July 7, 1942. H. A. WADMAN 2,288,661

METHOD OF SLIP CASTING COMPOSITE REFRACTORIES

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Fig. 1.

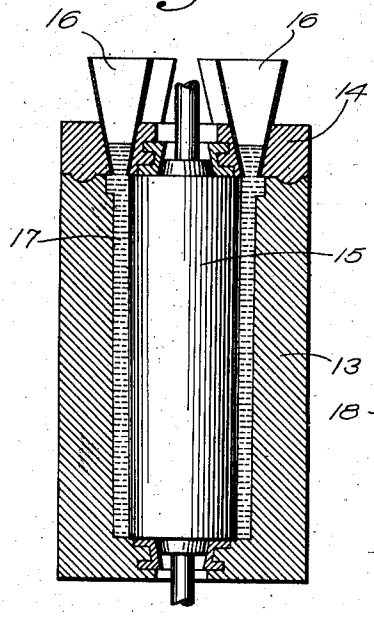


Fig. 2.

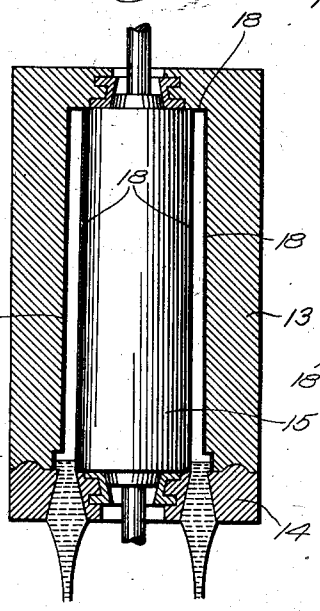


Fig. 3.

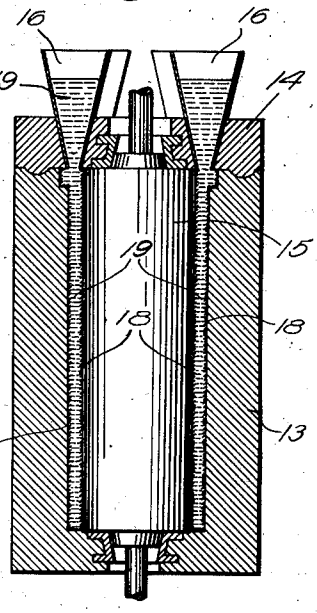


Fig. 4.

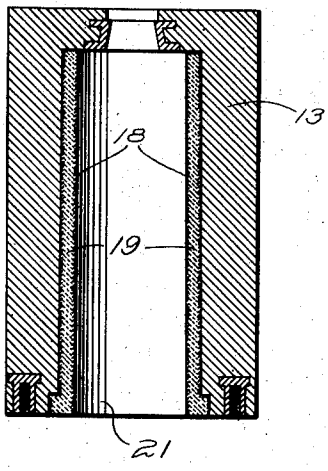


Fig. 5.

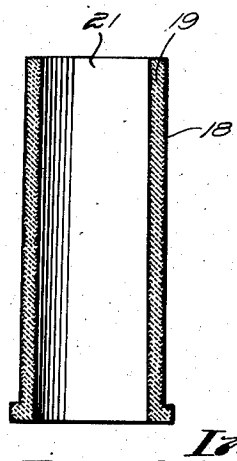
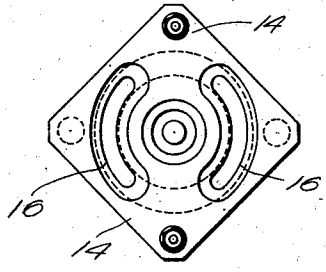


Fig. 6.



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METHOD OF SLIP CASTING COMPOSITE REFRACTORIES

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Fig. 7.

