se of Iowa Clays in mall-Scale Production of Ceramic Art

P. E. Cox

The Use of Iowa Clays in Small-Scale Production of Ceramic Art

By Paul E. Cox

IOWA ENGINEERING
EXPERIMENT STATION

BULLETIN 133

1937

IOWA STATE COLLEGE
OF AGRICULTURE AND MECHANIC ARTS

AMES, IOWA

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(*Continued on inside back cover*)

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By Paul E. Cox

Ceramic Engineer, Iowa Engineering Experiment Station

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Official Publication

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LETTER OF TRANSMITTAL

T. R. Agg, *Director*
Iowa Engineering Experiment Station
Iowa State College
Ames, Iowa

DEAR SIR:

I am submitting and recommending for publication by the Iowa Engineering Experiment Station a manuscript entitled "The Use of Iowa Clays in Small-Scale Production of Ceramic Art."

The information has been compiled from a large variety of sources, and has been verified in the ceramic engineering laboratories of the Station. The bulletin is intended to replace *Bulletin* 58 entitled "Possibilities of Pottery Manufacture from Iowa Clays," which is now out of print. The authors were staff members of the Station at the time of publication, and those portions of their work which are reproduced in this bulletin are too well done to be neglected or replaced by other material.

For the benefit of those readers who have become very interested in ceramic work there have been included photographs and drawings of practical ceramic kilns and other equipment. The author wishes to acknowledge cooperation from numerous sources for this material, particularly Dr. O. A. Brown of the Electrical Engineering Department, Iowa State College, for his consultation on the electric kiln.

Respectfully submitted,

PAUL E. COX
Ceramic Engineer

Ames, Iowa
Nov. 15, 1936

THE USE OF IOWA CLAYS IN SMALL-SCALE PRODUCTION OF CERAMIC ART

INTRODUCTION

This bulletin is compiled to furnish elementary information on how Iowa clays and shales can be used in the small-scale production of avocational and professional pottery, ceramic sculptures, terra cotta for structures and garden decoration, and modeling clay for education and recreation. While the field of ceramic engineering includes also the production of structural clay products and other industrial ceramic wares, this bulletin will deal only with the production of ceramic art.

Numerous letters from people interested in ceramics, which have been answered by the author in the past 16 years, indicate that the lay mind generally regards clay itself as something quite unusual and mysterious. The contrary is true. These letters also reveal that it is not generally understood that plastic clay is easily prepared and that its preparation is just as educational and recreational as its use.

Most persons feel that a good clay must be obtained from some remote point and that to be really good it must burn to a white product. Even technically trained men and women have, in many cases, this same erroneous idea. Ceramic equipment, such as kilns and molds, also appears to be more mysterious than it really is.

However, when interested persons can be made to realize that moldable clay is simply mud cleared of coarse matter, and that a ceramist can make pottery from any moldable clay, the foundations of the art are mastered, and the addition of new skills becomes a fascinating pursuit for either the amateur or professional.

It should be remembered that the clay itself is not responsible for fine ceramic art; it is what is done to the clay by human hands guided by the intellect and an artistic sense.

The present publication is merely a compilation of important material and is not intended to give a complete story of avocational ceramics; for further information, the reader is referred to the extensive literature listed herein. As the reader's skill increases, he will want to do more and more browsing in such publications.

SOURCES OF COMMERCIAL IOWA CLAYS

Clay is a very fine earthy material which is moldable when wet, non-plastic when dry, and permanently hard when baked or "fired." It is widely distributed and is often found mixed with sand in soils of a "loam" type. The deposits of relatively pure clay are usually not surface material, although in some cases they have been exposed by erosion.

The Iowa Geological Survey has made a rather complete investigation of the clays and shales of the state, and those interested in the geological point of view are advised to consult the 1902 report. Figure 1, which has been taken from this report, shows the division of the state into geological sections and the location of factories using clays and shales at that time. The small triangles in Fig. 1, since they indicate factories, also mark approximately the locations of workable clays and shales.

Iowa's section where easily fabricated shales are most readily found is that shown on the map as the "Des Moines" section and the next richest is the "Devonian." All parts of Iowa, however, have some clay which is suitable for pottery production, although it may have to be obtained by separating coarse matter from the soil.

Cretaceous Clays

The Cretaceous section (Fig. 1) has occasional clay deposits which, while too small to be worked into structural products on a commercial scale, are ample for rather extensive work in pottery, floor and wall tile, and kitchenware. Although the Iowa Geological Survey has not yet explored this region, local interest is likely to reveal many of the deposits. Sandstone generally covers the unsuspected deposits unless they have been exposed by water erosion.

Mason City Clays

Clays of the Mason City section are highly desirable for that type of "tin-enameled" clayware which is called "faience." The term "faience" comes from Faenza, Italy, and was originally applied to wares made in France in the 16th to 18th centuries of coarse fabric which was enameled and decorated. Today "faience" has come to include a large variety of products, some of which are not faience in the true historical sense of the word.

Clays similar to those of the Mason City section were used in the production of terra cotta by the celebrated Della Robbias and in the production of the pleasing blue-colored wares of Delft.

In France, Italy, Spain, and Mexico, beautiful "tin-enameled" wares are abundant and cheap. Tourists bring back peasant pottery from these countries because of the crude decorations in gay colors.

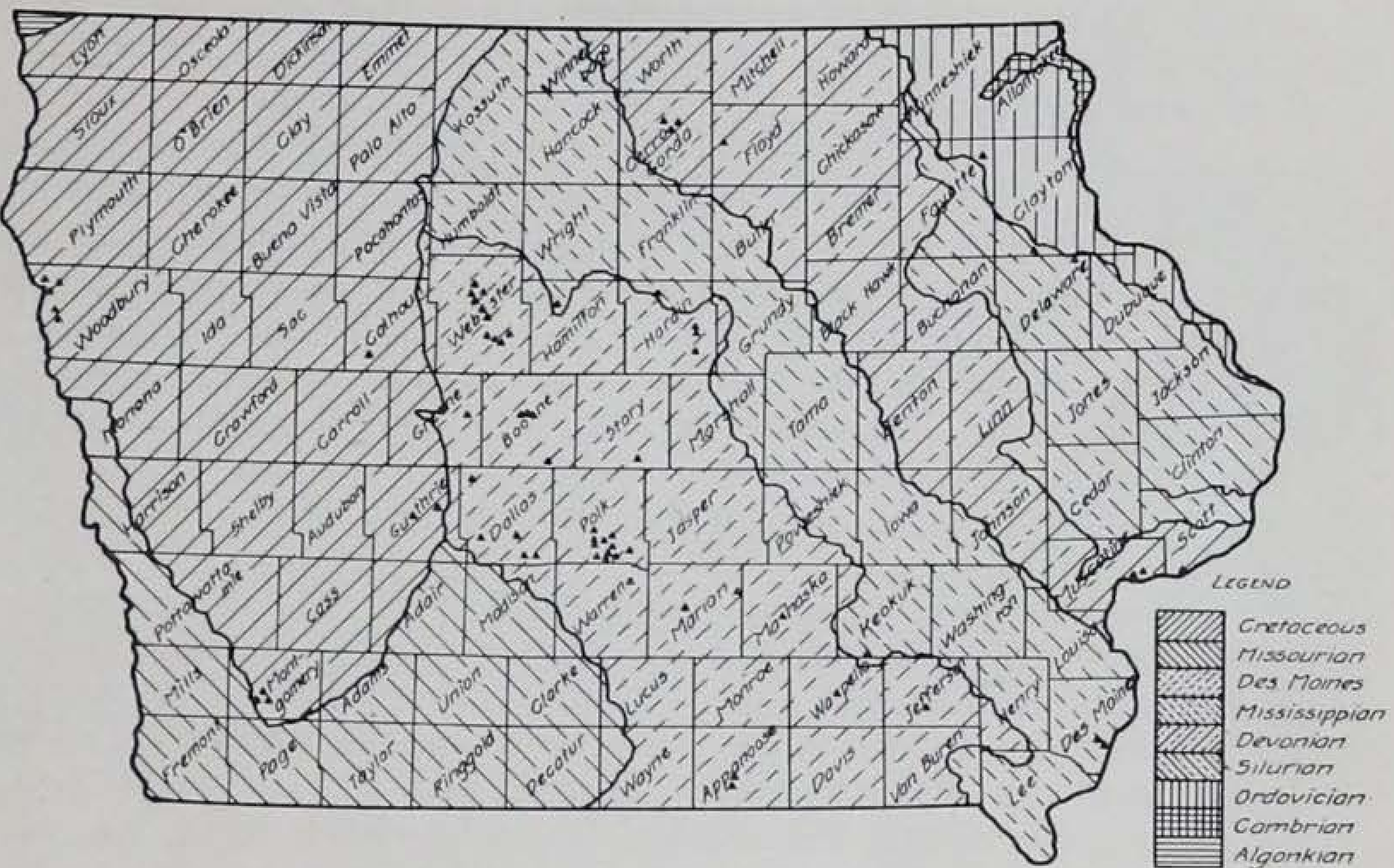

Fig. 1.—Iowa Geological Survey map (1902), showing the geological subdivisions of the state and the location (note triangles) of factories using clays and shales at that time.

It is not known by the average tourist that the lively colors result from the tin-oxide enamels which are necessary to cover the poor quality clay. Such clays, however, are easily worked and the glazes easily adjusted.

In three of the major American art potteries catering to the "popular-price" purchasing class, whiting is added to the clay mixture to bring it to approximately the same composition which nature has given northern Iowa clays. These clays mature, or bake to a hard product, at a lower temperature than those in the Des Moines valley or in the Cretaceous area. Any glaze carrying tin oxide is ideal for use with such clays, provided its "maturing" temperature coincides with that of the clays.

To the eastward, toward the Mississippi River, and southward to the mouth of the Iowa River lies an area with a large variety of clays which, in general, are likely to be less clean when burned than most clays. Although no particular section is strongly characteristic of the whole area indicated, most of the clays in this part of Iowa are of sufficiently high quality as far as the amateur is concerned.

Des Moines Valley Clays

The Des Moines valley has every type of clay except those which burn to a white product. Some are a little too refractory (highly resistant to heat) for use by the amateur, and many are too "fat" or sticky. In general it is more difficult to fit glazes to these clays, although selected strata in every locality are satisfactory for use with the common glazes.

Southern Iowa Clays

Along the southern tier of Iowa counties and in the southeast, soil erosion and limestone quarrying have opened up tremendous beds of buff-burning material, some rich in lime and ideal for faience wares, and much greater amounts of the stoneware type useful for a large variety of products.

Clay for Saggars

Saggars, which are the clay boxes used to separate and protect ceramic wares in kilns so that they may be properly "fired" without loss, are made from half-and-half mixtures of "grog" and plastic clay. "Grog" is made by crushing and firing such material as old firebrick, and can be purchased from manufacturers of firebrick. While the making of saggars is best learned by observation, the reader will be helped by the references in the book list.

The clay at Sergeant Bluff on the Missouri River below Sioux City is an excellent saggar clay. For lower temperature work, and in fact, for the bulk of the work done by both amateurs and professionals, nearly all clays which burn to a buff product will be found adequate for use in a saggar mix.

The halloysites of Clinton and Jackson Counties, if commercially exploited, should be superior materials indeed for saggars, other kiln furniture, and kiln parts.

In summing up Iowa clay resources, it can be said that a person would live a very long life, indeed, if he lived until they were exhausted.

WHAT CAN BE MADE FROM IOWA CLAYS

Since Iowa clays do not burn to a white product, it is impossible to use them in making white porcelain wares. Fortunately, however, there is just as much beauty in the red and buff pottery made from Iowa clays as in white pottery.

Tableware.—Instructions for making tableware from Iowa clays are to be found in the books listed at the end of this bulletin. If Iowa clays are processed in the proper manner, they can be used in the production of complete table sets.

Faience.—The decorative tin-enameled wares of peasant Europe, which are called faience, can also be satisfactorily made from Iowa raw materials. Tableware, kitchenware, tile table tops, wall decorations, and brick for fireplaces are all suggested as desirable products

Fig. 2.—Model of sculpture for courtyard of Dairy Industry Building at Iowa State College. From this a mold was made for the final terra-cotta sculpture.

Florists' Wares.—Flower pots made from red clays are generally unglazed, although there is some production of glazed wares for the florists who, at the present, handle wares made outside the state. Since florists are compelled to deal in low-priced articles and in novel pottery forms, production for this market must be highly organized so that low unit prices are profitable. Florists also sell a few higher quality wares which, since they are specially designed, are suitable products for the small pottery plant.

Kitchenware.—Ice-box vessels, mixing bowls, baking dishes, and the many little gadgets which brighten a kitchen are most profitably manufactured in good-sized plants since they must sell at low unit prices. Nevertheless the individual worker will find that ideas worked out in a small pottery can sometimes be patented and profitably sold to larger firms.

Common Stoneware.—Iowa has been a large producer of the jugs, jars, and milk crocks once used in every home. Since this type of pottery is made in one "burn" and is of high quality if well potted, a revival of its production under the direction of an individual with good taste and discretion might be profitable. The consuming public is not so much interested in the technical classification of pottery products as it is in their quality. Stoneware is dense and durable and lends itself to the development of interesting wares for the garden and the kitchen.

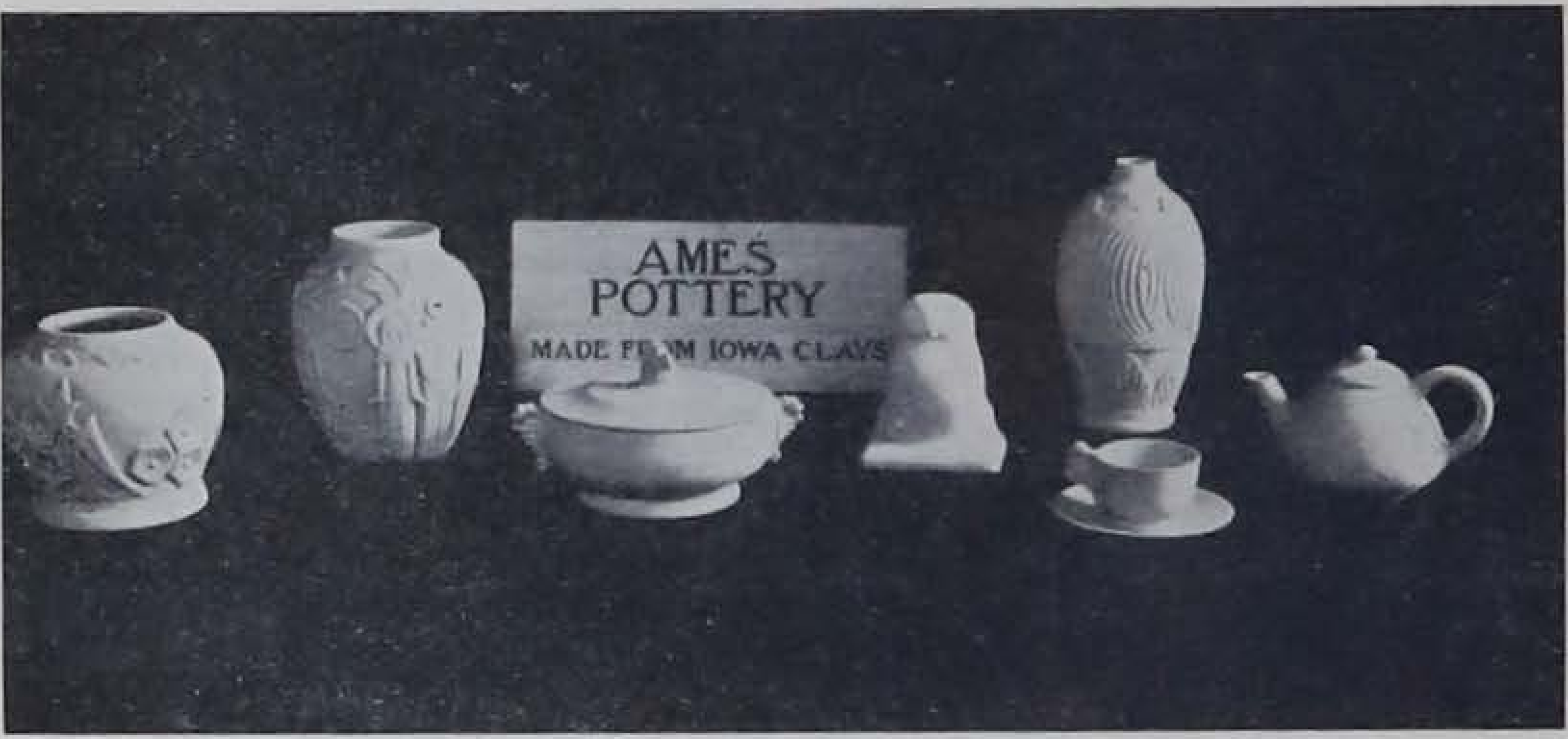

Fig. 3.—Biscuit pottery made from Iowa clays.

