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2,048,319

METHOD OF PRODUCING CAST REFRACTORY AND SIMILAR ARTICLES

Filed Feb. 25, 1933

2 Sheets-Sheet 1

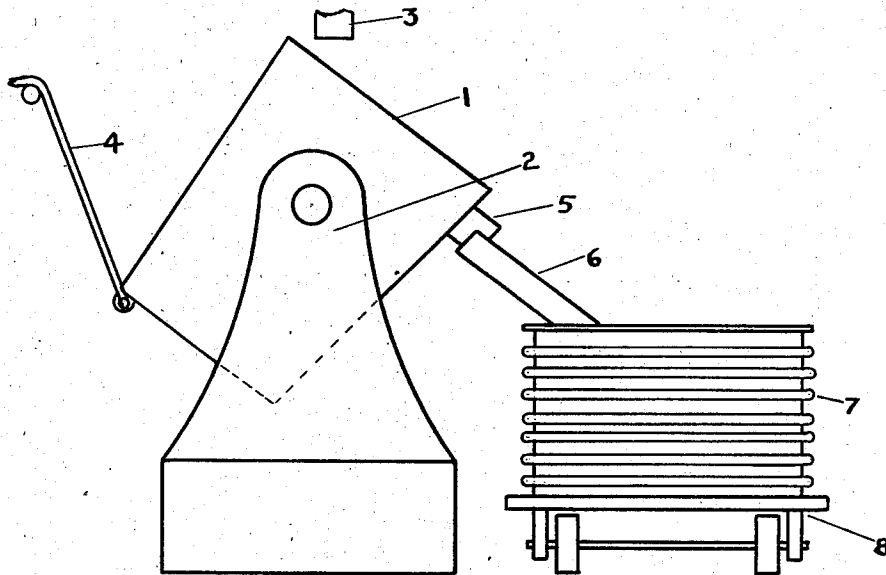


FIG. 1

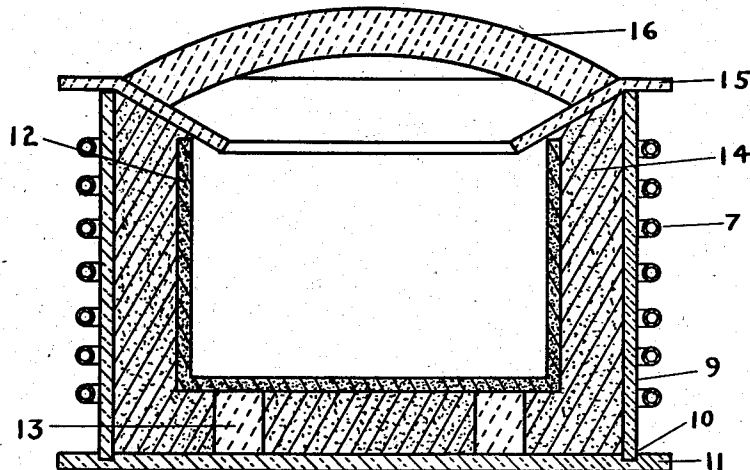


FIG. 2

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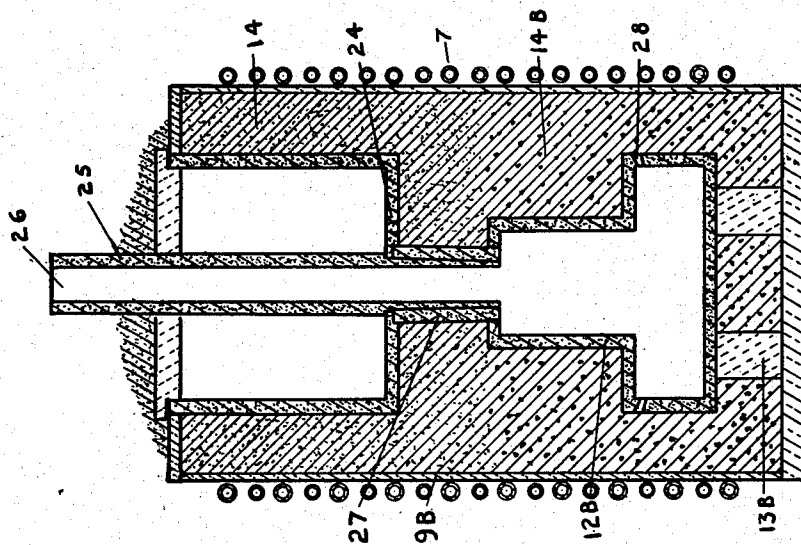