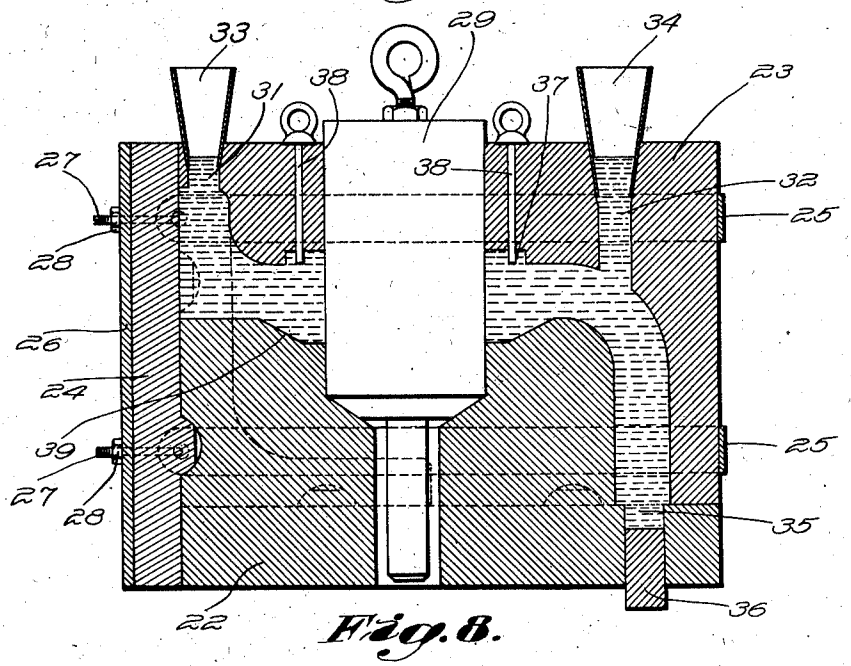
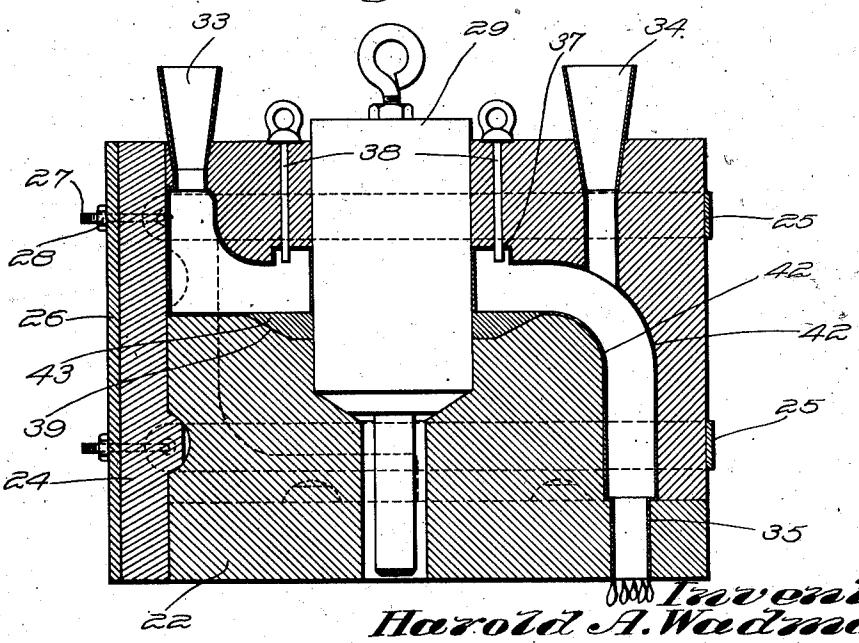


Fig. 8.



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METHOD OF SLIP CASTING COMPOSITE REFRACTORIES

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Fig. 9.