Garden Pottery.—A market for garden and fountain clayware has been created by the large number of home and garden magazines, garden clubs, and educational courses in landscape architecture. Most of such wares now produced in America are for persons not too particular about individuality of product. In addition to being machine-like, most of the products are not fired sufficiently dense to be very durable. However, since these products are so often in poor taste, it is very fortunate that they are not durable.

Most garden ceramic wares are monumental in character and require a good-sized kiln. It is desirable that such products be designed for specific locations in specific gardens.

A terra-cotta sculpture (Fig. 2), modeled by Christian Petersen and executed in the Department of Ceramic Engineering at Iowa State College, will be used to illustrate the type of "body" and firing method to use for outdoor wares. This product was made from a Fort Dodge clay mixed with grog. It was fired to "cone 10" (a cone is made of material similar to that being fired in a kiln and bends to show the effect of the kiln conditions) and resulted in a body which had a water absorption of less than 4 percent. The grog could have been made from the same clay as the plastic portion of the mix, but it was found convenient to use waste firebrick from a heating plant. Such a body, which can be glazed in many ways, is similar to the bodies used for outdoor groups by such factories as the Copenhagen Porcelain Works and Sèvres in France.

Artistic Tiles for Residences.—Architects are always on the lookout for tiles which are individualistic and not suggestive of machine methods. The very large factories therefore make great quantities of tiles by processes which were developed by primitive people.

Architectural Terra Cotta.—Terra cotta is a decorative covering material processed a little more carefully than the very excellent

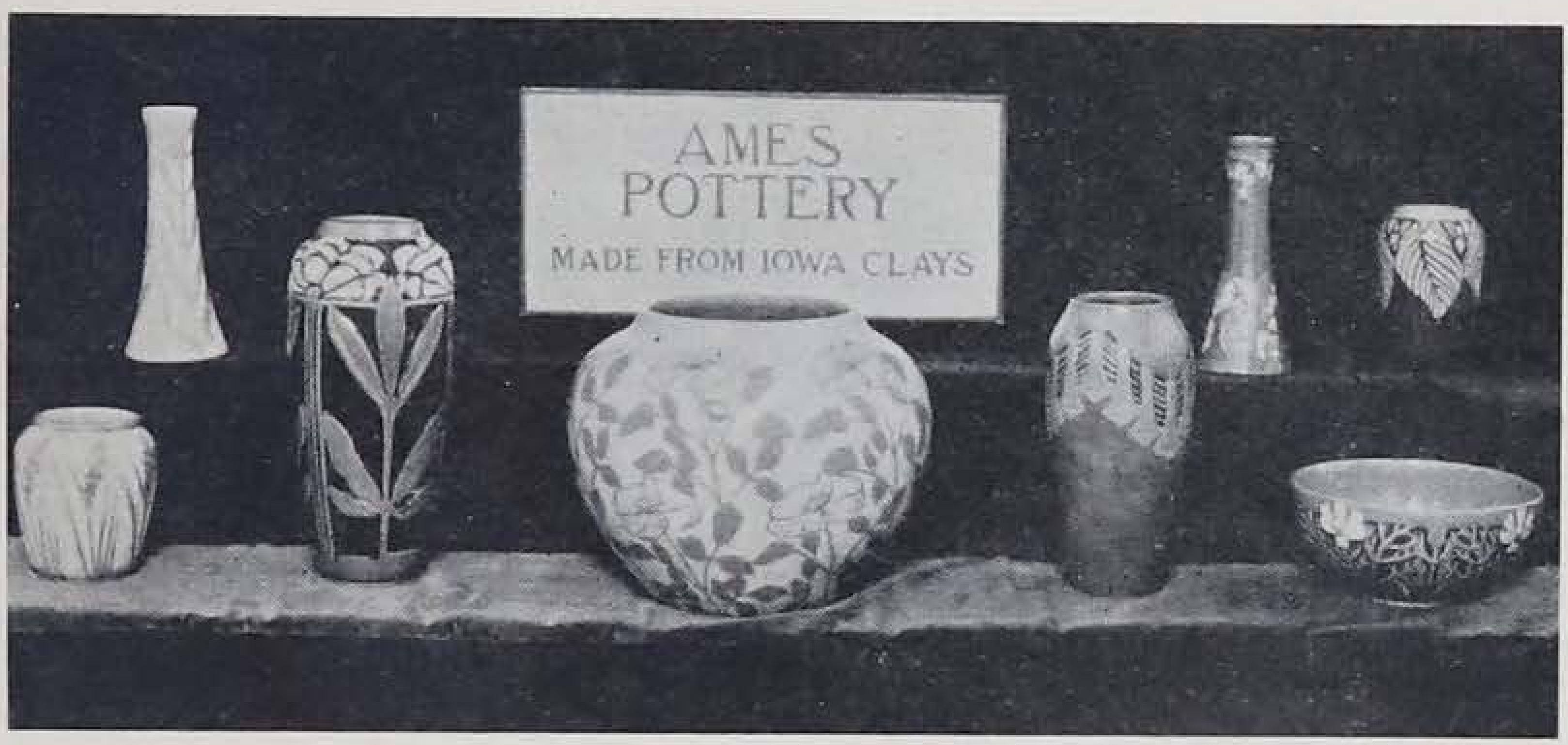

Fig. 4.—Pottery made from Iowa clays, illustrating decoration possibilities.

hollow building tiles made and used so much in Iowa. Due to refinements in hollow building tiles, however, they often approach terra cotta in excellence.

The terra-cotta manufacturer makes much of his product from plaster molds, and therefore has to exact higher prices per ton for his wares than does the hollow-tile manufacturer. Then, too, the product is processed more carefully. Not all Iowa clays are suitable for terra cotta, but many are excellent.

Manufacturers and architects have been too willing to imitate stone for the good of their business, and terra cotta will come into its own only when it is used as it should be—that is, simply as burned clay, glazed or unglazed. The Iowan with vision can meet this situation and bring business to himself if he really works clay into terra cotta as honest clay and not as an imitation of stone. Two or three eastern clay workers write their own terms with architects by designing in clay as clay demands and not as stone demands.

Ceramic Sculptures.—Nearly every school of art teaches work in glazed or hard-burned sculptures which people have always admired. Many European factories produce all sorts of quaint figures for gardens and homes and, occasionally, for art galleries. Because of the high quality of Iowa clays, they are rather widely used by out-of-state workers in such ceramic sculptures.

Fine Art Pottery.—Figures 3 and 4 indicate the possibilities of Iowa clays and shales for decorative pottery production. Such wares are made from the same clays used for bricks and tiles and serve to show that it is the potter's skill rather than his material which determines the character of the finished product.

While many pieces of pottery have the fault of crazing and leaking, wares made from Iowa clays, whether of the cheapest grade or the highest in art quality, are relatively free from these defects. The wares pictured have not leaked or crazed and are now over 10 years old—an age after which experts agree the faults will not develop.

Artistic Roofing Tiles.—The small producer might very well work at the idea of unusual artistic roofing tiles for de luxe jobs, making small tiles for small buildings rather than the overly large tiles which do not fit the small American house.

Such tiles can be glazed to result in a product which would not be at all praticable for the large factory to manufacture. Frankly, this small production of roofing tiles is practicable only for the consumer with ample means to indulge in a taste for custom work. On the other hand, a man might want to make tiles for his own home.

PREPARATION OF CLAYS

Methods which the amateur or small-scale worker can use in obtaining and preparing Iowa pottery clay in the simplest manner will be described in the following pages.

Mortar Mix as a Source of Raw Clay

Iowa brick-and-tile manufacturers supply finely ground clays and shales to masons for making their cement-sand mortars more workable. Such "mortar mix," which is very satisfactory for making pottery clay, can be bought in most building supply stores in small-sized sacks. Nearly all mortar mix sold in Iowa can be processed easily and quickly into excellent potter's clay and is strongly recommended for use by amateurs.

How to Prepare Potter's Clay

In preparing potter's clay, it is essential to start with dry clay, and if clay scraps are to be re-processed, they should therefore be thoroughly dried.

In large factories clay is stirred mechanically by paddles in vats called blungers, but a "tumbling-barrel" churn makes an excellent substitute. In fact, one of the major, small art potteries prepares all its clays in a 10-gallon churn. While power of some sort or other is ideal for turning such a churn, an hour of hand turning will "blunge" ample clay for a school or studio pottery.

Before being mixed, the clay is soaked overnight in galvanized-iron tubs, which, incidentally, will be found very useful in clay work. The mixture is transferred to the churn and mixed thoroughly so that the lumps are all slaked—that is, united with water. Next the mixture is screened through a 60-mesh phosphor-bronze screen such as can be ordered by any hardware dealer or tinner. A tinner can also make an excellent screen by cutting the bottom out of a strong "tinned-iron" dish pan, leaving a little of the bottom around the edge to serve as a support to which the screen wire may be soldered. Such a screen serves as a combination screen and funnel.

The blunged "slip," as a clay-and-water suspension is called, should be worked through the screen by flat hand rubbing. Experience will soon teach the reader to use plenty of water rather than to try to force a heavy suspension through the screen. This slip mixture must now be stiffened for use by drying out part of the water.

In preparing clay for an output which, for a long time, sold for $50,000 a year, one commercial pottery has used a cypress box with a porous plaster-of-paris bottom. The plaster of paris was cast into a slab 3 or 4 inches thick and reinforced with rods which also ran through the sides of the box and supported the slab. After the bottom was cast, legs were provided at the corners to lift the box to a convenient height from the floor.

When such a box is dry and filled to the brim with a rich slip, the water is first absorbed by the plaster which serves as a porous drain. The water runs on through, leaving the clay behind.

Since there is a limit to the drying action of such a box, a number of flat dish-shaped plaster molds should be provided to stiffen the clay to its final state by absorption of water. Such molds can be made by the "block-and-case" method described in pottery books or by taking a cast from a shaped mound of clay, which will result in a hollowed-out mold.

Storing Clay

The best place to store prepared clay, and also to store partially processed wares, is in a substantial cypress box which has been complelely lined with galvanized-iron sheets to make it air-tight. When provided with a hinged top, such a box is very convenient and, as long as the top is closed, it will keep clay in its initial condition. The author has in this manner kept clay for 3 years and found it ready for use when wanted.

Such a box will also be an aid in keeping clay clean. Clay containing dirt (dirt being "matter out of place") should never be used. In cleaning most plaster clays, a 60-percent or even 70-percent water content is required. Be content to waste a great deal of water.

Permanently Plastic Clays for Modeling

In preparing clays which will remain plastic or workable indefinitely, the base clay must be reduced to a fine flour. Dry clay which has been screened through a 200-mesh screen is satisfactory. If this "dust" is made wet with a mixture of one part glycerine and three parts water, the glycerine will take up additional water from the atmosphere when the mixing water has dried out, thus maintaining more or less of a balance over a long period of time. For economy, the cheapest grades of glycerine should be used.

A second process calls for 75 parts of clay dust which has been wetted with a mixture of 22.5 parts hot petrolatum and 2.5 parts paraffin. While some sort of machinery is almost essential for blending these wetting compounds with the clay, yet they can be mixed by hand if necessary.

If colored modeling clays are desired the start must be made with white clays. Umber added to most Iowa clays would probably make a color satisfactory to the sculptor.

The clay mixed with glycerine can be fired, but that mixed by the second process would probably lose its shape. Where such organic compounds are added to clays, the firing must be done cautiously and very slowly.

Artists have the general idea that the best modeling clay is made by mixing a fine clay with horse fat.

MAKING POTTERY

To show that skill in preparing pottery is more important than the raw materials used, one need only cite the case of the famous Italian majolicas referred to by C. Piccolpasso (1524-1579) in his "Three Books of the Potter's Art." The ancient Italian workers used very coarse clays; yet their works graced castles and palaces and today bring treasure-house prices from collectors. In these cases, the high quality could not possibly be due to the crude raw materials; it was a result of the workers' superior skill.

The amateur should not attempt to make pottery by the methods of the professional potter. While the professional has skill gained by a long apprenticeship, his product often has a machine-like character which is not a virtue. Very often, pottery produced by primitives is more interesting than wares reflecting advanced intellectual opportunities. Also, all wares not cylindrical in basic form must be produced, as far as the initial piece is concerned, by a process similar to that employed by primitive people. The civilized amateur potter should begin with the modeling processes employed by the beginners in civilization, which are described in detail in some of the books listed at the end of this bulletin.

The Potter's Wheel

Professional mold making and use of the potter's wheel are both difficult crafts. To learn either, the worker must expect to devote about 3 hours a day for a full year before confidence is attained. While one very capable potter known to the author mastered the potter's wheel after a single practical lesson and a study of photographs of potters at work, most persons will require several lessons from a well-trained potter in addition to much practice.

Nearly every amateur desires to try the potter's wheel, and all amateurs ask why a professional potter is so stupid as to use a foot-power wheel. Actually, the American professional potter no longer uses any kind of potter's wheel, but rather plaster molds and mechanical methods of production which demand little skill on the part of the workmen, yet greatly increase production rates. Professional potters use power wheels whenever a large production of just

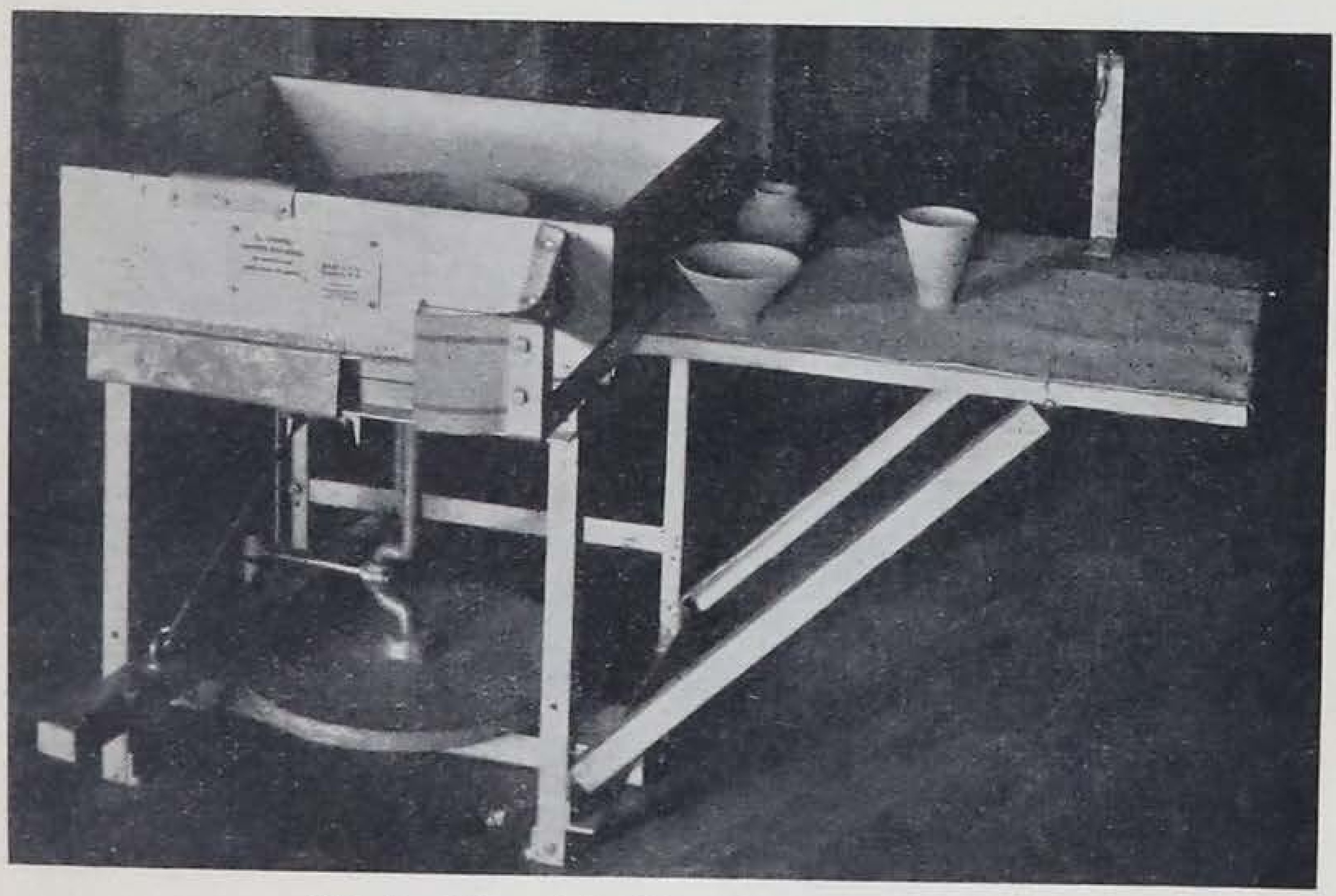

Fig. 5.—View of the Harwell potter's wheel.

one type of ware is wanted, and resort to foot-power wheels only for developing special shapes or a limited number of products.

