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SLIP CASTING OF CLAY POTS FOR THE MANUFACTURE OF OPTICAL GLASS AT THE NATIONAL BUREAU OF STANDARDS

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PREFACE

The purpose of this Circular is to give a general description of the plant at the National Bureau of Standards for the slip casting of refractory clay pots. Details of manufacture involving operations with which the experienced ceramic worker is familiar have been largely omitted. Sufficient information, however, is given to enable the operations involved to be successfully duplicated, especially if the same raw materials are used.

E. U. Condon, *Director.*

SLIP CASTING OF CLAY POTS FOR THE MANUFACTURE OF OPTICAL GLASS AT THE NATIONAL BUREAU OF STANDARDS

By Raymond A. Heindl, Gordon B. Massengale, and Louis G. Cossette

ABSTRACT

Between 1918 and 1940 the Refractories Section of the National Bureau of Standards manufactured about 70 slip-cast clay pots annually for use by the Glass Section for the production of optical glass. From 1940 to 1945, to meet the increasing military requirements for optical glass, the pot production was expanded gradually to a maximum of 2,300 annually. This Circular describes the plant changes made, the new machinery and equipment installed, and the general manufacturing procedure used to bring about this increased production. A description is also given of the two types of pots produced, namely, one with a low-porosity lining for the manufacture of the more corrosive glasses, the other without the lining for the less corrosive glasses. Information is given on the control of the density of the pot in order to obtain low gas permeability of the pot wall and on many of the difficulties that had to be overcome in order to produce satisfactory pots.

CONTENTS

I. INTRODUCTION

Approximately 28 years ago A. V. Bleininger reported [1] [1] the results of the first work undertaken at the Pittsburgh, Pa., station of the National Bureau of Standards for the development of a suitable refractory-clay slip-cast pot to be used as a container in the manufacture of optical glass. Stimulated research activity during World War I resulted in the publication of several other papers [2] dealing with this

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[1] Figures in brackets indicate the literature references at the end of this paper.

subject. Between 1918 and 1940, the manufacture of optical glass was continued at the Bureau on a small scale, and the clay pots used were made by the Refractories Section. The experience gained from this production made it possible for the Bureau to quickly expand its clay-pot manufacturing facilities to produce 2,300 units annually. The excellent opportunity afforded for observing the performance of pots in the glass-manufacturing plant led to the study and correction of defects in the pot structure, resulting in improvements in the quality of the glass. For example, the development of a pot containing a lining of low porosity and of a thimble having a coating of slip similar to that of the pot lining occurred during that period. This paper describes these and other developments, as well as the expansion that materialized with the beginning of hostilities in Europe in 1939.

During the period of small-scale production at the Bureau, the representatives of numerous glass companies, both here and abroad, sought information from the Bureau relating to the manufacture of clay pots and studied the methods of production for application in their plants. Those seeking such assistance included several domestic manufacturers of glass products; Research Enterprises, Ltd., Leaside, Ontario, Canada, who furnished much of the glass for the Canadian government; Australian Window Glass, Melbourne, Australia, through the Munitions Department of the Australian government; and later, a representative of the Chinese government.

II. DESCRIPTION OF PLANT

1. POT CASTING

Basically, the plant for the casting of the pots is about the same as that described by Riddle, and later by Geller and Finn [2]. However, the two blungers, each of which was only large enough for the slip required for one 650-lb pot, were superseded by one two-stirrer blunger, in which ample material can be mixed for casting four pots. The inside of the tank is 7 ft 5 in. long, 3 ft 3 in. wide, and 2 ft 10 in. high. Each stirrer has six round steel bars 27 in. long by 1¼ in. in diameter fastened vertically to two cross members 31 in. long. One of the discharge outlets was reduced from 4 in. to 2 in. for use in making a fluidity, or flow, test of the clay slip. With a 2½-hr overlapping of two shifts, eight pots can be cast during a 10-hr period. A ball mill is used for mixing 500 lb of a finely ground slip, which, when finished, is stored in a large-capacity single-blade blunger. These two machines were already available at the Bureau. Racks were provided for the storage of 44 plaster-of-paris molds. Electric heating units suspended in the shell of the mold provide a temperature of about 75° C for speeding up the drying of the molds. A scale suspended from an overhead trolley running parallel to the small pot-material storage bins was installed to increase the speed and accuracy of weighing.

2. POT SHELL CRUSHING

New space was allotted for setting up the machinery required for cleaning, crushing, grinding, and screening the reclaimed pot shell. The crushers and four-deck shaker screen are connected by an endless

