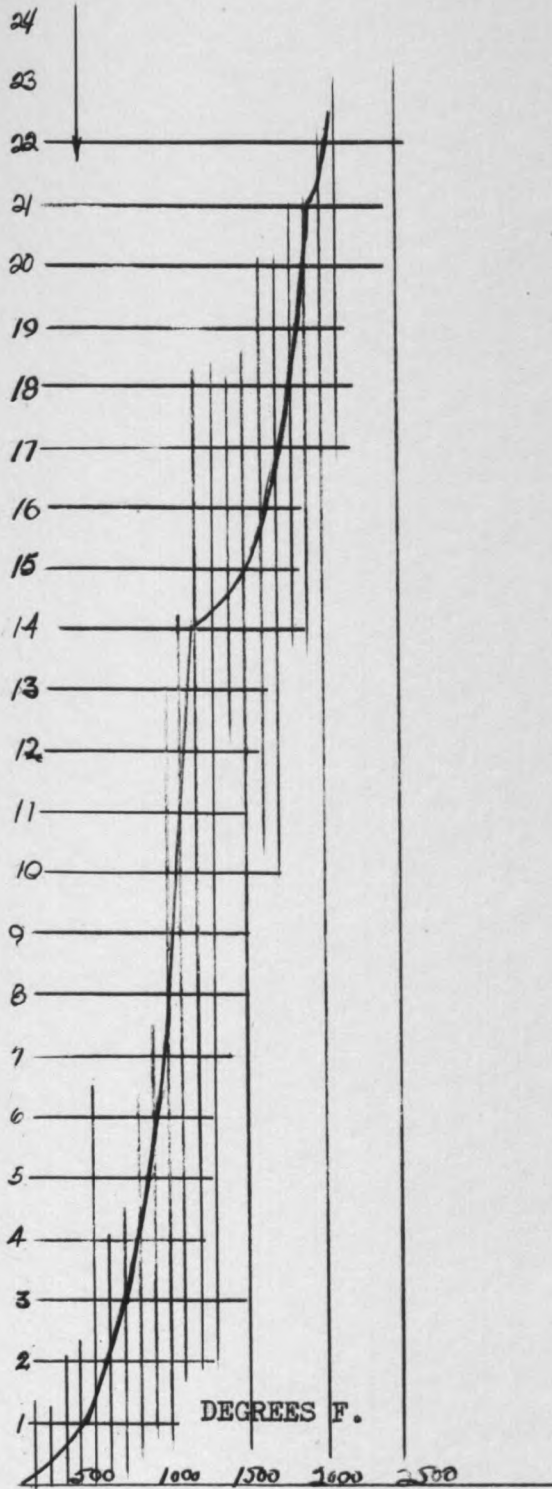


Figure 3

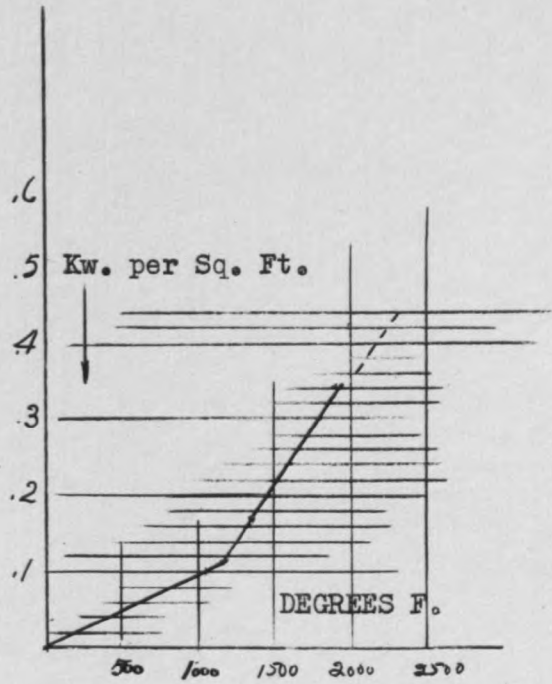


Figure 2

KILN DETAIL (EXPLODED VIEW)

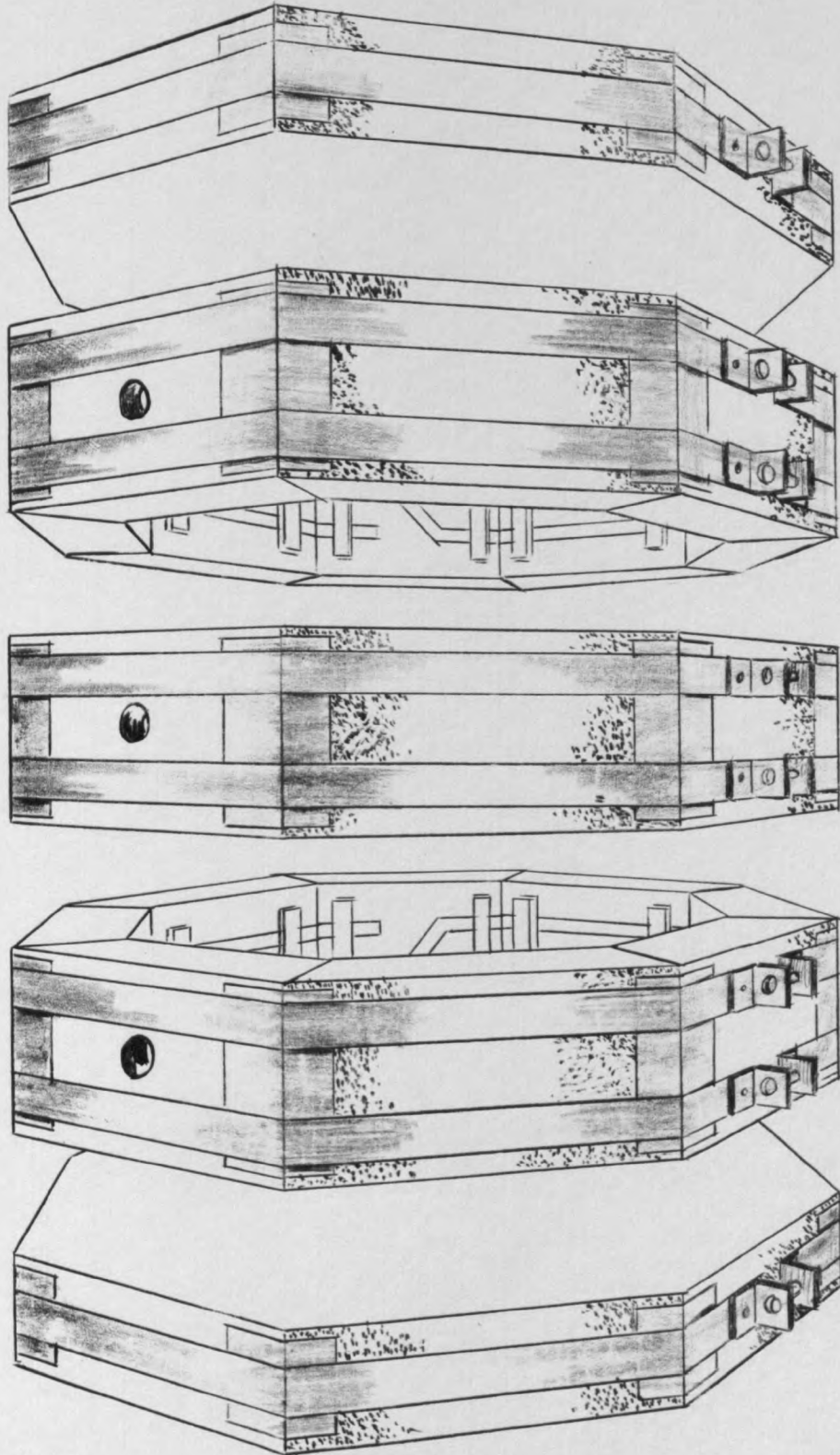
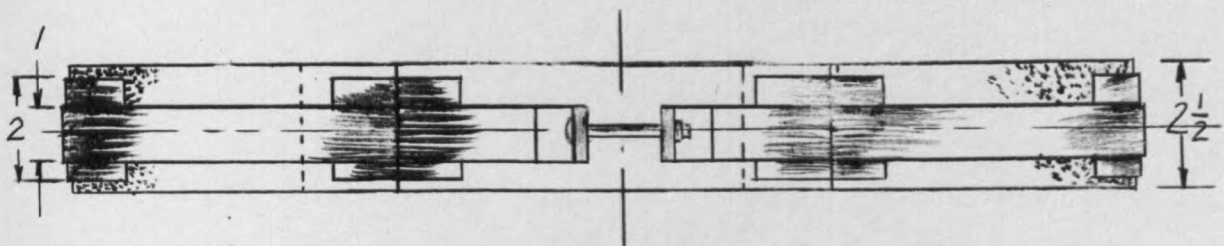
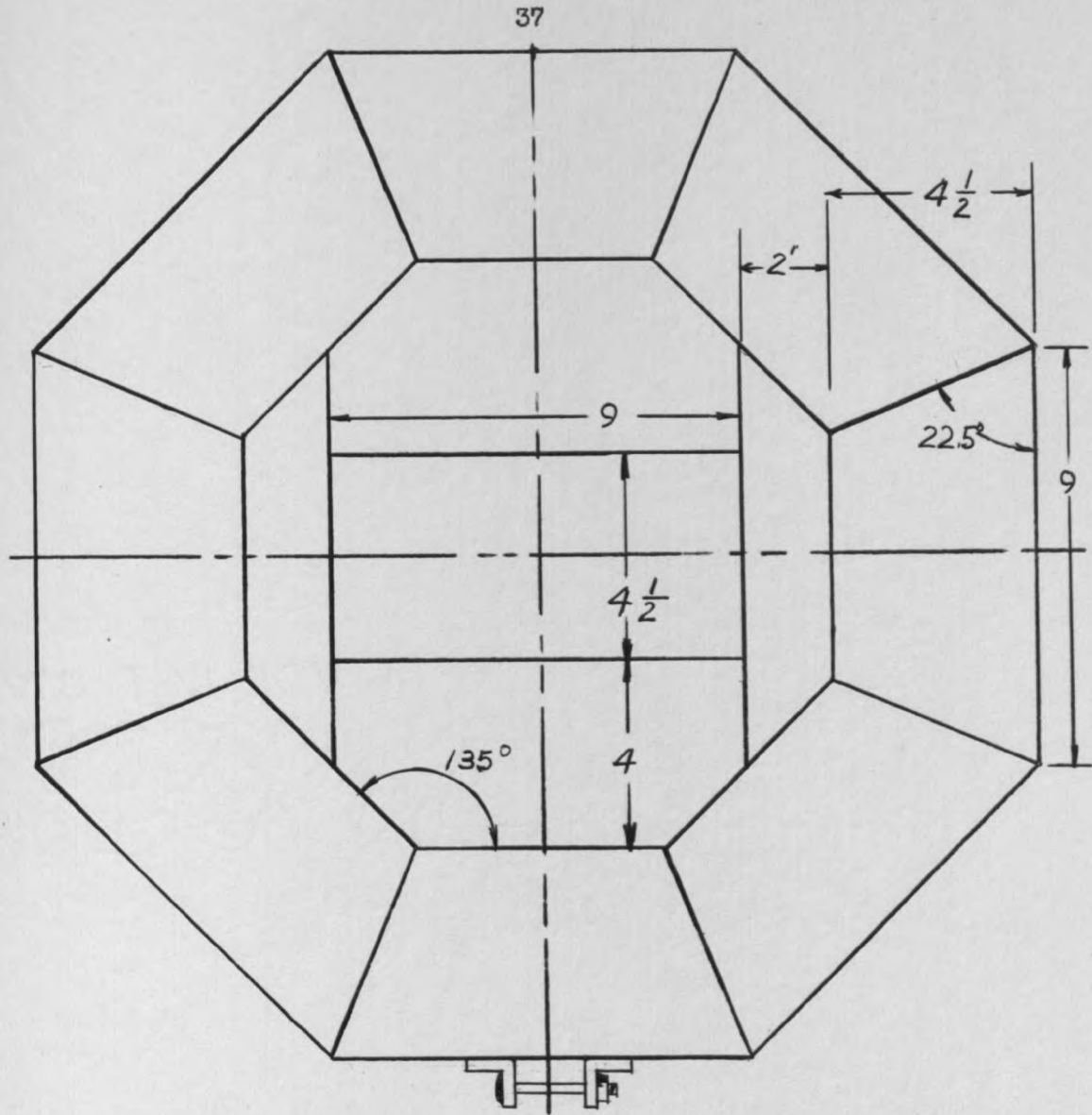
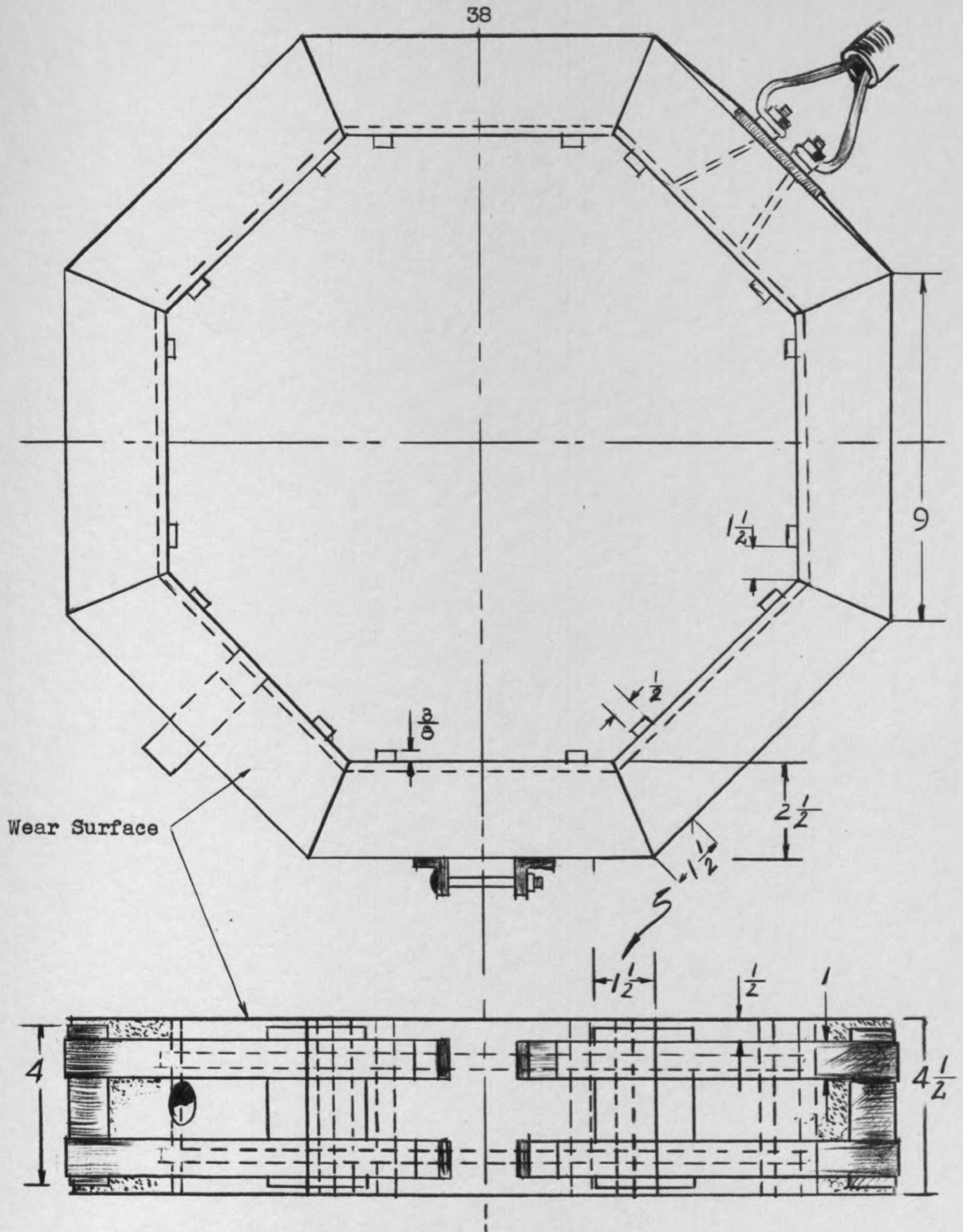