When a potter is producing large pieces, the nature of the work requires that he stand, and consequently he uses a foot-power wheel. However, when he is making small pieces the potter prefers to sit down since the leg upon which he stands (not the leg producing power) becomes very tired.

The wheel is still the ideal tool for the art potter, being cheaper for a relatively small production than machinery and molds or the casting process. It is cheaper, that is, if a potter can be found to do the work, but highly skilled "throwers" are not numerous. Figures 5 and 6 show a widely used type of potter's wheel.

Technique of the Potter's Wheel

While there are several types of potter's wheels and methods of using them, a person learning the art should adopt one method and adhere to it as a standard.

The American stoneware potter applied the treadle to the European type of "kick-and-paw" wheel (Fig. 7) and proved the worth of his idea by producing with his hands and no other power

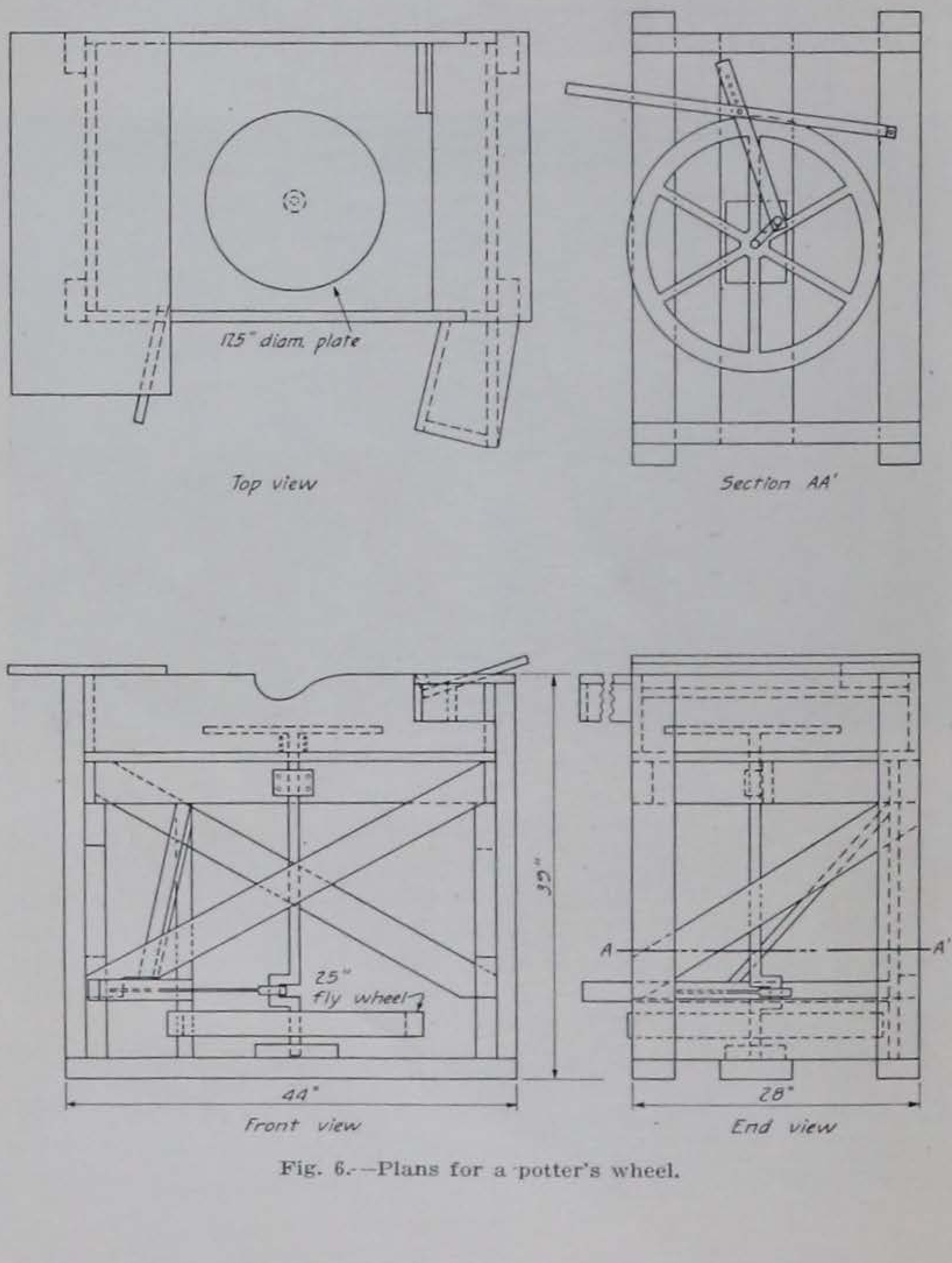

Fig. 6.—Plans for a potter's wheel.

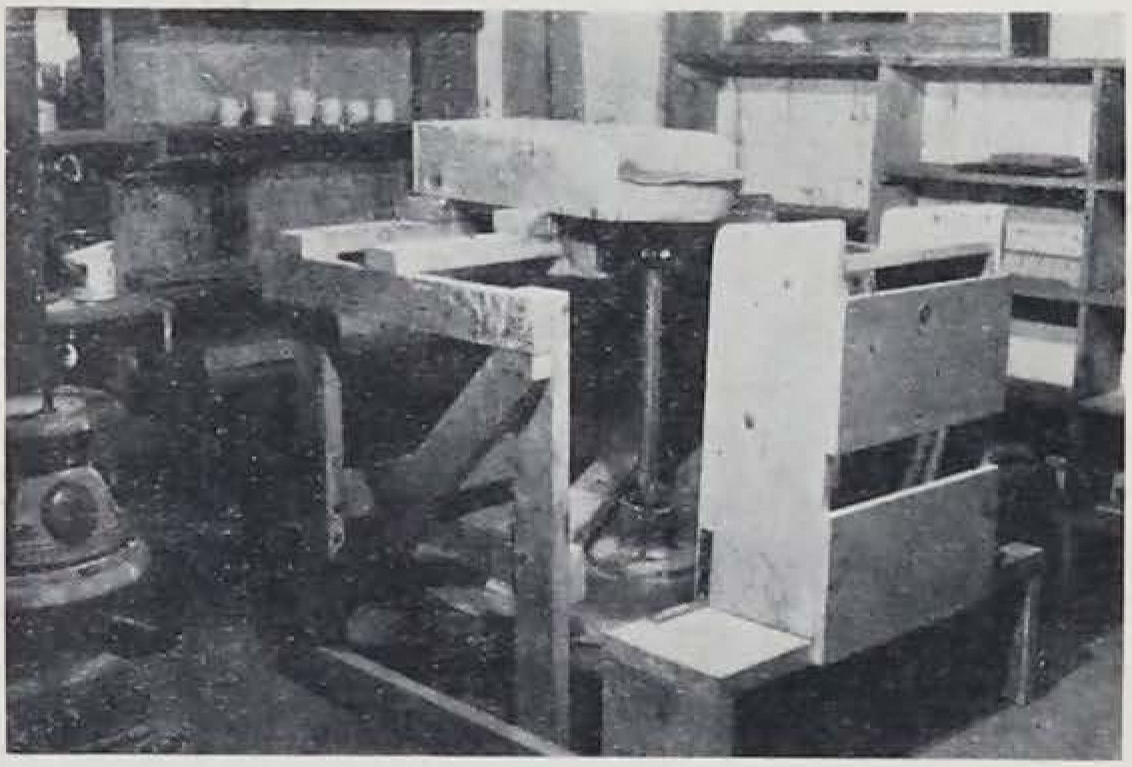

Fig. 7.—A "kick-and-paw" potter's wheel.

than his foot the largest wares ever made on such machines. Out of the wheels of the stoneware potter were developed nearly all of the machines which make our tableware.

There are two names for the potter's craft. The stoneware potter describes his work as "turning" and himself as a "turner" while all other potters speak of their work as "throwing" and themselves as "throwers." Since books show the workmen as "throwers" without exception, the reader is urged to visit a "turner" who has learned his trade in a stoneware shop.

Fig. 8.—Student centering a ball of clay on a potter's wheel as one of the first steps in the process of pottery production by this ancient art.

Fig. 9.—Student potter performing one of the first steps in pottery forming. Note what is called the "knuckle draft."

Skilled potters use different manipulations for different clays and types of wares. Figures 8 and 9 illustrate two of the steps in making pottery by means of a potter's wheel.

Making of Casting Slips

A simple method for reproduction of pieces of pottery, ceramic sculptures, and other objects is the process known as casting. In fact, some types of wares can be made in no other way.

While the casting process can be used for solid objects, it is more commonly used for hollow wares. In casting such hollow wares, a "soupy" suspension of clay in water is poured into a plaster mold.

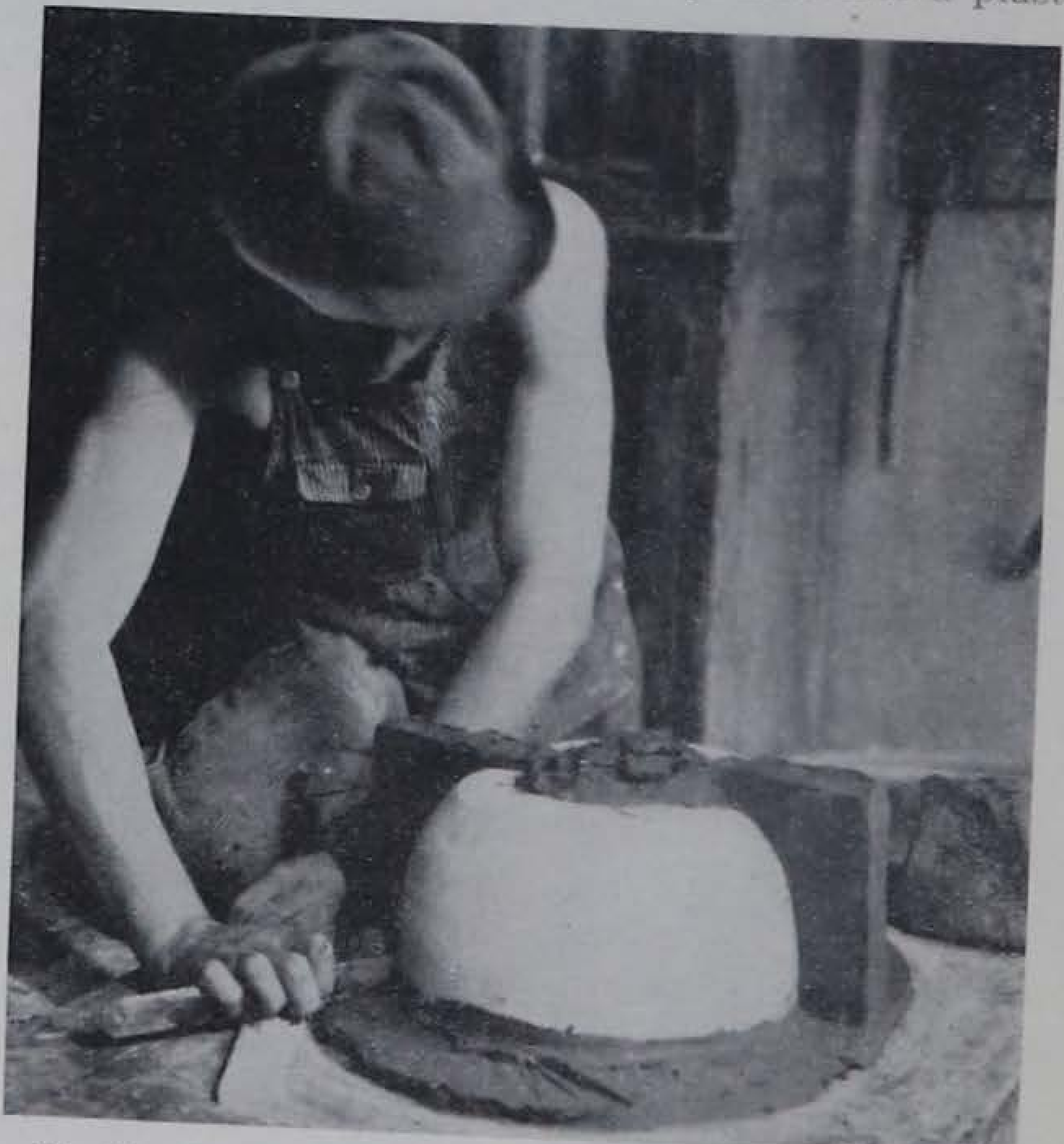

Fig. 10.—Student preparing a case mold for use in making the cover dish for a dinner service set.

Since the plaster is porous, it absorbs water and creates a "skin" of partially dry clay next to the mold. When this skin is as thick as desired, the rest of the slip is poured out of the mold. The adhering piece of ware frees itself from the mold by shrinkage, and when the mold is taken apart in sections the product is free and ready for the finishing of seams. Figure 10 shows a student preparing a case mold.

It is not at all necessary to make a special slip for the casting process, the thickened slip prepared by blunging, screening, and settling being satisfactory. In fact, it is only in the last half century that any other method was understood.

The most satisfactory slip pours like cream, yet contains no more water than clay stiff enough to use on a potter's wheel. Such a slip gives a greater production from the molds, and at the same time dries faster.

By use of certain chemicals it is possible to make a slip with 25 percent water rather than 50 or 60 percent, although for some unknown reason not all clays work well when so treated. This process of thinning a slip without adding water is known as "deflocculation," and the chemicals used are known as "electrolytes."

The Brongniart Formula

Napoleon was a busy fellow in many ways, and one of his ideas resulted in the employment of Alexander Brongniart to change the Sèvres Porcelain Works from an amateur pottery to a strictly professional one.

Brongniart did a thoroughly scientific job, and his three volumes contain the probable total of human knowledge about ceramics up to the time of his death. What Brongniart wanted to know and what everyone who makes slips will want to know is how much dry clay there will be in a known volume of slip. The reader will want to know how many ounces of dry clay there are in a pint of slip which weighs a definite number of ounces.

The Brongniart formula is as follows:

$$W = (P - 16.7) \times \frac{g}{g-1},$$

in which W is the dry weight of a pint of slip in ounces, P is the wet weight of a pint of slip in ounces, 16.7 is the weight of a pint of water (nearly) in ounces, and g is the specific gravity of the clay.

Nearly all clays and minerals used in slips approximate the value 2.6 for the specific gravity g in the formula, and it is sufficiently accurate to solve the quantity $\frac{g}{g-1}$ and write it as 1.625. The formula then becomes:

$$W = (P - 16.7) \times 1.625$$

The number of ounces of dry clay in a pint of slip is therefore found by subtracting 16.7 from the number of ounces of slip and then multiplying by 1.625.

While the literature will indicate that a slip weighing 30 ounces to the pint is commonly used, it must be remembered that this refers to white tableware body mixtures which deflocculate easily and which contain 50 percent non-plastic material. The user of Iowa clays and shales will find that a slip weighing 27 or 28 ounces per pint is about as rich as he can expect to pour into molds.

The solution of a definite problem in the preparation of slips may be helpful: *Wanted*—A slip weighing 27 ounces to the pint to be made from clay in the form of mortar mix. How much dry mortar mix, how much of each electrolyte used, and how much water will be needed for, say, 5 gallons of slip?

P equals 27, and subtracting 16.7 from 27 yields 10.3, which when multiplied by 1.625 gives 16.74 or *W*. Therefore a pint of slip weighing 27 ounces should contain approximately 16.74 ounces of clay and 10.26 ounces of water. Since 5 gallons equal 40 pints, approximately 670 ounces of mortar mix and 410 ounces of water should be used.

Making Mortar-Mix Slip

The something less than 40 percent of water called for by the Brongniart formula will not make a slip, however, without the addition of "deflocculants," or chemicals which thin the mixture. One-half of one percent of each of the two "electrolytes" commonly used for this purpose—silicate of soda and soda ash—will be required. It is ideal to secure a fluid slip with as little electrolyte addition as possible, necessitating trial-and-error methods.

In making the mortar-mix slip, place all the required water, preferably warm water, in a churn. Although the solution of the problem thus far calls for 3.35 ounces (one-half of one percent) each of silicate of soda and soda ash, try 3 ounces of each at first and turn the churn over a few times to dissolve the two electrolytes, making certain that solution is complete. Since silicate of soda is a fluid it should be weighed first in a suitable vessel, the vessel being washed in the churn to insure that it all has been added.

