ibilities of Pottery
ufacture from Iowa Clays

W. G. Whitford

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W. G. WHITFORD AND O. J. WHITTEMORE

BULLETIN 58

ENGINEERING EXPERIMENT STATION

AMES, IOWA

Published weekly by Iowa State College of Agriculture and Mechanic Arts, Ames, Iowa. Entered as Second-class matter, and accepted for mailing at special rate of postage provided for in Section 429, P. L. & R., Act August 24, 1912, authorized April 12, 1920.

PURPOSE OF THE STATION

' purpose of the Engineering Experiment
on is to afford a service, through scientific
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thods, educational technical information,
d tests and analyses of materials:

the manufacturing and other engineering
ulation and industries of Iowa;

For the industries related to agriculture, in
solution of their engineering problems;

or all people of the State in the solution of
engineering problems of urban and rural

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FRONTISPIECE. SHOWING PIECES MADE FROM IMPROVED IOWA SHALE. The body for these pieces was 80 per cent Mason City Shale and 20 per cent Mason City Yellow Clay.

POSSIBILITIES OF POTTERY MANUFACTURE FROM IOWA CLAYS

Clay is being used in an ever increasing number of schools, public and private, for all sorts of instruction, from kindergarten modeling to actual pottery making in the upper grades.

Pottery making in Iowa by kindergarten, grade and high school students and clubwomen can be carried on without a great outlay for equipment. There is a great variety of clays well distributed over Iowa and a large number of clay products plants where clay may be obtained and the burning of ware accomplished. In fact conditions are so favorable that such work, interesting, artistic and educational could be carried on to a much greater extent than at present.

Representative clays from all sections of the state were tested in the course of this investigation and the available supplies, together with their properties especially as concerns their adaptability to modeling or pottery manufacture, are brot out in detail. The results, showing general character, working, drying, and burning properties of each, are presented in tabular form.

Small Scale Operations. For benefit of those who would take up modeling or pottery making on a small scale only, a brief discussion of the procedure follows. The choice of a suitable clay must preceed the successful making of even the simplest pottery. After a clay has been selected and has proved satisfactory in test, small amounts, (25 to 50 pounds) may be broken or crushed either in a mortar, or wrapped in sack-cloth or canvas and beaten with a heavy mallet. This crushed clay is then rubbed thru a strong wire sieve, not coarser than 1/4″ mesh, into a wooden bucket or stoneware jar, three-fourths full of water. The vessel is then covered and allowed to stand over night. Next day the mixture is stirred vigorously with a wooden paddle until all the clay has been brought into suspension, that is, none is left on the bottom. This mixture is now known as "slip".

The slip may be passed thru a 48 mesh, or finer, sieve into a plaster box. (The finer the sieve that the slip is passed thru at this stage the more workable the clay will be later). In a few hours, perhaps a day, the plaster box will have absorbed sufficient water from the slip to change it from a fluid to a plastic condition, in other words from slip to moldable clay.

It is now ready to be removed from the plaster box and stored in a "damp box", where it will keep indefinitely, if always covered with a thoroly wet sack. It is advisable to prepare more clay than is needed for immediate use as it improves considerably with age.

Methods of Clay Working. When clay is in the slip form and properly sieved to remove coarse particles it is ready for the casting method of making clay ware, that is, it is suitable to pour into moulds. After it has stood in a plaster box, or has been put thru a filter press, to remove the excess water, and is in the plastic form, pieces may be made from it in a number of ways. It may be "spun" or thrown on a wheel, "coiled" or hand built, pressed in molds or jiggered.

Coiled or hand built ware is probably best adapted to the ordinary scale of operations carried on by kindergarten, grade or high school teachers. This ware is fashioned without the aid of molds, and without the use of the turning wheel or lathe. It may be made by coiling rolls of clay and filling and welding the joints as the shape progresses, by piecing or shaping from flat slabs of clay cut to the desired shape and size; or by carving from a solid piece of clay. Only a few pieces of equipment, such as wooden and steel smoothing and trimming tools and plaster slabs are needed in making ware by this method.

Drying the Ware. Clayware frequently cracks badly in drying. This difficulty may be overcome usually by placing the pieces on blocks or low racks inside large stoneware jars placed on radiators. The drying is started with a cupful of water poured into the bottom and a wet cloth stretched tightly over the mouth of the jar. As the water dries out the piece will progress safely thru the drying stages. Only pieces made from exceptionally poor drying clay or with exceedingly poor workmanship in welding the joints will crack under this system of drying.

Burning the Ware. If the scale of operations does not warrant the purchase of a kiln, arrangements may be made with a local clay products manufacturer, whereby the pieces may be placed in a commercial kiln and fired for a slight fee. If the ware is to be biscuit burned, later glazed and then put thru a glost burn, the pieces will have to be protected in the glost burn from the kiln gases by placing them in saggers or clay boxes and carefully mudding the cracks. Such saggers for use with small pieces, may be improvised from hollow building blocks by placing the pieces inside and mudding slabs of broken blocks into the openings.

In case much ware is to be burned it will probably prove advisable to secure a muffle kiln such as put out by the H. J. Caulkins Company of Detroit or the Denver Fire Clay Company of Denver. These kilns, by virtue of their style of construction protect the ware from the coaly or sooty flames and gases making it unnecessary to protect it in saggers.

Glazing the Ware. Artistic pottery can be produced without glazing . The ware in this case being similar to old Indian pottery. Glazing adds a great deal to such work, however. If glazing is attempted it will probably be worth while to send a small sample of the clay being used to the Ceramic Engineering Department of Iowa State College at Ames, and have a glaze developed that will exactly fit that particular clay body.

Making a Plaster Box. On a smooth, level surface place a block of clay equal in size and shape to the opening desired in the finished plaster box. Build about this a wooden frame of the height the box is to be, and sufficiently larger than the clay block to give the required thickness of walls to the finished box. Fill the frame with plaster of Paris mixed for casting. When the plaster has thoroly set, turn the box over, pull out the clay and allow the box to dry. When the paster has thoroly dried the box is ready for use as mentioned above. The size of the plaster box to be made is left to the judgment of the user but the proportions should agree with those suggested in Fig. 1. The wooden frame may be left about the plaster as it offers considerable protection to the walls which might otherwise become chipped and cracked.

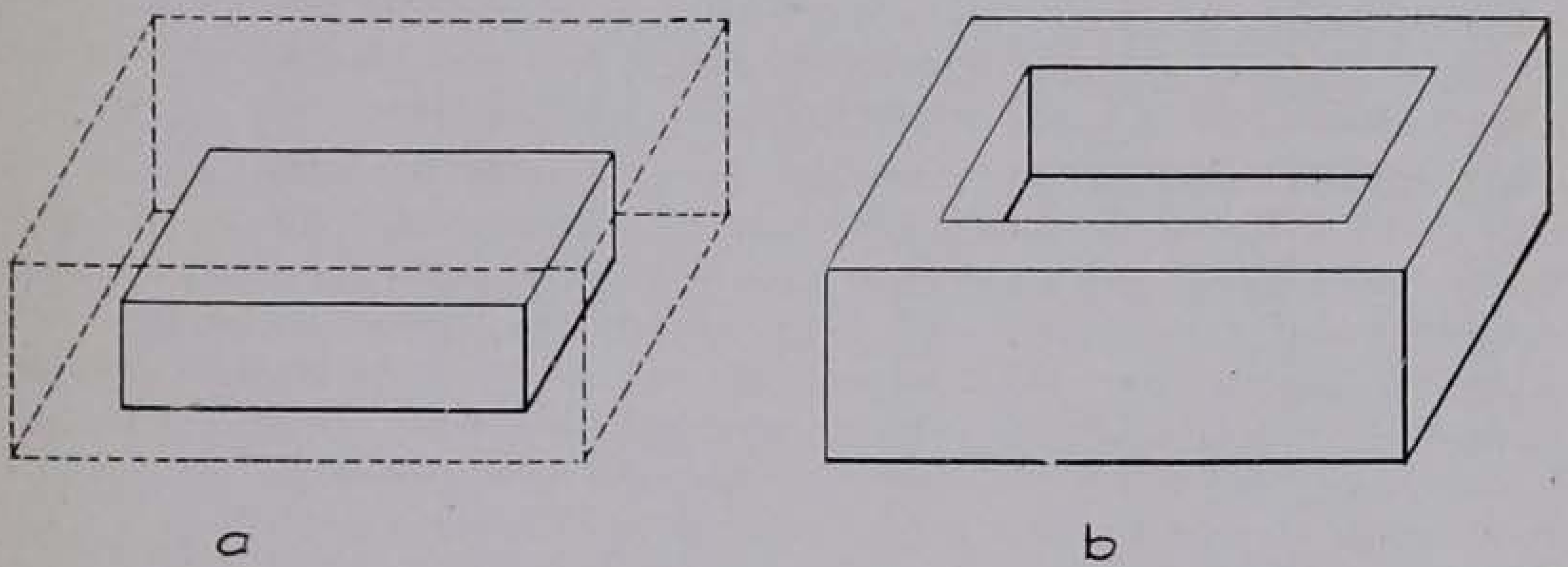


FIG. 1. SHOWING METHOD OF MAKING PLASTER BOX FOR DRYING SLIP. a. Slab of clay—dotted lines for frame. b. Completed box

SIZES OF PLASTER BOXES

	Length Inches	Width Inches	Height Inches	Thickness Sides and Base
1.	18	12	6	2½
2.	24	18	8	3½
3.	30	24	10	4½

Handling Plaster of Paris. Plaster of Paris mixed with water possesses the property of hardening to an absorbent solid. By varying the proportions of water and plaster and the length of time of stirring the degree of hardness and the power of absorption are increased or lessened which permits it to be so used that it will exactly meet the requirements of a particular process. Plaster for molds or boxes in which slip is dried must be highly absorbent and at the same time hard and strong enough to withstand repeated soaking and drying without disintegration.