FIG. 4

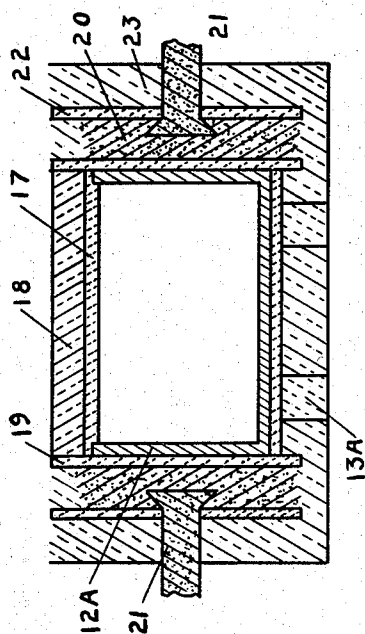


FIG. 3

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METHOD OF PRODUCING CAST REFRACTORY AND SIMILAR ARTICLES

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Application February 25, 1933, Serial No. 658,534

6 Claims. (Cl. 49—79)

This invention relates to an improvement in the method of producing cast refractory and similar articles from molten oxides and the like, and is particularly concerned with the method of molding and cooling such cast articles.

In the manufacture of glass tank blocks and other refractories as hitherto practiced, the component materials have been fused in an arc type furnace and from thence tapped into a sand mold or the like and the casting then covered with infusorial earth or the like to cool. It has, however, been found that this practice produces two types of defects in the castings so made. First, it is very difficult to overcome the tendency to form hollow "pipes" extending down toward the center of the casting from its upper surface. Second, regardless of this piping tendency, it has been found that blocks of the size ordinarily used for glass tanks, and even smaller pieces, frequently crack into pieces perhaps four inches on a side as a result of cooling and shrinkage of the outside of the piece at a more rapid rate than the inside.

In order to overcome this difficulty, we have attempted to preheat the molds for the blocks in a muffle or similar furnace. We have, however, experienced such difficulty in thus handling the molds that we have concluded that in order to secure the advantages of such a method it would be necessary to build a tunnel kiln in which the molds would be placed on cars, preheated, filled through a suitable opening in the kiln, and then cooled slowly while still in the kiln.

The interior of the molds may be preheated electrically by inserting an electrical resistance heater made of siliconized or recrystallized silicon carbide rods (which may be made by methods described in detail in the U. S. Patent #1,906,853 to Hediger and in the U. S. Patent #1,906,963 to Heyroth) within the mold while supporting the resistor on the mold cover, and bringing the temperature up to the desired point by passing electric current through the resistor. This method of preheating the interior of the mold directly permits molds to be made of cheap material, as for instance, a backing of sand which may if desired be faced with some more refractory material. It offers a considerably easier way of preheating the interior of the mold than is possible by inserting the whole mold in a furnace. It does not, however, permit as close control of the rate of cooling as is desirable, and as we have found possible by means now to be described.

An economical and easily workable solution of both the mold preheating and annealing problems

has been found wherein molds made of refractory materials, such as graphite or silicon carbide, have been heated electrically either by induction or resistance heating, the former being somewhat preferable on account of its greater flexibility of operation and mobility of apparatus. In this way it is possible to preheat the mold to any desired degree, hold it at a desired temperature to fill it, and retard cooling to a degree permitting the difficulties encountered under the old method to be readily overcome.

In the accompanying drawings, Figure 1 is a diagrammatic view of an inductively heated mold set on a car, into which molten material is being poured from a tilting arc furnace;

Figure 2 is a vertical section through the center of a mold such as we use, placed in a coil for inductive heating;

Figure 3 is a vertical section through the center of a similar mold arranged for resistance heating; and

Figure 4 is a vertical section through the center of a furnace in which both the mold and the material to be cast are heated inductively.

In the production of fused alumina, mullite, spinel, or the like to be cast into blocks for use as refractories or otherwise, we may use an arc furnace of the ordinary type used in the production of fused alumina abrasives in which a pot of bauxite or like material is fused in a water cooled iron shell and thereafter we tap or pour this fused material into our molds.

Figure 1 shows diagrammatically such an arc furnace 1 mounted in trunnions 2 and provided with electrodes 3 which in the drawings are indicated as raised out of the pot to permit pouring. The pot is tipped by means of a cable 4 in such a way that the molten material runs out of spout 5 and down an inclined trough 6 into the mold contained in an inductively wound coil 7, one or more of which molds are mounted on a truck 8. When one mold is filled, the cable 4 is slackened off while another mold is placed in position and the second one filled in a similar manner, spout 5 being cleared of congealed material as often as need be by the use of a crowbar. Other tapping arrangements can obviously be used in place of the tilting of the pot furnace.