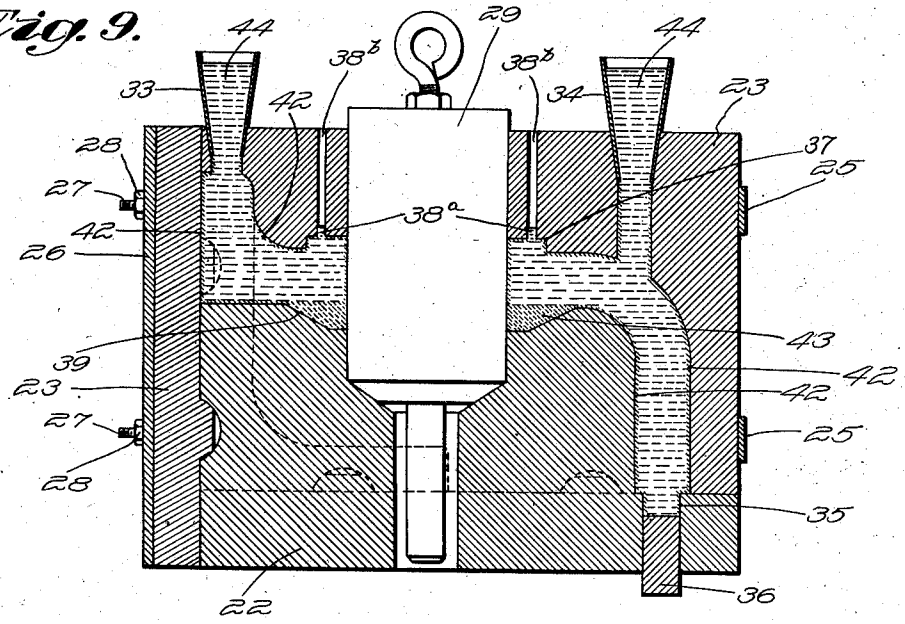
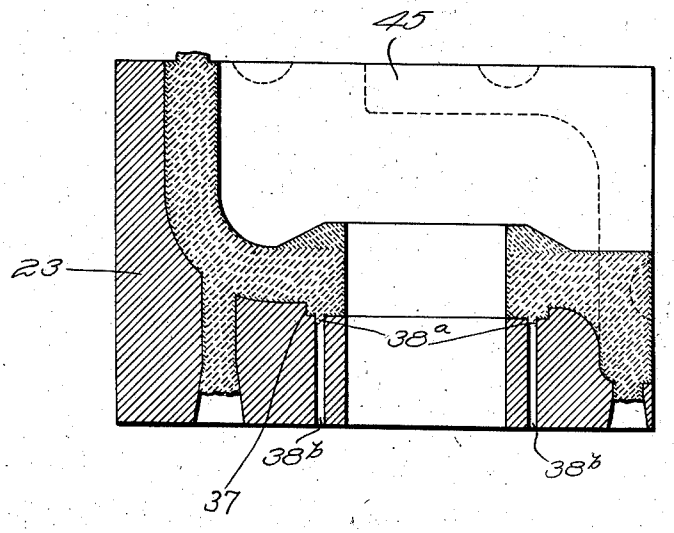


Fig. 10.



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METHOD OF SLIP CASTING COMPOSITE REFRACTORIES

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Fig. 11.