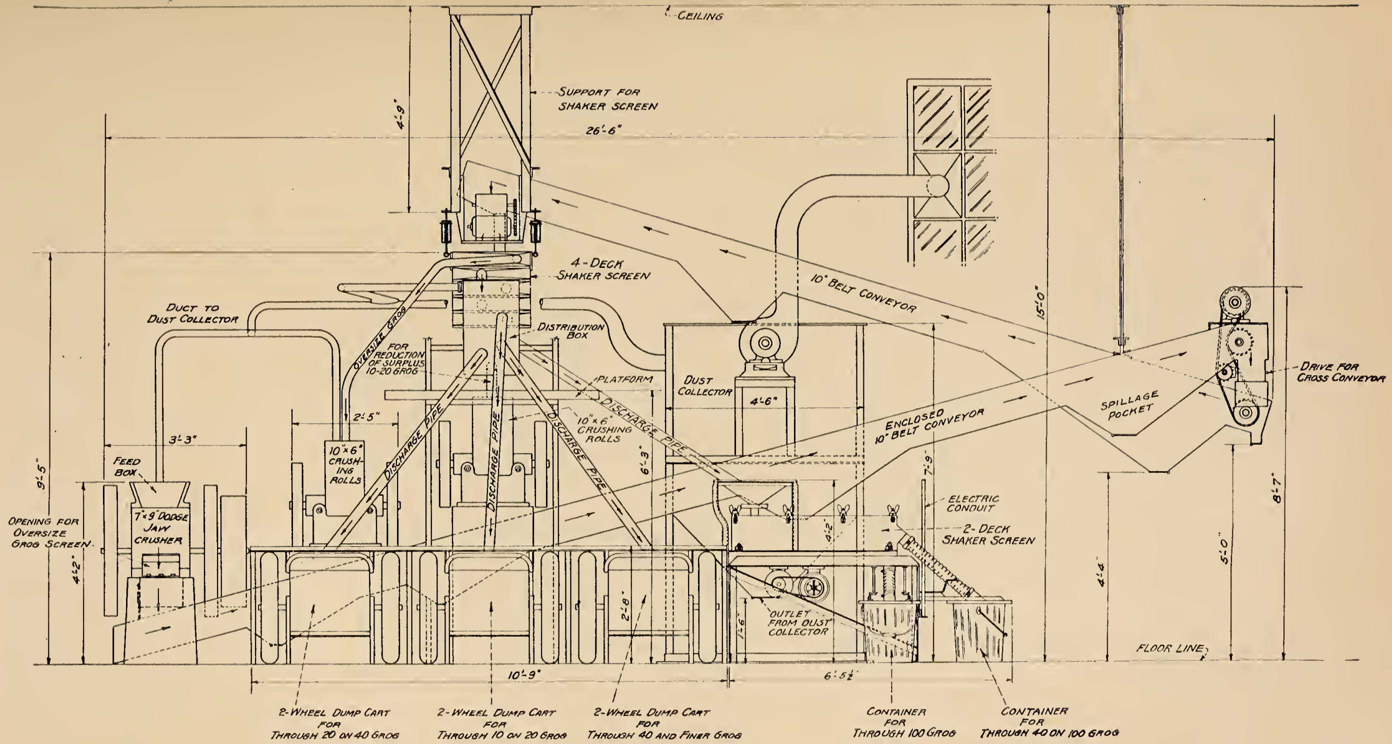

FIGURE 1.—*Plant for crushing, grinding, and screening reclaimed pot shell.*

belt, see figure 1. No work is required other than feeding the reclaimed chunks of pot shell, cleaned of adhering glass, to the jaw crusher except emptying the hopper carts into which the grog is discharged after being screened into three fractions. When the need arises, the third, or finest, fraction is diverted through a smaller two-deck shaker screen and further separated into useful fractions. Sheet-iron casings were placed around the conveyor and machinery. These casings are connected to a dust collector by pipes located at strategic places in the system.

3. POT STORAGE

A space approximately 45 by 55 ft is used for the drying and storage of the pots. By placing the pots in tiers three high, a stock of about 275 may be maintained, representing an 8- to 9-week supply at full production of the glass plant. The pots are removed from the plaster-of-paris bases and placed on 40-in. by 40-in. skids by means of an overhead trolley and hoist. A portable elevator, or stacker, with an electrically operated lift platform is used for placing the pots in the tiers.

Eleven bins were built of concrete for the storage of the clays and grog. Forty tons of clay may be stored in each of the largest bins.

III. MANUFACTURE OF POTS

1. TYPES

Two types of pots are in regular production. These differ only in that one has a low-porosity lining approximately ⅛ in. thick [3]. The dimensions of the pots are as follows: diameter at the top, outside, 35 in.; bottom, outside, 32½ in.; wall thickness at the top 2¾ in.; depth 24¾ in.; and thickness of bottom 3⅜ in. A shoulder around the outside of the pots, for convenience in handling, is 14 in. from the top. The batch composition of the body until the end of 1944 closely approached that referred to by Geller and Finn [2] as body No. 332. However, for many years reclaimed pot shell has been substituted for the whiteware bisque, and during the closing months of 1944 Delaware kaolin was no longer available, necessitating the substitution of Georgia kaolin. All the clays are received in finely pulverized or air-floated form instead of in lump form as formerly.

For many years the grog for the pots was screened into three fractions, namely, through a No. 10 screen and retained on a No. 20, through a No. 20 and retained on a No. 40, and through a No. 40. Experience indicated that the quality of the pot could be improved by increasing its density. Consequently, the triaxial diagram, figure 2, was prepared by using the above three fractions as the components. The bulk density of various combinations of the fractions was determined and these are indicated on the diagram. At present a portion of the grog passing the No. 40 screen is further separated into two fractions, namely, through a No. 40 screen and retained on a No. 100, and through a No. 100. The total grog [4] in the pot batch has not been significantly changed, but the percentages of the fractions were changed and one additional fraction, namely, that passing through the No. 40 and retained on the No. 100, was added, as indicated in table 1. The combination of the grog now used