Fill a lipped bowl or other wide-mouthed vessel of ample size about half full of clean water. Shake plaster of Paris thru a ⅛″ sieve into center of the vessel until the cone of plaster reaches the surface of the water. Very little more plaster will be needed to give the proper consistency. Stir the mixture vigorously with the hand, at the same time crushing the lumps with the fingers, until the whole mass appears to thicken perceptibly. At once pour the plaster in a steady stream into the desired cavity. It will become set or hard within fifteen minutes. It is important that the stirring be both vigorous and continuous until the plaster commences to thicken.

Making a Damp Box. A strong box of galvanized iron sufficient in size to meet the needs of a particular clay worker can be made by any tinner. The top should be hinged and tightly fitting. For a base inside the box, a slab may be made over the metal by pouring in prepared plaster of Paris until a layer two inches thick is formed. Water poured over the slab occasionally will help to maintain a damp atmosphere within the box. A pan of water should be kept in the box whenever there is any clay in storage. In addition wet cloths should be kept over the reserve supplies of clay and unfinished pieces at all times. The prime requisite of a damp box is that it be tight. For a class of ten students, a box 2′x2½′x6′ is ample. For larger classes 2 or more damp boxes will be found useful.

Apparatus. Simple, yet more elaborate equipment than that just outlined can be bought or built for preparing clay. A small coffee grinder may be rigged up with a mechanical drive, to do small amounts of clay grinding. Special clay grinding machines may be bought in a variety of sizes. For blunging (mixing the clay with water) a cylindrical tank may be fitted with a vertical shaft with paddles attached, so mounted as to be revolved inside the tank either by hand or by power. Such a machine will bring the clay into suspension, that is, into the slip form, much quicker than the soaking process. Needless to say that if much material is to be prepared the mechanical equipment placed on the market by a number of manufacturers would prove more economical than home-made machinery.

Bibliography. The following books are recommended to those wishing more information on the details of clayworking or to those wishing to add to a library.

"Pottery"—Geo. J. Cox.
"Studio Pottery"—Frederic H. Rhead.
"Seger's Collected Writings".
"Grand Feu Ceramics"—Taxile Doat.
"Architectural Pottery"—Leon Lefevre.
"The Chemistry of Pottery"—Langenbeck.
"Treatise on Ceramic Industries"—Emile Bourry.
"Coloring and Decoration of Ceramic Ware"—Brongniart.
"Notes on Pottery Clays"—James Farrie.
"Pottery Decorating"—R. Hainbach.

POSSIBILITIES OF POTTERY MANUFACTURE FROM IOWA CLAYS

PURPOSE

The purpose of this investigation was to determine what possibilities Iowa clays offer for the manufacturer of pottery wares. Consideration of clay deposits, supply and demand and other economic problems connected with the pottery industry are not considered in the discussion.

CLASSIFICATION

There are many kinds of pottery manufactured thruout the world, the quality of type of which is determined by the clays available for the purpose. These are known as hard and soft porcelain, china, stoneware, earthenware and in addition there are many varieties of art pottery made by using almost any kind of clay from the finest Kaolins to the commonest of brick clays.

The classification of pottery is not easy, but it is possible at the outset to make two very complete divisions, namely—I. Unglazed or "simple" pottery, and II. Glazed or "composite" pottery.

The first division comprises that type of wares made by primitive peoples of many races of which the pottery of the Pueblo Indians of New Mexico and early Greek vases are good examples. This type of ware has little commercial value and is of interest only as the relic of a passing race. Such pottery can be made from the commonest of clays. Within the class are the common unglazed flower pots and garden and architectural terra-cotta, (unglazed). This type of ware falls more within the scope of roofing tile and drain pipe production than the true pottery industry.

Brongniart, the great French authority on pottery, classifies pottery and porcelain according to the characteristics derived from the paste or body, and also according to the properties derived from the glaze. Essentially his classification is as follows:

1. **Porcelain, White Semi-transparent, and Fused only at High Temperatures.**

   (a) Hard porcelain—natural kaolin covered with a felspar glaze; example, porcelain of China and Japan.

   (b) Soft porcelain—artificial paste covered with a lead vitreous glaze; example, early Sevres porcelain.

2. Stoneware, Very Hard and Infusible.

(a) Very silicious clay covered with a lead vitreous glaze: example, old gray Flemish ware.

(b) Silicious clay covered with a salt glaze; example, ordinary stoneware jugs or crocks.

3. Soft Pottery, as Earthenware, Easily Fusible.

(a) Biscuit—simple baked clay, porous and without gloss; example, common flower pots.

(b) Glassy—Fine clay covered with an almost imperceptible vitreous glaze; example, early Greek vases.

(c) Glazed—Clay covered with a perceptible coating of glass; example, common white earthenware plates.

(d) Enameled—Clay covered with a vitreous coating made opaque by white oxide of tin; example, Italian majolica.

We may, therefore, consider the three principal varieties of pottery, namely, porcelain, stoneware, and earthenware, each of which is subdivided into many varieties, and all of which gradually merge, one into the other. The addition of a little more of one and a little less of another ingredient in the composition of the mass has brought about such a condition in the classification that frequently a name given to a variety of pottery is either entirely a misnomer or else a mere trade name.

Porcelain may be dismissed from the discussion because it is composed of pure natural Kaolin and very fine imported clays and offers no possibilities for production in Iowa. Stoneware and earthenware can be manufactured satisfactorily from Iowa clays, as will be shown by the tests and practical work conducted in connection with this study.

Stoneware. Stoneware is characterized by a dense mass and extreme hardness, not easily scratched by a knife, sonorous, fine grained, homogeneous, showing incipient fusion, scarcely translucent on the edges, and may be white or colored.

Stoneware is usually considered to refer to common butter crocks, jugs and jars, but a better ware of finer texture is made by the addition of other clays, known as "Flemish ware", because it has a silver gray body and resembles the Flemish gres. This type of body is suitable for making very high class art and novelty wares.

Glazes most commonly used on stonewares are those of the Bristol type, and a salt glaze. The latter is obtained by inserting common salt into the kiln, both from the top and the bottom. This salt vaporizes and forms a glassy semi-transparent glaze by combining with the clay body at high temperature. Many types of transparent lead glazes, various mat glazes and enamels may also be used on this class of ware.

Earthenware. Within the third classification, earthenware, are grouped the main types of common pottery being manufactured successfully at the present time, from flower pots to tableware. For the sake of clearness, this classification should be further divided into two groups:

1. Whiteware. The products of this class are known by various names, as "c. c. ware", white earthenware, ironstone china and white granite ware. These names designate all pottery with a white, or nearly white, porous body that is covered with a glaze.

2. Colored-ware. This class includes the great mass of pottery made from natural impure clays having a body ranging in color from a light buff to a brick red.

Pottery of the first group is usually composed of what is known as a "commercial" body, or one that is made up from a mixture of clays from different localities, often being imported or shipped from distant clay fields. Clays of this type used in many American factories are known as Florida and Georgia clays, North Carolina Kaolin and Tennessee Ball clay. As the purpose of this investigation does not permit the introduction of such clays, this class of pottery may be eliminated.

IOWA CLAYS CONSIDERED

There remain two large groups of clays quite extensive in area in Iowa to be considered, namely the clays of the stoneware type, locally called "fire clays", and the common earthy or impure red or buff burning clays and shales.

Many of these clays have been extensively tested and discussed, both in regard to chemical and physical properties by members of the Engineering Experiment Station. Records of such tests appear in Bulletin 40, "An Investigation of Iowa Fire Clays" by Milton F. Beecher, and Bulletin 43, "Practical Handling of Iowa Clays" by Homer F. Staley and Milton F. Beecher.

For the purpose of this investigation samples of twelve different Iowa clays were obtained and given locality names as follows: (1) Mason City Blue Shale; (2) Mason City Yellow Clay (Glacial); (4) Des Moines River Shale; (5) Sioux City Shale; (6) Ames Glacial Drift; (8) Des Moines Fire Clay; (9) Maquoketa Over-burden; (10) Anamosa Loess Clay; (12) Maquoketa Shale; (13) Danville Fire Clay; (14) Adel Fire Clay; (17) Fort Dodge Fire Clay.

Each clay was carefully tested to cover the following points:

I. General Character of the Raw Clay.

(a) Color
(b) Structure
(c) Fineness of grain
(d) Visible objectionable materials
(e) Presence of carbonates as indicated by acid test.

II. Working Properties.

(a) Ease of grinding
(b) Grade of plasticity
(c) Tendency to laminate
(d) Die troubles
(e) Modeling properties
(f) Jiggering and casting

III. Drying Properties.

(a) Rapidity of drying
(b) Shrinkage (washed and unwashed)
(c) Cracking and warping (pottery and brick)
(d) Tendency to scum

IV. Burning Properties

(a) Absorption (washed and unwashed)at cones 05, 02, and 2
(b) Hardness at same heat treatments
(c) Fire shrinkage at same heat treatments
(d) Total shrinkage
(e) Ease of oxidation
(f) Color

PREPARATION OF THE TESTS

I. General Character of Raw Clay. Samples of each clay were thoroly dried, and ground to pass thru an eight mesh screen, pugged or tempered in the pug mill and moulded into trial pieces without washin or purifying in any way. (Noted as unwashed in the tables.)

Samples were also prepared by slacking down the dried clays in water and washing them thru a 30 mesh sieve. The residue, (visible objectionable material), was saved and its contents noted. These samples were then dried-down on plaster bats to the right consistency, pugged and made into trial pieces, (noted as washed in the tables).

The general characteristics of the different raw clays, such as color, structure, fineness of grain, visible objectionable material and presence of carbonates were noted and listed in Table I.

II. Working Properties. The working qualities, such as resistance to grinding, behaviour during pugging, plasticity and modeling possibilities were noted and listed in Table II under working properties.

III. Drying Properties. For the purpose of determining the drying and burning shrinkage at different temperatures trial pieces were formed in the shape of bars one inch square and five and one-half inches long. A hundred millimeter line was marked off on the face of each bar to be used in computing the per cent of shrinkage at any stage of drying and burning. The bars were numbered appropriately, placed on plaster bats and carried to the dryer, where all trial pieces for the tests were dried.

Six bars of each sample, both washed and unwashed, were made and when thoroly dried, the drying shrinkage was computed and together with the data on rapidity of drying recorded in Table III. A standard sized brick and small drain pipe were also made of each sample in the brick, and pipe machines, labeled, dried and fired with the other trials.