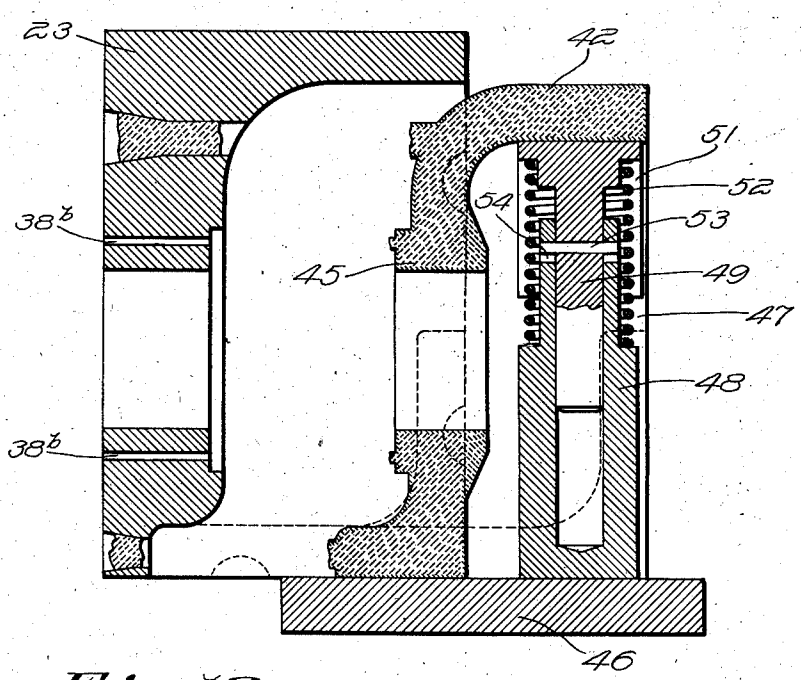
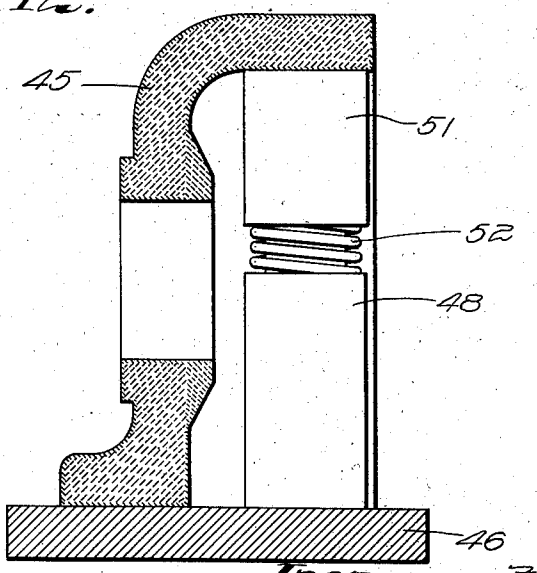


Fig. 12.



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2,288,661

UNITED STATES PATENT OFFICE

2,288,661

METHOD OF SLIP CASTING COMPOSITE REFRACTORIES

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Application September 7, 1939, Serial No. 293,753

7 Claims. (Cl. 25—156)

This invention relates to the production of refractories and has particular relation to the forming of refractory bodies of the composite or multilayer type by slip casting.

The type of composite refractory to which the invention relates is that in which an outer or surface layer having certain properties is formed integrally with an inner layer or the interior of the refractory having different properties from those of the outer layer. An example of the type referred to is a glass contact refractory having an outer layer or surface of exceptionally high resistance to the corrosion by molten glass and an inner layer having inferior resistance to corrosion but having superior thermal properties such as resistance to heat shock or low heat conductivity. A similar example is a composite glass contact refractory having exceptional resistance to heat shock but the components of which individually have little or no resistance to heat shock. By making refractories in composite form, compositions may be employed which are too expensive, or unsuitable because of their composition or properties, to be used individually for the entire refractory and composite articles may be made having properties not possessed by the individual components.

Although it has been proposed heretofore to make composite refractories by dipping, spraying and by other methods, such methods have not proved satisfactory or the articles produced are not suitable for the uses for which they have been made. For instance, composite integral refractories made by dipping are apt to spall, the outer layer or surface separating from the inner layer or interior because of an imperfect bond between the layers. Whatever the reasons, the use of composite refractories up to the present time has been inconsequential.

The object of this invention is to provide a novel method of forming composite refractories by slip casting whereby the difficulties in prior methods may be largely or entirely overcome, and composite refractories of improved character may be obtained.

Broadly considered, the method of the present invention involves slip casting a batch of the composition desired for the outer or surface layer of the part to be produced in a water absorbing mold, such as plaster of Paris, permitting this slip to set or jell until the outer or surface layer of the desired thickness is deposited on the surfaces of the mold, and then draining the surplus slip from within the shell thus formed. This surface layer may form both the outside surface and the inside surface of hollow bodies, the cavity of the shell being formed between these layers. A casting batch for the inner layer or interior of the part is now cast within the previously cast shell, preferably while said shell remains moist on its inside drain-formed surface, and after the slip cast in this second operation has set and the part is sufficiently strong for handling, it is removed from the mold, dried and fired in the usual manner.