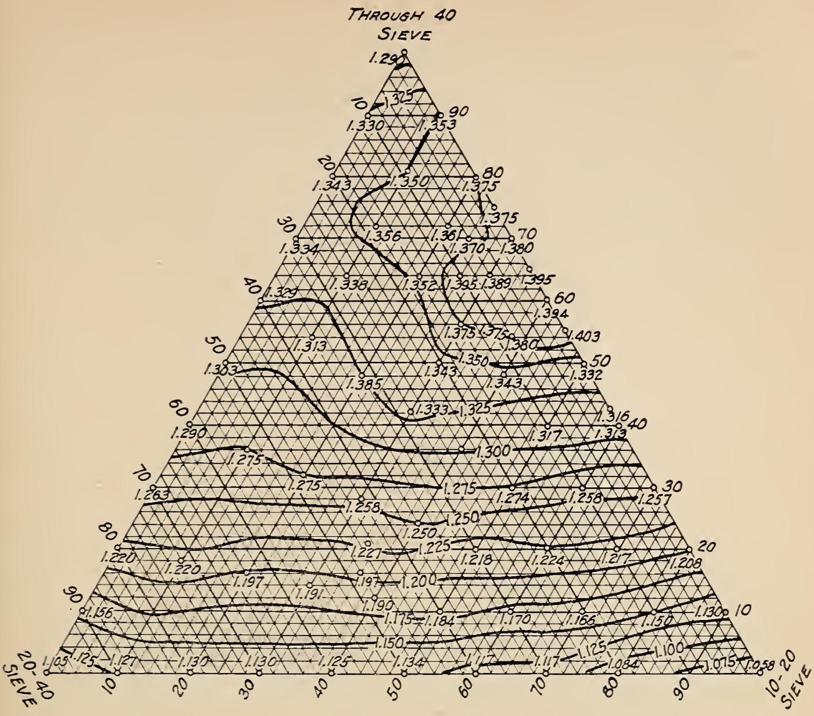

FIGURE 2.—*Triaxial diagram for selection of combinations of grog sizes of desired densities.*

was selected from the triaxial diagram. The selection resulted in a pot that still has a high resistance to thermal shock but has a considerably greater density than the pot formerly manufactured. The bulk density of the mixture of grog only as formerly used was 1.197, but that of the present composition is 1.30.

TABLE 1.—*Fractions and percentages of grog in refractory pots*

U. S. Standard Screen No.	Fraction formerly used	Fraction now used
	Percent	*Percent*
Through 10 on 20	35	34
Through 20 on 40	45	30
Through 40 on 100	0	18
Through 40	20	18

The composition of the pot batch as now used is given in table 2, and the chemical analysis of reclaimed, cleaned, and crushed pot shell is given in table 3. A few pots were cast in which the amount of silica was increased in steps up to 69 percent, but their manufacture was discontinued in favor of those of the regular composition. Other pots were made in which the coarsest fraction of grog passed a No. 16 screen and was retained on a No. 20. Indications are that these pots are superior to those manufactured from the pot batch given in table 2 and may be substituted for them. Still other pots were made in which one or more of the clays were eliminated in favor of larger percentages of the remaining clays. For example, the Kentucky ball clay was substituted for the Tennessee ball clay and vice versa; the North Carolina kaolin was replaced with either the Delaware or Georgia kaolins, and so on. No particular difficulty was experienced with the resulting casting slip or finished pots, indicating the adaptability of the original slip to any reasonable change in composition.

TABLE 2.—*Composition of refractory pot batch and pyrometric cone equivalent*

Material	Amount	Pyrometric cone equivalent
	Percent	
North Carolina kaolin	13	34
Georgia kaolin	9	35
Tennessee No. 5 ball clay	10	31
Kentucky No. 4 ball clay	10	32
Maine felspar	5	10
Grog (reclaimed pot shell)	53	32
Silicate of soda [a]	0.025	--------
Sodium carbonate [a]	.012	--------

[a] With only slight variation from day to day, to 100 lb of dry batch are added 57 ml of a 10-percent solution of sodium carbonate, 115 ml of silicate of soda (Philadelphia Quartz Co. "S" brand or equivalent) and 2.56 gallons of water.

TABLE 3.—*Chemical analysis of used pot or of the reclaimed pot shell*

	Percent
SiO_2	59.5
Al_2O_3 (by difference)	35.6
Fe_2O_3	0.8
Na_2O	.7
K_2O	2.2
TiO_2, ZrO_2, etc	0.8

The blunger is loaded in approximately 35 min by controlled discharge from portable hoppers, three of which are required to fill the mill of about 3,000-lb capacity. The top of the blunger tank is covered, except for an opening into which the lower edge of the hopper fits. A low vacuum is maintained in the tank to minimize dust during filling. A water meter and an ammeter are used for measuring the water and indicating the consistency of the slip, respectively. The slip is blunged for 3 hr before casting it into the molds. The stirrers, which rotate in the same direction at 30 rpm, are completely below the surface of the slip during operation of the blunger in order to prevent continual trapping and mixing of air into it. Just before casting the pot, a fluidity test of the slip is made by timing the filling of a 14-quart bucket from the 2-in. discharge outlet. With the machine in operation, and under the conditions existing, the time required ranged from 9 to 10 sec. For the unlined pots about one-half hour is required for placing the four molds in the casting pit, filling, and removing them. About 1 hr is required for casting the four lined pots. The cores are removed from the unlined pots within 12 to 14 hr after casting and from the lined pots within 6 to 10 hr, depending on the humidity of the atmosphere. The one-piece shell is removed from the pots 3 to 4 days later.

The composition of the slip used as the lining of the clay pots is given in table 4.