Figure 2 shows in detail a section through the mold shown in Figure 1 at a time when the mold is empty and is arranged for preheating. The inductively wound coil 7 has water circulating through it, preferably impelled by suction rather than by positive pressure in order that chances of an explosion may be minimized. The water

connections and electrical connections to this coil are of a type well known to users of induction furnaces of the Northrup type and hence have not been illustrated in detail. Within the coil there is a cylinder 9 of fused quartz, zircon or other suitable material mounted in grooves 10 in a composition asbestos board 11. Inside this cylinder the mold 12 is centrally supported upon blocks 13 made of silicon carbide or other suitable refractory. The mold is made of graphite and may be lined or coated with a silicon carbide mixture or other suitable compound to aid in resisting oxidation. The space surrounding the mold is filled with a thermal insulator such as lamp black 14. Above the crucible 12 and cylinder 9, a refractory collar 15 is placed in order to protect the various parts of the coil in the furnace from splashing molten oxides at the time that the mold is being filled. During the preheating stage, a cover 16 of insulating brick is placed over the mold in order to conserve heat. When the molten material is ready and the mold has been sufficiently preheated, the latter is placed in position adjacent the furnace containing the molten material, cover 16 removed and the molten material poured into the mold to the desired depth. The guard ring 15 is then removed and a graphite cover, not shown, is placed loosely across the top of the crucible 12 with insulating material such as lamp black 30 placed on top of this cover. A second cover, generally similar to cover 16, is then placed on the unit as a whole in order to reduce oxidation and to conserve heat.

The coil with the crucible within it is then moved along so that another mold in another coil may be filled, etc.

The temperature of the mold which has been filled is maintained by continuing to induce current into the walls of the mold. It is, however, gradually allowed to cool off at such a rate that practically the entire cast block solidifies simultaneously. In this way the upper surface of the poured material is kept sufficiently fluid to prevent serious cracking and after the whole block has solidified it is cooled very gradually so that the temperature gradient from inside to outside does not exceed 50° C. per inch until the temperature is sufficiently low for the block to be removed from the mold. The mold should, preferably, be tapered outward slightly toward the top so that the block can be removed without the necessity for disassembling the mold.

Figure 3 illustrates an alternative construction which, while serviceable, is somewhat more cumbersome to manipulate, particularly where a large number of molds are to be handled simultaneously. In accordance with this construction, the mold 12a is provided with a refractory cover 17 and an insulating cover 18, the entire assembly being mounted in a silicon carbide cylinder 19, which is illustrated as surrounding the mold so closely as to aid in supporting it. Both the mold and this cylinder should be tapered outward slightly toward the top to facilitate the removal of the cast piece. In this arrangement the heat is generated by passing current through granular graphite 20 surrounding the cylinder 19, current being introduced at opposite ends of the furnace through graphite electrodes 21. The granular graphite is enclosed on the outside by an additional silicon carbide cylinder 22 and silicon carbide fire-sand 23 is used to thermally insulate the outside of the entire assembly. Other suitable materials might obviously be sub-

stituted for those mentioned if desired. In utilizing this type of equipment, the covers are removed while the mold is being filled and are then replaced in the position shown. Otherwise, the operation is practically similar to that described in connection with Figure 2.

As an alternative method of procedure, the material which is to be made into a solid block may be placed directly in a mold as shown in Figure 2 or 3 in granular form and melted directly therein, cooling being done as above described.

Figure 4 shows an alternative device in which the material is melted in a crucible 24 arranged to be inductively heated by the surrounding coil 15 which is illustrated as separated from the thermal insulating material within it by a mica sheet 25. Connected to this crucible is mold 12B arranged to be similarly heated. Plug 25, which is provided with a vent 26 along its axis and is tapered slightly at the bottom, is provided to prevent premature flowing of the molten material from the crucible into the mold. Collar 27, which is split vertically into two or more sections, is used to connect the crucible and the mold. As the plug 25 is raised, the molten material contained in the crucible flows down around the outside of plug 25 into the mold and the air from the mold escapes through vent 26. Small vents 28 provided near the corners of the mold provide for the escape of any entrapped air in those portions of the mold, but are not large enough for molten material to flow into them. The joints between the various pieces of graphite are sealed before the furnace is started by means of a paste made of powdered graphite and a temporary binder such as dextrin. The mold is illustrated as surrounded by granular carbon 14B rather than by lamp black 14 as is the crucible since the carbon is a poorer insulator and it is desirable that the mold be slightly cooler than the container from which the material is fed to it. The amount of material originally placed in the crucible is so adjusted that when the mold is filled all the molten material is out of the crucible and its upper surface is within the connecting passage between the mold and the crucible where it remains molten and fills in the center of the piece below as shrinkage occurs; thus giving added protection against the formation of cracks and giving a solid cast piece. The mold may be readily separated from the collar after casting has been completed, although it is desirable to allow the coil and its contents to remain undisturbed and cool gradually as indicated previously.