By employing this procedure, the above and other advantages of composite refractories may be obtained. Furthermore, an excellent bond can thus be obtained between the outer layer and the inner layer or interior, this bond being so strong, in fact, that the layers will not separate in service and cannot be broken apart without breaking the weaker material. The excellence of the bond is attributed to the fact that the inner surface of the shell may be sufficiently moist when formed by draining. In addition, the thickness of the outer or surface layer may be controlled and if desired or required a uniform thickness obtained which cannot be done, or can be done only with great difficulty or skill, by dipping or spraying.

The novel method of this invention also permits the use of refractory materials which have not been successfully combined heretofore in the production of composite refractories and permits slip casting certain types of refractory materials in porous molds which heretofore could not be formed into refractory articles by slip casting in porous molds because of their tendency to adhere to or clog the pores of the mold, this preventing withdrawal of the castings from the molds or preventing the escape of water from within the casting. Also, non-plastic materials which cannot be deflocculated and made into a slip and which also adhere to porous molds may be cast, utilizing suspensions of such materials and casting them in a shell as above explained.

In order that the invention may be more fully understood and its various advantages appreciated, the method will be described in its application to the production of articles for contact with molten glass, it being understood, however, that the method may be employed for making various other types of refractory articles and that variations may be made in the performance of the method without departing from the scope of the appended claims. In describing these examples of the method, reference is made to the accompanying drawings in which:

Figs. 1 to 5, inclusive, are views in vertical

section illustrating several steps in slip casting a composite tube of the type used in glass feeders, Fig. 6 being a view in top plan of the mold shown in Figs. 1 and 3; and

Figs. 7 to 12, inclusive, are views in vertical section illustrating several steps in slip casting a spout for a glass feeder.

Referring to Fig. 1, there is shown at 13 a plaster of Paris mold having a top 14 and containing a core 15 for forming a feeder tube. The top 14 is provided with a pair of funnels 16 through which slip 17 is poured of the desired composition or character to form the outer or surface layers of the tube. This slip is allowed to stand until it is set to the desired thickness, as indicated at 18, Fig. 2, on the inner surfaces of mold 13 and on core 15 as the result of the absorption of water by the plaster of Paris mold. The surplus slip now is drained from within the inside and outside walls of the shell thus formed as by tilting or inverting the mold into the position shown in Fig. 2.

The mold 13 is now returned to upright position, as shown in Fig. 3, and a slip 19 for the interior of the body is poured into the shell formed by the outer or surface layers 18 and allowed to stand until jelled or set as a result of the removal of water through the outer or surface layers 18 as it is absorbed by the porous mold. An excess of slip is allowed to remain in the funnels 16 or additional slip is poured into the funnels to compensate the shrinkage which occurs during the setting of the interior material.

When the interior slip 19 has sufficiently set, the top 14 of the mold is removed, the core 15 is withdrawn, and the composite tube indicated at 21 is removed from the mold as by turning the mold upside down and raising the mold, leaving the tube 21 standing on a suitable support (not shown). Upon further drying, the tube is placed in a kiln and fired in the usual manner.

Experience has shown that composite refractory tubes produced in the above manner from certain compositions, examples of which are given below, give unusually good performance in service, there being no tendency of the outer layer or surface to spall or scale from the interior and such tubes having high resistance to corrosion and heat shock which are very desirable properties in this type of article.

Considering now the illustration of the method in Figs. 7 to 12, there is shown a mold for forming a spout which comprises a bottom portion 22 which forms the inside of the spout, an upper L-shaped portion 23 which forms the bottom and front of the spout, and a side portion 24 which forms the rear side of the spout, these parts being clamped together by straps indicated at 25, and a plate 26 on the side portion 23 of the mold, through which plate extend screw bolts 27, nuts 28 on these bolts serving to tighten the straps to hold the parts of the mold together.

Located within the mold is a core 29 for forming an orifice in the spout and at opposite sides of the upper part 23 of the mold inlets 31 and 32 are formed, these containing funnels 33 and 34 through which slip is poured to make the casting. At one side of the bottom portion of mold part 22 a drain opening 35 is provided into which fits a plug 36.