TABLE 4.—*Composition* [a] *of refractory clay pot lining slip*

Material	Amount
	Percent
North Carolina kaolin	9.2
Georgia kaolin	6.4
Kentucky ball clay	7.8
Tennessee ball clay	7.8
Maine felspar	4.6
Grog (reclaimed pot shell through 100 screen)	32.1
Dust [b]	32.1

[a] To each 100 lb of dry ingredients are added 275 ml of sodium silicate (Philadelphia Quartz Co. "S" brand), 140 ml of a 10-percent solution of sodium carbonate and about 26 lb of water. After ball-milling the slip for 20 hr, it is stored in a single-blade blunger.

[b] Obtained from dust collector connected with the grog-crushing plant.

The sequence followed in the application of the lining to a pot is illustrated in figures 3 to 7, inclusive. Briefly, figure 3 shows the core suspended above the empty slip receiver; figure 4 shows the slip being poured into the receiver after the core had been lowered and locked into position to prevent it from floating; figure 5 shows the coated core suspended above the receiver to permit surplus slip

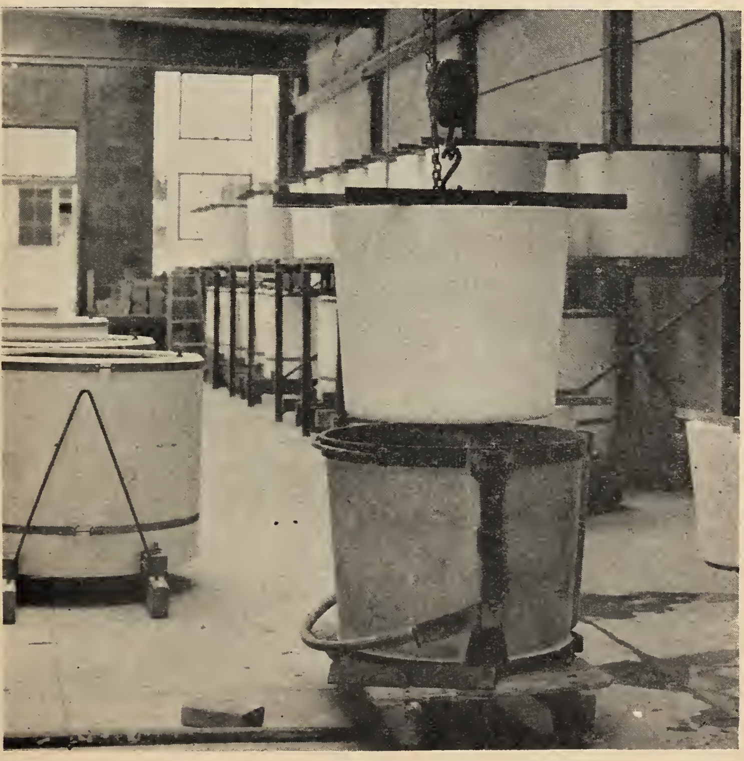

FIGURE 3.—*Core of pot mold ready to be lowered into empty clay-slip receiver.*

Figure 4.—*Clay slip being poured into receiver after core had been lowered and locked into position.*

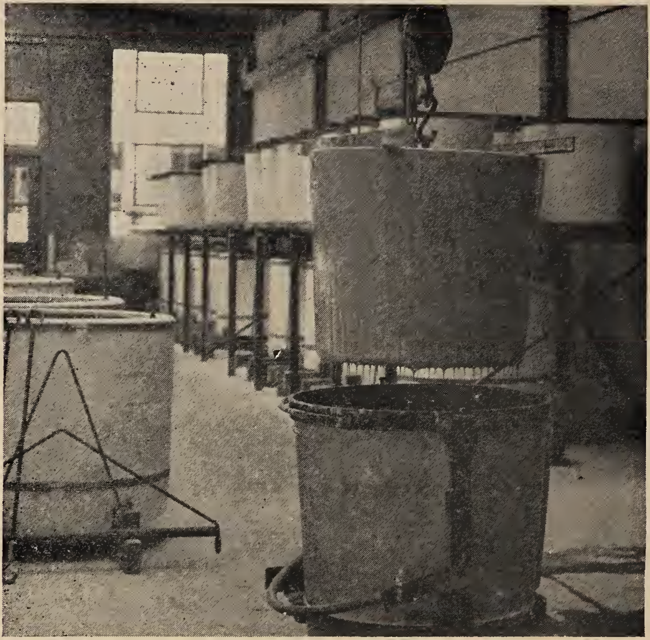

Figure 5.—*Excess slip draining from the coated core after having remained in the clay slip for 6 minutes.*

Figure 6.—*Slip-coated core being lowered into the shell of the mold.*

Figure 7.—*Casting the pot around the lining.*

to be lightly scraped from the core; figure 6 shows the coated core being lowered into the shell; figure 7 shows the casting of the pot around the lining. The mold is slightly tilted during the initial stage of casting, and the slip is permitted to flow from only the lowest of the three openings in the distributing reservoir. This arrangement causes the slip to flow uphill underneath the core, and there is less tendency of entrapping air bubbles between the lining and pot.

The mold is brought level after the bottom is filled, the gates of the other two openings in the reservoir are opened, and the mold is rocked lightly on a cradle resting on a 1-in. pipe until the pot is completely cast. The rocking serves the dual purpose of leveling the slip as it is cast and of freeing the air trapped in the slip during the casting operation.

The core remains in the lining slip for 6 min. before being transferred to the shell. Pots are also cast with linings ¼ in. or more in thickness and composed of double and of triple layers. In such cases the core remains in the slip for 3 min for the first coating and for an additional 5 min for the second coating, and also for the third, if it is applied. The coatings, or layers, are applied by removing the core from the container of slip in which it is immersed and repeating the entire operation already described for casting the lining slip to the core. The core is removed from the completed lined pot, as shown in figure 8. It was found advisable to remove the cores as soon as practicable in order to prevent cracking of the lining.