Add the mortar mix 100 ounces at a time to the water in the churn. Be certain that a smooth suspension is obtained before adding the next increment, and continue until the total of the required mortar mix has been added. One need not be greatly surprised if at some stage of this addition he finds a very thick slip made thinner by the addition of dry mortar mix since too much electrolyte will thicken a slip just the same as the right amount will thin it. It is possible that at first there will be too much electrolyte for the clay present and that the additional clay puts the slip back into the desired balance.

Some clays will not be at all suitable, and no benefits will be derived from deflocculation unless the clay is changed. It is not necessary to make a large amount of slip to discover this.

Assuming that a nicely deflocculated slip has been obtained, it is weighed to learn how close it is to 27 ounces per pint. If the resulting slip is too heavy add some water and weigh again; if too light add some clay, stir well, and weigh again. A shrewd estimate concerning an altered value for g will give the proper figure for future use of that particular mix. If the slip weighs less than 27 ounces, increase g a little; if more than 27 ounces, decrease g. The same correction for g would be used the next time a slip is made.

If the slip has the proper weight per pint, but does not flow readily, take out a small cupful of slip and add silicate of soda a drop at a time, stirring well after each addition. One of three things will occur: The slip may thin greatly immediately, it may coagulate at once, or it may require a decidedly liberal increase of silicate of soda before it begins to coagulate. In the first and third cases make an estimate of the required total of silicate of soda to be added to the churnful of slip, and let the turning of the churn mix it. In the second case, add water for thinning.

This exercise in slip making must be done a number of times with a clay before precision can be enjoyed, but the results justify the trouble. As an illustration of this, an incident from consulting practice is cited:

A high-grade art pottery had designed a difficult ash tray in the form of a flying duck. When the clay slip was not deflocculated, relatively few pieces could be taken from the molds, and those salvaged had to remain all day in the molds. The objects, consequently, had been unprofitable to produce. A properly deflocculated slip, however, permitted a production of five daily from each mold without loss.

CERAMIC KILNS

For art pottery work the author prefers small kilns which are copies of large commercial kilns. First costs are relatively high, though decidedly low when contrasted with the prices asked for some of the portable kilns so widely sold. Repairs costs are almost negligible; for example, a large kiln at Iowa State College has had less than $100 in repairs during 16 years of service, and it is good for an indefinite term of service with no repair costs of consequence. A portable kiln is a fine piece of equipment and worth what the manufacturers ask, but this type exists because users fear to tackle the task of building a kiln of a more permanent sort.

The kilns illustrated in this bulletin have been used in over fifty small and large factories and studio potteries, and in no case have they been a disappointment. For detailed plans of some of the kilns see the Appendix, page 43.

An Electric Kiln

An easily constructed kiln (Figs. 11 and 12) for the use of the amateur potter, teacher, sculptor, or small-scale professional worker was developed through the cooperation of Dr. O. A. Brown.* This electric kiln, which can be built to any desired size, is steel-jacketed and lined with light-weight refractory brick.

* Department of Electrical Engineering, Iowa State College, Ames, Iowa.

When built with a ware chamber 16 inches square and 2 feet deep and provided with shelves of silicon carbide or similar material, the kiln can hold a dozen good-sized pieces or as many as fifty pieces of the size usually made in public schools. The cost of firing this size of kiln to come 06 is $1.50 when electrical power sells for 2½ cents per kilowatt hour.

For the needs of nearly all amateurs and many professionals,

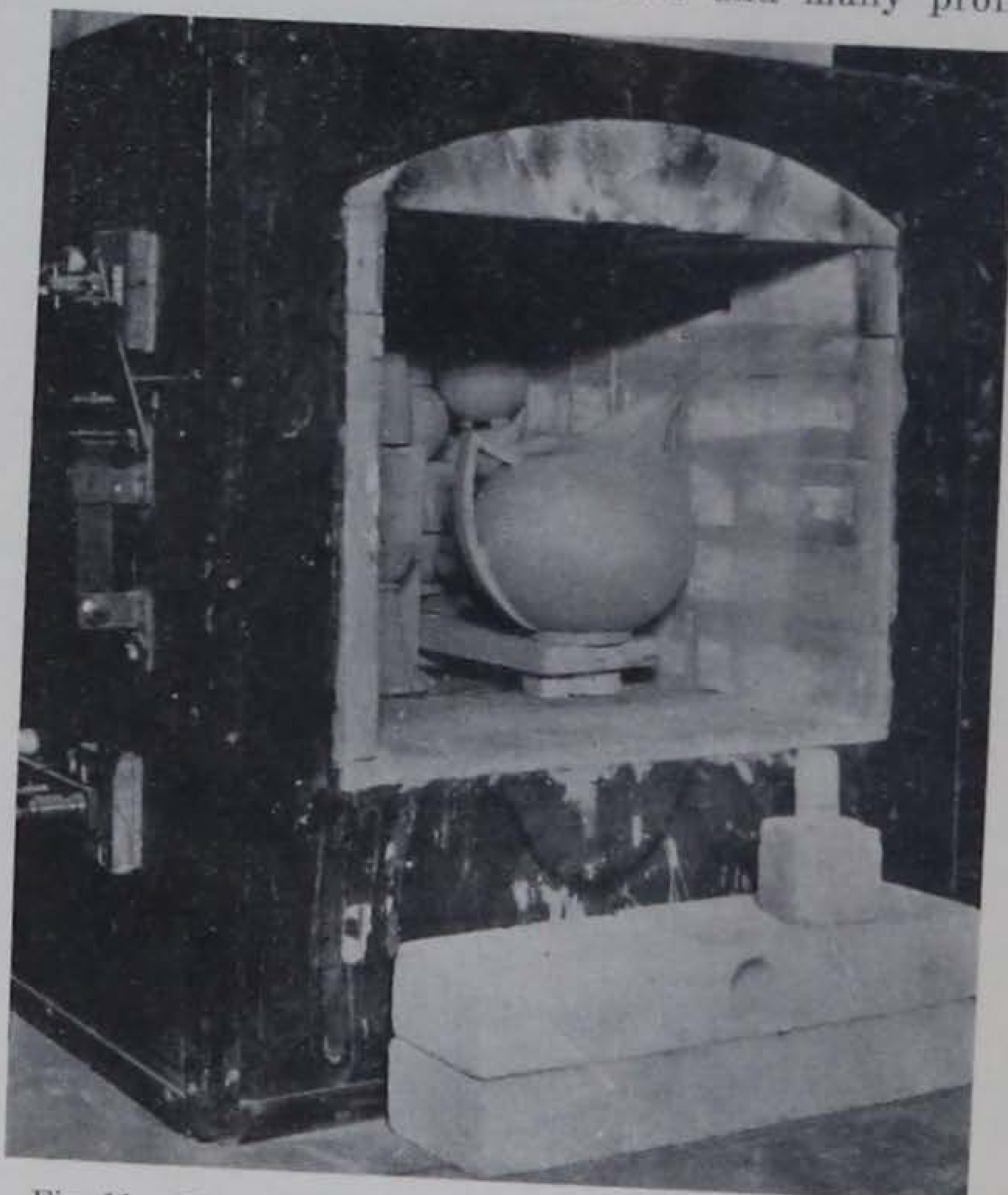

Fig. 11.—Electric kiln developed at Iowa State College for use in small-scale ceramic work.

nichrome wire coils (good to cone 06) are best for this type of kiln. Two-thirds of the common glazes are suitable for use at cone 06, and the best of the Iowa clays, other than the high-temperature buff-burning clays, are sufficiently dense under such a condition. This small and cheap electric kiln is therefore an excellent one for the readers of this bulletin to construct.

For firing at higher temperatures, the heating elements should be made from higher-temperature alloys and the bricks should be developed to stand 2,500° F. The light-weight refractory bricks are ideal for the person constructing a small kiln as they can be cut with a hack saw like soft wood or worked into shape with a wood rasp. The bricks combine heat insulation and refractory (heat-resistant) qualities with extreme ease of construction.

The electric kiln of Figs. 11 and 12 is controlled by a voltage transformer of 15 kva. capacity and has a double-throw switch so that either 110- or 220-volt current may be used. When the transformer is used, the kiln is operated at 25 volts for the first 3 hours, at 40 volts for the next 3 hours, and at 50 to 55 volts for the rest of the operation. A transformer of this type costs about $160, F.O.B. point of origin.

For those who want to avoid the cost of a transformer, Brown sug-

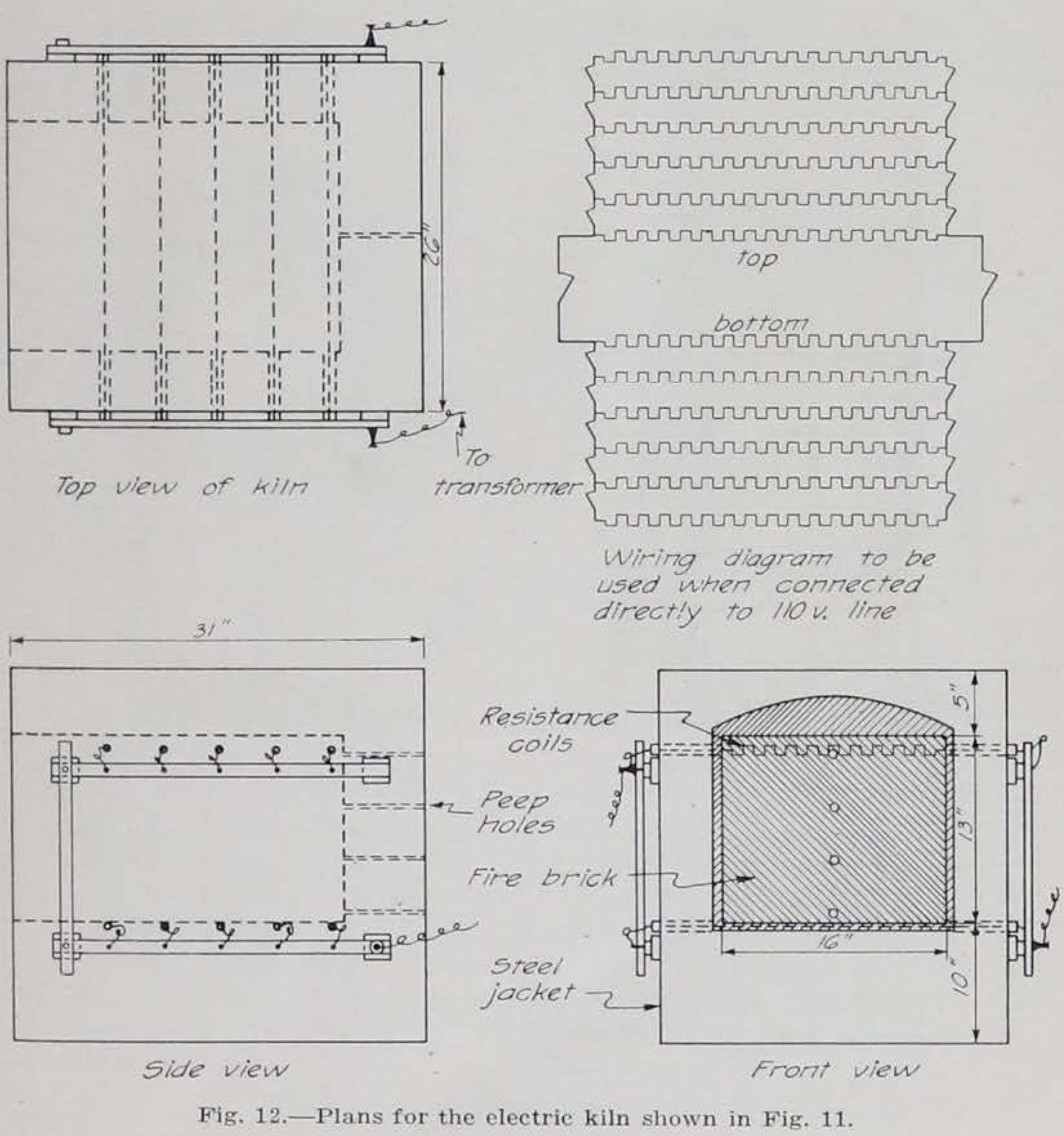

Fig. 12.—Plans for the electric kiln shown in Fig. 11.

gests the following procedure for putting the kiln directly across the line:

For the first 3 hours of heating, use two coils in parallel, six combinations in series.

For the next 3 hours of heating, use three coils in parallel, four combinations in series.

Finish the "burn" with six coils in parallel, two combinations in series.

The coils are connected according to the above-mentioned procedure by means of switches between consecutive coils, as shown in Fig. 12. Brown proposes six coils at the top of the kiln and six at the bottom.

A Gas-Fired Kiln

A small gas-fired kiln, which is jacketed with sheet iron, lined with light-weight refractory brick, and fired with a Méker-type burner, is

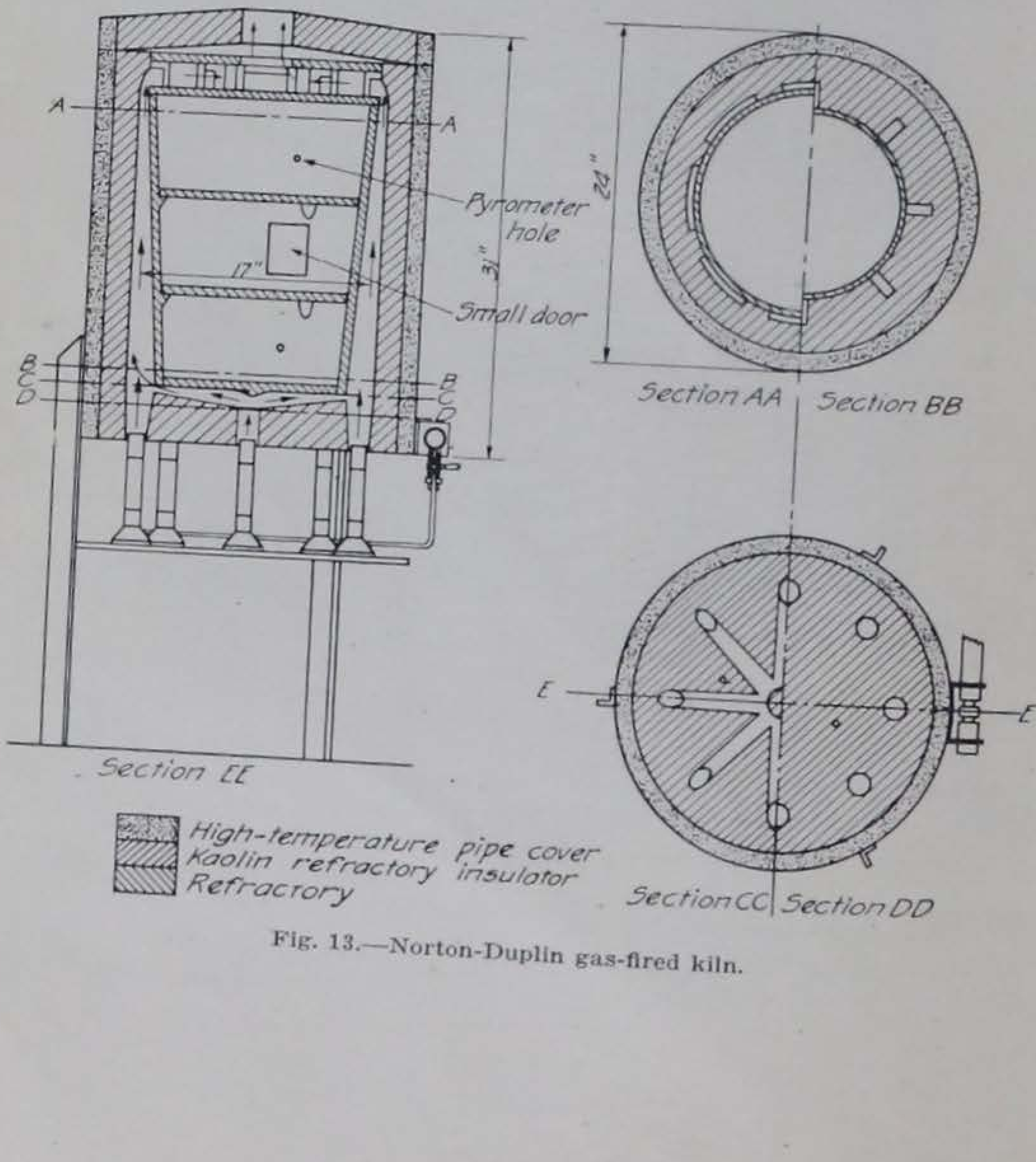

Fig. 13.—Norton-Duplin gas-fired kiln.

shown in Fig. 13. It is more fully explained by F. H. Norton* on page 152 of the March, 1933, issue of the *Journal of the American Ceramic Society*. Such a kiln is remarkably efficient and can be built by any handy person at a cost of about $60, less burners. The gas cost for wares burned in these small kilns is under $2 for a day's run.