As the possibilities of using a certain clay for pottery purposes are determined largely by its drying and shrinking behavior before it enters the kiln, small pieces of pottery from all the clays were made representing the three chief processes of pottery fabrication, namely, jiggering, casting and hand-building or modeling.

Slip. When a clay is being tempered for use in the manufacture of the coarser wares such as brick or sewer pipe, the practice is to add only enough water to produce the necessary plasticity. In the finer wares, however, this will not serve because some means must be adopted whereby the impurities which occur in every clay will be removed. An excess of water is added to the clay and the mixture is thoroly stirred on the "blunger". The cream thus formed is called slip. The cleansing is accomplished by straining thru very fine sieves, 80 mesh, by which all sand and foreign particles are removed. Slip is ready for use at once in the casting process but for the most part it is merely a stage in the preparation of clay. Its main purpose is the straining process which could not be performed without the excess of water. The conversion into clay ready for use, is accomplished by squeezing out the water in a

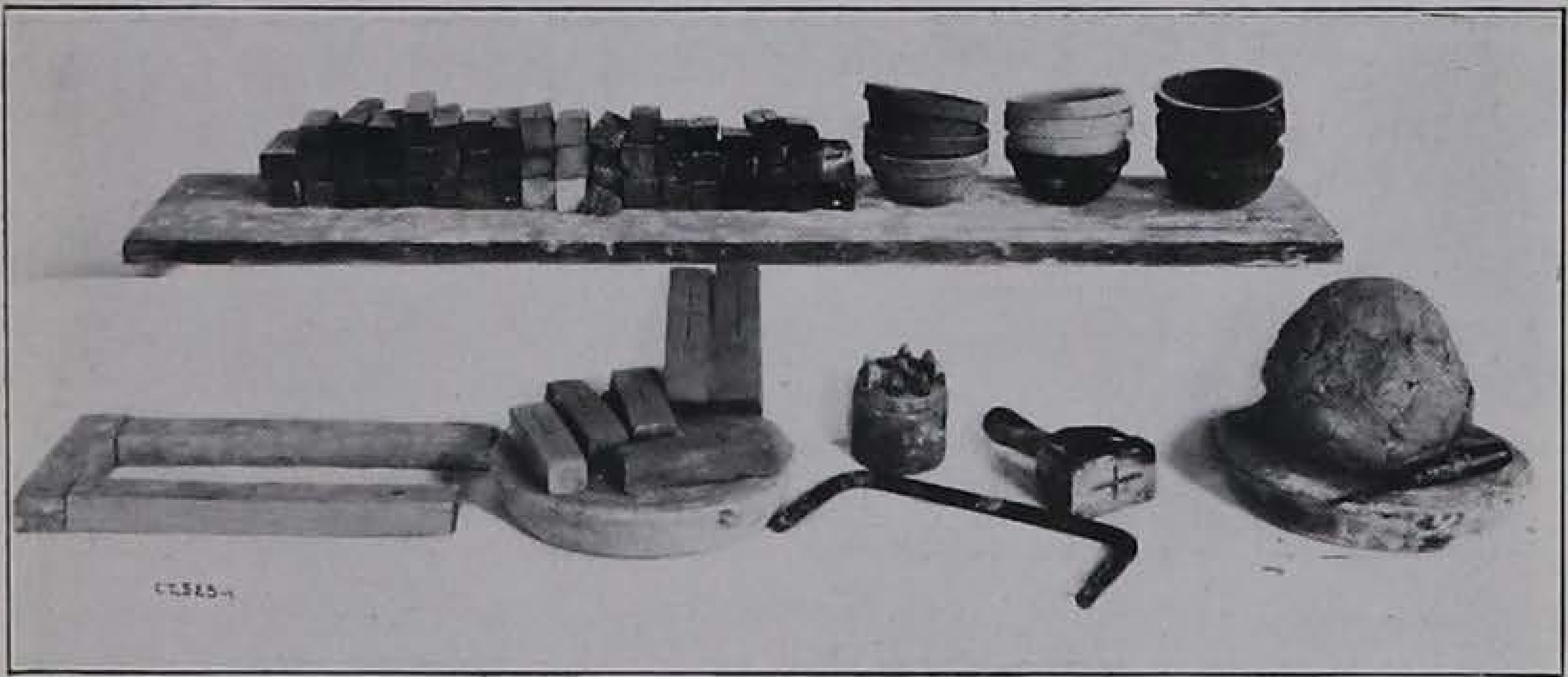


Fig. 2. SHOWING THE EQUIPMENT USED IN MAKING THE TEST BARS. Test bars were made from each sample of clay studied in this investigation to determine the exact behavior at each step of the drying and firing.

filter-press. Quantities of clay and slip were prepared by this method from each of the promising samples and stored for future use.

Moulding. One piece plaster moulds were made in the form of small cooking pots. By use of the jigger and pull-down a number of these pots were formed from each sample of clay, prepared by means of the blunger and filter press.

Also a number of small cylindrical forms were built up by hand by the coil process, and a number were made on the potter's wheel by the method technically known as "throwing". Both of these processes are used extensively by craftsmen and in public and art school pottery work. These pieces were made, of course, only from the washed and prepared clay from each sample.

Casting. Several two and three piece plaster moulds in the form of small vases were made for the casting process, and cast pieces made from each sample.

These pieces were all dried as nearly as possible according to factory conditions. The results are tabulated under drying properties, Table III.

Figure 2 shows the tools used in making the test bars, and the cooking pots made on the jigger. Figure 3 illustrates types of pieces made by the casting process.

IV. Burning Properties. Fourteen specimens of each sample, both washed and unwashed, including test bars, bricks, drain pipe, pots and pieces which were cast, hand-built and "thrown," were burned at each of the following heat treatments—cones 05, 02, and 2. These trials were burned in a Caulkins Revelation Kiln, using oil for fuel, with a gradually increasing temperature following as nearly as possible conditions of factory burning. Care was taken that the burns should be oxidizing

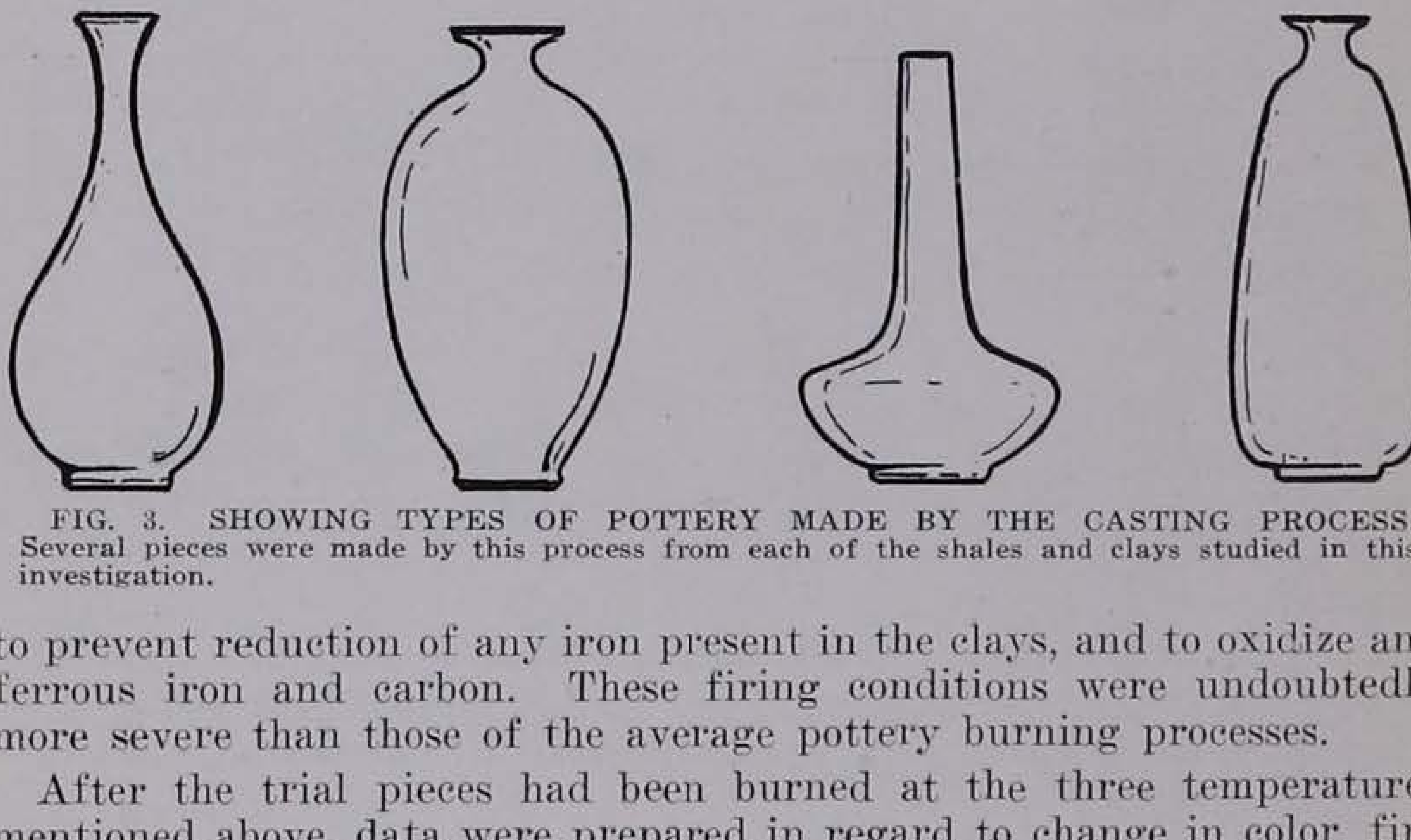


FIG. 3. SHOWING TYPES OF POTTERY MADE BY THE CASTING PROCESS. Several pieces were made by this process from each of the shales and clays studied in this investigation.

to prevent reduction of any iron present in the clays, and to oxidize any ferrous iron and carbon. These firing conditions were undoubtedly more severe than those of the average pottery burning processes.