Figure 4



ELEVATION FLOOR AND LID

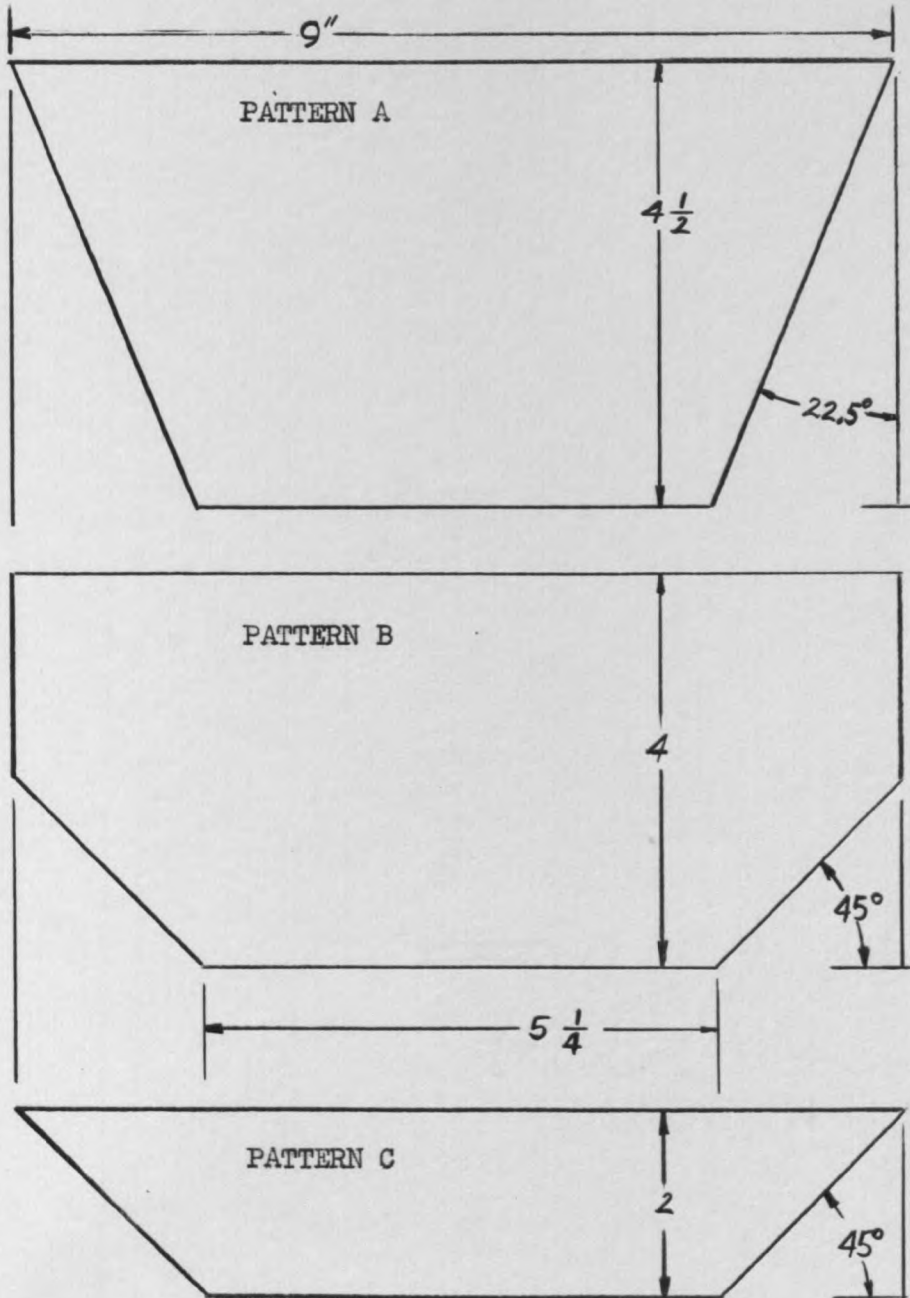


ELEVATION ELEMENT UNIT

KILN DETAIL

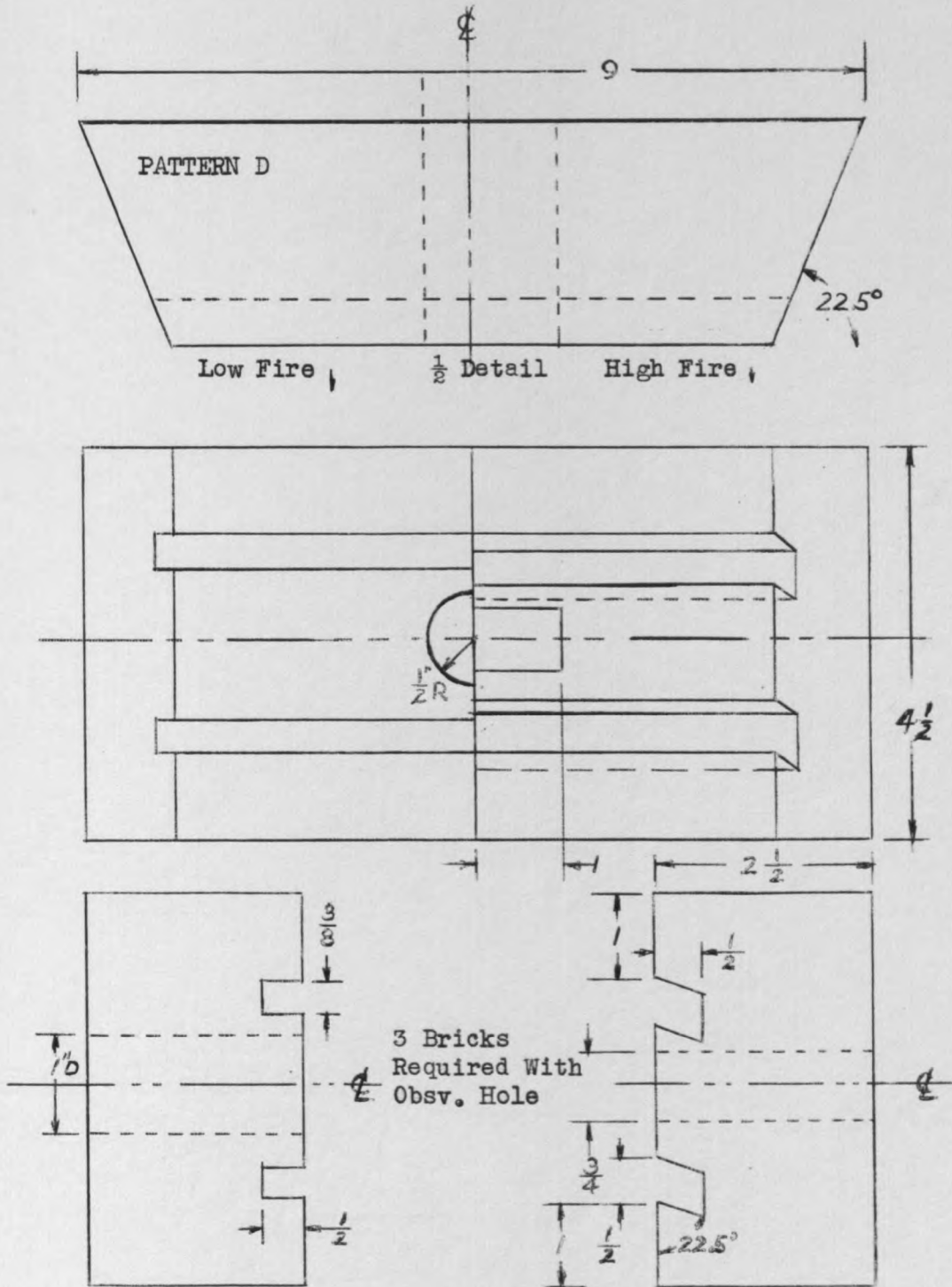
Figure 6

SCALE 1/4" = 1"



Pattern A - 16 Required
 Pattern B - 4 Required
 Pattern C - 4 Required
 Full Brick - 2 Required