Adjacent the core 29 and projecting into an upwardly extending annular portion 37 of the mold cavity are cores 38 for forming vents in the outer layer of the casting as explained below.

It will be observed that the cavity of the mold is shaped to form a spout in inverted position, the opening or orifice through the spout being formed by the core 29, a flange or projection being formed on the bottom of the spout around the orifice by the upwardly projecting cavity portion 37 and a projection or curb being formed on the inside of the bottom of the spout around the orifice by a recess or cavity 39 in mold part 22.

In casting a spout, slip of the desired composition and properties for the outer or surface layer is poured through funnels 33 and 34 until the mold cavity is filled and this is allowed to stand until the outer or surface layer of the desired thickness is jelled or set on the walls of the mold cavity, as indicated at 42. The excess slip is now drained from within the shell thus formed by removal of plug 36. By providing the recess 39 in the mold part 22 the slip for the outer layer forms the thick curb portion 43 of the spout because of the fact that the slip cannot flow from the recess 39 during the draining operation. This has the advantage that the curb of the spout may be formed largely or entirely of material having exceptional resistance to corrosion and erosion.

When the excess slip has been drained from within the shell or from between the spaced surface layers 42, the cores 38 are removed, this leaving holes 38*a* in the layer 42 which is deposited on the top of the upwardly projecting cavity portion 37, these holes communicating with holes 38*b* in the mold part 23 previously occupied by cores 38. Slip indicated at 44 for the interior of the spout is now poured through the funnels 33 and 34 until the shell is filled and the slip rises in the funnels. As the mold cavity is filled, air which otherwise would be trapped in the upward projection 37 of the mold cavity is vented through the holes 38*a* in the layer 42 and through the holes 38*a* in which the cores were mounted. This venting of the air is necessary to avoid bubbles or pockets in the flange or projection formed on the bottom of the spout by the cavity portion 37 of the mold. These bubbles would constitute imperfections in the spout which would impair its usefulness or prevent its use altogether.

Slip is maintained in the funnels 33 and 34 as long as is necessary to feed the shrinkage within the mold cavity and when the interior material or slip 44 has set, the core 29 is removed as also are funnels 33 and 34, the mold then being inverted as shown in Fig. 10 to place the spout 45 right-side up and parts 22 and 23 separated from the casting and from the mold part 23. To remove the spout 45 from the mold part 23, this part with the spout therein is turned on end and rested on a support 46 whereupon the mold part 23 may be withdrawn from over the spout. See Fig. 11.

In order to support the spout 45 during the removal of the mold part 23 therefrom and during the drying of the spout, the spout preferably is supported by a spring cushion device indicated at 47 and comprising a tubular base 48 containing a plunger 49 which has a rounded head portion 51 fitting within the rounded front end portion of the spout and yieldingly held against the spout by spring 50 which is compressed between a shoulder or base 48 and the head 52 as

shown. Upward movement of the head **52** is limited by a pin **53** which passes through the plunger **49** of the cushioning device and the ends of which pin work in slots **54** in the reduced upper portion of the tubular base **48**.

It will be seen that the cushioning device will support the spout and prevent deformation thereof during the drying of the spout and will yield as shrinkage occurs in the spout while holding the spout in the shape in which it was cast. The expansion of the device to sufficient extent to distort the spout is prevented by pin **53**. The spring **52** is so designed as to yield with the shrinkage of the spout, yet is strong enough to support the spout and prevent its deformation by the action gravity or by drying shrinkage or by both of these effects.

It will be understood that projections on the bottom of the spout where the slip entered the mold and where the slip rose in the vents are removed and the spots smoothed over and, if desired, covered with material having the same composition and properties as that forming the outer or surface layer **42**.

The following table contains examples of batches for composite bodies identified by the numbers 1 to 5, inclusive, each number being opposite two lines which contain respectively the batches for the outer layer or surface and the inner layer or interior of the composite bodies. Where the mesh size of an ingredient is specified, it will be understood that all or substantially all of the ingredient passes a screen of the given size together with a large proportion of fines.