A kiln of this sort can be fired with butane or with the compressed natural gas sometimes used in rural kitchens. Care must be exercised in ordering burners to state to the manufacturers the fuel to be used since the burners differ somewhat. Burners are obtainable from dealers in chemists' supplies or from wholesale drug houses.

Changes (Fig. 14) in the Norton-Duplin kiln (Fig. 13) are suggested to simplify construction for the builder who does not have other kilns already built in which to burn the muffle shown in Fig. 13.

Figure 14 shows how thin bricks known as "splits" may be used

* Director of the Department of Ceramics at the Massachusetts Institute of Technology, Boston, Mass.

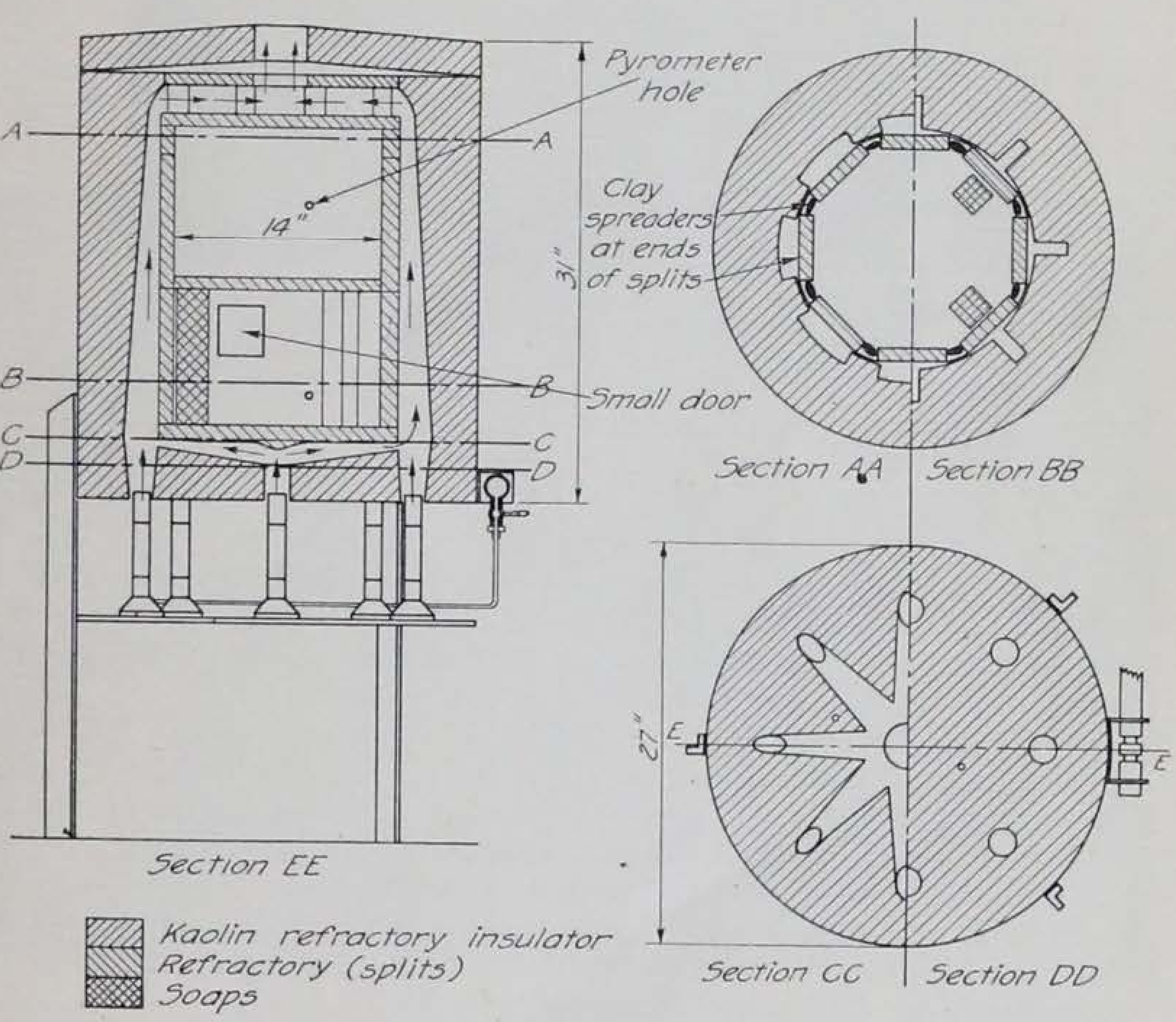

Fig. 14.—Norton-Duplin kiln shown in Fig. 13, as simplified.

Fig. 15.—Glazing a piece of pottery by the amateur's method of dipping the wares in the glaze which is a suspension of powdered solids in water. The pottery is slightly porous and absorbs the water, leaving a uniform coating of the mixed powders adhering to its surface. The coating melts into a layer of glass when the pottery is fired again.

in place of the muffle construction. "Soaps" (firebricks with one-half the usual width) serve as posts for the shelves, and if the spaces need to be arranged differently, the soaps may be broken in shorter lengths to arrange the shelf spacings. Since silicon carbide transfers heat very rapidly, silicon-carbide splits can be substituted for fire-clay splits in correcting cold portions of the kiln.

In making shelves for these kilns, use greased metal hoops of about 1/8-inch thickness and of suitable depth. Pack the half-and-half mixture of grog and clay previously described for saggar making into the hoop, and cut off the surplus with a tautly held wire so that a disk of grogged clay results. Jar the hoop in two or three places with a hammer so that the disk shelf can be removed and dried. The top covers of the muffle portions are made in a similar manner and can be burned in the kiln itself.

Under no circumstances should any sort of chimney be attached to this type of kiln. It is specifically designed to operate only when it has no chimney, which is a great advantage. There are no fumes from this kiln at any time, other than gases of combustion and gases evolved from the wares, which are not offensive.

PREPARATION OF GLAZES

A glaze is a thick glassy coating which under heat treatment becomes firmly attached to the body of a ceramic ware. It makes the ware more or less impervious to water and gives it a sanitary and serviceable surface. It also gives gloss or texture, which is one of the chief charms of pottery.

A description of glazes which work well with Iowa clays and simple equipment will first be listed. Later, a method will be demonstrated whereby the individual without any knowledge of chemistry can adjust five basic glazes, or any glaze, to develop certain colors or other physical properties of glazes which he might desire. Figures 15 and 16 show glaze work being done by students in the ceramic engineering laboratories at Iowa State College.

A Simple Mat Glaze

For the individual not equipped to do elaborate work, there has been developed a mat (dull-finish) glaze maturing at cone 03. It is

Fig. 16.—The wares pictured above have been dipped in the glaze jars shown in the background. Some of the students are evening the glaze layers, while others are applying glazes of other colors by means of brushes, knives, and medicine droppers.

suitable for the oil- or gas-fired portable kilns often used in schoo[ls].

The colorless mat glaze is made from the following:

Red lead	137 parts (by weight)
Whiting	30 parts
Potash feldspar	56 parts
Kaolin	65 parts
	288 parts

The kaolin must be coarse-grained and not too plastic. If ba[ll] clay is used, substitute 33 parts of ground calcined kaolin and 2[…] parts of any high-grade ball clay for the 65 parts of kaolin.

Assuming that the reader has a portable kiln and no equipme[nt] other than scales and suitable tubs or jars, the method of preparatio[n] is as follows:

Weigh the dry materials and place them in a container two-third[s] filled with water. Allow this weighed-out batch to soak overnigh[t] without handling of any sort. Then stir with the hands into a sus[-]pension, and screen back and forth about three times through a 60[-]mesh sieve. Rub all material through the sieve, and use plenty of extra water. The solids will settle down overnight and permit easy removal of surplus water.

For coloring the glaze, make the following additions (by weight):

Green	Add 11 parts of copper carbonate.
Blue	Add 5 to 10 parts cobalt carbonate.
Brown	Add 8 to 16 parts red oxide of iron.
Rose	Add 10 percent of any pink stain.
Yellow	Add 10 percent of any yellow stain.

While all colors are not obtainable, the most desirable ones can be had by adding 10 percent of the dry powdered color to the weighed batch. Obviously the coloring materials are added to the base batch and all screened through together. The carbonates of copper and cobalt are suggested rather than the oxides to provide uniformity of color. Further information on color will be given later.

A Simple Glossy Glaze

The wares illustrated in Fig. 4 were all glazed with the following glossy glaze:

White lead	116 parts (by weight)
Whiting	20 parts
Potash feldspar	111 parts
Zinc oxide	12 parts
Ball clay	21 parts
Flint	28 parts
	308 parts

The coloring is imparted by the same methods explained for the cone-03 glaze. A pure white enamel is possible by the use of an additional 10 percent of tin oxide. It is frequently wise to use tin oxide with colors as well, but *not with yellow and rose.*

The above glaze should be fired with a highest cone value of 2 and a lowest cone value of 04. In a large kiln of the Ceramic Engineering Department at Iowa State College, the custom is to fire to cone 2 at the top of the kiln and to cone 04 at the extreme bottom.

Users of Iowa clays and shales will find that nearly all of those made into mortar mix will work well with these glazes. There is no crazing of the glazes, and the wares do not leak.

The above-mentioned glossy glaze can be converted into a mat glaze for the same cone range by use of the rules laid down elsewhere in this bulletin, or the mat glaze for cone 03 previously presented may be used in the colder portions of the kiln along with the glossy glazes of this second series.

The clays from Sergeant Bluff, Iowa, and some others from the southeastern and southern edges of the state have higher maturing temperatures than those in the rest of the state. If the reader learns that common stoneware has been made at some time from such clays, he will know that they should be matured at about cones 4 to 8.

A Thoroughly Tested Mat Glaze

The following mat glaze, which has been thoroughly tested by the author, is suitable for high-temperature clays:

Potash feldspar	56 parts (by weight)
Whiting	50 parts
White lead	103 parts
Coarse-grained kaolin	103 parts
	312 parts

The above mat glaze may be colored in the same manner as the others. If a ball mill is available the coarse-grained kaolin should be replaced with 26 parts of high grade ball clay and 66 parts of calcined clay. With this much raw clay it will be found necessary to apply a thin coat of glaze by dipping and a second coat by means of a spray gun. This means that an exhaust system must be provided to take away the lead-bearing dust from the operator's quarters. The non-plastic calcined clay permits the usual dipping methods. Do not grind any glaze too much; a 60-mesh sieve is amply fine.

A Warning About Lead Glazes

While lead-bearing glazes are easiest to use and in general yield the best results, carelessness in their use is dangerous. By working only occasionally in glazes, using dipping processes exclusively, and exercising common sense in regard to the mouth and nostrils, no harmful results have been noticed among Iowa State College students at any time.

Spray-gun methods, on the other hand, demand a booth which e haus\ts into the open air and away from any passing persons. Th author suffered one case of severe lead poisoning resulting from fai ure to insist on being supplied with a spray-booth system. Raw lea glazes, however, are not dangerous unless sprayed without the pro tection of such an exhaust system. Women are more prone to suffe from effects of lead poisoning than men.

Lead poisoning may be completely avoided by the use of fritted glazes in which the lead is introduced into the glazes as a bisilicate

The symptoms of lead poisoning are a sweetish taste in the mouth and cramps. In the most severe cases, the gums turn black near the base of the teeth. The antidote for lead poisoning is epsom salts If any doubt exists about lead poisoning, the sensible and cautious worker will seek the advice of a physician.

HOW TO CHANGE GLAZE RECIPES

Since the standard glaze recipes may not suit a definite set of conditions exactly, it is often desirable to make adjustments. In order to alter glaze recipes, and to more nearly attain perfection of the finished product, the ceramic engineer or other person with a knowledge of chemistry makes use of the "empirical formula." Those without a knowledge of chemistry, however, can do the same work by means of batch-weight recipes which will be presented together with the formulas.

It seldom pays to use an untested glaze recipe without some further experimental work. Nevertheless, a recipe does give a starting point from which glazes can be developed to fit any temperature or type of clay.

Five Type Glazes

As basic glazes, which can be combined or changed, there will be listed five decided "type glazes" that have been used extensively. A glaze for any set of conditions can be obtained by varying the five types. (The five listed are raw glazes; that is, they do not involve the use of a "frit," or base compound of specially prepared glass.)

The chemist's empirical formulas are first listed, followed by the recipes, or tables of batch weights. Each glaze is identified as to the temperature required to mature it and the products on which it can be used. Note that it is not stated that the five types will fit all sets of requirements exactly. Rather, it is said that they will serve as starting points for the development of other "tailor-made" glazes.

Glaze No. 1—Hard porcelain glaze maturing at cone 13. Used on a suitable fire-clay body, it is satisfactory at cone 9. Mixing a box of No. 4 cones in water and using the resulting cream as a glaze on a good fire clay results in a clear glaze in the neighborhood of cones 9 to 13:

Formula			Recipe (parts by weight)	
K_2O 0.30	Al_2O_3 0.50	SiO 4.00	Potash feldspar	167
CaO 0.70			Whiting	70
			Ball clay	52
			Flint	108
				397

Glaze No. 2.—Bristol glaze maturing at cone 7. Used on common stoneware pottery and some types of enameled brick, glazed brick, and terra cotta.

Formula			Recipe (parts by weight)	
K_2O 0.30	Al_2O_3 0.40	SiO_2 2.00	Potash feldspar	167
CaO 0.30			Whiting	30
ZnO 0.40			Zinc oxide	32
			Ball clay	26
				255

Glaze No .3.—Uncolored mat glaze maturing at cone 5. Used for over 20 years by a famous art pottery.

Formula			Recipe (parts by weight)	
K_2O 0.10	Al_2O_3 0.50	SiO_2 1.40	Potash feldspar	56
CaO 0.50			Whiting	50
PbO 0.40			White lead	103
			Ball clay	103
				312

Glaze No. 4.—Faience glaze, an enamel maturing at about cone 04. This is the type of glaze used to make the well known tin-enameled wares of Italy, France, Spain, and other countries. It is also useful to the brick-and-tile man in the production of white enameled products.

Formula			Recipe (parts by weight)	
PbO 0.70	Al_2O_3 0.15	SiO_2 1.75	White lead	181
CaO 0.20		SnO_2 0.30	Whiting	20
ZnO 0.10			Zinc oxide	8
			Ball clay	39
			Flint	87
			(Made white with 45 parts of tin oxide)	335

Glaze No. 5.—A red-ware glaze maturing close to cone 010. This glaze was used in the early period of the well-known Rookwood Pottery's history. It is used for red cooking wares and kitchen bowls and for such low-fired wares as jardinieres.

Formula

PbO	0.77	Al_2O_3 0.15		
K_2O	0.15		SiO_2 1.59	
CaO	0.08	Fe_2O_3 0.07		

Recipe (parts by weight)

White lead	1
Potash feldspar	
Whiting	
Red oxide of iron	
Flint	
	3

Study of the five selected glazes will show that they are made fo clays which mature at five different cone temperatures.

Use of Cones

If the reader is not familiar with the use of cones in determining kiln conditions, he should consult the literature before experimenting with glazes. Most clay plants that use pyrometers are content to take the readings from the region of the crown hole, and the variation is very great in the true temperatures of different portions of the kiln. Hence in experimenting with glazes the worker should place cone pats close to his glaze trials and have his glaze trials in many places in the kiln. A few dollars spent for cones to make a "cone-pat" study of any kiln is a very profitable investment.

Discussion of the Five Type Glazes

Glaze 1 is an excellent glaze when applied to the better class of stoneware clays and to certain true porcelain bodies, and is the type of glaze used largely for fine white European tableware. If it is kept in mind that fine hard stoneware, firebrick, chemical stoneware, chemical porcelain, electrical porcelain, and any other wares fired to cone 13 are likely to require a glaze similar to European table porcelain, a satisfactory recipe is easily written. Above cone 13, the feldspar or whiting content should not be changed under any circumstance, but variations in the ball clay and flint are permissible.

Common stoneware is made from clays which are similar to the fire-clay type, but less heat resistant. In other words, a fire clay not good enough for firebrick is excellent for making terra cotta, common stoneware, enameled brick, buff and gray face brick, art pottery, and many other glazed articles. Glaze 2 is the one to use for such wares.