For High or Low Fire Kiln



Low Fire Kiln - 2l Required

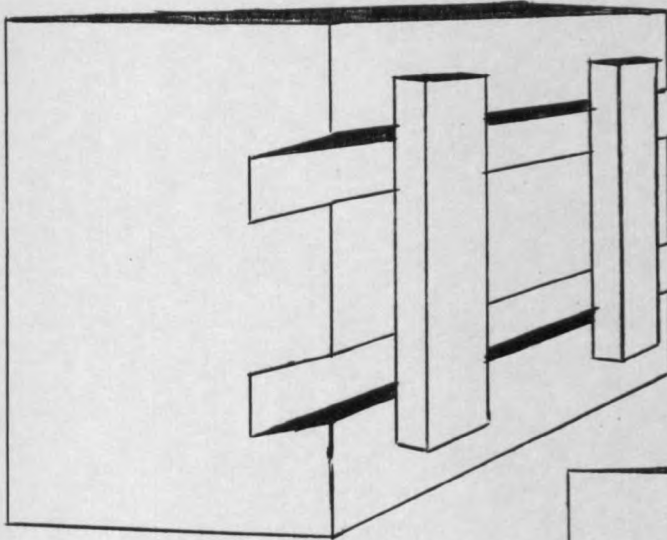
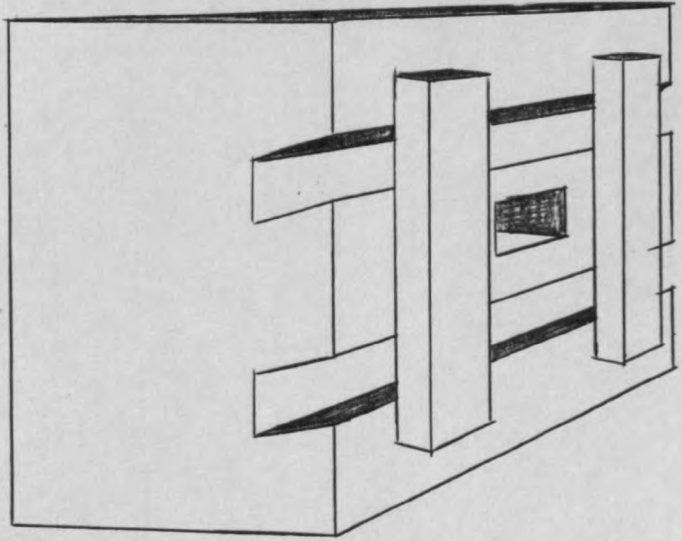
High Fire Kiln - 2l Required

ELEMENT BRICK DETAIL

Figure 8

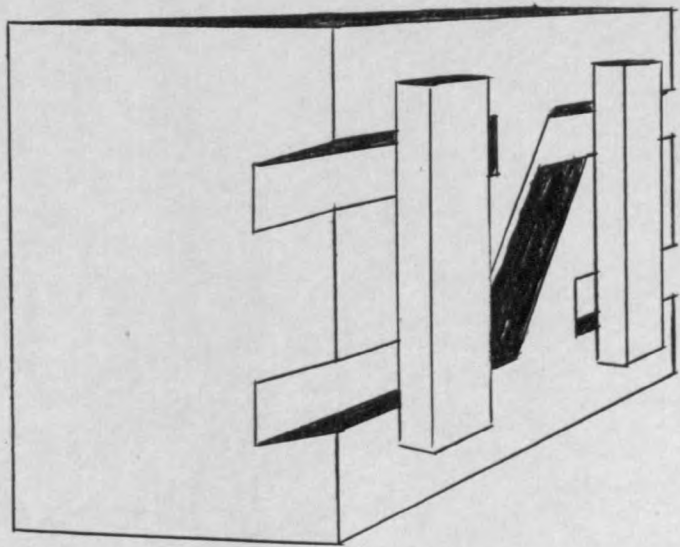
SCALE 1/2" - 1"

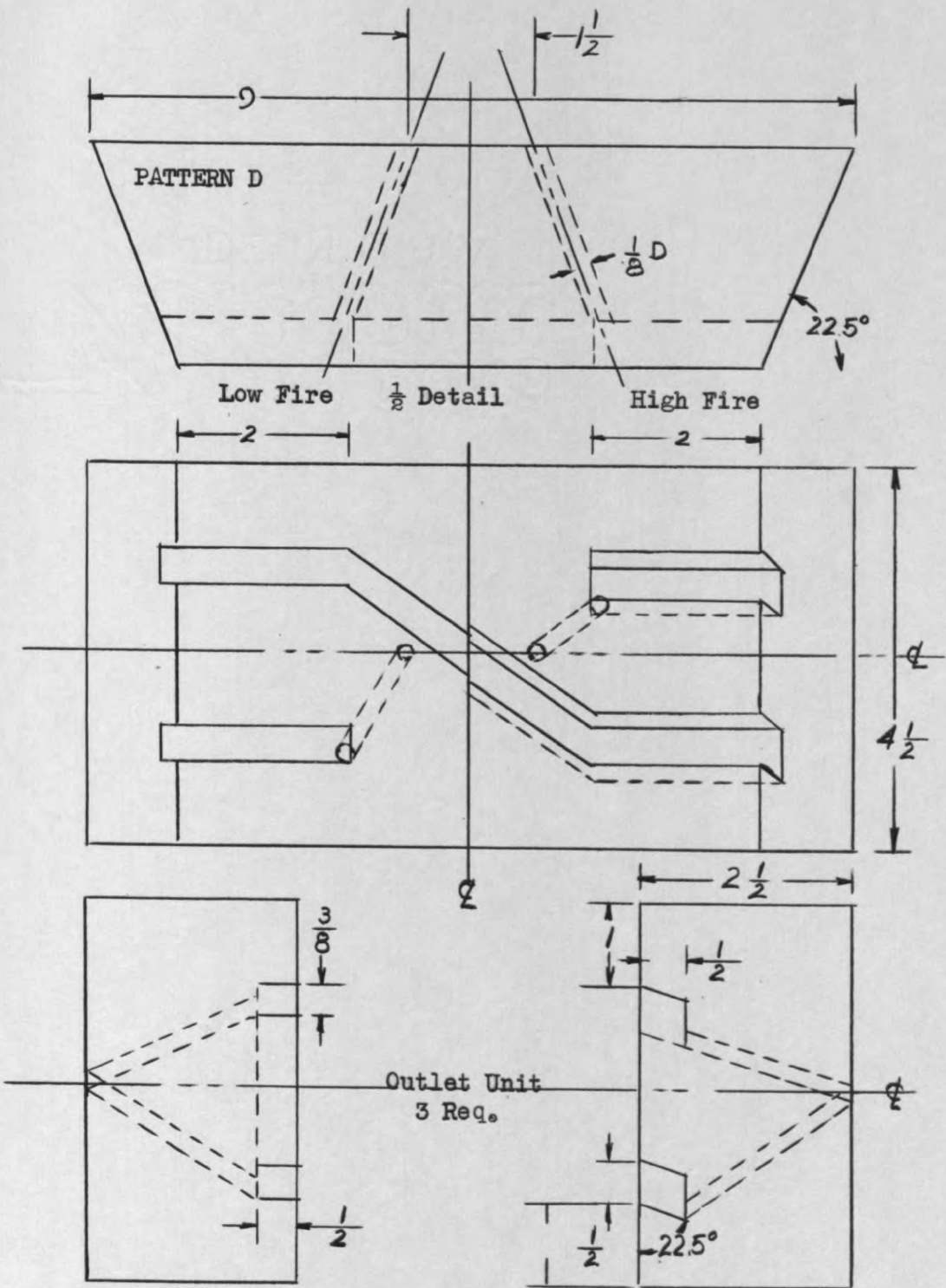
Unit Brick with Observation Hole



Unit Brick

Outlet Brick

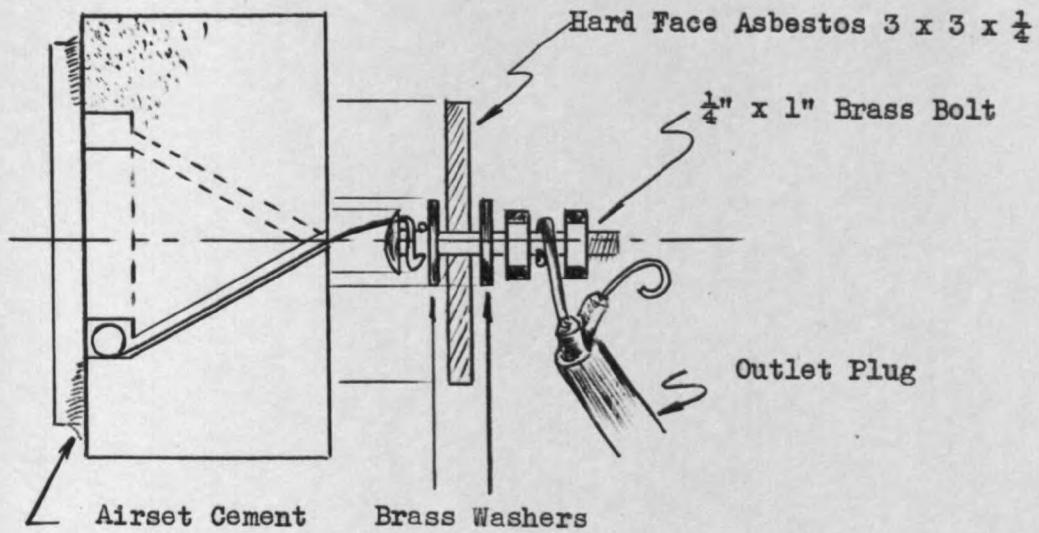
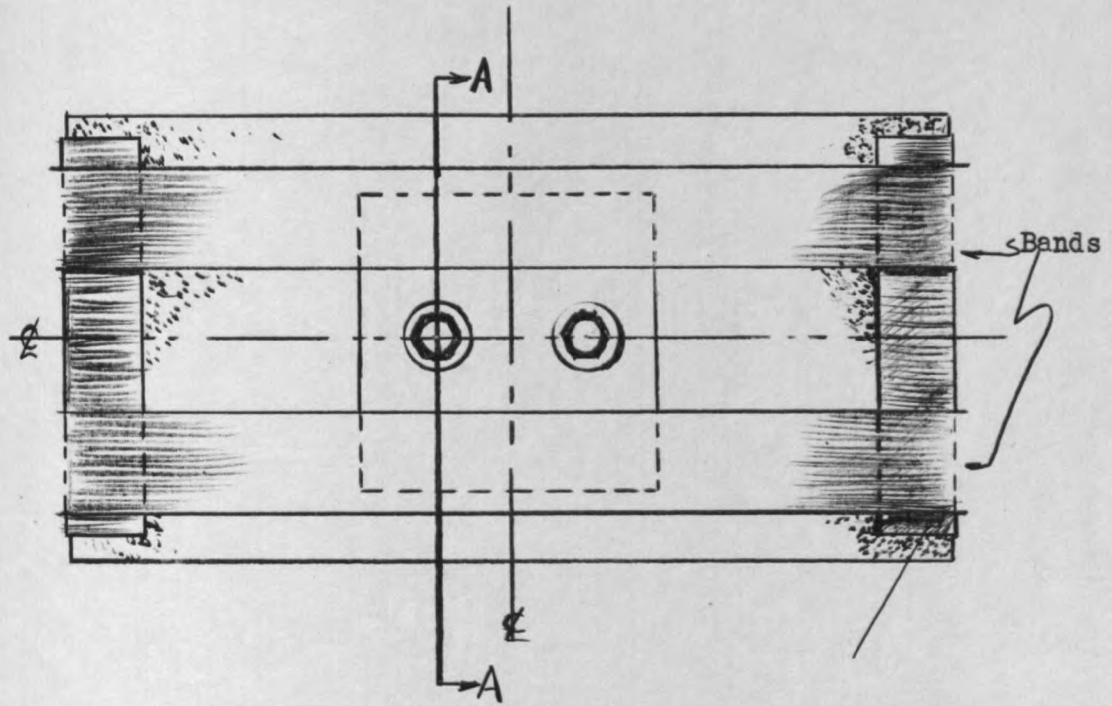