The reason for the double and triple coating is to eliminate the possibility of air bubbles extending through the pot bottom lining.

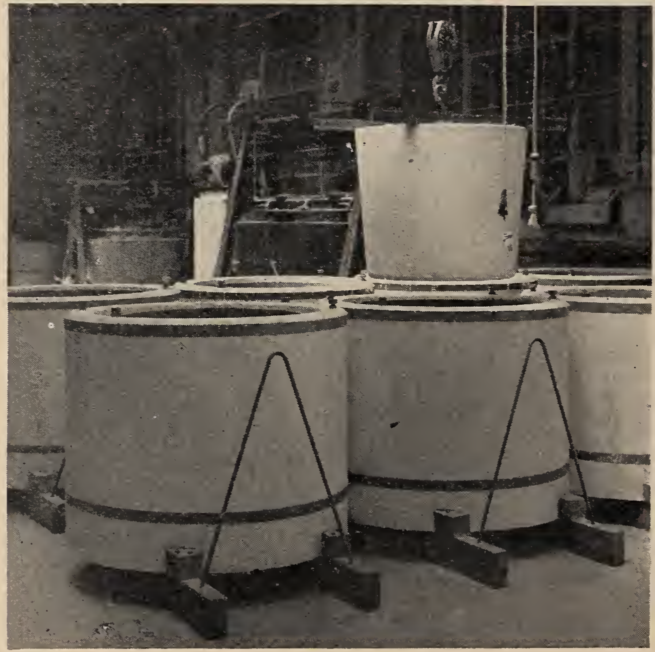

Figure 8.—*Core removed from pot 8 hours after casting.*

When used with the more corrosive glasses the pot with the single coating is apt to leak glass after the very thin walls of the air bubbles, if present, are destroyed. These bubbles are not evident on examination of the unfired pot. The corrosive glasses, however, are successfully fined in the pots lined with multiple layers, or coatings.

Several pots were cast with a lining in which synthetic mullite was used in place of the reclaimed pot-shell grog. The ingredients of this slip, in addition to the mullite, were alumina and clay in the approximate alumina-silica ratio of mullite. Although the lining developed no cracks during drying, they developed so seriously during firing at about 1,400° C that the usefulness of the lining was nullified. Furthermore, this temperature was too low to develop the quantity of mullite [5] desired in the lining.

2. FINISHING AND DRYING

As soon as the shell is removed the rim is leveled by cutting off the surplus material. As a precaution, the inner edge is rounded to minimize the cracking of the pot at the rim. In figure 9 the pot in the foreground shows the rim in three stages of completion. Very little trowling is done to the inside of the pot as this has a tendency to start incipient cracking. This cracking, although invisible in the dry state, may develop into "nuisance" cracks during the heating of the pot to high temperatures.

FIGURE 9.—*Unfinished and finished pots.*

The pot in the foreground has the rim only partially finished; the other three are completely finished with two showing the manner in which the stirring thimbles are supported during heating of the pot.

The pots remain on the plaster-of-paris bases of the mold for a total of 9 days, after which they are removed to 40-ft by 40-in. skids. The pots require about 1 month to dry during the time of the year when the buildings are heated and about 2 weeks longer during the spring and summer months. Drying the pots under humidity control is not practiced, but proceeds under ordinary atmospheric condition while the pots are in storage. During the months in which the humidity is low, cloth is placed around the rim of the finished pot for 10 days to prevent too rapid drying.

3. DIFFICULTIES AND REMEDIES

(a) CRACKING

There are a number of different causes of cracks that may appear between the time the pot is cast and when it becomes dry. One type of crack that appeared at the inside corner of the wet pot almost immediately after removal of the core was eliminated by withdrawing the core 2 or 3 hr earlier or as soon as the danger of slumping of the pot no longer existed.

A type of crack that appeared across the middle of the inside bottom of the pot from 1 to 3 days after removal of the core was eliminated by making certain that the base section of the mold was damp before being used. The crack started from the outside and gradually extended its way upward.

Cracks that started at the heel of the pot caused large sections of the outer pot wall to shear off. The cause was eliminated by having the plastic clay, which seals the opening between the circumference of the base and of the shell, of a fairly stiff consistency to reduce its shrinkage to a minimum and to have ample clay forced into position and feather-edged to meet the plaster. Furthermore, the base of the mold, as well as the surface of the sealing clay, is coated with a refractory dust to prevent possible sticking of the slip during the initial stages of drying of the pot.

Figure 7 shows the three-opening distributor through which the pot slip flows into the mold. If the slip was permitted to pour through the three openings simultaneously before the bottom of the mold was completely filled, radial cracks would develop, during drying, across the inside bottom of the pot along the lines of meeting of the slip.

Another type of crack developed frequently in the corner of the pot approximately below the spout through which the slip flows first. This crack appeared only when the slip accumulated between the walls of the mold before the bottom was formed, either because it was too thick or was permitted to flow more rapidly from the spout than it would flow across the base of the mold.

Vertical cracks occasionally occurred in the lining of the wall of the pot where the body slip from the different spouts joined. The use of a more fluid slip eliminated such cracks. Cracks starting at the rim during low humidity weather were eliminated by placing sacking around the rim during the first 10 days of drying.

The blade of a knife is used to separate any adhering lining from the core of the mold at the top inside edge of the rim of the pot about 2 hr after the casting operation to prevent cracks from starting there.