For the purposes of inductively heating the molds, we utilize a coil to which rapidly alternating potential is applied, the number of alternations being from 1,000 to 50,000 per second.

As noted above, we find that one of the principal requirements for securing cast blocks free from cracks is to maintain as small a temperature gradient as possible from the center to the outside of the cast piece. This is particularly vital during the stage where the entire block is solidifying, but even after that it is necessary to cool the blocks so slowly as to maintain very small temperature gradients. At the moment of solidification, the temperature gradient of 50° C./inch should not be materially exceeded. This value may be determined in test runs by measuring the thickness of shell between a spot on the outside of the shell where the temperature has been measured and the inner edge of the

shell which is left when the material composing the center of the casting is suddenly allowed to flow out, the inner surface so left being at a temperature corresponding to the freezing point of the material. In order to maintain such small temperature gradients, it is necessary that the mold continue to be heated after the material is poured into it, although at a decreased rate. It is readily possible to manipulate a series of coils and molds with a single alternator in such a way that the temperature gradient in each is controlled to the desired amount without interference with the others. The mechanism for such control is well known to the art and we have not, therefore, felt that it is necessary to describe it as it constitutes no part of our invention.

It is somewhat more difficult to estimate the temperature gradient in the piece after the middle has solidified, although we believe that a gradient not over 100° C./inch is the maximum which can be safely permitted at any time during the cooling of the cast piece.

We have further found that in case the temperature gradient becomes so great as to cause the piece to crack, it is sometimes possible to heat the mold to a temperature which causes the piece to again coalesce. This, however, is a very slow process and it is in general better to prevent the formation of cracks rather than to try to cure them after they have formed.

Having thus described our invention, what we claim is:

1. Apparatus for producing solid refractory castings comprising a graphite crucible arranged above a graphite mold, a duct connecting the crucible with the mold, a primary coil distributed around the crucible and mold for the passage of a high frequency alternating current which causes heating of both the crucible and the mold, a hollow plug extending through the crucible and disconnecting the crucible from the mold when the plug is in its lowest position, and permitting the flow of molten material from the crucible to the mold in the raised position of said plug while efflux of air takes place from the center of the mold through the hollow plug, and small orifices in the sides of the mold which permit efflux of gas from the sides of the mold without substantial loss of liquid.

2. The art of casting refractory articles in close succession which comprises mounting a series of electrically conducting molds so that each is surrounded laterally by thermally insulating material and also by a primary induction coil, heating each mold by induction and passing it adjacent to a supply of molten refractory when the temperature has reached a predetermined value, filling the mold from the supply of molten refractory, and gradually diminishing the heating after the mold has been filled with molten refractory and covered with insulating material.

3. Means for casting dense refractory articles

comprising a conducting crucible mounted above a conducting mold, a primary induction coil surrounding the crucible, a primary induction coil similarly surrounding the mold, a hollow cylinder connecting the bottom of the crucible with the top of the mold, and a second hollow cylinder fitting into the first hollow cylinder and projecting up through the crucible to shut off the connection between the crucible and the mold when said second hollow cylinder is in its lowest position, whereby slight elevation of the second cylinder permits flow of molten refractory into the mold and also permits outflow of air from the unfilled portion of the mold through said second cylinder as the mold is being filled.

4. The steps in the method of casting refractory articles which comprise mounting an electrically conducting crucible containing refractory material above an electrically conducting mold, heating the conducting bodies by subjecting them to the same rapidly varying magnetic field until the refractory material has melted and subsequently thereto, and transferring the molten material by downward flow around a central vent through which the displaced air flows during the process of casting.

5. The steps in the method of casting refractory articles which comprise mounting an electrically conducting crucible containing refractory material above an electrically conducting mold, heating the conducting bodies by subjecting them to similar rapidly varying magnetic fields from a common source until the refractory has melted and for some time thereafter, transferring the molten material by downward flow adjacent a central vent through which the displaced air flows during the process of casting, and dissipating the heat slightly more rapidly from the mold than from the crucible.

6. Apparatus for casting successively a series of articles composed of high melting refractory, said apparatus comprising an electric furnace mounted for pouring such refractory material in molten condition, a series of molds mounted for transportation to and from the outlet of said furnace, each mold having a graphite receptacle lined on the inside with oxidation resisting material, an insulating layer of finely divided packing material beneath said receptacle and around the sides thereof, a primary induction coil mounted outside of said insulating layer, a refractory collar covering the insulating layer and projecting into the mold to catch ejected refractory material, and an insulating cover supported on said collar and sealing the mold on its upper side, whereby each mold of the series can be preheated prior to being filled with molten refractory and heated at a gradually decreasing rate subsequent to the pouring of the refractory.

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