OUTLET BRICK

Figure 10

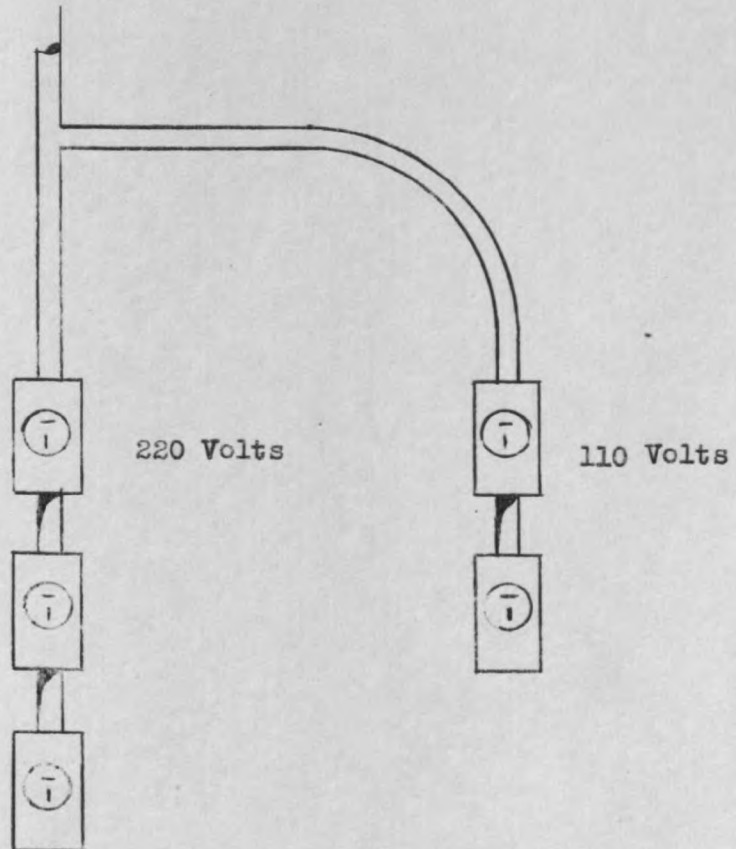
SCALE $\frac{1}{2}'' - 1''$



OUTLET DETAIL

Figure 11

SCALE 1/2" - 1"



Hour	Element	Voltage
1	Bottom	110
2	Middle	110
3	Bottom	220
4	Top	110
5	Middle	220
6	Top	220

SUGGESTED OUTLET HOOKUP

Figure 13

FIRING CHART

POTTER'S WHEEL AND A PLAN FOR CONSTRUCTION

Sooner or later the individual who works in ceramics feels a desire to throw on the wheel. The many other methods of ceramic expression have their place but they never seem to match the feeling of satisfaction derived from seeing a well turned piece grow from a lump of clay deftly raised by the potter.

There are many wheels on the market today. Some of them are good while others are only satisfactory.¹ If it is decided to purchase rather than build one, much care in selection and questioning of present owners of wheels should precede the final purchase. In any event a manufactured wheel will be expensive both in original cost and in shipping charges.

This thesis has not been intended in any way to belittle equipment now on the market or to discourage those who plan to buy such equipment. Rather, it has been the aim to show that a ceramics shop is not beyond the financial or mechanical scope of schools, adult groups or the individual who desires to set up such a shop.

It was desired to have a wheel that could, if necessary, be moved from place to place, or wheeled out of the way when not in use. This seemed essential when it was realized how small the amount of room allotted to a ceramics shop in the average school might be.

A wheel, in order to be of suitable design, must be smooth and easy in action. It must be variable in speed to allow for high speed at the centering operation and a slow, steady movement when tall, thin

1. See List of Supply Houses P. 81.

pieces are being finished. A constant speed machine is not suitable for the best work. A lever type kick wheel has the disadvantage that at the end of each stroke there tends to be a slight hesitation which makes it almost impossible to throw completely symmetrical pieces.

The wheel described in this thesis was built with the following things in mind:

1. Economy of construction.
2. Minimum number of tools required.
3. Semi-portable.
4. Smooth, accurate action.
5. Long life.
6. Minimum upkeep and repair.

The basic principle involved is to transmit the vertical power produced by the treadle of an old sewing machine frame to horizontal power needed to run the turning head of the potter's wheel. Finding a good method of hanging the shaft to which the turning head was fastened proved to be the greatest problem. Due to the short power transmission it was necessary for the entire unit to be in perfect alignment. The difficulty was overcome when it was found that a 5LL Schwinn cone, race and bearing set would produce the bearing surface necessary when set in both ends of a 2-inch pipe and the shaft operating through these. Perfect alignment is possible and drag is reduced to a minimum in a bearing mechanism of this type.

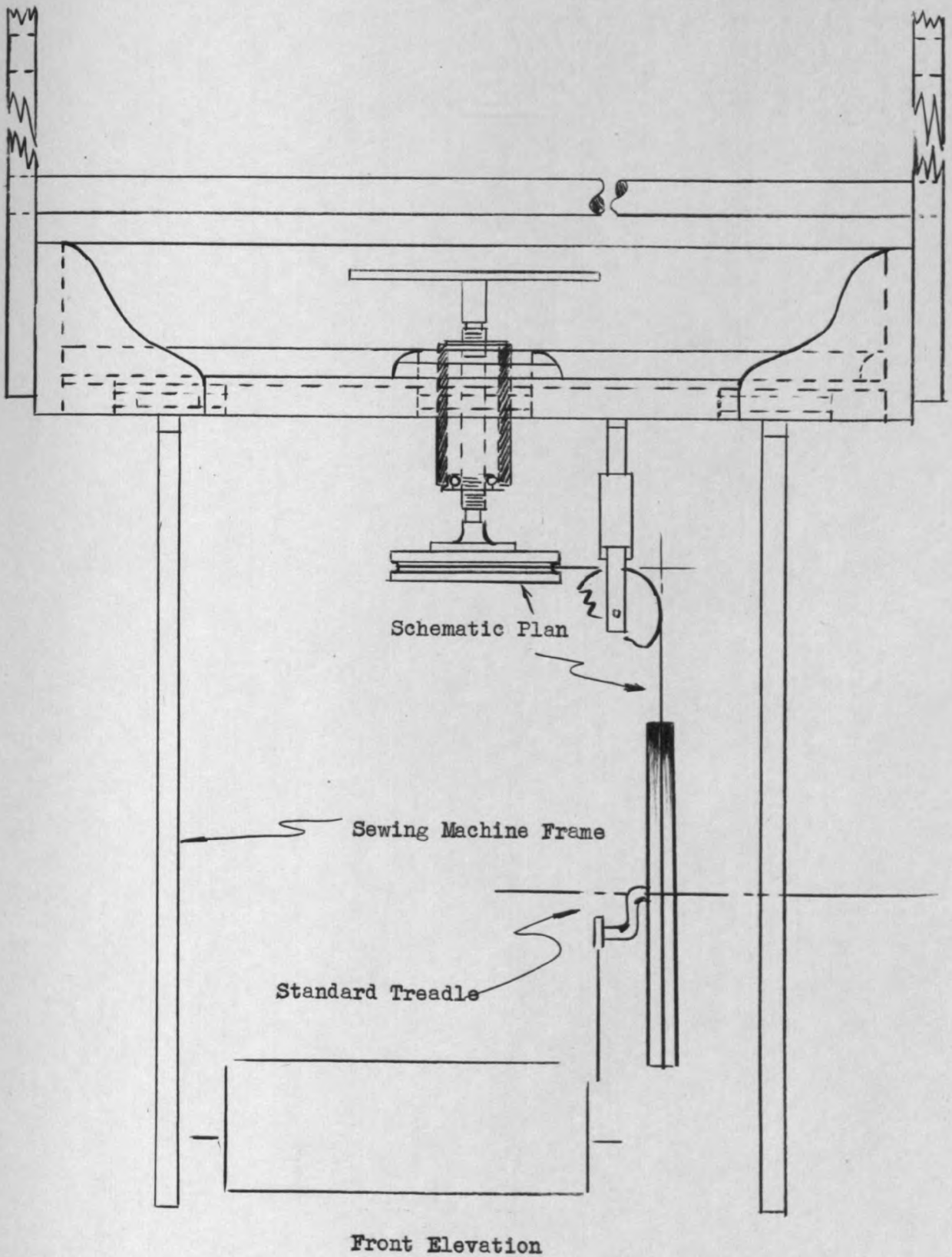
Two wheels have been made from this plan. One is on an old Singer frame and the other on a White frame. The overall measurements of the two machines are equal except for the power wheel on the frame itself.

The wheel on the Singer frame is larger and sits lower to the ground. Mention is made of this fact not because of any difference in efficiency but because the idler wheels must be adjusted accordingly. A close inspection of the plans as presented will make this evident. Special attention is called to the schematic diagrams included in the front and side elevation to clarify the need for adjusting the idler pulleys to the sewing machine frame being used.

One turning head was fabricated of boiler plate and a welded sleeve. This makes a good problem for shop classes and has been a successful turning head but presents problems for those without welding equipment and a lathe. The second turning head was made from a flat belt pulley with a set screw tapped into the shaft. A plaster head has been cast over both of these in order to add weight and increase momentum. This plaster turning head has an added advantage in that it can be leveled with a turning tool and rasp, thus allowing for accuracy in the head at all times.

The cost of supplies used in constructing either of the potter's wheels made in this manner was approximately \$7.50.