(b) DEFLOCCULATION AND THIXOTROPY OF CLAYS

The manner in which the clays reacted to deflocculants differed greatly [6]. There was also some difference in such reaction with the same clay but from different shipments. Difficulties in deflocculation of the pot batch were also encountered owing to change in concentration of the silicate of soda caused by freezing or long storage. However, after the quantity of deflocculants had been adjusted for change in shipment of clay, no further adjustment was necessary as a rule until a change in clay again occurred. Changes in concentration of the solution of silicate of soda were eliminated by periodic agitation to prevent segregation of the constituents. Thixotropy [2] [7] was more pronounced in the ball clays than in the kaolins, the Kentucky No. 4 being more so than the Tennessee No. 5. The North Carolina kaolin exhibited this property much more than either the Georgia or Delaware.

4. BURNING OR ARCHING

The pot is supported on a circular frame of four piers of silica shapes during burning. It is placed on the piers by means of a pot carriage, the tongs of which contain a spacer to prevent squeezing of the pot and possible rupture. The shapes measure 12 by 6 by 3 in., and the piers are built of three of these laid flatwise. The outside edge of the pot is flush with the outer edge of the pier; thus the wall of the pot is supported directly by the pier, and sufficient of the bottom is supported to prevent sagging. If it is necessary to level the tops of the piers, a small amount of sand is used. Carelessness in setting a pot in either the pot arch or the melting furnace may cause it to fail.

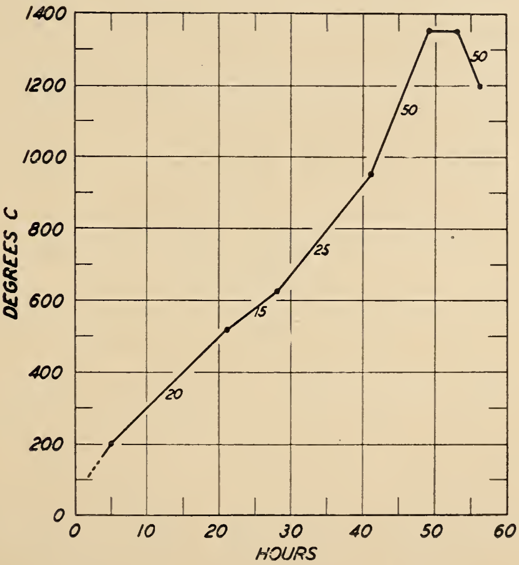

Figure 10.—*Heating schedule for the raw pot.*

Figures adjacent to the curve indicate rates of temperature rise during different periods

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[2] Webster's unabridged dictionary defines "thixotropy" as the property or phenomenon exhibited by some gels of becoming fluid when agitated. The property is reversible.

The burning schedule for the average pot is shown in figure 10. The pot arch does not cool below 75° or 80°C before it receives an unfired pot. The pot is heated to 1,350°C in 49 hr and maintained at that temperature for 4 hr. The temperature is then permitted to drop to 1,200°C during the next 4 hr, after which time the pot is ready for transfer to the melting furnace. In the heating stage the rise in temperature is controlled in accordance with the relative speed with which the pot could be heated through certain temperature ranges without harm to the pot. The rates range from 15 to 50 degrees centigrade per hour, as shown in figure 10.

(a) CHANGE IN LENGTH

(1) *During heating.*—The linear expansion and contraction occurring during the heating of a specimen of raw pot body from 20° to 1,000°C and cooling back to 20°C are shown in figure 11. Most raw clays [8] have a small expansion up to about 500°C, then contract as the endothermic reaction takes place. The pot body expands considerably more than the raw clay because of the 53 percent of prefired clay, or grog, it contains. However, a corresponding slight contraction was indicated between 525° and 550°C. Above 800°C the contraction was continuous up to 1,000°C. The result of heating the specimen to 1,000°C and cooling it back to 20°C was a shrinkage of 0.5 percent. The time to reach the maximum temperature was about 8 hr, and the specimen was removed from the cold furnace 16 hr later.

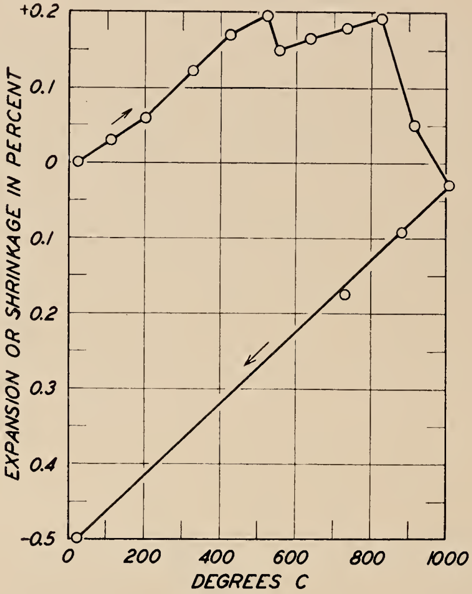

FIGURE 11.—*Linear expansion and contraction occurring in a specimen of raw pot body during heating up to 1,000°C and cooling back to 20°C.*

The data used for the construction of figure 11 were the basis of the firing schedule for the pots.

(2) *After heating.*—The shrinkage of the body, based on the dry length, after heating it at least 1 hr at each temperature and then cooling, was as follows for the average of three 1½- by 1½- by 4-in. specimens: 0.4 percent from the dried unfired condition to 850°C; 1.9 percent from 850° to 1,250°C; 1.3 percent from 1,250° to 1,400°C. As the drying shrinkage of these same specimens was 3.0 percent, it made the over-all shrinkage 6.6 percent. The over-all shrinkage of the lining slip after it had been heated at 1,400°C for 3 hr was 8.1 percent. The pot, on the other hand, had a total shrinkage of 5 percent. This value was obtained by measurements on the mold and the cooled pot after completion of the melting operation.