Many kinds of art pottery, terra cotta, brick, tile, and other similar wares made from the clays suitable for stoneware manufacture, from some red-burning clays that stand rather high temperatures, or from mixed bodies of the white earthenware type, demand a mat glaze maturing at high temperatures. Glaze 3 is very good for such work. Other work later on will show how mat glazes can be developed for any desired temperature.

Many "structural-materials" clays react readily when tested with cold dilute hydrochloric acid, which indicates a rather high calcium-carbonate (limestone) content.

It is common practice to add about 20 percent or less of whiting to a clay to make it burn whiter, carry glazes well, and work readily for art-pottery work. Lime so introduced bleaches buff clays and last, but not least, makes them more satisfactory for tin enamels. So we can expect to use glaze 4 in working with such clays.

The man who has red-burning clays which will not stand very high temperatures will make use of glaze 5 for structural materials, art pottery, and cooking wares.

Most red-burning clays will stand an average fire of cone 1, and most buff-burning clays will be commercially well fired from cone 1 to cone 5. Many of the buff-burning clays if burned much harder than cone 5 turn gray, which is really not a disadvantage. Nearly all red-burning clays are sufficiently well burned for most purposes from cone 010 up to cone 04. Thus, it is seen that pleasing results in many fields of production are possible with glazes based on types 3, 4, and 5.

It will have been noted that potash feldspar, white lead, zinc oxide, whiting, tin oxide, red oxide of iron, ball clay, and flint are the raw materials used in making the five basic glazes and that the white lead and zinc oxide are the materials which make the glazes softer.

It is not so apparent that whiting is a powerful flux when it can work on the ball clay, but such is the case. Red oxide of iron is a flux but is really used in glaze 5 to make the color yellowish brown. Tin oxide is used to make glaze 4 a white opaque enamel.

Eight Rules for Changing Glazes

When the common glazes will not suit a specific clay exactly, the ceramic engineer makes use of chemical formulas which allow him to understand what happens when he makes a change. The following set of rules, which can be used more easily than formulas, are simply statements of how to do the same things a ceramic engineer would do by means of chemistry:

Rule 1.—When taking out 56 parts potash feldspar, add 26 parts ball clay and 24 parts flint. At the same time add one of the following materials in the amounts named: 26 parts white lead, 8 parts zinc oxide, or 10 parts whiting.

When adding 56 parts potash feldspar, take out 26 parts ball clay and 24 parts flint. At the same time take out one of the following materials in the amounts named: 26 parts white lead, 8 parts zinc oxide, or 10 parts whiting.

It should be obvious that multiples or fractions of the number 56 call for proportionate changes in the other values listed.

Rule 2.—Leaving feldspar alone: When taking out 56 parts white lead add 8 parts zinc oxide or 10 parts whiting.

When adding 26 parts white lead, take out 8 parts zinc oxide or 10 parts whiting.

Rule 3.—Leaving feldspar alone: When taking out 8 parts zinc oxide add 26 parts white lead or 10 parts whiting.

When adding 8 parts zinc oxide, take out 26 parts white lead or 10 parts whiting.

Rule 4.—Leaving feldspar alone: When taking out 10 parts whiting add 26 parts white lead or 8 parts zinc oxide.

When adding 10 parts whiting, add 26 parts white lead or 8 parts zinc oxide.

Rule 5.—When adding 26 parts ball clay, take out 12 parts flint.

Rule 6.—Flint may be taken out or increased without paying attention to any other material. Even if a glaze has no flint the rule still applies.

Rule 7.—To make a mat glaze from a bright or glossy glaze, take out flint by rule 6, allowing, however, for the flint figure in rule 5, because ball clay is to be added by rule 5. Add whiting by rule 4 at the expense of white lead.

Rule 8.—If calcined Florida kaolin is used instead of ball clay, replace each 26 parts of ball clay by 22 parts of calcined Florida kaolin.

(To prepare calcined Florida kaolin, screen dry clay through fly-mesh screen after crushing, and burn in saggars or other suitable containers in the kiln in which the material is to be used.)

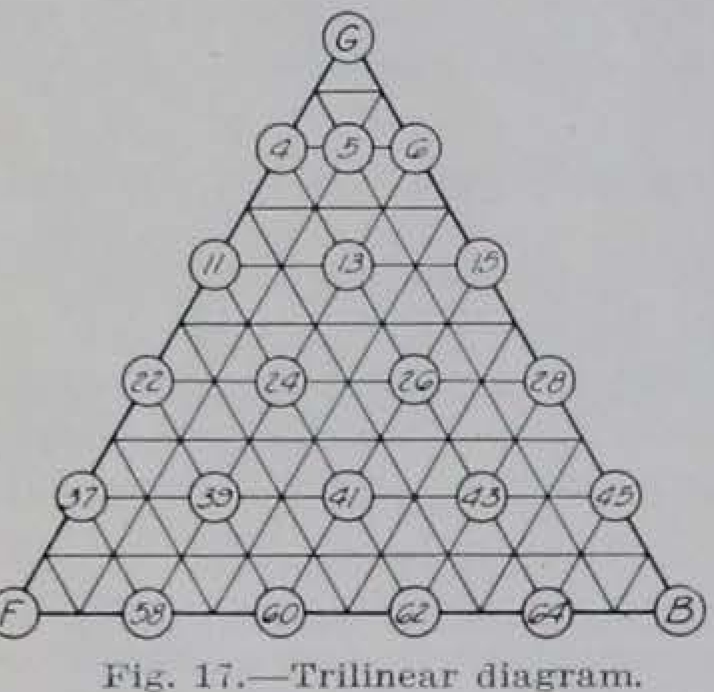

Fig. 17.—Trilinear diagram.

Glaze Adjustment by Use of Trilinear Diagrams

Glazes can be adjusted and new glazes developed by means of a trilinear diagram such as shown in Fig. 17. The trilinear coordinate paper is obtainable from dealers in engineers' supplies, or the experimenter may make his own.

In the trilinear method, three different glazes are chosen as basic glazes for the work. Samples containing different ratios of each of the three basic glazes are arranged inside the triangle with the three basic glazes themselves at the points. All the glazes indicated by intersections in the diagram in Fig. 17 are mixtures of the basic glazes *B*, *F*, and *G*, giving a total of 26 blends.

The percentage of each glaze in a mixture is found by beginning at one of the base lines and reading up toward the glaze, each division being 10 percent and the point of the triangle therefore being 100 percent. A study of Fig. 17 shows that the *G* glaze is 100 percent *G*; glaze 13 is 60 percent *G*, 20 percent *B*, and 20 percent *F*; and glaze 24 is 20 percent *B*, 40 percent *G*, and 40 percent *F*.

Suppose that type glaze 5 is to be converted from a glossy glaze into a mat glaze. Calling this *G*, the next step is to select a trial glaze for the place *F* on the diagram. Rule 7 is applied in taking out as much flint from glaze *G* as possible, according to the amount of clay added. Though there is no clay in glaze *G*, rule 7 implies that clay in excess of that in the usual run of glossy glazes is essential for a mat glaze. This is borne out by an examination of type glaze 3 which is a mat glaze at cone 5 and which has a relatively high clay content. Clay must therefore be added, but since ball clays are refractory, not as much clay is wanted as there is in type glaze 3. Let the figure be 50 parts.

Using rule 5 it is noted that for 26 parts of clay, 12 parts of flint must be taken out. Dividing 50 by 26 gives 1.9 which when multiplied by 12 gives 22.8 parts of flint to take out of the 41 parts already present. So if it is desired to experiment with no flint, the rest can be taken out for glaze *F*.

An examination of glaze 3 will show that the whiting content is quite high compared with all the other glazes except No. 1. Suppose then that there is set up a trial glaze *B* which has a rather large amount of whiting, say 50 parts. Rule 4 governs the next procedure. Having added 42 parts of whiting to the glaze, there must be taken out 4.2 times 26, or 109.2, parts of white lead.

Since the glazes may "crawl" with so great an amount of ball clay, this ingredient can be changed to calcined clay by rule 8. That is, 22 parts of calcined clay are added for each 26 parts of ball clay.

The next step is to write the recipes for the three glazes to be blended so that they can be weighed out prior to a 2-hour grinding in ball mills. If calcined clay is to be used the ball mill is essential and if raw clay is used the ball mill is desirable but not absolutely essential. The three test glazes and the number of parts of each ingredient are as follows:

Glaze G

White lead	199 parts (by weight)
Potash feldspar	84 parts
Whiting	8 parts
Red oxide of iron	11 parts
Flint	41 parts
	343 parts

Glaze F

White lead	199 parts	(by weight)
Potash feldspar	84 parts	
Whiting	8 parts	
Red oxide of iron	11 parts	
Ball clay	50 parts	
or		
Calcined clay	42 parts	
	352 or 344 parts	

Glaze B

White lead	90 parts	(by weight)
Potash feldspar	84 parts	
Whiting	50 parts	
Red oxide of iron	11 parts	
Ball clay	50 parts	
or		
Calcined clay	42 parts	
	285 or 277 parts	

In test runs it is always permissible to use the nearest whole number.

Preparation of Glaze Samples

When each of the above three glazes have been ground enough to pass readily through a 60-mesh sieve, it is best, perhaps, for the average worker to completely dry his glazes in plaster-of-paris molds before blending. There are other methods, but less confusion and labor really result from the "drying-out" method. Heat other than that of a warm room should not be applied.

It is next desired to make a blend to match each circle shown in the trilinear diagram and also to know the appearance of the three basic glazes. Consequently, sample clay pieces are first dipped in the three basic glazes before the samples are dried. A wise worker will dip more pieces than he needs to guarantee against kiln accidents, and he will keep half of his samples out of the first "burn" to make sure he does not have to do all of his work over again.

A study of what has been outlined will enable one to make any desired type of glaze. It is never desirable to change the temperature of the kiln to match the glazes in the experiments. Rather the glazes should be made to suit the best maturing point of the clay being used. Any altering of glazes must either be done by means of chemical formulas such as are used by ceramic engineers or by means of the rules listed.

Some place in the trilinear diagram of test batches just described will be found a mat glaze suitable for the particular clay used if the burning is not higher than cone 1 in any part of the kiln. Some of the test glazes will be glossy, some not matured, likely, and all will be yellowish-brown due to the iron oxide. If a red-burning clay is used the brown will be quite pronounced.

Once the right glaze is found, it will be unnecessary to repeat the blending process since the same proportions of each ingredient would be used no matter how large an amount of glaze is desired.

HOW TO COLOR CERAMIC WARES

Color may be added to the body of a ceramic ware, to the glaze itself, or used either over or under the glaze. If applied as an underglaze, it is coated with a clear, transparent glaze and refired to mature the glaze and bring out the color. A safe procedure for a beginner is to buy prepared underglaze colors and add about 10 percent to the glaze batch.

Where tin oxide or coloring oxides are used, a limiting figure must be suggested and the desired value obtained by experimental batches. Generally about 10 percent of the total batch weight of a glaze should be tin oxide added to make a clear glaze an opaque white one. If light colors are wanted, it is desirable to use the 10 percent of tin oxide in addition to the coloring oxides.

For use in coloring the five type glazes, and other glazes with approximately the same number of parts (300 to 400) of each ingredient, the following amounts (by weight) of coloring oxides are approximately correct in the quantities indicated:

About 8 parts cobalt oxide give a very dark blue, while 2 or 3 parts are usually sufficient.

Green is obtained from 8 parts black oxide of copper or 15 parts green oxide of chrome.

About 8 parts nickel oxide give either a green, a blue, a brown, or a gray, depending upon the glaze in which it is used. Only by experimentation can one be sure what color will result from the use of nickel oxide.

About 7 parts of black oxide of manganese or from 8 to 6 parts of red oxide of iron give a brown.

The following points should be kept in mind:

Zinc oxide kills greens, warms browns, and lightens blues.

Boric acid and borax help greens and offset the effects of zinc oxide to some extent.

Zinc oxide is not good for the reds obtained from chrome-tin pink stains.

A smoky fire ruins reds obtained from chrome-tin pink stains.

Good reds and yellows are difficult to make.

Rutile is useful in making mat glaze textures.

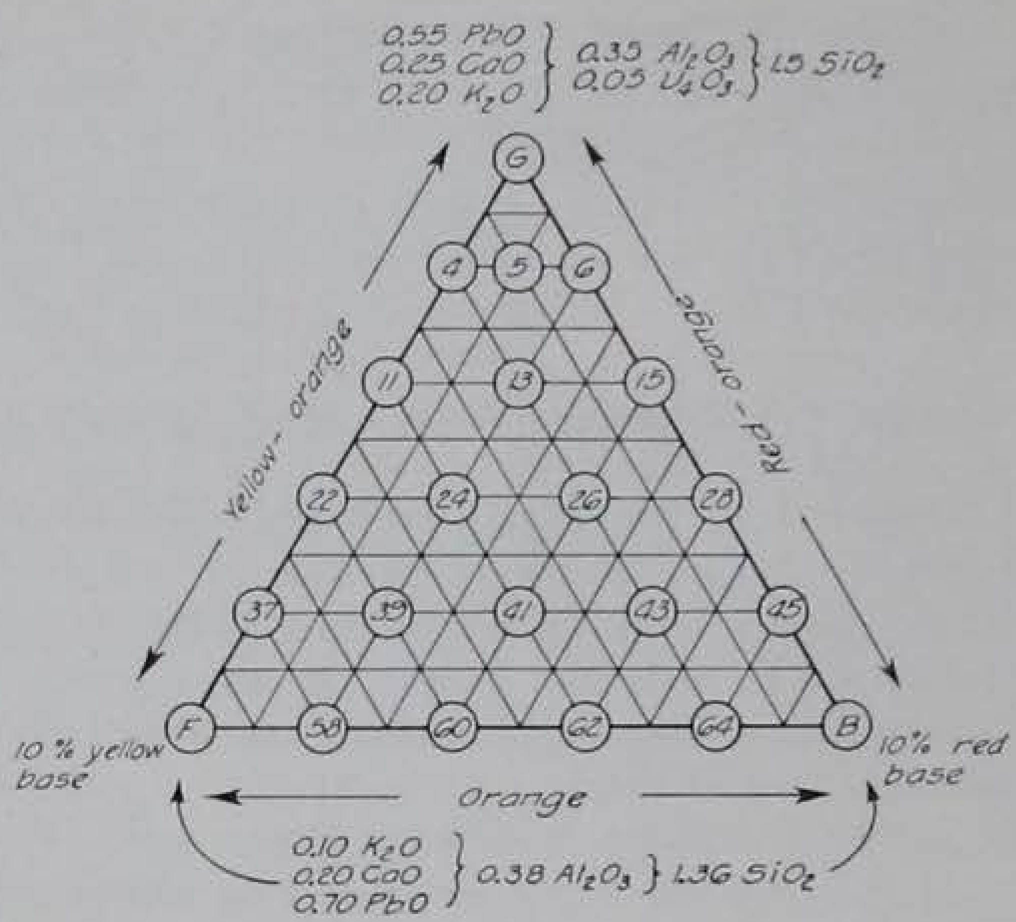

Fig. 18.—Trilinear diagram used by Whittemore and Whitford (*Bulletin* 58) for developing colored glazes.

Use of Trilinear Diagrams in Color Work

If different shades of color are desired, the trilinear diagram scheme, which has already been explained, is useful. Such a scheme was used by Whitford and Whittemore (*Bulletin* 58 of the Iowa Engineering Experiment Station) in a series of glaze experiments to develop a "wider range of color tones than was afforded by the basic glazes." There were produced "more than sixty different glaze mixtures very pleasing in color, quality, and texture, having a soft velvety surface well adapted to the display of the color of the glaze."

The trilinear diagram used in the experiments is shown in Fig. 18. The percentages of the different basic glazes in each mixture are shown in the following table:

No.	Percent			No.	Percent		
	Glaze *G*	Glaze *F*	Glaze *B*		Glaze *G*	Glaze *F*	Glaze *B*
4	80	20	—	37	20	80	—
5	80	10	10	39	20	60	20
6	80	—	20	41	20	40	40
11	60	40	—	43	20	20	60
13	60	20	20	45	20	—	80
15	60	—	40	58	—	80	20
22	40	60	—	60	—	60	40
24	40	40	20	63	—	40	60
26	40	20	40	64	—	20	80
28	40	—	60				

While Fig. 18 shows basic glazes which will give red, orange, and yellow combinations, the same scheme can be used for other basic combinations. Three basic glazes are, in each case, chosen for the corner positions, and from these the other mixtures are prepared.

Fritted Glazes

Frits (specially prepared glasses) for fritted glazes can be made from a recipe or else obtained from the manufacturers of frits for use in sheet-steel enamel plants. In developing frits, use the trilinear diagram scheme that has been demonstrated, and set the frit at one apex and two glazes that are too hard in the other corners. Proceed as in the development of a raw glaze, and it will be apparent that many colors and other properties not obtained from raw glazes result from the use of the frit.