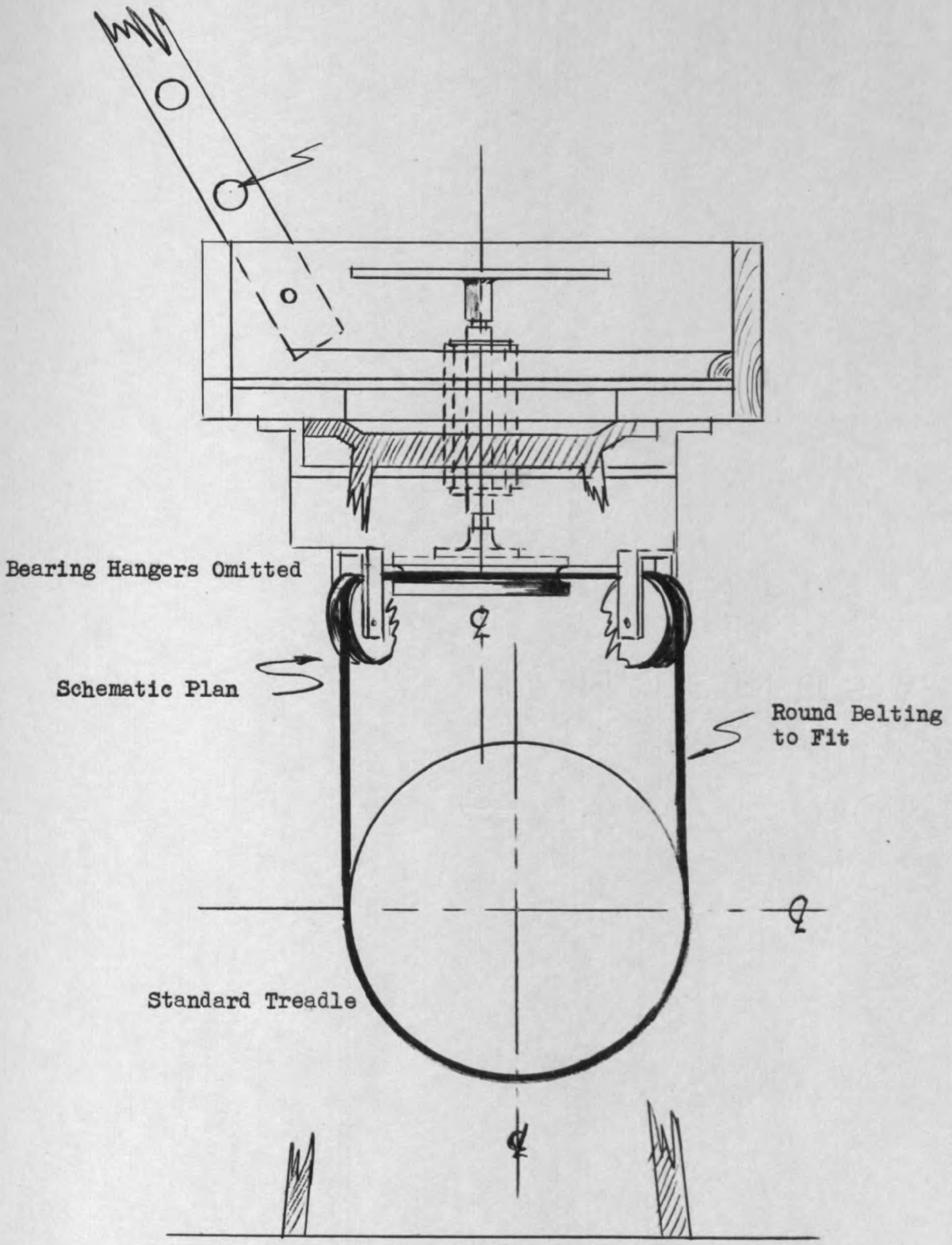




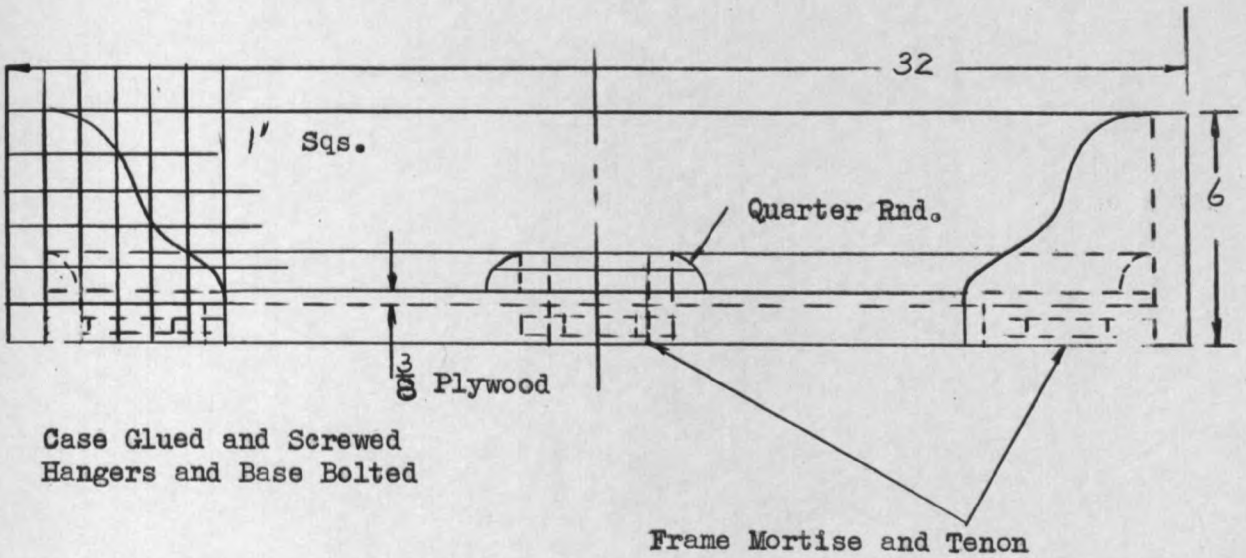
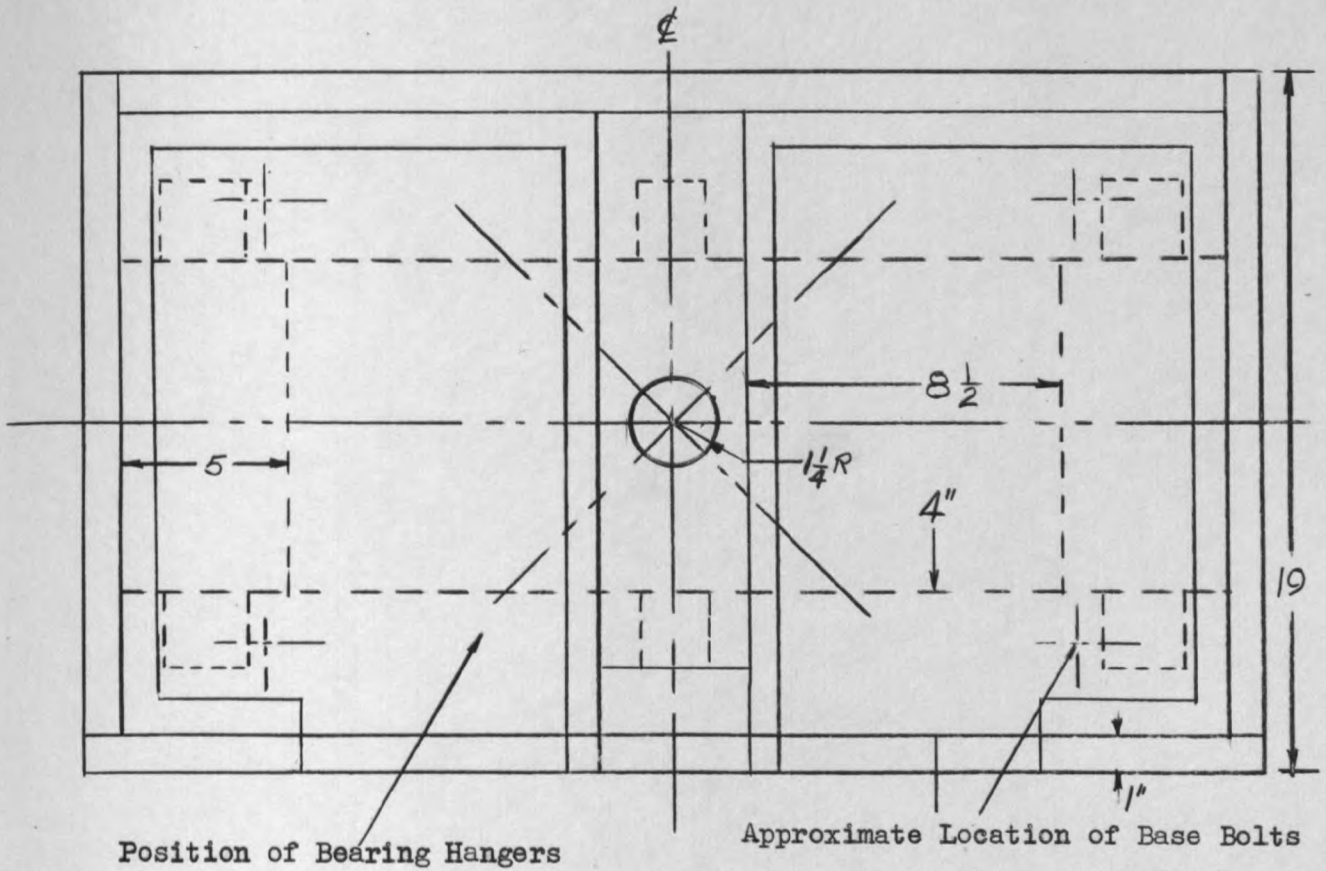
POTTER'S WHEEL DETAIL

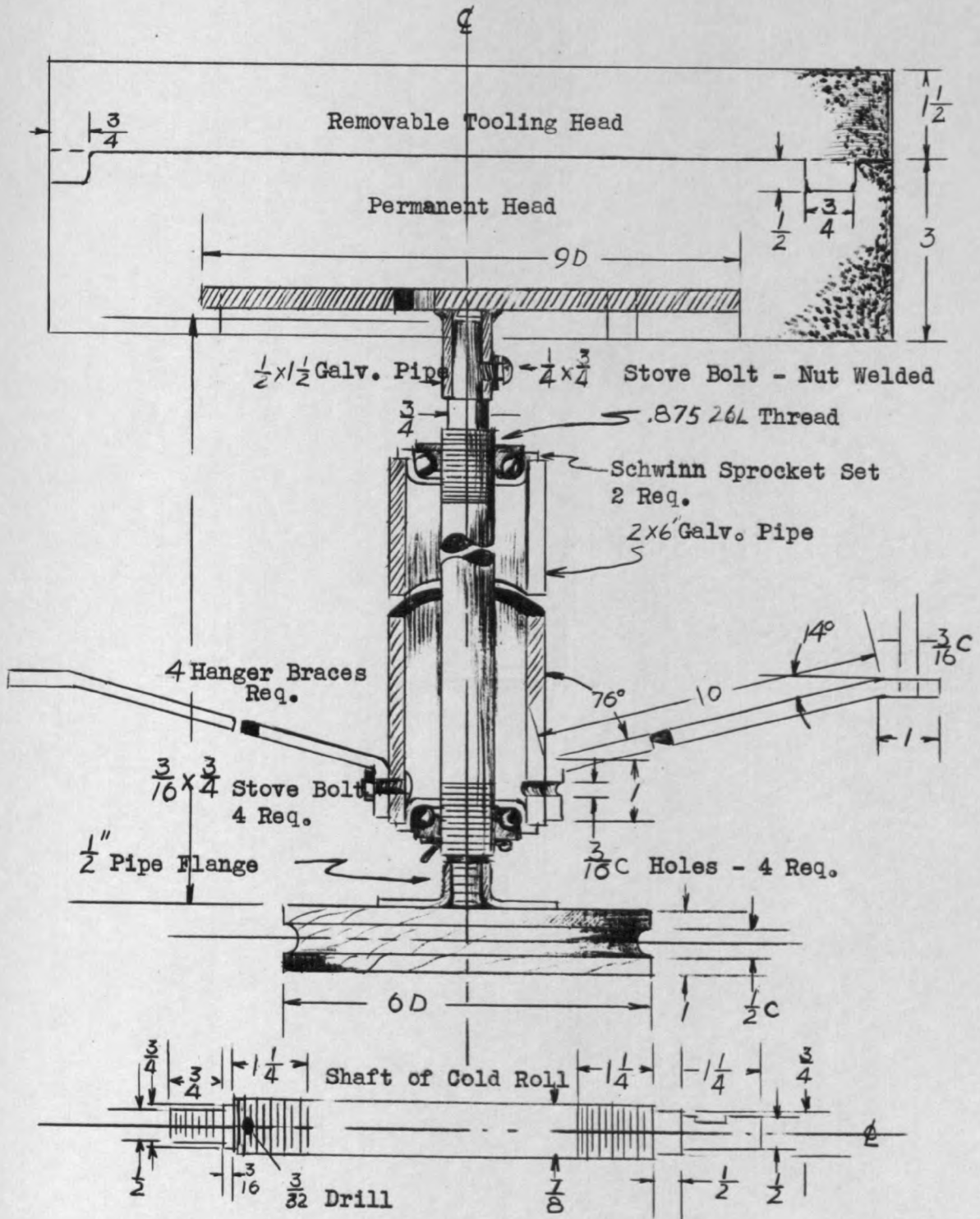
Figure 14

SCALE 3/16"- 1"



Side Elevation

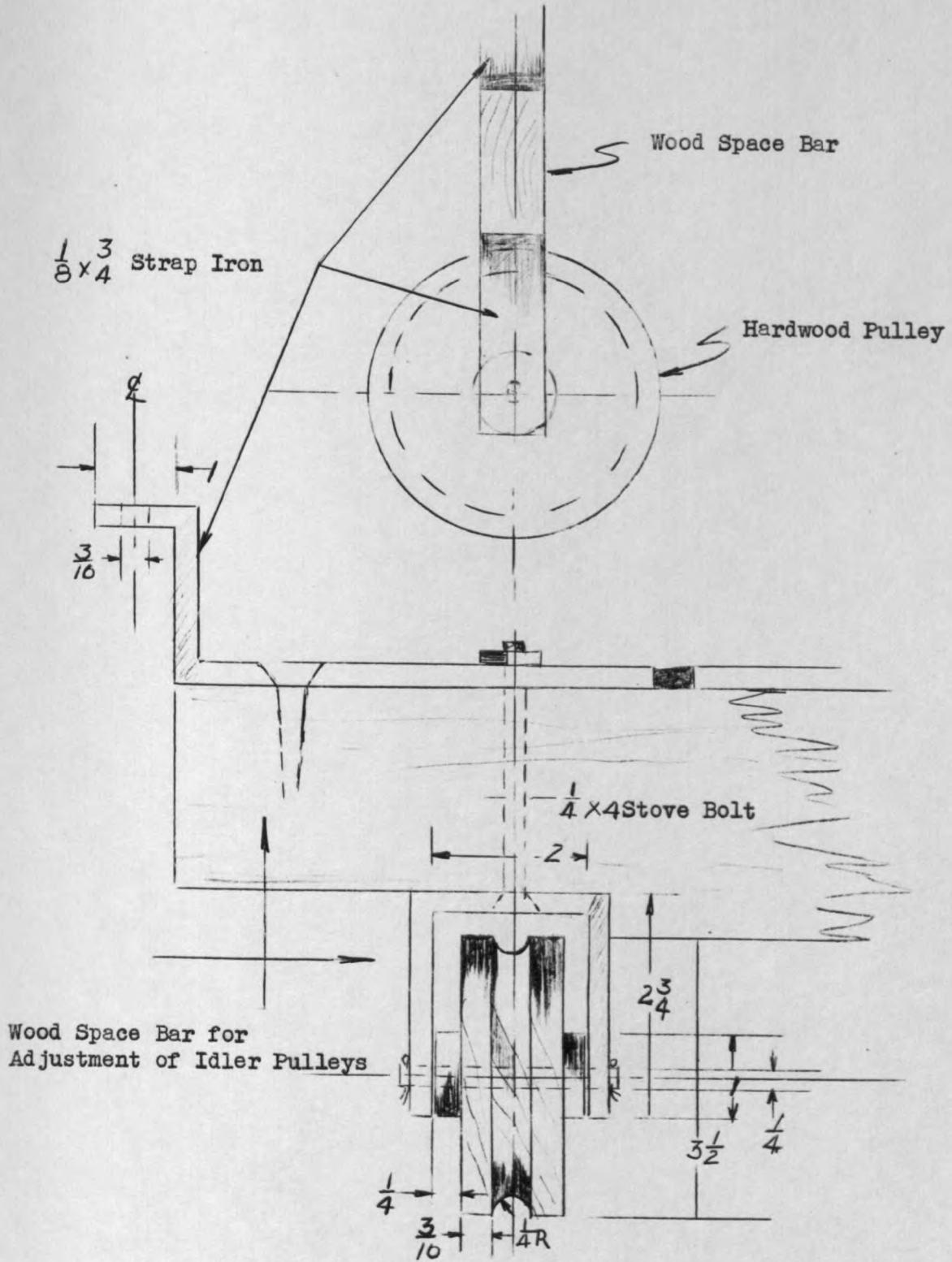




BEARING DETAIL

Figure 17

SCALE $\frac{3}{8}$ " - 1"