(b) POROSITY AND PERMEABILITY

The porosity, or absorption, of the pot varied, depending on the section of the pot from which the specimens for test were taken. Pyrometric cones distributed about the pot indicated a difference of heat-work of three cones between the bottom front and top back of the pot. Specimens taken below the shoulder of the pot at six places equally spaced around its circumference had a range in porosity from 19.7 to 22.7 percent. These values corresponded to the position of the high and low pyrometric cones nearest which the specimens for test were taken. The specimens on which shrinkage data were obtained had an average porosity of 21.6 percent after heat treatment at 1,400° C.

A comparatively small change in the relative proportions of the different fractions of the grog made little significant difference in the porosity, but had a pronounced effect on the air permeability [9] of the fired pot body. For example, the apparent density of the grog mixture used in the pots for a number of years was about 1.197. A change in grog mixture, resulting in a density of 1.26, caused a decrease in the porosity from 24.0 to 20 percent approximately. The permeability, on the other hand, dropped from 0.100 to 0.038 cm^3/sec, indicating there was a decided change in the size of the pores. Figure 12 shows a piece of the bottom of each of two pots after use and illustrates the extent of the penetration of the glass in the more permeable pot. The pots now manufactured have a gas permeability of approximately 0.04 cm^3/sec. In use, they have slightly less resistance to thermal shock than the more permeable pots.

A pot should be well burned before the glass batch is charged into it. The optimum temperature of firing, however, depends largely on the composition of the pot and its bulk density as well as the composition of the glass batch.

(c) STRENGTH

The modulus of rupture of the raw pot body dried at 110° C and determined on 9- by 4- by 1½-in. slabs over an 8-in. span averaged 125 lb/in^2. After heating the pot body at 1,400° C, the average modulus was 1,645 lb/in^2.

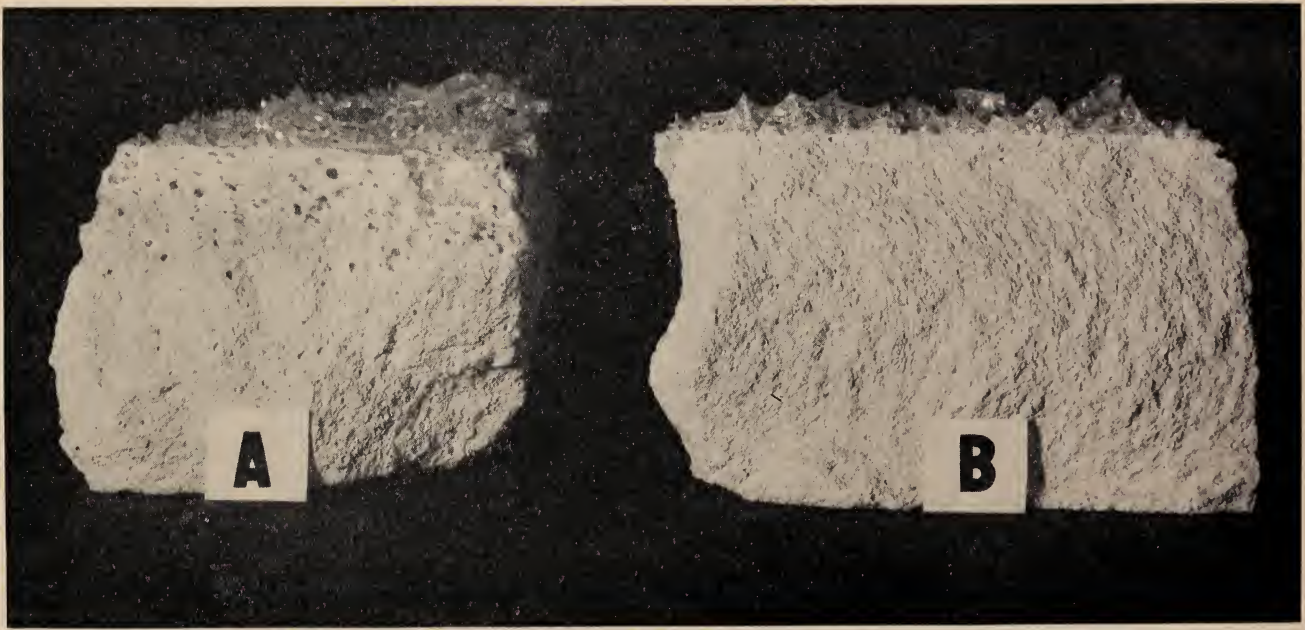

FIGURE 12.—*Specimen from the bottoms of two pots having an appreciable difference in gas permeability, in which borosilicate glass had been melted.*

The extent of the glass penetration in the more permeable pot *A* is clearly visible, whereas pot *B* has no visible penetration.

(d) THERMAL EXPANSION

The total linear thermal expansion from room temperature to 1,000° C of the pot body after having been heated to 1,500° C was 0.425 percent. As shown in figure 13, the expansion throughout that range was fairly uniform, the coefficient averaging 4.4×10^{-6} per degree centigrade.