After the trial pieces had been burned at the three temperatures mentioned above, data were prepared in regard to change in color, fire shrinkage, absorption, hardness, total shrinkage and ease of oxidation. These are recorded in Table IV. The burns show that these clays range in color from cream to dark red or nearly brown, with no white clays at all.

ELIMINATING UNDESIRABLE CLAYS

The kind of ware to be made from any clay and the machinery and processes to be used depends upon the physical and working properties of the clay and its behavior in burning. The most important of these are plasticity and modeling properties, drying and shrinkage, cracking and warping, absorption or density after firing ,and color.

It is evident that clays of low plasticity, normally called "short", and those of high plasticity, (too fat or sticky), are not suitable because they can not be modeled or moulded into shape. Also, clays that crack and warp badly in the drying are of no value, by themselves, for pottery use.

The following clays possess these faults to such a degree that they are of no practical value for pottery and were dropped as unimportant subjects for further trials:

No. 2—Mason City Yellow Clay (glacial)—short, crumbles and cracks badly in the moulds.

No. 6—Ames Glacial Drift—short, cracks badly in the moulds.

No. 9—Maquoketa Over-burden—cracks very badly in the moulds.

No. 10—Anamosa Loess Clay—short, cracks badly in the moulds.

These clays also contain quantities of visible objectionable material, such as sand, gravel, limestone, roots and stems, and all gave trouble with the dies on the brick and pipe machine. They are not suitable for modeling, have to be dried very slowly and carefully, are high in shrinkage and absorption and are objectionable in color.

Such clays possess qualities, however, that may make their use advantageous in connection with other clays if they exist in sufficient quantities and are near at hand. This is illustrated by the following experiment to improve the working qualities of Mason City Blue Shale.

Combining Shales and Clays. Mason City blue shale is a fine grained soft shale, very free from impurities, low in absorption, burning to a pleasing salmon color. This is a good grade clay, but it is found to be too fat or sticky for modeling or pottery purposes.

Mason City Yellow Clay, (glacial), which occurs in the same vicinity is an unsatisfactory grade clay of low plastictiy and too short for modeling and pottery purposes.

Trials were made combining these clays in the following proportions:

	I	II	III	IV	V
Mason City Blue Shale, percentages	50	60	70	80	90
Mason City Yellow Clay, percentages	50	40	30	20	10

Tests were made after the same manner as for the other samples.

It was found that the 80-20 combination was the best and possessed suitable modeling properties. In addition the drying shrinkage was lowered and the tendency to crack in the moulds eliminated. The color was not changed to any great extent and the ease of oxidation lowered. The absorption was slightly increased and the burning shrinkage became a little greater, but its total shrinkage remained the same, hence these faults are not important.

This sample was adopted for use in the college, (hand-built) pottery class and gave satisfactory results thruout the year. The biscuit ware was fired to cone 02 and the glaze, (various types of mat and bright glazes and enamels) fired at cone 05 and 02 with good results. (See Frontispiece.) The only fault noted was a slight tendency for the pieces to crack in the glaze fire. This, however, could be overcome by more careful methods of firing.

A record of this body, No. 3 of the trials, is shown in Tables I, II, III and IV. It is evident that these short clays may be used in combination with the sticky clays for decided improvement in quality of the latter.

IOWA SHALES

This group includes (1) Mason City Blue, (4) Des Moines River, (5) Sioux City and (12) Maquoketa Shales. These shales all gave satisfactory records in the trial tests, Tables I, II, III, and IV.

Mason City Blue Shale. This shale is a little fat but this fault can be remedied as suggested.

Des Moines River and Sioux City Shales. These shales are both a little short for good modeling, but this can easily be remedied by adding a small amount of Kaolin or fat clay. Sioux City shale has a high absorption, at the heat treatment most suited to its use, which is not desirable from the potter's standpoint as it is difficult to fit a glaze to a very porous body.

Maquoketa Shale. Maquoketa Shale forms a good modeling clay of low absorption, but it will not stand firing much above cone 02. At cone 2 it bloats and becomes useless.

Treatment. All of these shales tend to turn dark at cone 2 and will not stand much greater heat. However, for the type of ware for which they offer possibilities it would not be necessary, or desirable, to fire above cone 05 and 02. These shales are suitable for the making of common unglazed flower pots and similar products.

Cast and jiggered pieces were made from all of these shales, fired to cone 02 for biscuit and glazed with transparent lead and mat glazes maturing at cone 05, with good results, except that there was too much wastage in the glaze fire due to cracking of the pieces during this second firing process.

To eliminate this fault and to improve the body generally the Fort Dodge fire clay, (the fire clay showing most promising results in the test) was mixed with these shales in the proportion of thirty parts of the former to seventy parts of the latter. Any good fire clay or stoneware clay could be used for this purpose. The results of these tests show that in all cases a good body was obtained that became fairly dense at cone 02. Pieces were made from these bodies by casting, wheel-throwing and by hand building in the college classes. All of the glazes, to be described later, were used on these pieces with very good results.

These shales as improved may be satisfactorily used for making a great variety of glazed art and novelty products at temperatures of cone 05 and 02 and for the manufacture of flower pots, jardiniers and fancy garden and architectural terra-cotta.

The type of body described above is very similar to that used in many public and art schools and art potteries of this country for the making of a type of ware finished with rich mat glazes and enamels that has won the distinction abroad as being purely American and of meritorious art quality.

These shales can be used satisfactorily for purposes stated above as has been demonstrated in the laboratory, however, it is the opinion of the writers that the fault noted, namely the "dunking" or cracking of the ware in the glaze fire, which sometimes occurred even with the improved bodies, does not permit their use on a large scale or where expensive machinery and equipment would be required. The body obtained is too brittle and inelastic to withstand the expansion and contraction necessitated in the second fire. Wastage would be too great.

THE FIRE CLAYS

This group includes (8) Des Moines, (13) Danville, (14) Adel, and (17) Fort Dodge fire clays.

As will be observed by a study of the results of the trial tests, Tables No. I, II, III and IV, these clays constitute a group far superior to the shales. They are very valuable clays of fine grade and almost perfect working properties for pottery. They offer possibilities for the production of a wide range of wares.

Nos. 8 and 14 are hard shales, Nos. 13 and 17 soft shales. All are fine grained and easily ground, possess excellent plasticity and modeling properties, dry safely and rapidly, do not warp or crack, do not scum and are free from carbonates. The kind of ware to be made from them, therefore, will depend largely upon their color and absorption or density at various temperatures.

Density of body is a prerequisite of pottery making for any wares that are intended to hold water or other liquids. The body must become dense enough to permit the fitting of a glaze. This requires a coefficient of expansion of the body closely related to that of the glaze. It is evident that a glaze cannot possess a wide range of expansion, hence, the body must become dense enough to come within the limit of glaze possibilities in this respect. High refactory fire clays for this reason are suitable for pottery use only at extreme temperature ranges.

Des Moines Fire Clay.* Des Moines fire clay becomes very dense at cone 2 and fires to a dark red color. This clay is suitable for making wares of low temperature, as it becomes sufficiently dense at cone 02 for all practical purposes. Its color, however, limits its use to cooking pots glazed with transparent leadless glazes, similar to the popular Guernsey cooking ware, and is, for novelty ware, glazed with opaque mat glazes and enamels.

Danville Fire Clay. This clay burns to a cream colored body and has high absorption at cone 2. It represents one of the best types of Iowa refractory or semi-refractory clays. Previous tests in the laboratory show that its fusion point is at cone 22. It can be mixed with a short,

*A local misnomer; this is not a true fire clay.

easily fusible clay and used for stoneware, and thus remedy its slight stickiness in modeling as well as its porosity.

Adel Fire Clay. Adel fire clay burns to a light buff and becomes fairly dense at cone 2. Previous laboratory tests show that it will not fuse below cone 15.

Fort Dodge Fire Clay. This clay burns to a cream body and has satisfactory density at cone 2. Previous laboratory tests show that its fusion point is at cone 20.

These last two clays have superior plasticity and modeling properties and offer possibilities for a wide range of wares using glazes maturing from cone 02 to cone 9.

Both of these clays contain particles of iron pyrite in fine granular form that turn black in the fire and show as very small black specks in the biscuit ware. This is not objectionable, however, if the ware is to be treated with an opaque glaze. Metallic iron specks can be removed during the sieving process by the use of strong electro-magnets placed in a trough thru which the slip is allowed to run, but it is practically impossible to remove the pyrite specks, so it is advisable to refrain from using transparent glazes on these clays. The color of the burned body prevents the use of these clays for whiteware.

KIND OF WARE

The field of practical utilization of these so called fire clays would include:

First. Art pottery which employs low temperature glazes from cone 05 to cone 3. Products from similar clays are being made commercially with a high degree of success by the Rookwood Pottery Company, Cincinnati, Ohio; Van Briggle Pottery, Colorado Springs, Colo.; Marblehead Pottery, Marblehead, Mass.; Newcomb Pottery, New Orleans, La.; Walworth Pottery, Rochester, N. Y.; Cowen Pottery, Cleveland, Ohio, and many other firms.

Second. Enameled table-ware, (white and colored). This type of ware is illustrated by the bowls, tea sets and table ware of the Paul Revere Pottery, Boston, Mass. This is a type of pottery that has no great commercial value, however, depending more on its novelty or artistic merit than its ceramic quality for saleability.

Small trial pieces were successfully produced using these clays glazed with opaque tin enamels, both white and colored, at cone 02, similar in character to the ware mentioned above.

Third. Stoneware. The tests show that the Danville, Adel and Fort Dodge fire clays are suitable for making ordinary stoneware. However, this industry seems to be losing its value as a commercial proposition.

Fourth. High temperature art pottery of the stoneware type, glazed with crystalline, mat and flambe glazes offer possibilities. Wares of this type are not manufactured, extensively at present in the United

States, tho the production had reached some importance in Europe before the war.

Examples of products of this character in America are the wares of the Fulper Pottery Company, Trenton, N. J., and the high fire exhibition vases made by Professor Binns of the New York State School of Ceramics. These wares are produced at temperatures ranging from cone 3 to cone 9.

No examples of this ware were made in the laboratory as these experiments were limited to a heat treatment of cone 2, but the writers have made wares of this character, as well as those of all types discussed in this article, from clays very similar in character to the Iowa fire clays.