IDLER PULLEY DETAIL

Figure 18

SCALE 1/2" - 1"

WEDGING BOARDS, DRY BOXES, TURNING BATS

A good deal of plaster work is necessary in equipping a ceramics shop. Low consistency plaster is considerably cheaper and serves the purpose just as well as the more refined types of Plaster of Paris. If much mold work for casting is to be done, potters' plaster is recommended for the contact coat inasmuch as a smoother finish is thereby possible. For wedging boards, dry boxes and turning bats, low consistency plaster is satisfactory.

The size of a wedging board is usually left to the discretion of the builder and user. In some class or group shops a wedging board is made large enough for two or more persons to work on at one time. This is all right if there is no danger of the clay being mixed. If red or dark clays as well as lighter colored clays are used at the same time, it is advisable to have two wedging boards, each for the exclusive use of light or dark clay.

Wedging boards are used for equalizing the consistency of clay before its use, no matter what method of forming is to be employed.¹

Figure 19 indicates a serviceable type of wedging board for most shop use. The dimensions are adjustable to suit the needs of the shop. The top area of the wedging board, the plans for which are included in this paper, has proven satisfactory in handling up to ten pounds of clay during wedging. Two such wedging boards are sufficient for 17 students during a class period at the college.

After a clay body has been prepared as a slip, some means is necessary to draw off the excess water and render it plastic enough

1. Ford, F. A., "The How and Why of Good Wedging," Ceramic Age, December, 1947, PP. 354-355.

for wedging. A dry box made of plaster is needed for this purpose. When plaster is dry it is highly receptive to water. As the plaster draws off the water, the clay is left in a plastic state. Dry boxes are also used for complete drying of washed local clay for dry storage for later use. For best use a number of shallow boxes are better than a few deep ones. Figure 20 gives dimensions and a cross sectional view of a good dry box. The original for the master mold is modeled from scrap clay. The scrap clay is used inasmuch as the master pattern does not have to be fired and the bits of plaster that will naturally get into the clay will cause no harm.¹ While the clay is still leather hard a retaining wall of tin or linoleum is placed around the pattern and plaster cast over it. When the plaster has set firmly the clay can easily be removed, leaving the finished box. It is advisable to cast a master mold from the first finished dry box in order that more boxes may be cast as needed.²

A "bat" is the term given to a piece of plaster upon which the clay is thrown. The bat is round and flat in order that the thrown piece will have a perfectly smooth base. The diameter of the bat will vary according to the size of the piece being thrown. It is not necessary to use a bat large enough for a plat when only a cup is to be thrown. Varied size pie plates and pyrex dishes make excellent molds for bats. Smooth bottomed pie plates of the tin or aluminum variety are easily emptied of a finished bat by simply springing

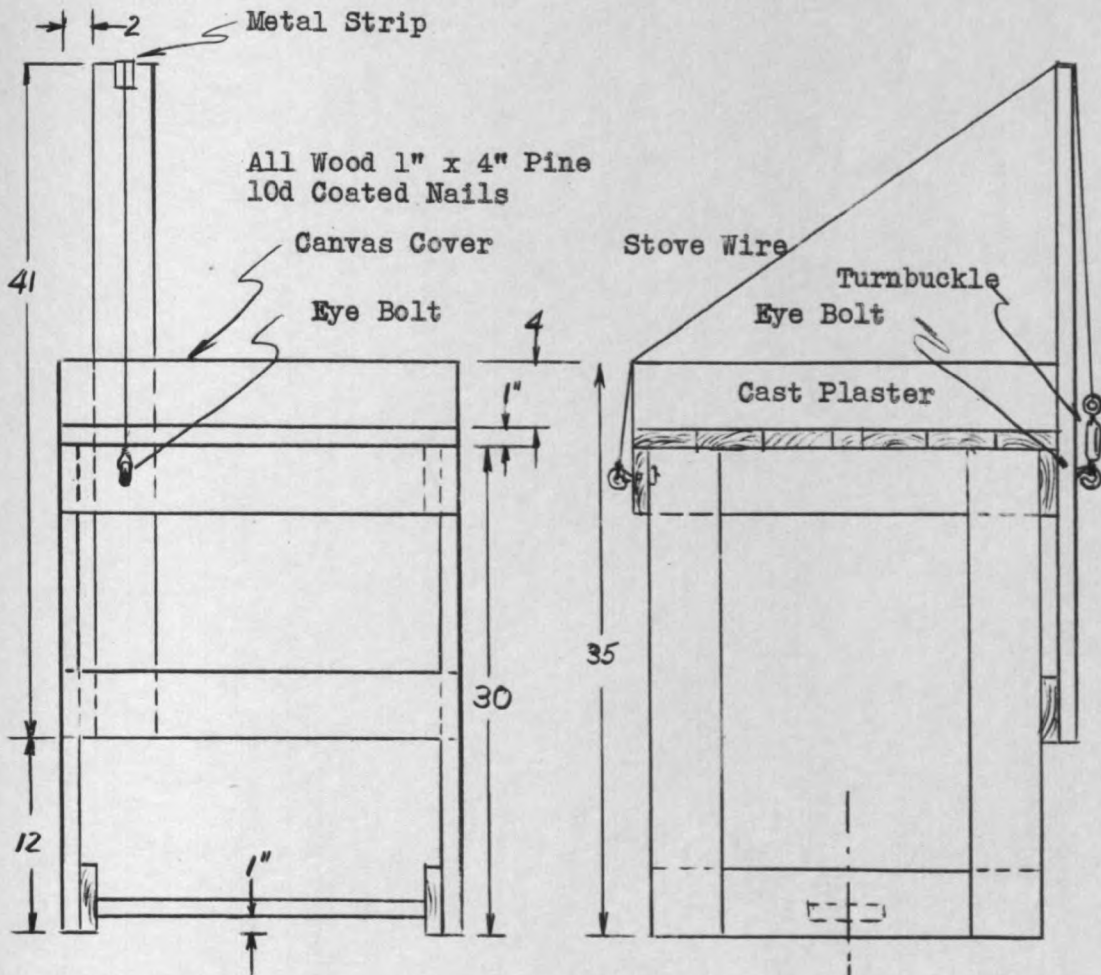
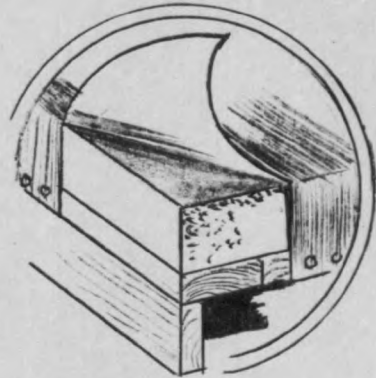
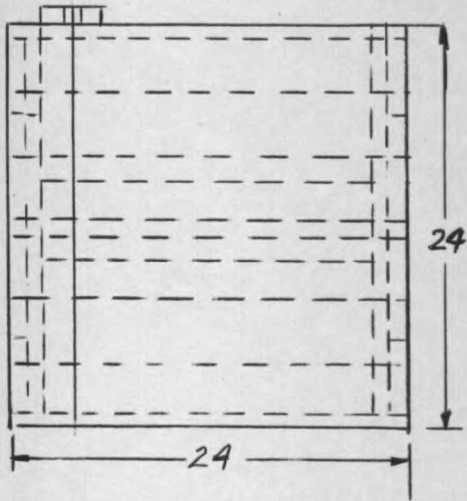
1. Care should be taken at all times to keep Plaster of Paris from contaminating clay that will be fired. Plaster of Paris will cause soft spots in the ware and glaze will not adhere.
2. At least one dry box should be provided for each student.

the plate slightly. Pyrex dishes lightly soaped will release under warm water. A cast iron skillet also soaped will release when tapped on the bottom. In any event a little care in making the bats will result in no harm to the utensils. If shallow containers of no greater depth than 1" to $1\frac{1}{2}$ " are used, these should be filled to the top and trimmed smooth, using the edge of the container as a guide. Should deeper dishes or the skillet be used, it is best to prepare a perfectly level surface on which to place the container while the plaster is setting. If a bat is not level, difficulty will be experienced during the throwing.

A damp box is needed to store unfinished pieces between work periods. A damp box should be as air tight as possible, as well as resistant to rust. For use at the college, war surplus ice boxes have proven very satisfactory. In order to keep the humidity high, broken dry boxes and old bats are soaked thoroughly in water and placed inside. From time to time these broken pieces of plaster are removed and re-soaked. When these boxes were first put into use some mold was noticed. The mold had no ill effect upon the ware and after a few weeks disappeared.

When constructing a damp box a zinc lining resists the rust brought about by the constant moisture.

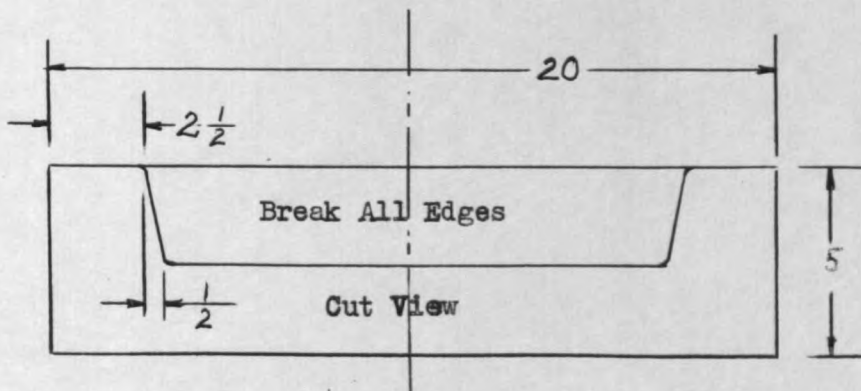
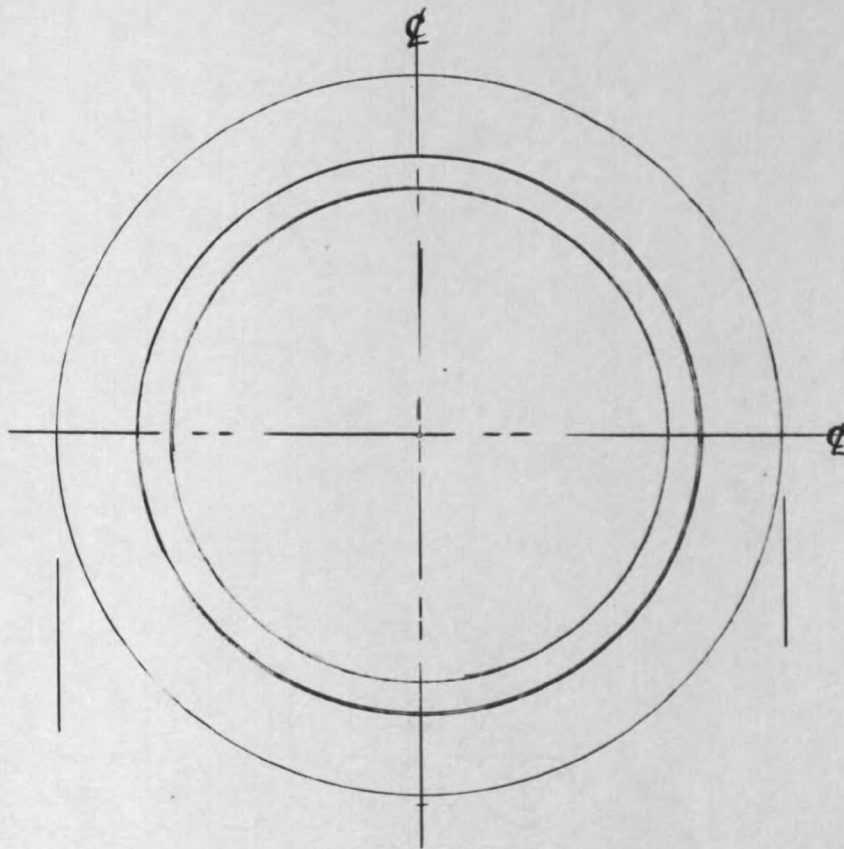
No size of constructed damp box has been given but it has been left to the discretion of the ceramist to construct an air tight container that will best fit his needs in maintaining unfinished ware in a leather hard state for the final stages of finishing.