Albany and Michigan slip clays used in blends with a frit and a Bristol type glaze will yield some interesting and useful glazes. That is, the frit goes in one corner, either Albany or Michigan clay in another, and a Bristol glaze in the third. Colors might be added to the Bristol glaze and many sets of diagrams run, or the color material might be ground with the frit to move the intense-color field toward that corner.

Those using buff-burning clays will want to experiment with type glazes 1, 2, and 3 and with a white-ware glaze.

SELECTED LITERATURE

Individuals desiring to learn more about ceramics will soon discover that nearly every publishing firm lists books in the field. For convenience, however, some selected books and periodicals for both amateur and professional craftsmen are listed in the following pages.

Books

Andrews, A. I. "Ceramic Tests and Calculations." John Wiley & Sons, Inc. New York. 1928. Price $2.25.

Ansell, H., and A. B. Searle. "Making and Burning of Glazed Wares." H. G. Montgomery, 43 Essex St., Strand, London, W.C. 2. 1929. Price 12 sh. 6d.

Binns, C. F., ed. "Manual of Practical Potting." 5th ed. rev. D. Van Nostrand Company. New York. No date. Price $8.00.

Binns, C. F. "Potters Craft." 2d ed. rev. and enl. D. Van Nostrand Company. New York. 1922. Price $2.50.

Bourry, E. "Treatise on Ceramic Industries." Revised translation from the French. D. Van Nostrand Company. New York. No date. Price $6.00.

"Ceramic Equipment and Material Catalogs; Ceramic Products Cyclopedia; a Comprehensive Volume Combining Practical Working Information, Tabular Data, and Catalogs of Equipment and Materials Pertaining to the Manufacture of Ceramic Products." 6th ed. Industrial Publications, Inc., 59 E. Van Buren St., Chicago. 1932. Price $12.00.

Cox, G. J. "Pottery; for Artists, Craftsmen, and Teachers." The Macmillan Company. New York. 1926. Price $1.50.

Cox, P. E. "Potteries of the Gulf Coast." Reprint from *Ceramic Age*, 25:116-119, 140:152-156; 196-198. 1935. Price $0.50.

De Sager, W. A. "Making Pottery." (How to Do It Series, No. 7) Studio Publications, Inc., 381 Fourth Ave., New York. 1934. Price $3.50.

Doat, T. M. "Grand feu Ceramics." Keramic Studio Publishing Company, 307 S. Franklin St., Syracuse, N. Y. No date. Price $5.00.

Duthie, A. L. "Decorative Glass Processes." D. Van Nostrand Company. New York. No date. Price $2.50.

Eberlein, H. D., and R. W. Ramsdell. "Practical Book of Chinaware." J. B. Lippincott Company, Philadelphia. 1925. Price $5.00.

Eden, F. S. "Ancient Stained and Painted Glass." The Macmillan Company. New York. No date. Price $1.00.

Forsyth, G. M. "Art and Craft of the Potter." Chapman & Hall, Ltd., 11 Henrietta St., Covent Garden, London, W. C. 2. 1934. Price 10 sh. 6 d.

Gall, I. M., and V. M. Van Etta. "Art of Pottery." Bruce Publishing Company, 524-544 N. Milwaukee St., Milwaukee. 1930. Price $1.35.

Hainbach, R. "Pottery Decorating." 2d rev. English ed. D. Van Nostrand Company. New York. No date. Price $3.00.

"Handbook on Pottery and Glass Ware." Revised edition. Scott, Greenwood & Son, 8 Broadway, Ludgate Hill, London, E.C. 4. 1935. Price 5 sh.

Hobson, R. L. "Chinese Art." The Macmillan Company. New York. 1927. Price $12.50.

Hooper, W. H., and W. C. Phillips. "Manual of Marks on Pottery and Porcelain." New Edition. The Macmillan Company. New York. 1879. Price $2.00.

Jacobs, M. "Art of Colour." Doubleday, Doran & Company, Inc. New York. 1923. Price $7.50.

Miskella, W. J. "Practical Color Simplified." Simmons-Boardman Publishing Company, 30 Church St., New York. 1928. Price $3.50.

Noke, C. J., and H. J. Plant. "Pottery." Pitman Publishing Corporation. New York. 1924. Price $1.00.

Piccolpasso, C. "Three Books of the Potters' Art." The Victoria and Albert Museum. London. 1934. Price 30 sh.

Rhead, G. W. "British Pottery Marks." Scott, Greenwood & Son, London. 1910. Price 7 sh., 6 d.

Sandeman, E. A. "Notes on the Manufacture of Earthenware." C. Crosby Lockwood & Son, Ltd., 7 Stationers' Hall Court, Ludgate Hill, London, E.C. 4. 1917. Price 7 sh. 6 d.

Seger, H. A. "Collected Writings; Prepared from the Record of the Royal Porcelain Factory at Berlin by H. Hecht and E. Cramer; Translated by the Members of the American Ceramic Society, 2 Volumes." American Ceramic Society, 2525 N. High St., Columbus. No date. Price $7.50 per volume.

SPARGO, J. "Early American Pottery and China." D. Appleton-Century Company, Inc., 35 W. 32d St., New York. 1926. Price $4.00.

SUFFLING, E. R. "Treatise on the Art of Glass Painting." D. Van Nostrand Company. New York. No date. Price $3.50.

WREN, H. D., and D. WREN. "Pottery; the Finger-Built Methods." Pitman Publishing Corporation. New York. 1932. Price $1.50.

Periodicals

Journal of the American Ceramic Society. Published monthly by the American Ceramic Society, 2525 North High Street, Columbus, Ohio. Price $15.00.

Bulletin of the American Ceramic Society. Published monthly by the American Ceramic Society, 2525 North High Street, Columbus, Ohio. Price $1.50.

In addition to the above periodicals, the American Ceramic Society publishes bibliographies of ceramic literature. Of especial interest are an abstract section and a series of inspirational historical sketches.

Transactions of the Ceramic Society. Published monthly by the Ceramic Society, the North Staffordshire Technical College, Stoke-On-Trent, England. Price 45 sh. per volume.

This publication covers the history of English ceramics in addition to current technical progress. Its abstract section resembles, and duplicates to some extent, the corresponding sections in the publications of the American Ceramic Society.

Every possible type of formula or recipe can be had from the files of the publications of the two above-mentioned ceramic societies. The abstract sections are inexhaustible sources of tested information about ceramic bodies and glazes. Membership in each organization, which is granted to all interested persons, entitles one to receive the current publications of the society.

Brick and Clay Record. Published monthly by Industrial Publications, Inc., 59 East Van Buren Street, Chicago, Ill. Price $5.00.

Devoted to the interests of manufacturers of structural materials.

Ceramic Industry. Published monthly by Industrial Publications, Inc., 59 East Van Buren St., Chicago, Ill. Price $4.00.

Devoted to the interests of manufacturers of pottery, glass, and enameled metals.

Both *Brick and Clay Record* and *Ceramic Industry* frequently present translated articles from foreign-language journals dealing with valuable methods of production. The publications also give sources of machinery and materials supplies.

Ceramic Age. Published monthly by Ceramics Publishing Company, Inc., 170 Roseville Ave., Newark, N. J. Price $3.00.

Ceramic Age, a journal devoted mainly to the interests of the finer types of clayware, carries many items of interest to the amateur as well as the professional worker.

Directory of Plants in the White Ware Branches of the Ceramic Industries in the United States and Canada . . . compiled under the direction of the editorial staff of *Ceramic Age*. Published annually by the Ceramics Publishing Company, Inc., Directory Dept., 170 Roseville Ave., Newark, N. J. Price $5.00.

Lettered on cover: Ceramic Trade Directory.

This directory gives the addresses of all American pottery plants, together with the products which they produce. The directory is rich in information useful to the art potter.

Pottery Gazette and Glass Trade Review. Published monthly by Scott, Greenwood and Son, 8 Broadway, Ludgate Hill, London, E.C. 4, England. Price 15 sh.

This English journal is devoted to the interests of British china, glass, and art pottery. Although many technical articles are included, the journal uses many illustrations of popular interest which show style trends. An annual feature is a 200-page directory of British firms and products.

China, Glass, and Lamps. Published monthly by Commoner Publishing Company, Century Building, 7th St., Pittsburgh, Pa. Price $2.00.

A useful directory entitled "China and Glass Trade Directory" is an annual feature.

Crockery and Glass Journal. Published monthly by Haire Publishing Company, Inc., 1170 Broadway, New York. Price $2.00.

The two above mentioned journals are useful mostly because of their profuse illustrations which show style trends and suggest designs.

Design. Published monthly by the Design Publishing Company, 20 South Third St., Columbus, Ohio. Price $3.00.

Design was started in 1899 as *Keramic Studio* and known by that name for a quarter of a century. In May, 1924, it changed its title to *Design-Keramic Studio*, and in May, 1930, it changed to the present title of *Design*. Developed originally to supply the needs of the china painters, it is now published in the interest of the decorative arts.

Those interested in ceramics will profit by subscribing for at least one trade journal devoted to style trends. Of the books which have been mentioned, the following are suggested for first purchase:

Binns, C. F. "Potters Craft."
Doat, T. M. "Grand feu Ceramics."
De Sager, W. A. "Making Pottery."
Binns, C. F. "Manual of Practical Potting."
Cox, G. J. "Pottery; for Artists, Craftsmen, and Teachers."
"Ceramic Equipment and Material Catalogs."
Forsyth, G. M. "Art and Craft of the Potter."
Cox, P. E. "Potteries of the Gulf Coast."

This last named publication is suggested because it deals solely with pottery produced by individuals imbued with ideals of the type which the present bulletin is designed to foster.

APPENDIX

The following drawings (Figs. 19 to 23) illustrate kilns which have been thoroughly tested and which are economical to construct. They include a periodic car kiln, oil- or gas-fired kilns for large-scale and for small-scale production, and a steel-jacketed kiln for coal or wood firing.

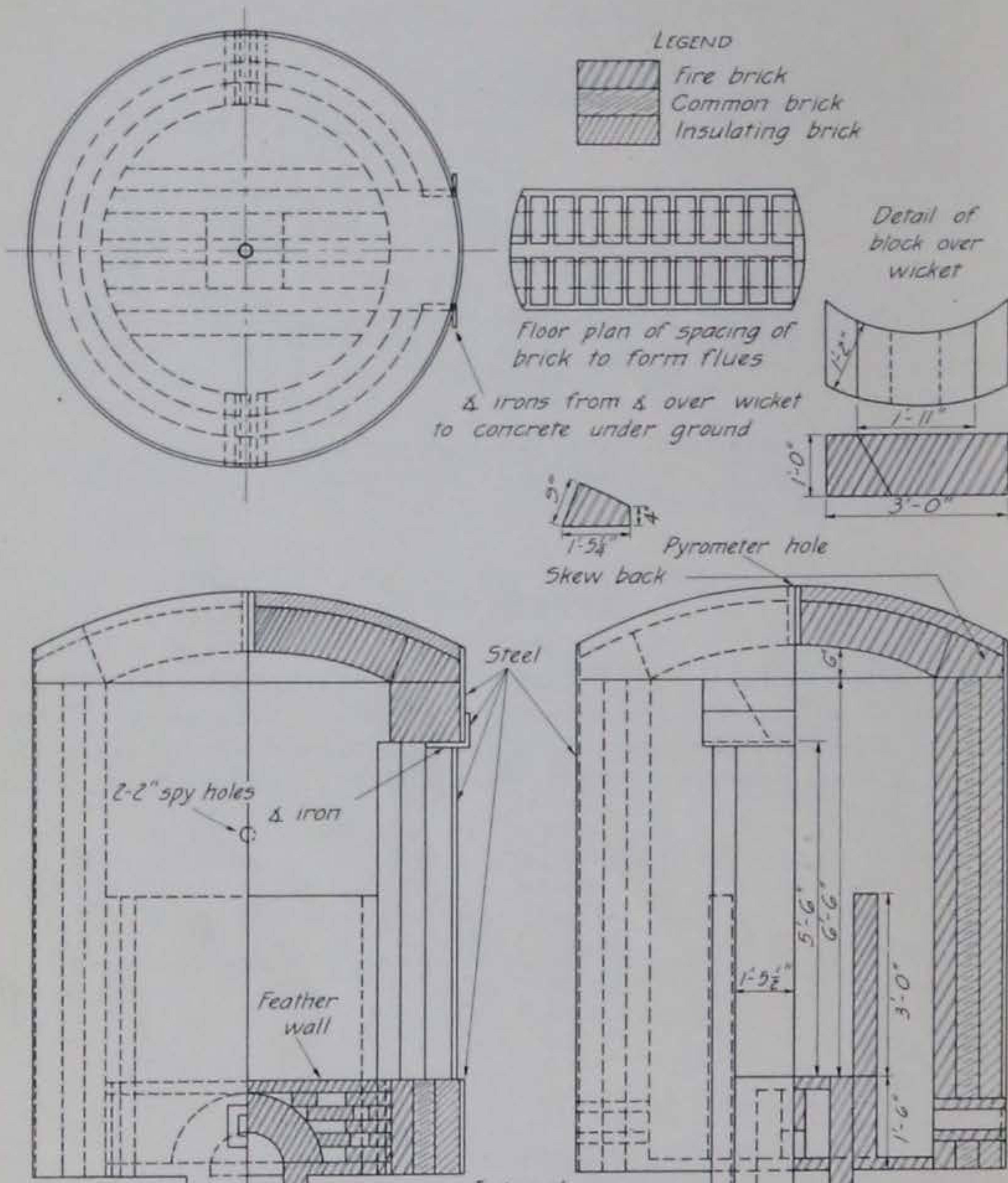

Fig. 19.—Recommended small steel-jacketed kiln for schools, studios, or small factories (kiln may be oil- or gas-fired).

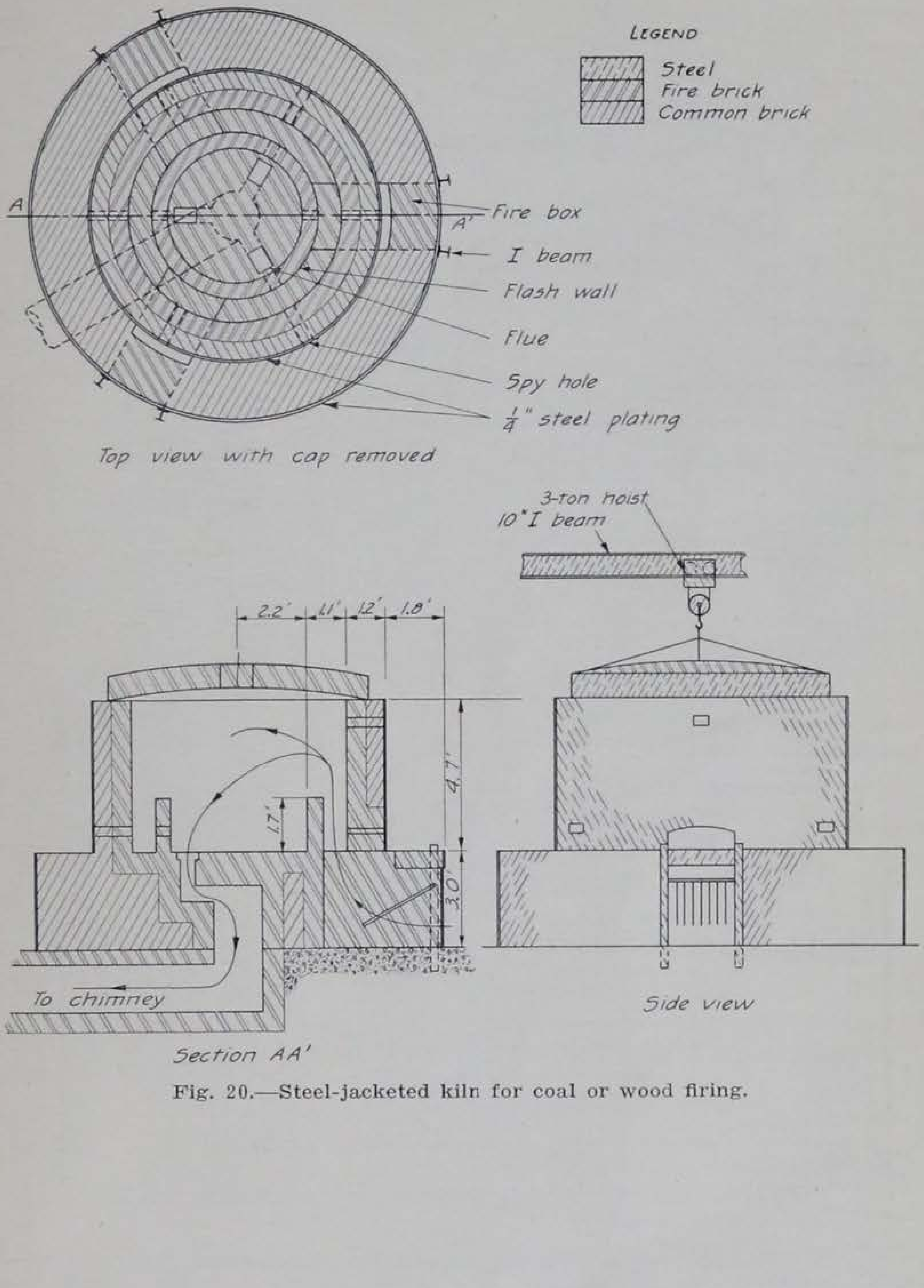

Fig. 20.—Steel-jacketed kiln for coal or wood firing.