Batches for composite bodies

		Tabular corundum, 80-mesh	Raw kyanite, 30-mesh	Fused silica, 8-mesh	E. k. k. grog, 8-mesh	E. k. k. grog, 30-mesh	E. k. k. grog, 100-mesh	Sillimanite, 8-mesh	Powdered aluminum	Georgia white kaolin	K. t. ivory ball clay	Total
									Grams			
1	Surface	80								10	10	100
	Interior				35	35				15	15	100
2	Surface	80								10	10	100
	Interior		30	15	25					15	15	100
3	Surface	80								10	10	100
	Interior						90		10		10	100+
4	Surface	80								10	10	100
	Interior	100										100
5	Surface	80								10	10	100
	Interior							80		10	10	100

The above batches excepting those for the interiors of bodies numbers 3 and 4 are compounded by the usual methods of grinding, mixing and blunging, and formed into a slip by use of a deflocculant, ammonia being preferred as the deflocculating agent because it volatilzes and does not clog the pores of the mold and because it does not leave a deleterious residue in the refractories as is the case with other deflocculants, the residue of which reduce the resistance of the bodies because of their fluxing action.

The batches for composite bodies numbers 1 and 2 result in articles having exceptional resistance to corrosion and to heat shock when brought into contact with molten glass, although in both bodies the surface layer has poor resistance to heat shock and the interior of body number 1 has little or no resistance to heat shock. It will be understood that the batch for the surface layer is first made into a slip, cast in the mold and a shell formed by emptying the excess slip after which the shell is filled with slip made from the batch for the interior.

Composite body number 3 is an example of a body having a relatively dense refractory surface or surface layer and a porous interior having good insulating properties which is protected and reinforced by the surface layer. The porosity of the interior results from the reaction of the ammonia used as deflocculant upon the powdered aluminum. This generates gas (hydrogen) which is beaten into the slip by stirring or blunging to form fondu. The gas is expelled in drying and firing leaving pores in the material and the aluminum compound formed by the reaction decomposes leaving a small amount of aluminum oxide in the material. The amount of aluminum powder employed may be varied between wide limits, depending upon the degree of porosity desired. The grog or other non-plastics should be finely ground for best results. First, the surface or surface layer is cast and a shell formed as described above, after which the fondu is cast in the shell. The shell prevents the fondu from clogging the pores of the plaster of Paris mold yet permits water in the fondu to be absorbed by the mold so that the fondu sets sufficiently for handling and firing. The shell also prevents the fondu from so adhering to the mold as to prevent withdrawal of the casting as it would do if cast in direct contact with the mold.

Similarly, by first casting the batch for the surface of composite body number 4 and forming a shell, non-plastic material, tabular corundum being an example, may be cast in the form of a suspension within the shell. This shell is sufficiently thick and strong in the green state to support the non-plastic interior for handling and firing. The interior is bonded by firing the article to an unusually high temperature, say 3000° F. This permits the production of articles, the interiors of which consist of materials or ingredients of non-plastic character and in a relatively pure state. Thus, the interior of body number 4 consists of pure alumina and is therefore highly refractory because its refractoriness has not been lowered by the addition of other materials or clays. Here again, the shell prevents the non-plastic material from so adhering to the mold as to prevent withdrawal of the casting as it would do if cast in direct contact with the mold because of the sharpness of the particles.

Composite body number 5 is an example of a composite refractory, the outer or surface layer containing a large amount of corundum and the interior a large amount of sillimanite, such as the mineral sillimanite, or andalusite, or dumortierite, or natural or synthetic mullite. Thus, a single body may be produced having the properties of both the composition for the outer layer and the composition for the interior.

The various bodies referred to above are fired to 2400° F. or higher. Body number 2, and other

bodies containing kyanite, should be fired to 2600° F. or above to remove the expansion from the kyanite.