WEDGING BOARD

Figure 19

SCALE 1" = 1'



Made from Low Consistency Plaster

MISCELLANEOUS EQUIPMENT

The utilization of odds and ends around the shop with a view to simplification of work and economy is as unlimited as the ingenuity of the individual. It is not necessary to make a ceramics shop so expensive that it is out of the question for the school, adult group, or individual. Listed below are a few examples of this utilization of odds and ends other than those already mentioned during the course of this paper:

1. Broken hacksaw blades taken from hand hacksaws are adaptable as trimming tools. The toothed edge assists in removing the larger areas as well as being used for textures. The smooth side works well for final finishing and polishing.
2. Scrapers cut from scrap copper, aluminum or stainless steel obtained at a tin shop are easily made. The shapes are cut to suit the job.
3. Cellulose sponges of the square shape serve as a good substitute for elephant ear sponges for use on the turning wheel and for cleaning slab work. A good elephant ear sponge costs about \$1.50 at the present time whereas a cellulose sponge is about 10¢.
4. A feed mill works very well in grinding local clays. This is not absolutely necessary in work with local clays but it does increase the amount of clay adaptable.
5. When the legs are cut off an old swivel-top stool, a good banding wheel is the result.
6. Rubber bowl scrapers replace the potter's usual rubber kidney scraper.

Many other items can be put to good use. It is up to the individual how far he wishes to go. The many means of using less expensive equipment and returning to use items that would otherwise be thrown out makes it possible to use the money that would be spent for such items in purchasing a good gram scale for weighing glazes, a pound scale for

balancing clay batches, a mortar and pestle for grinding glazes and, last but not least, some good reference books on ceramics and glazing.

CLAY AND CLAY BODIES

There are many good clay bodies on the market designed for the studio potter and school use that mature at cone 04. For the individual who is not interested in fitting glazes to the clay but prefers a clay and glaze already designed to work together, purchasing materials from ceramics supply houses is the best. The cost of shipping brings the pound value of the clay flour up considerably. In many ways, however, the cost is balanced by the convenience.

During the time that ceramics has been offered at Montana State College visitors have continually asked if any clays used are found locally. A growing interest has been noted in the possibilities of clays found within the state for use other than in the production of brick and building tile. In the past year samples have been collected from seven different areas. A report of these clays will be found on the following pages.

It is best to understand the makeup and requirements of a good clay before considering the clays tested and discussing the methods used to prepare them for use.

Quite often the name "clay" has been given to all earth of a slick, adhesive quality. While this may be indicative to the average person, it is misleading. To illustrate why this is so and what goes to make up this familiar clay, take a dry amount of raw material and place it in a jar of water. After allowing it to soak for 24 hours, or until it has become completely dissolved in the water, shake it until the material takes on a blended quality. The "clay" mixture will have been absorbed by the water to form a homogeneous mass.

Allow the slip, as a clay water substance is called, to settle until the water has again separated and risen to the top. What vegetable matter was contained will float and may be drawn off as the first residue. The settled mass will show two main strata. The sand contained will settle to the bottom of the jar, leaving the finer material on top of the sand. This finer material is the plastic substance commonly referred to as clay. By carefully drawing the top layer off, a reasonably pure clay may be obtained. Successive washing such as this will continue to separate the purer clay and the heavier sand. By this simple method it is easy to see that what was originally given the name of "clay" contained a large percentage of sand. Actually very little pure clay may exist.

To quickly illustrate the relationship between the raw material taken directly out of the earth and clay as recognized by the potter, take a piece of clay of a quality workable on a wheel and, allowing it to dry completely, repeat the same process used to illustrate the makeup of the raw material. The same results will be evident with the exception that the vegetable matter will not be present. The heavier ingredients will tend to settle, leaving the pure, true clay at the top.

The results of these tests will indicate that the mass referred to by the potter by the all-inclusive term of clay is more than that clay which is the final result of washing either the raw or the prepared mass. The potter's clay is also composed of many ingredients, just as the raw piece. It would then be an apparently simple matter to stop at the raw material and use it for our work. This is not

necessarily so as the amounts of sand and true clay substance found in the raw material may not be in proper balance to give the required properties.¹

Clay bodies must have three main properties for potters' use.

1. Plasticity
2. Porosity
3. Density

The first two characteristics appear in the unfired ware and the third is to be found in the fired piece.

Plasticity in a clay refers to the capacity of the clay to be fabricated. In order for a clay body to be plastic it must contain water. A good water content is approximately 25%. The degree of plasticity will vary as to the means of shaping the ware. A clay body that is to be used on the wheel will be more plastic than one to be used for slab work. For most individuals not concerned with speed of production and not having space to store many types of prepared clay, it is more convenient to mix all bodies as if to be used on the wheel.

Unless a body is porous the water content will not pass off as evenly or as fast as necessary to avoid extreme warpage or, in many cases, actual breakage during the drying period. Warpage may also occur while the piece is being fired. Porosity is achieved through the presence of tiny passages in the clay brought about by the structure of the body itself. Porosity and plasticity are the reverse of each other and to produce a satisfactory clay body a working balance

1. Op cit, Binns, C. F., PP. 4-11.

must be made between the two.

The ware fuses or vitrifies to a hard, non-soluble state as a result of the firing process. The degree of vitrification is the third quality required of a workable clay body, or in other words, density. If the piece is fired above its point of best vitrification, it will continue to fuse to a point where it will melt and become glass. The vitrification factor is the factor that controls the amount of heat necessary to produce satisfactory density. Density can be checked by the tone produced when the finished piece is struck with a pencil. Proper density will produce a clear tone. Another check of porosity is the strength of the piece.¹

Some clays will have all three qualities just as they are removed from the ground and after the foreign matter has been removed. Clays that are sufficient in themselves for most pottery processes are rather rare.

Clays in one form or another are to be found in almost every section of the country. It is the job of the potter to choose these clays and mix them into a clay body that is satisfying to him. The one thing to keep in mind when dealing with local clays is that for the most part local clays will be red, buff or blue-gray. Very few white firing clays are found that can be used directly. Kaolin, or china clay, is white firing and is found in large quantities in the Lewis-town area. Due to the physical properties of kaolin, however, it is not used by itself in low fire kilns.

1. Searle, A. B., "What is Clay?", Ceramic Age, July, 1946, PP.-16-18 and following.

As previously noted, not all clays are immediately suitable for pottery work. For the individual who plans to prepare his own clay body, whether it is from local material or from commercial clay flours, he should understand the use of some of the better known ingredients that may be purchased to modify the local material.

Kaolin, or china clay, is the basic ingredient for porcelains. Kaolin is highly refractory, or in other words, it requires a high heat to mature. Kaolin is very often used as an ingredient to raise the maturing point of a low firing clay. Kaolin, like most residual clays, is not too plastic and is hard to work. When using it in a clay body, it will raise the maturing point but at the same time the working quality of the body will be reduced. Since this clay fires white there will be some loss in color and the new body will fire lighter in tone. This loss of color may not be harmful and may even be desired when it is known that such a change will take place.

Ball clay is the most plastic of the commercial clays. When low plasticity is encountered, ball clay may be added to overcome such a deficiency. Ball clay fires buff and will tend to discolor the white clay bodies on the market. Due to the plasticity of ball clay, care must be taken not to overbalance the recipe and reduce the porosity that is required to allow for even drying and minimum warping of the finished ware.

Porosity is obtained in a body by adding materials that are not dissolved by the action of the water. Clean sand, flint, ground glass, grog and, to a degree, feldspar open a clay and allow the air to escape through fine holes present around the undissolved particles

of these ingredients.

Flint not only aids in porosity but in doing so tends to reduce shrinkage in the ware. During the firing flint remains almost inactive and provides the rough edged particles around which the feldspar and clay form a bond, thereby producing the density or third requirement of a clay body.

Ground glass reacts in the same manner as feldspar within the clay body.

Feldspar or spar, as it is more commonly known, is considered among the sand groups along with flint and ground glass during the working period before firing. Spar is used in a clay body for its fluxing action whereby it dissolves the clay particles themselves and at higher temperatures to a degree attacks the flint or silica particles present. Such an action blends the entire clay body into a well fused mass producing the third quality or density. Spar may be used to reduce the vitrification point of the ware. The action of spar is noted in ware fired as low as cone 09.¹

Nepheline Syenite is a product mined in Montana as well as other states. The composition is high in feldspar and nepheline with no free quartz. Nephsy, as it is commonly called, acts as a flux in the same manner as spar. Nepheline Syenite, when added to a clay body, reduces the maturing point of the body.²

Grog is the common name given to fired clay that has been ground and screened to remove the larger particles. Clay once fired becomes

1. "Ceramics Materials," Ceramics Industry, January, 1946, P. 103.

2. Ibid, P. 14.

insoluble and the only way to change its character is to pulverize it. Even after pulverization it retains its insoluble state and has all of the characteristics of silicate sands in the unfired ware. It is used to introduce porosity, and in some cases texture, to the ware. Grog does not fuse when it is refired.

Excellent references to clay and clay bodies are available in the writings of Charles F. Binns, Bernard Leach and A. B. Searle whose works are listed in the Bibliography. These references have been used extensively during the preparation of this chapter.

PREPARATION OF LOCAL CLAYS

The eleven samples of clay received from various parts of the state were all prepared for testing in the same way.

Before anything else can be done with a local clay it must be thoroughly dried. The drying is necessary since clay, when moist, forms a slick surface that prevents the water from penetrating into the inner mass with the result that clay does not break down into a slip state. The larger lumps of clay are broken up in order to speed the drying process. All rock and vegetable matter that can be removed at this time should be taken out.

Large aluminum stock pots have been utilized in the process of levigating or washing the clay and storing it during the aging period. Wood barrels, aluminum vats or earthenware crocks are the most adaptable for the preparation of clay since no rusting will take place in these containers.

Enough water is placed in the container to completely cover the sample and the batch is set aside to soak for several days. Clay improves by soaking and aging. The vegetable matter decays and adds its share to the body. The aging tends to increase the plasticity and provide a better working material. Leach describes this action as souring¹ and allowed the souring to take place after the local material had been washed and levigated. In the tests made at Montana State College the raw clay has been made into slip and allowed to sour in some cases as long as three months before any washing has taken place. Every day or so the mass has been completely stirred and allowed to settle.

1. Leach, Bernard, A Potter's Book, 1946, PP. 48.

A few days before the levigation was to be started the batch was thoroughly mixed and allowed to settle for the last time. The water that had come to the top was siphoned off into another container. Using a sieve made of copper window screen, the slip was strained off to a point where the sand became too abundant. The slip collected was added to the water previously drained off and the entire mass thoroughly mixed. If more water is needed, this is added from time to time. After a few days the slip was again stirred and settled for a second washing. The same process was repeated as in the first washing except that this time a number 40 mesh screen was used. The material strained off this time was set out in dry boxes made of plaster to completely dry. Fortunately a meal pulverizer was available and this was used to grind the dry clay after the second screening. The finished clay was then ready for testing.

The method described above may be a little more time consuming than some persons may wish. The results seem to have been worth it inasmuch as of the eleven clays tested only one was completely unusable.

Charles F. Binns suggests a quicker method of working up local clay.¹ Rather than allow for such long settling periods before screening, he suggests that the batch be allowed to settle for only a few minutes. Then all but the heaviest sand, which has settled on the bottom of the container, is taken off. Such a process is repeated several times.