FIG. 4. SHOWING TYPES OF WARE MADE FROM THE IOWA FIRE CLAYS. These pieces were "thrown" on the ordinary potter's wheel. This method of manufacture is employed by practically all art potteries.

Several large pieces of pottery were "thrown" on the potter's wheel from each sample of the fire clays, ranging in shape from low bowls to vases eighteen inches in height. The pieces were decorated and fired with glazes of various types maturing from cone 05 to cone 2, with very satisfactory results, as illustrated in Fig. 4. In addition many cast and jiggered pieces were made from these clays and used with various glazes with good results, but no trials in connection with these clays were made above cone 2.

PROCESSES OF MANUFACTURE

According to processes of manufacture clay praducts may be classified under three heads:

(1) Slip or Fluid Casting Process. In this process the clay contains a high per cent of water (75% to 100% as much water as clay);

(2) Plastic Process. In this method the clays contain just enough water to produce the desired workability (15% to 45%);

(3) Dry Process. In this method the clay contains a very low per cent of moisture, (6% to 15 %).

Pottery wares are only produced by the first two methods. The different processes are as follows:

(1) Hand-built or Coil-built Pottery. This method was used by primitive peoples and is now used extensively in public school and craft work. It also becomes necessary to resort to hand building or modeling in the construction of glass pots, chemical stonewares and complicated architectural terra-cotta units.

(2) Wheel-throwing or Spinning. This consists of shaping the piece by hand on the potter's wheel. Considerable skill is required in this process for the soft clay must be formed into the desired shape by hand while revolving on the turning wheel. This method is employed

FIG. 5. UNGLAZED PIECES MADE IN BEGINNING GIRLS' POTTERY CLASSES AT IOWA STATE COLLEGE. These pieces were made with little mechanical equipment and illustrate the type of ware for which Iowa shales and clays are well adapted.

in practically all art potteries. It permits of more distinctive and artistic forms than can be produced by casting or mechanical means alone.

A lump of clay, which should be very plastic and fine grained and thoroly prepared by "wedging", pressing and rolling to expel all the air, is thrown, as nearly as possible, on the center of the plaster bat of the potter's wheel. This is done while the wheel is revolving quite rapidly. The ball of clay must then be centered, worked into a low conical form and then gradually drawn out to suit the fancy of the potter. Skill and strength both are required in this process and the potter must know the possibilities and limitations of his medium or he will meet with failure.

(3) Forming in Molds. Plaster, wood or metal molds may be used for this process. The soft clay is usually pressed into the molds by hand but this can be done by machinery in many cases, after the manner of making roofing-tile or sewer pipe.

(4) Jiggering. This process is partly hand work and partly machine work. It is a combination of the potter's lathe or turning method and hand pressing. By this method the clay, almost too soft to stand alone, is thrown into the mold. The mold is set upon a wheel which is revolving from 200 to 400 revolutions per minute. The clay is then formed in the mold by the pull-down or jigger tool. From 60% to 75% of common pottery is produced in this way.

(5) Fluid or Slip Casting. This process is used to a great extent in most potteries, as pieces of almost any shape can be produced by this method. Plaster molds are used because of the peculiar qualities afforded by plaster.

The method of working consists in the absorption of the water of the clay by the plaster, the evaporation of the water from the outside of the mold, and the shrinkage of the clay on account of loss of water. The shrunken piece can be removed from the mold easily for clay bodies will not adhere to plaster under proper conditions.

Molds are made usually in two or three parts to allow for the removal of complicated pieces with rims, lips, spouts and handles.

DECORATIVE PROCESSES

Pottery offers greater decorative possibilities than any other industry. The variety of decorative processes and wide range of ceramic colors and glaze textures are almost unlimited.

Pottery wares may be decorated by modeling or building up the decoration upon the piece itself, by incising or cutting out the design in various ways, by adding color to the body, by painting upon the body with different colored clays, and by inlaying clays of different color. All these can be done before the piece is fired, while it is still in the "green" clay stage.

Use of Color. After the piece has been fired to the "biscuit" stage, the firing necessary to transform it from clay to pottery, it can be decorated by underglaze, or mineral color painting. It is then coated with a clear, transparent glaze and refired to mature the glaze and bring out the color. This is a very practical form of decoration because the design and color is beneath the glaze and is thus protected and will last as long as the glaze lasts.

Color offers the greatest decorative possibilities. As has been mentioned, the color may be added to the body or painted upon the body. It may be used in the glaze itself, under the glaze or upon the glaze. With the present knowledge of ceramics it is possible to produce the finest colorings and textures upon the commonest and crudest clays.

Glazes. The term glaze as used in Ceramics refers to a thin vitreous coating that become firmly attached to the body of the ware under heat treatment. This makes the ware impervious to water and gives it a surface that is sanitary and easily cleaned, rendering it hard and serviceable. It gives to pottery its gloss or texture, which is one of its chief charms. The function of the glaze is two-fold, it makes the ware serviceable and beautiful. In commercial pottery the former is the essential consideration; in school and studio work the latter plays the important part, but in all cases both considerations are important features and should not be ignored.

The decorative use of glazes can not be measured for new glazes are being developed almost every day. There are transparent, mat, crystalline, enamel, lustre, opalescent and hundreds of varying types, textures and colors of glazes maturing at various temperature treatments being used successfully in the pottery industry today.

POLYCHROME DECORATION

Several pieces produced during this investigation were decorated by incising the design upon the green clay. The pieces were then fired to the "biscuit" and finished with rich golden brown, red, blue, green, violet and yellow tones of mat glazes.

The decoration was carried out by the "inlay mat" process. The pieces were first glazed, then when sufficiently dry to permit handling the design motifs were traced upon the glaze, (unfired), and cut out. Different colored glazes were then painted into the pattern and the pieces were fired to mature the glaze. All pieces were glazed inside with a transparent lead glaze to make them more impervious to water.

It was discovered by accident that by adding a small amount of red burning clay to the cream colored fire clays during the process of "wedging" and tempering of the plastic clay, preparatory to its use on the potter's wheel, that a striped effect of body could be obtained with spirals and streaks of red and cream colors. This was produced by the revolution of the mixed clays through the hands as the piece was being shaped on the wheel. Several very pleasing pieces were produced in this way, and the clear transparent lead glaze was used on these, both inside and out.

PREPARATION OF GLAZES

The following basic glazes were prepared and used in a series of experiments to produce pleasing tones and textures of glazes for use on the pieces of the tests. These basic mat glazes were compounded using the mineral oxides for coloring agents. The chemical formulae and batch weights are given below.

Chemical Formulae — Batch Weight

(A) Yellow brown mat, (Fe_2O_3).

.55 PbO	.35 Al_2O_3	1.5 SiO_2
.25 CaO	.10 Fe_2O_3	
.20 K_2O		

Iron Oxide	16.0 Gms.
Felspar	111.4 Gms.
Whiting	25.0 Gms.
White lead	141.9 Gms.
N. C. Kaolin	38.7 Gms.
	333.0 Gms.

(B) Red mat, ($K_2Cr_2O_3$).

.70 PbO	.38 Al_2O_3	1.36 SiO_2
.20 CaO		
.10 K_2O	Red base (Drakenfeld) 10%	

Red base	34.0 Gms.
Felspar	56.0 Gms.
Whiting	20.0 Gms.
White lead	180.0 Gms.
Florida clay	72.0 Gms.
Flint	12.0 Gms.
	374.0 Gms.

(C) Blue mat (CoO).

.03 CoO	.35 Al_2O_3	1.5 SiO_2
.52 PbO		
.25 CaO		
.20 K_2O		

Cobalt oxide	2.4 Gms.
White lead	134.2 Gms.
Whiting	25.0 Gms.
Felspar	111.4 Gms.
N. C. Kaolin	38.7 Gms.
	311.7 Gms.

(D) Green mat (CuO).

.10 CuO	.35 Al_2O_3	1.5 SiO_2
.45 PbO		
.25 CaO		
.20 K_2O		

Copper oxide	7.9 Gms.
White lead	116.1 Gms.
Whiting	25.0 Gms.
Felspar	111.4 Gms.
N. C. Kaolin	38.7 Gms.
	299.1 Gms.

(E) Purple mat (MnO_2).

.07 MnO_2	.35 Al_2O_3	1.5 SiO_2
.53 PbO		
.25 CaO		
.20 K_2O		

Manganese dioxide	6.09 Gms.
White lead	136.74 Gms.
Whiting	25.00 Gms.
Felspar	111.40 Gms.
N. C. Kaolin	38.70 Gms.
	317.93 Gms.

(F) Yellow mat (Sb_2O_3).

.70 PbO	.38 Al_2O_3	1.36 SiO_2
.20 CaO		
.10 K_2O	10% Yellow Base (Drakenfeld)	

Yellow base	34.0 Gms.
White lead	180.0 Gms.
Whiting	20.0 Gms.
Felspar	56.0 Gms.
Florida clay	72.0 Gms.
Flint	12.0 Gms.
	374.0 Gms.

(G) Gray Orange mat (U_2O_3).

.55 PbO	.35 Al_2O_3	1.5 SiO_2
.25 CaO	.05 U_2O_3	
.20 K_2O		

Uranium oxide	26.2 Gms.
White lead	141.9 Gms.
Whiting	25.0 Gms.
Felspar	111.4 Gms.
N. C. Kaolin	38.7 Gms.
	343.2 Gms.

(H) Light Gray mat (NiO).

.03 NiO	.35 Al_2O_3	1.5 SiO_2
.55 PbO		
.22 CaO		
.20 K_2O		

Nickle oxide	2.25 Gms.
White lead	141.90 Gms.
Whiting	22.00 Gms.
Felspar	111.40 Gms.
N. C. Kaolin	38.70 Gms.
	316.25 Gms.

(I) Light Blue mat.

.0060 CoO	.36 Al_2O_3	1.32 SiO_2
.5400 PbO		
.2900 CaO		
.1500 K_2O		
.0025 MnO_2		
.0150 CuO		

White lead	138.00 Gms.
Whiting	29.00 Gms.
Felspar	83.00 Gms.
N. C. Kaolin	54.00 Gms.
Cobalt oxide	.48 Gms.
Copper oxide	1.17 Gms.
Manganese dioxide	.29 Gms.
	305.94 Gms.