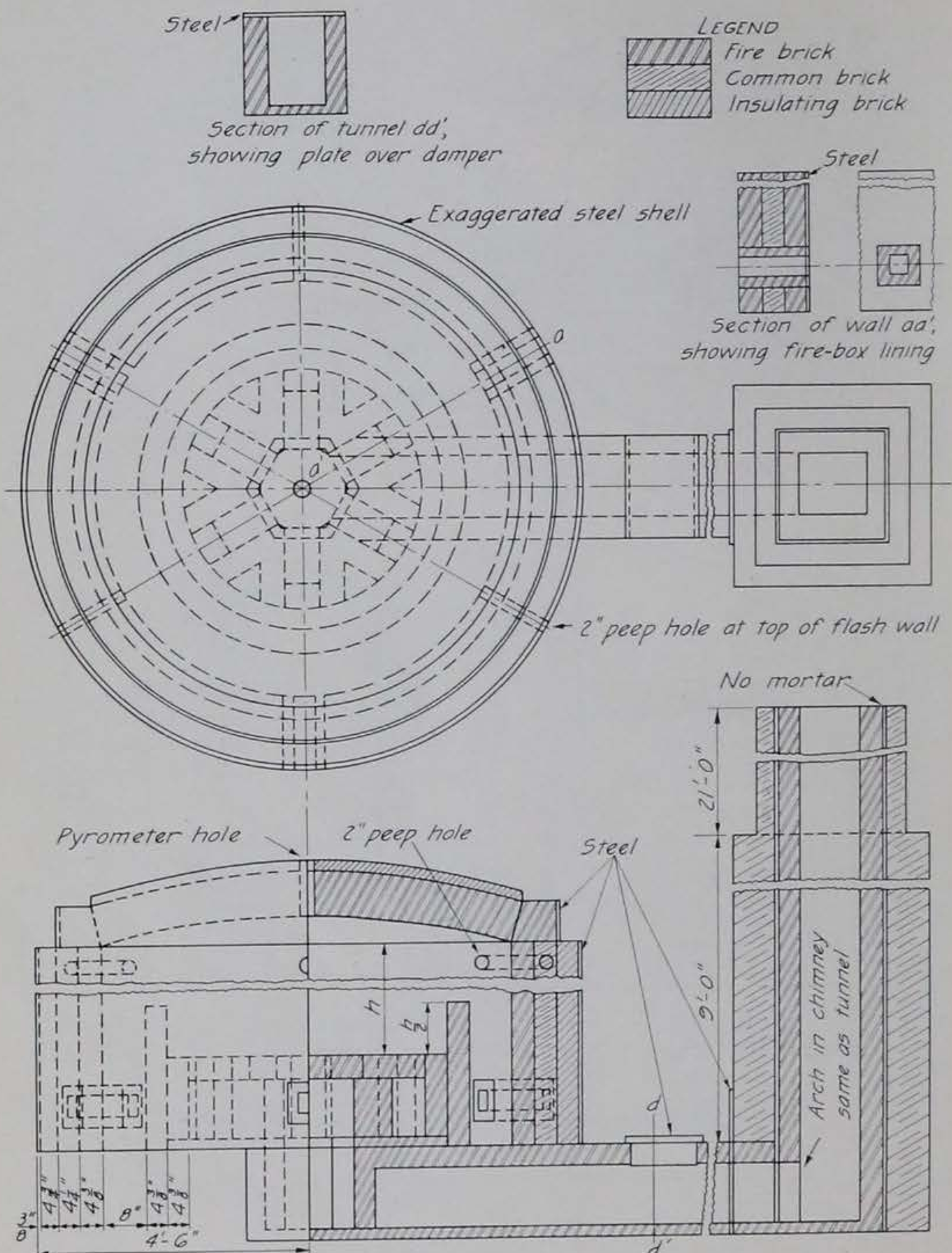

Fig. 21.—Plans for a steel-jacketed kiln, either oil or gas-fired, for a relatively large production.

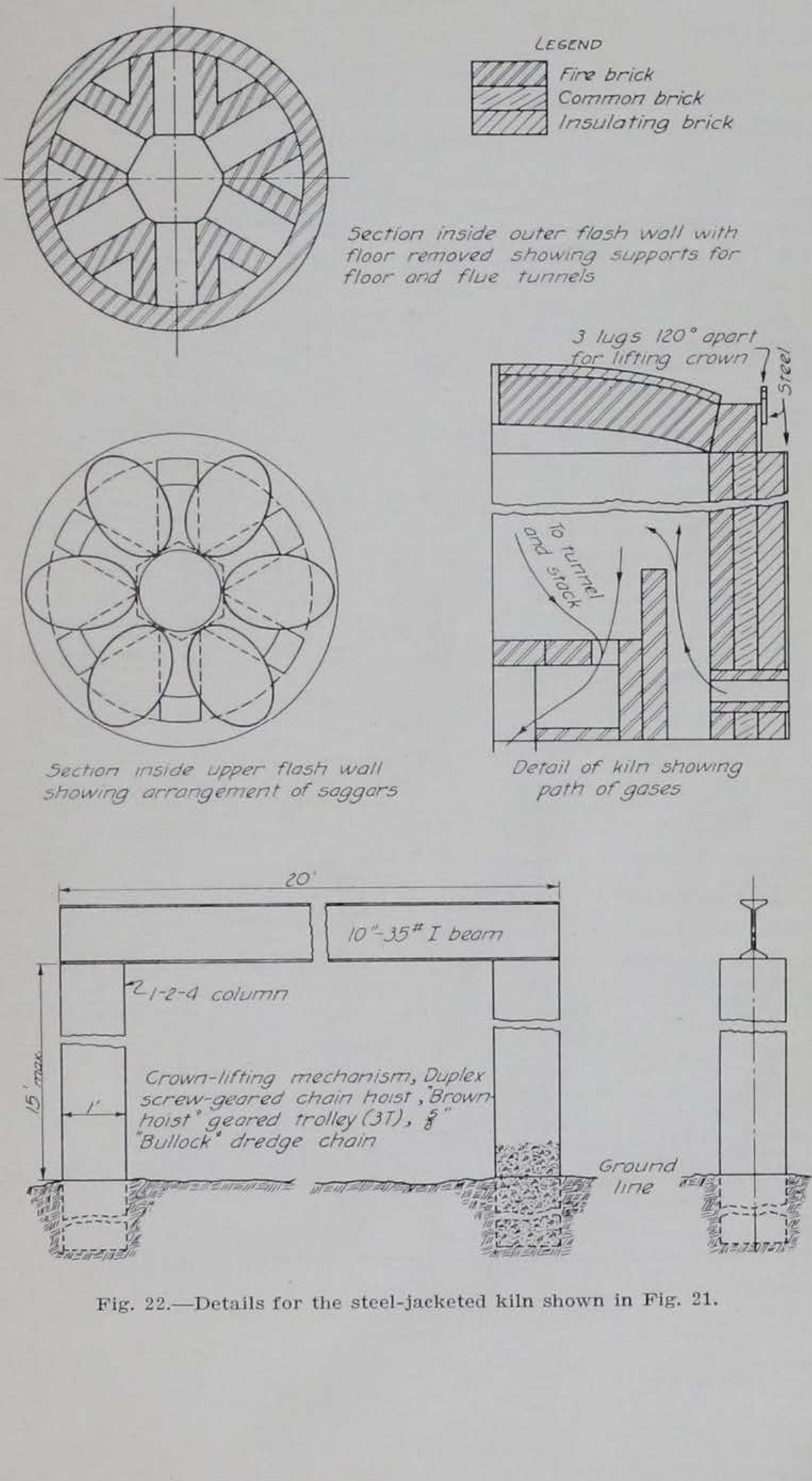

Fig. 22.—Details for the steel-jacketed kiln shown in Fig. 21.

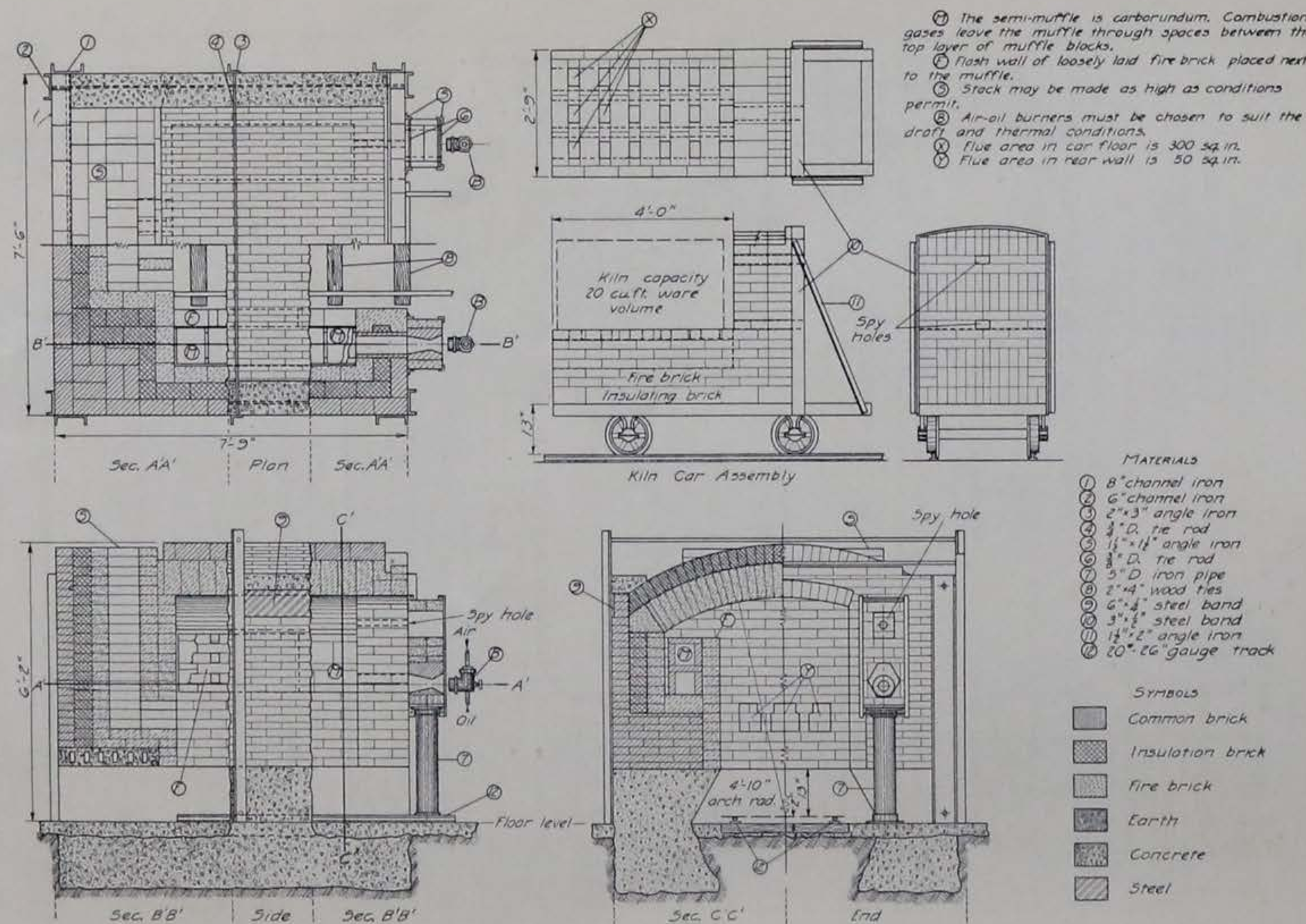

Fig. 23.—Removable car periodic kiln (either oil- or gas-fired).

BULLETINS OF THE IOWA ENGINEERING EXPERIMENT STATION

(Continued from inside front cover)

*No. 92. Life, Service, and Cost of Service of Farm Machinery. J. B. Davidson. 1929.
No. 93. Supporting Strength of Concrete-Incased Clay Pipe, Determined from Tests with Commercial Vitrified Salt-Glazed Clay Pipe. W. J. Schlick. 1929.
No. 94. Power Requirements of Custom Mills for Grinding Feed. J. K. McNeely and H. S. Bueche. 1929.
*No. 95. Removal of Milk Constituents by Filtration. M. Levine, G. W. Burke, and J. H. Watkins. 1929.
No. 96. The Theory of External Loads on Closed Conduits in the Light of the Latest Experiments. A. Marston. 1930.
No. 97. Burning Pulverized Iowa Coal. E. B. Smith. 1930.
No. 98. Cornstalks as an Industrial Raw Material. O. R. Sweeney and L. K. Arnold. 1930.
No. 99. Field Inspection of Concrete Pipe Culverts. R. W. Crum. 1930.
*No. 100. The Production of Paper from Cornstalks. O. R. Sweeney and L. K. Arnold. 1930.
No. 101. Physical Properties of Earths. J. H. Griffith. 1931.
*No. 102. Experimental Studies on the Production of Insulating Board from Cornstalks. O. R. Sweeney, C. E. Hartford, Jr., R. W. Richardson, and E. R. Whittemore. 1931.
*No. 103. Life Characteristics of Physical Property. R. Winfrey and E. B. Kurtz. 1931.
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No. 105. The Location and Elimination of Radio Interference. J. K. McNeely. 1931.
*No. 106. Automobile Operating Cost and Mileage Studies. R. Winfrey. 1931.
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No. 108. Loads on Pipe in Wide Ditches. W. J. Schlick. 1932.
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No. 110. Destruction of Carbohydrates and Organic Acids by Bacteria from a Trickling Filter. M. Levine and J. H. Watkins. 1932.
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No. 113. A Proposed System for the Analysis and Field Control of Fresh Concrete. W. M. Dunagan. 1933.
No. 114. Statistics of Motor Truck Operation in Iowa. R. Winfrey. 1933.
No. 115. Purification of Creamery Waste on Filters at Two Iowa Creameries. W. E. Galligan and M. Levine.
No. 116. Effect of Bottom Ventilation on Purification by Experimental Trickling Filter. M. Levine and H. E. Goresline. 1934.
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No. 121. Recommendations for the Control and Reclamation of Gullies. Q. C. Ayres. 1935.
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No. 123. A Study of Torque and its Influencing Factors as Related to Commercial Tapping of Metals. H. L. Daasch and J. Hug. 1935.
No. 124. Effect of Nature of Filling Material and Dosing Cycle on Purification of Creamery Wastes. M. Levine, G. H. Nelson, and H. E. Goresline. 1935.
No. 125. Statistical Analyses of Industrial Property Retirements. R. Winfrey. 1935.
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No. 127. Strength and Elastic Properties of Cast Iron. W. J. Schlick and B. A. Moore. 1936.
No. 128. Thermal Expansion of Typical American Rocks. J. H. Griffith. 1936.
No. 129. Analysis of Thin Rectangular Plates Supported on Opposite Edges. D. L. Holl. 1936.
No. 130. Experiments on Purification of Packing-House Wastes at Mason City, Iowa. M. Levine, F. G. Nelson, and E. Dye. 1937.
No. 131. Physical Properties of Typical American Rocks. J. H. Griffith. 1937.
No. 132. Germicidal Properties of Chlorine Compounds. D. B. Charlton and M. Levine. 1937.
No. 133. The Use of Iowa Clays in Small-Scale Production of Ceramic Art. P. Cox. 1937.

THE COLLEGE

The Iowa State College of Agriculture and Mechanic Arts conducts work in five major fields:

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ENGINEERING

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Four-year, five-year, and six-year collegiate courses are offered in different divisions of the College. Non-collegiate courses are offered in agriculture. Summer sessions include graduate and collegiate work. Short courses are offered in the winter.

Extension courses are conducted at various points throughout the state.

Four special research institutes have been organized: the Agricultural and Engineering Experiment Stations, and the Veterinary and Industrial Science Research Laboratories.

Special announcements of the different branches of the work are supplied, free of charge, on application.

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