After the clay was ground it was put into a plastic state by the

1. Binns, C. F., The Potter's Craft, 1947, PP. 24-27.

addition of water and thoroughly wedged before testing. One method of determining the ability of the clay to stand throwing on the wheel or to take bending to any degree is to roll a coil about three inches long and 3/8" in diameter. Bend the coil into a circle and stand it on edge, flattening it at the base for support. Should the clay show signs of cracking during the bending of the coil, indications are that the clay is "short."¹ By "short" it is implied that the clay lacks in plasticity and will probably present difficulty in throwing. After a little experience in handling clay the individual begins to develop a feel for the material and can judge the shortness of a clay quite easily.

If a clay under investigation shows signs of being short, it may be corrected in one or more of three ways. Ball clay may be added to the batch as needed. Here again, after some experience the potter begins to get a "feel for the material" that will help him in correcting the faults of a clay body. Another local clay that is too dense before firing, and as a result is quite plastic, may be added. This is the case of two local clays tested for this paper. A sample received from the Alder area tended to be a little short whereas a sample from the Middle Creek area was very plastic but dense. The two were mixed together, making a usable clay. Bentonite, a clay body found extensively in Montana, may be used but it is not advised. Bentonite is difficult to handle and might even be said to be unstable. Plasticity is gained but shrinkage and warpage are very apt to occur, especially during the last stages of drying or during the firing period.

1. Op cit, Leach, Bernard, PP. 46-47.

Cox tells of the action of Bentonite on work in connection with tests made at the State Penal Farm at Angola, La. The clay worked well on the wheel and to all appearances was going to dry correctly. During the final stages of the drying extreme cracking and warpage took place. About one per cent of common table salt was added to the tempering water with good results.¹ The addition of ball clay will also help to counteract such a condition.

Not only does a clay body have to be workable, but it must be firable. Kaolin is a good example of a clay that is workable for most persons but it requires too high a temperature for normal use. The peak heat obtained by the high fire kiln discussed previously is still too low for vitrification of kaolin. The greater majority of local clays are low firing in character. During the testing of local clays only one type was found to mature higher than cone 04. A type of pink clay found in the Lewistown area is slightly underfired at 1950° F.

Aside from adding a local clay with a lower or higher firing point, as the condition may require, two alternatives are possible to reduce the vitrification point. Feldspar or nepheline syenite may be added. The characteristics of these two chemicals have already been discussed. Kaolin serves very well to raise the vitrifying point of a clay body. Kaolin does tend to lower the plasticity of the body so that it may also be necessary to add some ball clay.

1. Cox, Paul E., "A Salty Story," Ceramic Age, January, 1949, P. 26.

TESTS PERFORMED ON LOCAL CLAYS

Eleven sample clays were tested and, with one exception, they were found to have some possibilities. No effort was made to estimate their possibilities for commercial use insofar as quantities were concerned. Some clays were sent in by interested persons who were desirous of finding a clay in their vicinity that could be used for hobby work. Others were collected by the author in connection with this thesis. Two samples were taken from excavations on the campus to illustrate the possible places where clay may be found. One was taken from the basement excavation of the new Physics Building and one from a frost boil excavated near the Service Shop.

Listed are the samples and their locations as well as identifying marks:

1. Physics Lab., M.S.C. Campus	Ph. Lb.
2. Frost Boil, M.S.C.	F.B.
3. Middle Creek.	M.C.
4. Hyalite Canyon, Ranger Station	Hyalite
5. Fromberg #1	Fromberg
6. Fromberg #2	Fmb.
7. Kalispell	K
8. Alder Area	A
9. Phillipsburg	Ph.
10. Lewistown Brickyard	Lewis.
11. Lewistown Railroad Cut	Pink

1. The clay was washed and aged for about three months before the first tests were made. There was a tendency during the turning of the clay on a wheel for pieces of clay to pull away, indicating some "shortage." During the drying period the clay did not shrink unduly but it did dry too fast and unevenly. The fired piece had only a fair tone when struck, revealing lack of density when fired. Ad-

ditions were made in the following percentages.

63.75%	Ph. Lb.
10.00	40 Mesh Grog
10.00	Nephsy
10.00	Kaolin
6.25	Kentucky Ball

The resulting clay handled well for throwing, carving and slab work. When fired the ware had a good tone and was a salmon pink in color. Of interest in this test is the fact that 63.75% local material may be utilized.

2. Sample F.B. was taken from a location about a block distant from the Physics Lab sample. There was a considerable increase in foreign matter that had to be removed before the clay could be ground as compared to the sample Ph. Lb. A shorter time was allowed for aging. This time only about two months elapsed before the first tests were made. The washed clay is much lighter in appearance when in the dry state and fires buff. The uneven drying was not as evident but still noted. This clay worked moderately well in itself. Later tests were made by mixing F. B. clay with Hyalite with good results.

3. Due to the small sample received of the Middle Creek clay no thrown pieces of any size were possible in order to test it for working properties and drying characteristics. The general characteristics of sample M.C. were closely similar to sample #4 Hyalite. The fired color was a slight degree redder.

4. Hyalite is a very good base clay that is easily distinguished by its brick red color before and after firing. When it was first brought in it contained a quantity of vegetable matter as well as considerable gravel. The vegetable matter was allowed to remain for

souring as an aid to plasticity. The earlier samples made from this clay worked well on the wheel and for slab work. As the material aged the plasticity increased but the porosity decreased. The clay body is quite smooth and strong for use on the wheel but due to the loss of porosity, the drying has to be carefully controlled. A fifty-fifty mixture of Hyalite and F.B. balances the porosity-plasticity factor. Hyalite has also been added to Alder for the same reason in the same amounts with good results. A 10% addition of flint was tried with a Hyalite base. When drying is slow this works all right but an additional 10% of 40 mesh grog could be added to speed drying and reduce possible warping. In general, it can be said that Hyalite clay is a good body clay for use with clays that are comparatively short.

5. Fromberg #1 was also received in too small an amount to conduct extensive tests upon it. The sample was quite clean with almost no foreign matter present. With little aging--a few weeks--it was highly plastic and, like Hyalite, could be used as an extender for less plastic clays. Like most local clays, Fromberg #1 fired red. This particular clay was a deep red with a clear, even tone when fired at cone 04.

6. Fromberg #2 was the only clay tested without any possibilities whatsoever. The body was so short that the only way a test was possible was in a press mold. The sample, as received, was extremely sandy and contained a large amount of dirt. The fired sample matured at cone 04 and was red.

7. Sufficient clay for a press mold was all that was received from Kalispell. Press molds are used to make test firings for matur-

ing inasmuch as they can be used at a later date for testing glazes. Another advantage of press mold buttons is that shrinkage may be easily measured. This clay showed the highest degree of shrinkage of any clay tested to date. Average shrinkage may be estimated at $1/8$ " per every surface inch. The shrinkage of this sample was approximately $1/4$ " to every surface inch. No further samples have been received from this area to date.

8. Alder Creek clay tends to be lacking in strength during the fabrication period. The general action of it would seem to indicate a Bentonite condition as it develops soft sections during turning. Cracking develops during the drying period, a further indication of Bentonite tendencies.¹ Two tests are under way which indications show will remedy this condition. Twenty-five per cent of ball clay has been added to a sample. A 50-50 mix of Alder and Hyalite sample is also under test. Both samples are being allowed to age slightly before use. In any event, Alder clay is usable as a means of introducing porosity.

9. Phillipsburg clay requires a high degree of washing before it can be used. This is not due to the sand present but to the extreme amount of crushed rock present. The raw clay is a yellow-tan in color but fires a brick red and matures well at cone 04. Like the Alder Creek clay, the Phillipsburg sample appears to run high in Bentonite. A 2% addition of table salt was tried but this did not alleviate the breakage during the drying period. To Phillipsburg clay 35% ball clay has been added. This new clay body has not been fully tested as yet but indicates a better working condition during wedging.

1. Op cit Paul E. Cox, Ceramic Age, January, 1949.

10. Through the generosity of Mr. Grethencourt of the Lewistown Brick Yard, two different supplies of the clay used by the brickyard have been received. This clay, like the Hyalite clay, is dense in character when wet and must have a silicate body added to it for best results. Mr. Grethencourt has also noted this as the second quantity supplied by him had already had clear river sand added to it. The amount of sand used with the clay body in the manufacture of bricks is insufficient for pottery use. This clay is also too coarse for potters' work but can be adjusted for ceramic sculpture. In order to use the brick clay from Lewistown it must either be screened and the finer clay used or ground to a finer state.

11. Judge DeKalb of Lewistown located a virgin clay in crystal form in an abandoned railway cut just out of Lewistown on the Billings road. With his help about two hundred pounds of this clay was collected. The strata of the deposit turns from white to deep purple. These strata are so close it is impossible to collect samples of the separate colors. The sample brought in for testing was a mixture of white and the deep purple. Since the clay is still in crystal form it must be ground in some manner before it is usable. After grinding and curing for two weeks the clay was used. Plasticity and porosity are adequate for casting, throwing, slab work and sculpture. When fired, the result is a pleasing pink. At cone 04 the pink clay is too soft for pieces to be given rough use. A higher heat is necessary for firing without the addition of nephsy or feldspar. This clay will no doubt work well in the higher ranges of the stoneware kiln under construction and test. Twelve and one-half per cent of nepheline syenite will reduce the

maturing point of the clay with no loss in workability.

In summary, of all clays tested to date it has been found that the majority of local clays have features that make them worthwhile, either straight or as a part of a mixed clay body. While most qualities could probably be blended of completely local clays, it is deemed advisable to stock such items as Ball Clay, Kaolin, Nepheline Syenite, Feldspar, Flint and Grog to supplement the local clays. As will be noted in the above tests, never less than 50% of local clay has been used in the clay body. This represents a considerable saving in operating cost for the school, adult group or individual in ceramics. Aside from the economic standpoint, the satisfaction of having found and developed a local native product is not to be overlooked.

CONCLUSION

The aims set forth in the introduction were to design a ceramics workshop and to show the possible use of local clays in the ceramic process. It is felt that these aims have been accomplished.

Little need be said at this point regarding the success of the low fire kiln. The firing record of the kiln, already covered amply in earlier pages, speaks for itself.

In designing the high fire kiln every effort was made to produce a kiln that would reach about 2350° F. firing on three elements of 230V each. Notation has been previously made, but it is thought advisable to again bring to the attention of those persons contemplating construction of a high fire kiln, that this kiln has not been fully tested as to its potential. The same general method whereby the low fire kiln specifications were set up was employed in the early stages of designing the high fire kiln. In addition to the facts gained in this way, additional tests, as well as correspondence with the Kanthal Co., were utilized. Incorporating all of these into the final specifications would indicate a successful kiln. To date only two firings, which were in the 04 range, have taken place in this kiln. The two firings were to act as a "curing" period before attempting to reach the higher temperatures. The kiln reacted adequately up to cone 04.

The other pieces of equipment built during the course of this thesis have been successful in all respects and can be highly recommended.

The results of the tests performed on the local clays revealed the high degree of adaptability of local products for ceramics use. If a

longer period of time could have been spent on this project, larger amounts of local clay could have been set out for longer aging to ascertain whether or not their quality would improve with the aging. The Hyalite clay prepared nine months ago increased in plasticity to a high degree. To fully carry out such a study it would be necessary to extend the program for testing local clays over a period of several years.

CONE TEMPERATURE CHART 010 - 10

<u>Cone No.</u>	<u>Deg. Fah.</u>	<u>Cone No.</u>	<u>Deg. Fah.</u>
010	1643	1	2120
09	1706	2	2129
08	1742	3	2138
07	1814	4	2174
06	1859	5	2201
05	1904	6	2246
04	1940	7	2282
03	2039	8	2300
02	2057	9	2350
01	2093	10	2381

NOTE: This chart is for use when firing rapidly 150° C. per hour.

LIST OF SUPPLY HOUSES

American Art Clay Co., Indianapolis, Indiana

Armstrong Cork Co., Minneapolis, Minnesota

The Denver Fire Clay Co., Denver, Colorado

B. F. Drakenfeld and Co., New York, N. Y.

Driver Harris Co., Harrison, N. J.

O. Hommel Co., Pittsburgh 30, Pennsylvania

The C. O. Jelliff Mfg. Corporation, Southport, Connecticut

Jack D. Wolfe Co., New York, N. Y.

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