DEVELOPMENT OF GLAZES

The following series of glaze experiments was planned to develop a wider range of color tones than was afforded by the basic glazes tabulated above. These experiments produced more than sixty different glaze mixtures very pleasing in color, quality and texture, having a soft velvety mat surafce well adapted to the display of the color of the glaze. In each series three of the basic mat glazes were selected and used as end members of the triaxial diagram.

All of the blends of the series produced good colors at cones 05 and 02, and from a Ceramic palette for use in polychrome decoration.

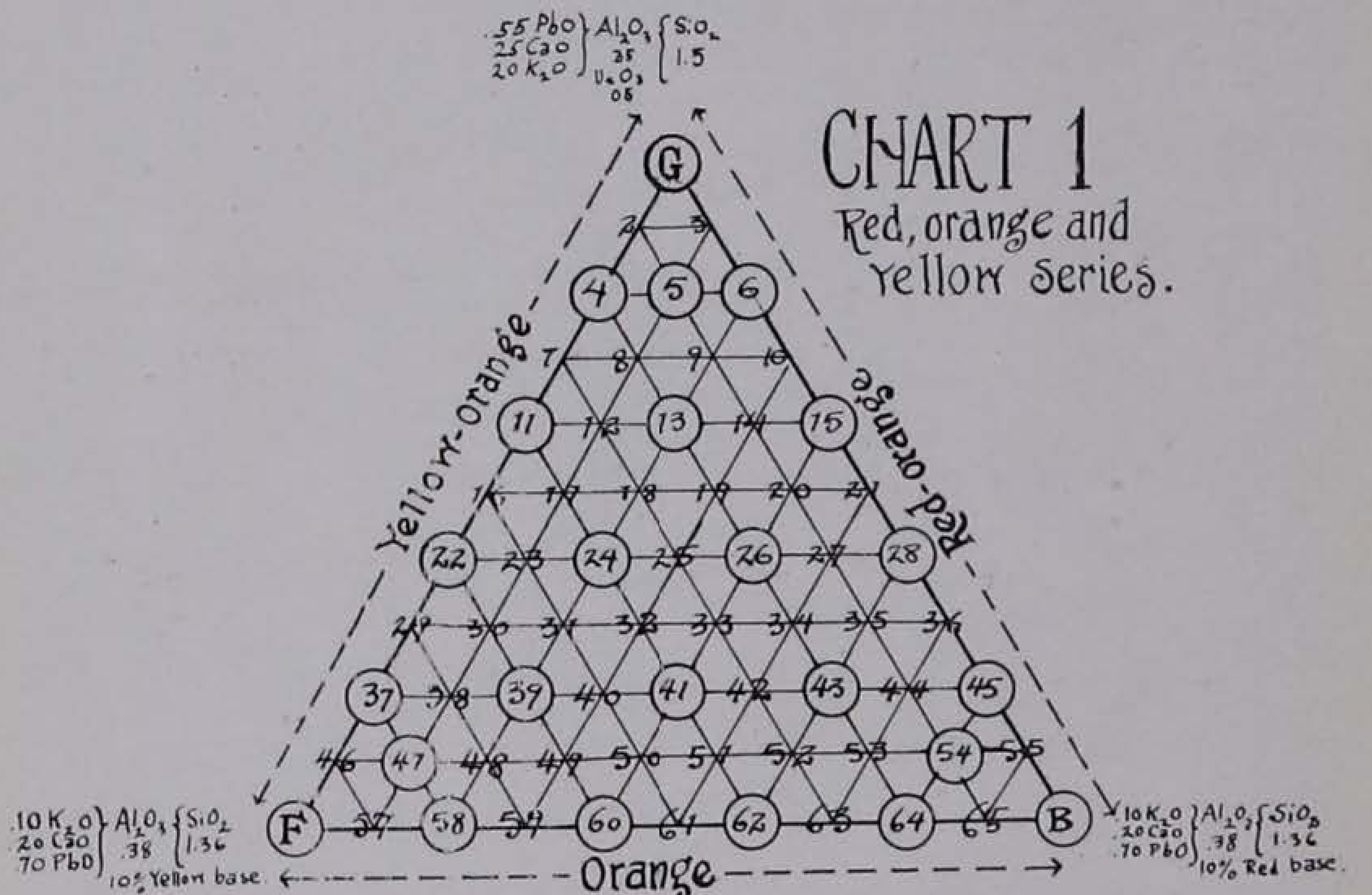


CHART 1. SHOWING METHOD OF MAKING UP GLAZES OF VARYING SHADES OF RED, ORANGE AND YELLOW

Series No. 1. To Develop Red, Orange, Yellow, Red-orange, and Yellow-orange Colors. In this series the end members were:

Basic Glaze (G) Gray orange, equiv. wt. 343.0 M. F. 1.6
Basic Glaze (F) Yellow, equiv. wt. 374.0 M. F. 1.95.
Basic Glaze (B) Red, equiv. wt. 374.0 M. F. 1.65.
Blends, (Table shows percentages and fluid weights in grams).

No.	G (GLAZES) % wt.	F % wt.	B % wt.	No.	G (GLAZES) % wt.	F % wt.	B % wt.
4	80=440	20=146		37	20=110	80=584	
5	80=440	10=73	10=62	39	20=110	60=438	20=124
6	80=440		20=124	41	20=110	40=292	40=248
11	60=330	40=292		43	20=110	20=146	60=372
13	60=330	20=146	20=124	45	20=110		80=496
15	60=330		40=248	58		80=584	20=124
22	40=220	60=438		60		60=438	40=248
24	40=220	40=292	20=124	63		40=292	60=372
26	40=220	20=146	40=248	64		20=146	80=496
28	40=220		60=372				

Only about one half of the possible mixtures for each diagram were made because previous experience had shown that in mixing two different glazes only about five steps could be determined in the resulting glaze trials. The mixtures used are noted by circles on the diagram. See Charts No. 1, 2 and 3.

The equivalent weight (equiv. wt.) and moisture factors (M. F.) were computed for each glaze used and the mixtures were made by the fluid method. The per cent of each glaze for the various trials was weighed, put into quart jars and thoroly mixed by shaking. This mixture was then applied to white wall-tile biscuit, properly marked and fired to cone 05 and cone 02.