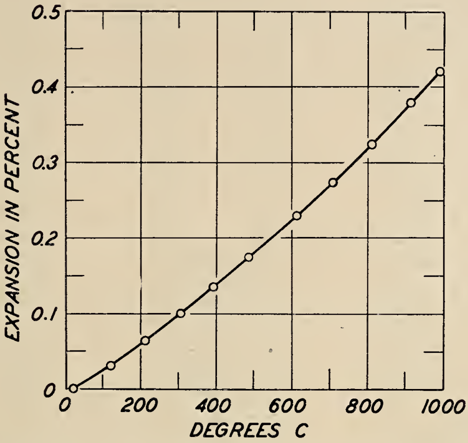

Figure 13.—*Linear thermal expansion of the pot body between 20° and 1,000° C, after having been preheated at 1,400° C.*

IV. MANUFACTURE OF THIMBLES

The refractory thimbles, used for stirring the glass during fining, are supported during burning as illustrated in figure 9. A section of a thimble and mold is shown in figure 14. The wall of the thimble consists of coarse-grained pot slip and a coating, about ⅛ in. thick, of the same fine-grained slip used to line the pots. The thimble weighs about 12¼ lb and has a wall thickness of one-half in., a length of 26½ in., and an outside diameter below the collar of 4¼ in., which tapers to 3 in. near the closed end. A battery of 12 molds is used. The thimbles are slip cast during the day, remain in the molds overnight, and are surface finished the following day. The desired thicknesses of the low-porosity coating and the wall of the thimble are obtained by draining the excess slip from the mold as soon as each slip in turn reaches a predetermined gage mark on a small reservoir of slip placed at the top or over the mouth of the mold. This requires less than 10 min for the coating and approximately 2 hr for the wall. The mold must be filled with the coarse-grained slip immediately after the fine-grained slip has drained; otherwise, knitting of the two layers may not occur. The time of finishing must also be correctly judged; if started too soon, the thimble will collapse; if too late, the surface will have hardened to such an extent that it is impossible to develop a smooth surface.

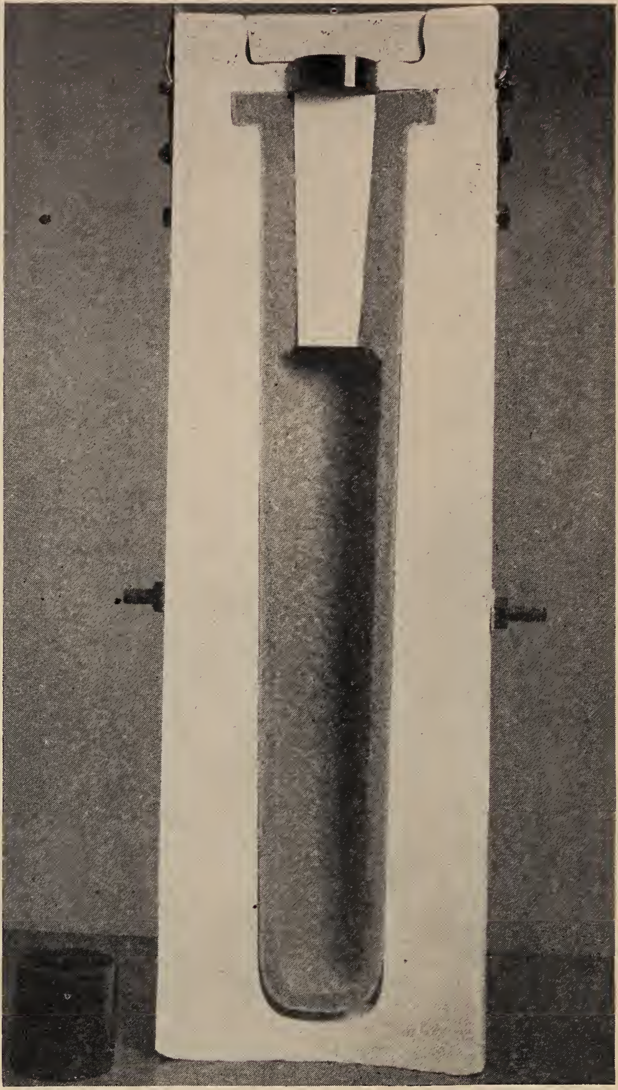

FIGURE 14.—*Section of mold and thimble.*

The low porosity coating, the reservoir in position at the top for the fine-grained slip and also that for the coarse-grained slip near the base of the mold may be observed. The manner of locking the lid in position and inverting the mold by means of lugs is also shown.

V. GENERAL REMARKS

The clay casting slip described in this paper is readily amenable to limited changes in composition and consistency without affecting the quality of the pot. However, at the time of casting it is especially desirable to have the slip at maximum fluidity consistent with minimum shrinkage of the dry product to obtain a pot relatively free from pores due to entrapped air and other defects. It is also desirable to proportion the various sizes of grog in such ratio as to obtain a finished body of low gas permeability but still having good resistance to thermal shock. There is a very general relation between permeability and porosity. However, apparently two bodies may have the same porosity, but because of a difference in pore size, the permeability could be quite different. The porosity is, therefore, not a dependable indicator of permeability, and not too much reliance should be placed on the former when changes in pot structure are contemplated.

The control of the air permeability is much more important for the unlined pot than in the lined, as in the latter the lining has a very low porosity, which is especially effective in resisting attack by glass.

During the past 20 years numerous publications dealing with glasshouse pots have appeared. The majority of these deal with the handmade pot. However, many of the details of manufacture, as well as the destructive action [3] of the glasses produced in the pots, are common to both the slip-cast and handmade varieties. A number of selected references [10] on both methods are therefore included in section VI.

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