Having described my invention, what I claim is:

1. In the method of forming a composite refractory body comprising an outer layer formed integrally with the interior of said body, the steps comprising deflocculating a clay batch having the composition and properties desired for the outer layer, casting the slip thus formed in and filling a water-absorbing mold having surfaces for forming all exterior surfaces of said body except where the slip enters the mold, allowing the slip to set in the mold until a partially closed shell of the desired thickness is formed over all surfaces of said mold used to form said body, draining the surplus slip from within said partially closed shell, filling the partially closed shell thus formed, and while its interior drain-formed surface is still moist, with sufficient slip of the desired composition and properties for the interior of the body to fill said shell, which slip is held out of contact with any mold part by said shell, permitting moisture from this additional slip to be absorbed by said mold solely through said shell, and removing the composite body from the mold.

2. In the method of forming a refractory article from material incapable of being slip cast in direct contact with a porous mold because of its tendency to adhere to said mold, the steps comprising casting a deflocculated clay slip in a water-absorbing mold, allowing the slip to set in the mold until a shell is formed of the desired thickness, draining the surplus slip from within said shell, filling the shell, while its interior drain-formed surface is still moist, with a slip of said adherent material, permitting moisture from said last named slip to be absorbed by said mold through said shell while said shell prevents said adherent material from adhering to said mold, and removing the composite body thus cast from the mold.

3. In the method of forming a refractory from non-plastic material incapable of cohering sufficiently for handling when slip cast, the steps comprising casting a deflocculated clay slip in a water-absorbing mold, allowing the slip to set in the mold until a shell is formed of the desired thickness and green strength to retain its shape when filled with said non-plastic material, draining the surplus slip from within said shell, casting a suspension of the non-plastic material in said shell while the interior drain-formed surface of said shell remains moist and filling the shell therewith, permitting moisture from said suspension to be absorbed by said mold through said shell, and removing the composite body from the mold.

4. In the method of forming a refractory having good heat insulating properties, the steps comprising casting a deflocculated clay slip in a water-absorbing mold, allowing the slip to set in the mold until a layer or shell of the desired thickness is formed, draining the surplus slip from within said shell, generating gas in a second slip to form fondu containing pore-clogging material, casting said fondu in and against the drain-formed inner surface of said shell while said surface remains moist and filling said shell with said fondu, allowing the fondu to set by permitting water therein to be absorbed by said mold through said shell while absorption of the pore-clogging material by said mold is prevented by said shell, and removing the body from the mold.

5. In the method of forming a composite refractory body comprising an outer refractory layer formed integrally with the refractory interior of said body, the steps comprising casting a deflocculated clay slip of the composition and properties desired for the outer layer in a water-absorbing mold, allowing the slip to set in the mold until a shell of the desired thickness is formed, draining the surplus slip from within said shell, casting within, and against the drain-formed surface of, the shell thus formed and while said shell is still moist on its inner surface, sufficient slip of the desired composition and properties for the interior of the body to fill said shell, permitting this additional slip to set, and removing the composite body from the mold.

6. In the method of forming a composite refractory body comprising an outer layer formed integrally with the interior of said body, the steps comprising casting a deflocculated clay slip of the composition and properties for the outer layer in a partially closed water-absorbing mold having an upwardly projecting portion in the cavity thereof, allowing the slip to set in the mold until a partially closed shell of the desired thickness is formed, forming vent holes in the part of the shell formed in the upwardly projecting mold cavity portion, withdrawing the surplus slip from within said shell, casting within and filling the shell thus formed with slip of the desired composition and properties for the interior of the body while venting the upwardly projecting portion of the shell through said vent holes therein, permitting this additional slip to set, and removing the composite body from the mold.

7. The method of forming a hollow composite refractory comprising a surface layer on the inside and outside thereof formed integrally with the interior of said refractory, which comprises casting a slip of the composition and properties desired for the surface layer in a water absorbent mold and around a water absorbent core for forming the inside of the body, allowing the slip to set in the mold until a hollow walled shell is formed constituting the inside and outside surface layer of the refractory, of the desired thickness, withdrawing the surplus slip from the hollow walled shell, and casting within the walls of said shell slip of the desired composition for the interior of the refractory, permitting this additional slip to set, and removing the composite body from the mold.

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