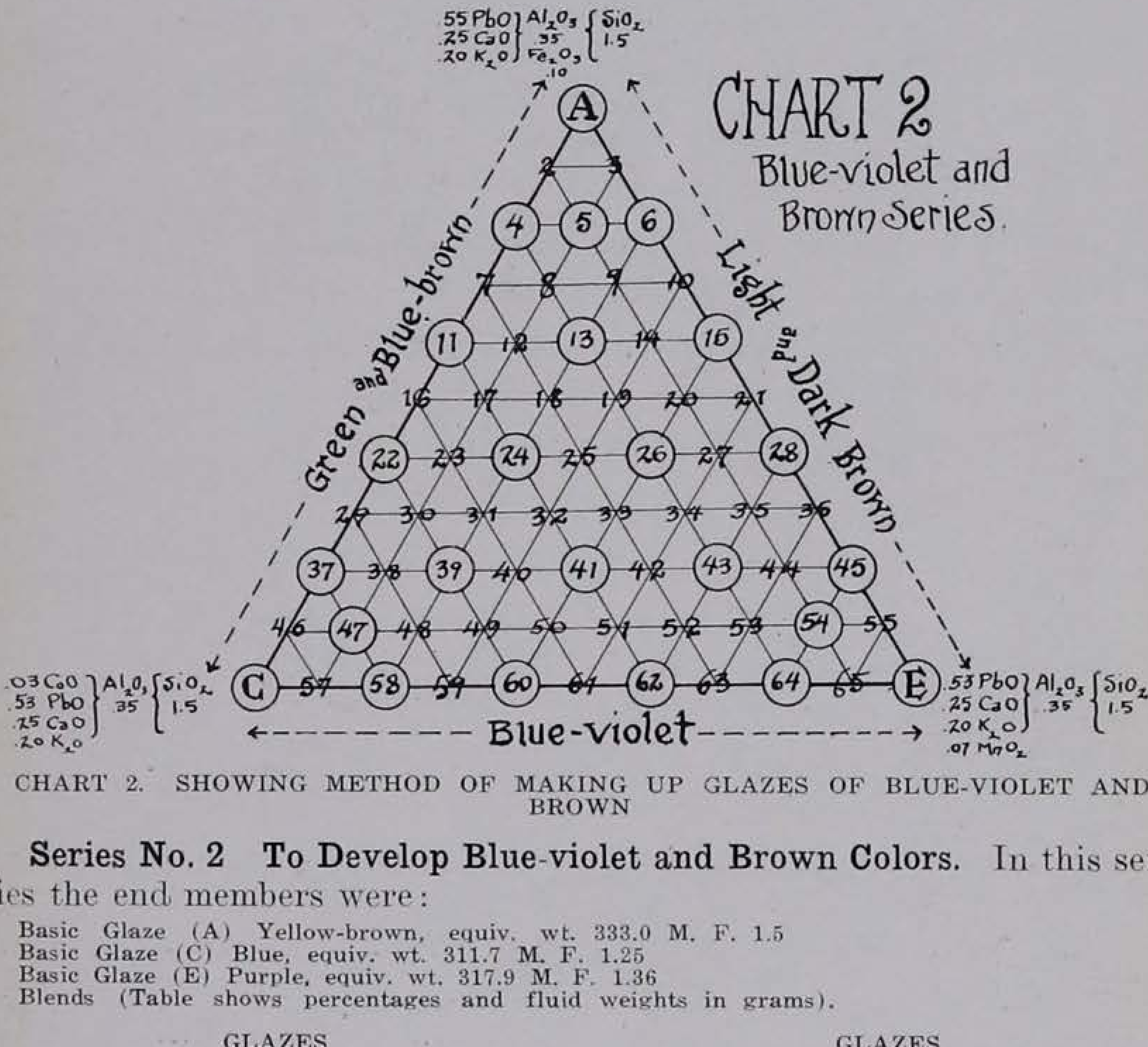
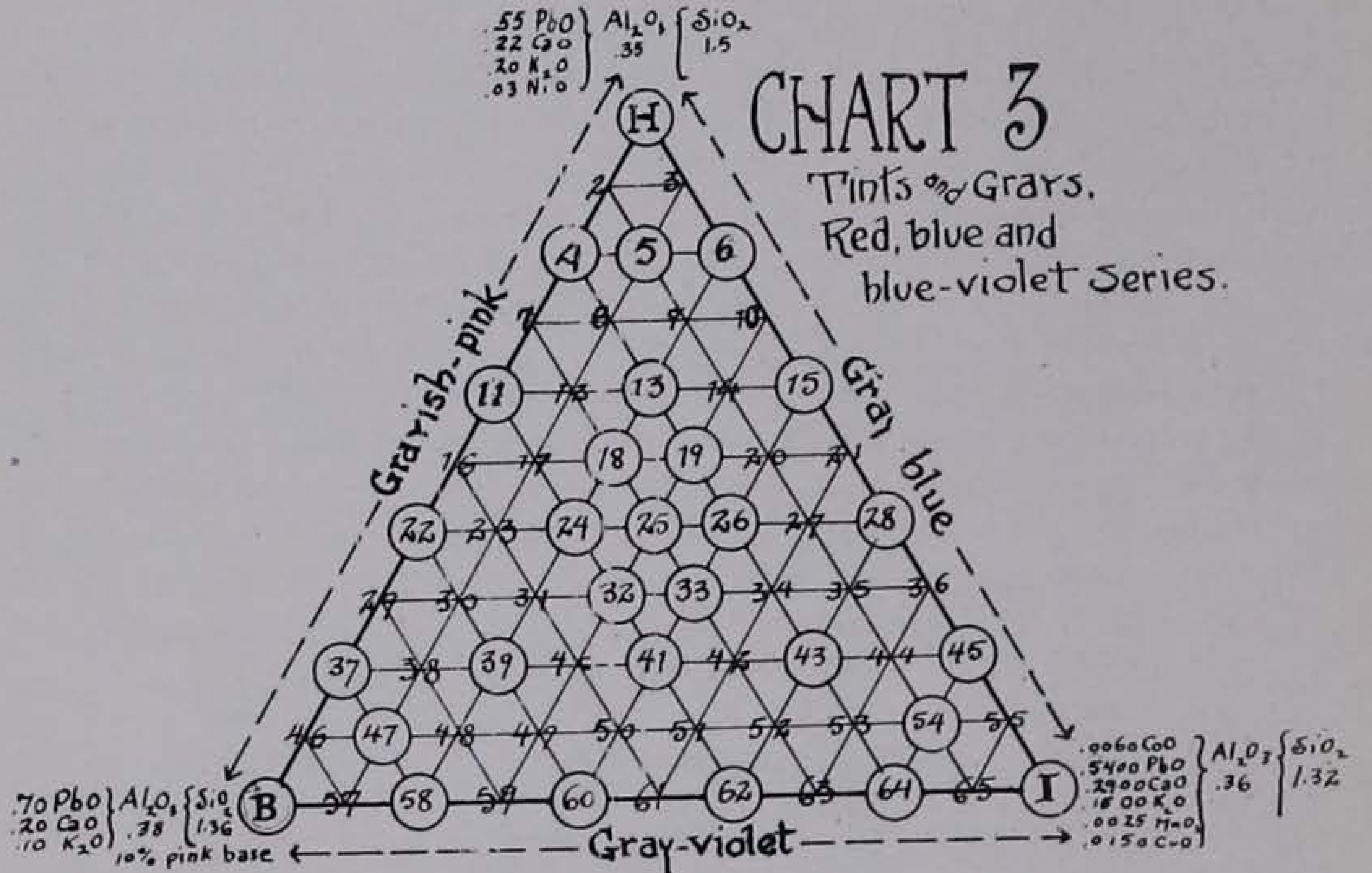


CHART 2. SHOWING METHOD OF MAKING UP GLAZES OF BLUE-VIOLET AND BROWN

Series No. 2 To Develop Blue-violet and Brown Colors. In this series the end members were:

Basic Glaze (A) Yellow-brown, equiv. wt. 333.0 M. F. 1.5
Basic Glaze (C) Blue, equiv. wt. 311.7 M. F. 1.25
Basic Glaze (E) Purple, equiv. wt. 317.9 M. F. 1.36
Blends (Table shows percentages and fluid weights in grams).

No.	GLAZES A	GLAZES C	GLAZES E	No.	GLAZES A	GLAZES C	GLAZES E
	% wt.	% wt.	% wt.		% wt.	% wt.	% wt.
4	80=400	20=80		37	20=100	80=320	
5	80=400	10=40	10=43	39	20=100	60=240	20=86
6	80=400		20=86	41	20=100	40=160	40=172
11	60=300	40=160		43	20=100	20=80	60=258
13	60=300	20=80	20=86	45	20=100		80=344
15	60=300		40=172	58		80=320	20=86
22	40=200	60=240		60		60=240	40=172
24	40=200	40=160	20=86	62		40=160	60=258
26	40=200	20=80	40=172	64		20=80	80=344
28	40=200		60=258				



Series No. 3. To Develop Grays and Tints of Red, Blue, and Blue-violet. In this series the end members were:

Basic Glaze (H) Light gray, equiv. wt. 316.25, M. F. 1.54
Basic Glaze (B) Red, equiv. wt. 374.00, M. F. 1.65
Basic Glaze (I) Light Blue, equiv. wt. 305.90, M. F. 1.40
Blends (Table shows percentages and fluid weights in grams).

No.	GLAZES H % wt.	B % wt.	I % wt.
4	80=376	20=134	
6	80=376		20=60
11	60=282	40=268	
13	60=282	20=134	20=60
15	60=282		40=120
18	50=235	30=201	20=60
19	50=235	20=134	30=90
22	40=188	60=402	
24	40=188	40=268	20=60
25	40=188	30=201	30=90
26	40=188	20=134	40=120
28	40=188		60=180
32	30=141	40=268	30=90
33	30=141	30=201	40=120
37	20=94	80=536	
39	20=94	60=402	20=60
41	20=94	40=268	40=120
43	20=94	20=134	60=180
45	20=94		80=240
58		80=536	20=30
60		60=402	40=120
62		40=268	60=180
64		20=134	80=240

The following transparent lead glaze was used with good results: It is a good bright or shiny glaze at temperatures from cone 05 to cone 3.

.70 PbO, .20 CaO, .10 K_2O } .20 Al_2O_3 } 1.6 SiO_2

White lead	180.6 Gms.
Whiting	20.0 Gms.
Felspar	55.7 Gms.
N. C. Kaolin	25.8 Gms.
Flint	48.0 Gms.
	330.1 Gms.

This opaque tin enamel was used with good results at cone 02:

.40 PbO, .25 CaO, .20 K_2O, .15 ZnO } .25 Al_2O_3 } 1.75 SiO_2, .30 SnO_2

White lead	103 Gms.
Whiting	25 Gms.
Felspar	111 Gms.
Zinc oxide	12 Gms.
N. C. Kaolin	13 Gms.
Flint	27 Gms.
Tin oxide	45 Gms.
	336 Gms.

CONCLUSION

It has been demonstrated by this investigation that Iowa clays of the low grade fire-clay group can be used successfully in the production of a good grade of pottery of the stoneware type.

A better grade of ware could be made, however, by the use of several Iowa clays in combination and the addition of some felspar and flint. Good results will be obtained by the following mixture, thirty-three parts of a plastic clay, twenty-five parts of a more sandy clay, twenty-two parts felspar and twenty parts of flint.

If the temperature at which the body is to be burned is either too high or not high enough the mixture should be changed accordingly, i. e. more felspar to lower the heat treatment, and more flint to increase it.

All Iowa clays tested show traces of iron, therefore, the color of the body obtained from Iowa clays will vary from red to cream or yellow ivory, depending upon the iron content of the clays used.

TABLE I. GENERAL CHARACTER OF RAW CLAY

Name of shale	Color	Structure	Fineness of grain	Visible objectionable material	Carbonates by acid test
1. Mason City Blue shale	Light gray	Soft shale	Fine	None	Medium
2. Mason City Yellow clay (Glacial)	Yellow	Soft, earthy	Coarse	Sand, limestone roots and stems	High
3. 80% Mason City Shale 20% M. C. Yellow	Light gray				Medium
4. Des Moines River shale	Light gray	Soft shale	Fine	Sand	Slight trace
5. Sioux City Shale	Dark gray	Hard shale	Fine	None	None
6. Ames Glacial Drift	Light yellow	Soft, earthy	Coarse	Fine sand, gravel, limestone, organic matter	High
8. Des Moines Fire clay	Dark gray	Hard shale	Fine	Coarse sand, organic matter	Slight trace
9. Maquoketa Over-burden	Yellow	Soft, earthy	Coarse	Fine sand	None
10. Anamosa Loess clay	Light yellow	Soft, earthy	Sandy	Much fine sand	None
12. Maquoketa Shale	Light yellow	Hard shale	Fine	None	None
13. Danville Fire clay	Very light gray	Soft shale	Fine	None	None
14. Adel Fire clay	Light gray	Hard shale	Fine	Few grains of iron pyrites	None
17. Ft. Dodge Fire clay	Very light gray	Soft shale	Fine	Modules of iron pyrites	None

TABLE II—WORKING PROPERTIES

	Grinding	Plasticity	Lamination	Die troubles	Modeling properties	Jiggering and casting
1. Mason City Blue Shale	Easy	Very plastic	Much	Lamination	Rather sticky but surfaces up well. Does not crumble or crack	Tendency to crack in the moulds
2. Mason City Yellow Clay (glacial)	Easy	Low plasticity, short and sandy	Little	Tears	Crumbles badly and crackles in modeling, does not surface up wel.	Cracked badly in the moulds
3. 80% Mason City Shale 20% M.C. Yellow	Easy	Good	Much	Lamination	Good modeling clay. Does not crumble or crack. Surfaces up well.	Dried safely without cracks
4. Des Moines River Shale	Easy	Fair plasticity	Medium	None	Models well, but coils have tendency to crackle.	Dried quickly without cracks
5. Sioux City Shale	Hard	Low plasticity, short	Much	Lamination	Does not surface up well, coils crackle slightly.	Dried safely without cracks
6. Ames Glacial Drift	Easy	Low plasticity and short	Some	Tears	Not a suitable modeling clay hard to surface.	Cracked badly in moulds
8. Des Moines Fire Clay	Medium	Very plastic	Some	Lamination	Good modeling clay in every way.	Dried quickly without cracks
9. Maquoketa Over-burden	Easy	Medium	Little	Tears	Models well, but trifle short and tends to crackle. Takes good surface.	Cracked very badly
10. Anamosa Loess Clay	Easy	Low plasticity, short	Little	Tears	Not a suitable modeling clay. Does not surface up well.	Cracked very badly
12. Maquoketa Shale	Easy	Good	Medium	Lamination	A good modeling clay.	Dried safely without cracks
13. Danville Fire Clay	Easy	Very plastic	Medium	Lamination	A trifle fat and sticky but good modeling clay.	Dried safely without cracks
14. Adel Fire Clay	Easy	Good	Medium	Lamination	Fine modeling clay.	Dried safely without cracks
17. Fort Dodge Fire Clay	Easy	Very plastic	Medium	Lamination	Good modeling clay in every way.	Dried safely without cracks

TABLE III. DRYING PROPERTIES

Name of shale	Rapidity of drying	Shrinkage		Cracking		Warping		Tendency to scum
		Un-washed	Washed	Pottery	Brick	Pottery	Brick	
1. Mason City Blue Shale	Rapidly and safely	% 8.0	% 8.5	Very slight	None	Very little	None	Slight
2. Mason City Yellow Clay (glacial)	Medium	8.0	8,5	Badly	Very little	Cracked too badly to tell	None	Very slight
3. 80% Mason City Shale 20% M. C. Yellow	Rapidly and safely	7.5	8.0	None	None	None	None	Slight
4. Des Moines River Shale	Rapidly and safely	7.0	7.5	None	None	None	None	Slight
5. Sioux City Shale	Rapidly and safely	4.0	5.0	None	None	None	None	Not noticeable
6. Ames Glacial Drift	Had to be Dried slowly	4.5	5.0	Badly	Very little		None	Slight
8. Des Moines Fire Clay	Rapidly and safely	7.0	7.5	None	None	None	None	Not noticeable
9. Maquoketa Over-burden	Had to be dried slowly	10.0	11.0	Badly	Some		None	None
10. Anamosa Loess Clay	Had to be dried slowly	7.5	8.5	Badly	Some		None	Slight
12. Maquoketa Shale	Medium	7.0	7.5	None	None	None	None	Slight
13. Danville Fire Clay	Rapidly and safely	6.5	7.5	None	None	None	None	None
14. Adel Fire Clay	Rapidly and safely	9.0	10.0	None	None	None	None	None
17. Ft. Dodge Fire Clay	Rapidly and safely	6.5	7.5	None	None	None	None	None

TABLE IV—BURNING PROPERTIES

Name of Shale	Cone	Absorption: Un-washed	Absorption: Washed	Hardness: Un-washed	Hardness: Washed	Fire Shrinkage: Un-washed	Fire Shrinkage: Washed	Total Shrinkage: Un-washed	Total Shrinkage: Washed	Color	Oxidation
	No.	%	%			%	%	%	%		
1. Mason City Blue Shale	05	15.1	21.2	S. H.	S. H.	2.0	1.5	10.0	10.0	Salmon	Medium
	02	11.2	12.1	Hr. S.	Hr. S.	2.0	2.0	10.0	10.5	Salmon	
	2	4.7	4.2	Hr. S.	Hr. S.	2.5	2.5	10.5	11.0	Salmon	
2. Mason City Yellow Clay (glacial)	05	24.7	23.8	Soft	Soft	1.0	1.5	9.0	10.0	Light red	Easy
	02	21.5	21.4	S. H.	S. H.	1.0	2.5	9.0	11.0	Light red	
	2	17.4	16.1	S. H.	S. H.	3.0	3.0	11.0	11.5	Light red	
3. 80% Mason City Shale 20% M.C. Yellow	05	15.0	15.6	S. H.	S. H.	1.5	2.0	9.0	10.0	Salmon	Easy
	02	12.8	13.2	Hr. S.	Hr. S.	2.5	2.5	10.0	10.5	Salmon	
	2	5.6	5.3	Hr. S.	Hr. S.	3.0	3.0	10.5	11.0	Salmon	
4. Des Moines River Shale	05	9.4	7.5	S. H.	S. H.	3.0	3.0	10.0	10.5	Salmon	Medium
	02	4.5	3.2	S. H.	Hr. S.	5.0	5.5	12.0	13.0	Light red	
	2	0.7	.4	Hr. S.	Hr. S.	6.0	6.5	13.0	14.0	Dark red	
5. Sioux City Shale	05	21.0	17.0	S. S.	S. H.	1.0	0.0	5.0	5.0	Light salmon	Easy
	02	15.9	14.2	S. S.	S. H.	2.0	1.5	6.0	6.5	Salmon	
	2	12.5	8.0	S. H.	S. H.	3.0	2.5	7.0	7.5	Dark salmon	
6. Ames Glacial Drift	05	24.7	18.0	V. Soft	S. S.	1.0	1.0	5.5	6.0	Salmon	Easy
	02	19.0	17.1	Soft	S. S.	1.0	1.0	5.5	6.0	Buff	
	2	11.0	5.1	S. H.	S. H.	4.0	6.0	8.5	11.0	Buff	
8. Des Moines Fire Clay	05	9.9	10.3	S. S.	S. H.	3.5	4.0	10.5	11.5	Light red	Easy
	02	6.3	5.2	S. H.	S. S.	4.0	4.5	11.0	12.0	Light red	
	2	2.5	1.6	Hr. S.	Hr. S.	7.0	6.5	14.0	14.0	Dark red	
9. Maquoketa Over-burden	05	16.0	16.8	S. S.	S. S.	0.0	1.5	10.0	12.5	Red	Easy
	02	15.2	11.2	S. H.	S. H.	3.0	3.5	13.0	14.5	Red	
	2	5.0	4.7	S. H.	Hr. S.	6.0	6.0	16.0	17.0	Dark red	
10. Anamosa Loess Clay	05	18.7	18.7	S. S.	S. S.	1.0	1.5	8.5	10.0	Red	Easy
	02	14.2	12.3	S. H.	S. H.	3.0	3.0	10.5	11.5	Red	
	2	5.8	5.1	S. H.	S. H.	6.0	6.0	13.5	14.5	Dark red	
12. Maquoketa Shale	05	7.2	6.5	S. H.	S. H.	5.5	5.0	12.5	12.5	Salmon	Easy
	02	2.1	1.6	Hr. S.	Hr. S.	6.0	6.0	13.0	13.5	Salmon	
	2	.7	.6	Hr. S.	Hr. S.	Bloated	Bloated	Bloated	Bloated	Dark salmon	
13. Danville Fire Clay	05	13.5	14.8	Soft	Soft	0.0	0.0	6.5	7.5	Cream	Easy
	02	13.3	14.7	S. S.	S. S.	0.0	0.0	6.5	7.5	Cream	
	2	12.6	12.6	S. S.	S. S.	1.0	0.0	7.5	7.5	Cream	
14. Adel Fire Clay	05	11.4	11.2	S. S.	S. S.	1.0	0.0	10.0	10.0	Light buff	Easy
	02	11.1	10.2	S. S.	S. S.	1.0	1.0	10.0	11.0	Light buff	
	2	8.7	8.6	S. H.	S. H.	2.0	1.0	11.0	11.0	Light buff	
17. Fort Dodge Fire Clay	05	11.6	13.4	S. S.	S. S.	3.5	2.5	10.0	10.0	Cream	Easy
	02	7.3	7.1	S. S.	S. S.	4.5	5.0	11.0	12.5	Cream	
	2	3.0	2.9	S. H.	S. H.	7.5	5.5	14.0	13.0	Cream	

Note: S. S.—Softer than steel; S. H.—Steel hard; Hr. S.—Harder than steel.

GLOSSARY

Blunger—Machine used to mix water and clay in preparing slip.

Blunging—Mixing of clay with water to form slip.

Coiled—Pottery ware that is coiled, is made by rolling out bits of clay into coils and then building coil on coil until the shape is finished.

Damp Box—Box in which air is kept moist, so that pieces of pottery and clay will not dry.

Dunking—Cracking of ware during the cooling period, after firing.

Felspar—An abundant rock-forming mineral; potassium, calcium, or sodium or combinations of the same with aluminum-silicate; used in body and glaze compositions.

Filter Press—Machine for removing water from clay slip by forcing the water under pressure through canvas or cloth, leaving the plastic clay in the press.

Glaze—Any fusible composition transparent or otherwise, which is deposited on the clay or biscuit ware for the purpose of decoration and protection; colors being given it by the varying additions of different metallic oxides.

Jigger—The wheel on which clay shapes are moulded with the aid of a jolley or profile.

Jiggered—Ware made on a jigger which is a modification of a potter's wheel and on which the shapes are made mechanically instead of by hand as on the potter's wheel.

Lathe—A machine on which to turn pottery pieces for trimming, etc.

Lead Vitreous—Lead, oxides and carbonates of, used as a flux in glazes for low temperatures.

Mat Glaze—A dull glaze, opaque usually, which has a velvety or sheen-like surface.

Plaster Bats—Slabs of plaster of Paris, on which clay can be wedged or worked easily.

Pug Mill—Machine used to mix water and clay to prepare clay in the plastic state.

Pull Down—One part of a machine used in potteries to obtain the interior form of pieces of pottery.

Sagger—A box made of clay, usually fire clay, in which delicate pieces are placed while being fired.

Slip—Clay in a creamy liquid state.

Spun—Pottery ware that is "spun" is made on a potter's wheel, where the clay is turned or "spun" into shape.

Tempering—Preparing of clay with water by mixing and cutting to form clay in plastic condition.

Wedging—Working of clay, by cutting wedge-like masses of clay and dashing the wedges together, to expel the air bubbles.

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