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J. A. UPPER

2,601,647

INGOT MOLD

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FIG. 1

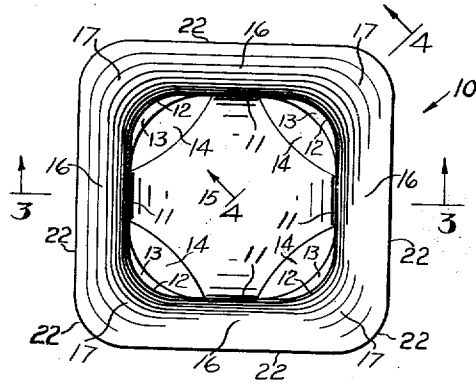


FIG. 5

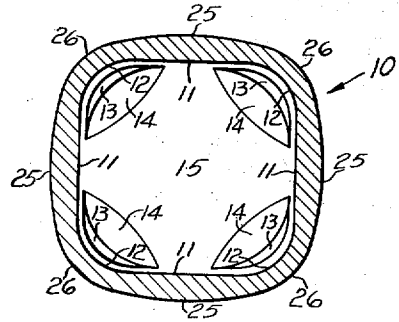


FIG. 6

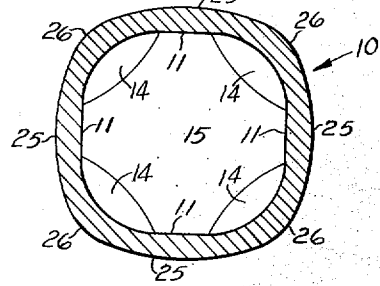


FIG. 2

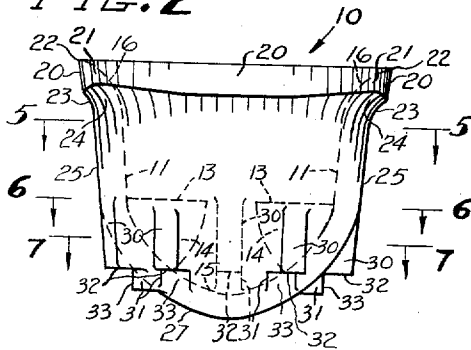


FIG. 7

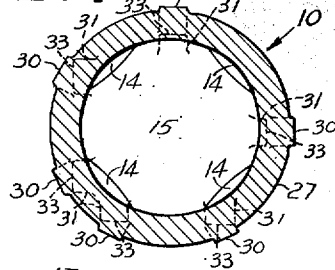


FIG. 3

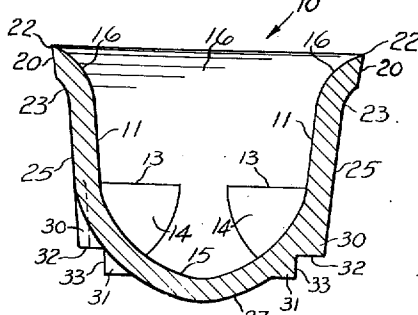
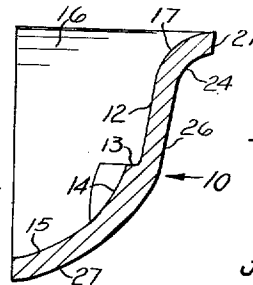


FIG. 4



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INGOT MOLD

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9 Claims. (Cl. 49—65)

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The invention relates to ingot molds particularly for casting molten refractory materials, for example molten oxides of which aluminum oxide is a good example. Molten aluminum oxide has a temperature on the order of 2000° C. This application is a continuation in part of my copending application Serial No. 634,993, filed December 14, 1945, now abandoned.

One object of the invention is to provide an ingot mold capable of receiving and retaining a charge of molten alumina without melting or fracturing. Another object of the invention is to provide an ingot mold into which molten alumina may be poured and from which the ultimately solidified ingot of alumina may be readily discharged simply by inverting or partly inverting the mold. Another object of the invention is to provide an ingot mold of such material and shape that it can withstand being filled with molten alumina and retaining same until solidification thereof many times before it is so burned that it has to be discarded. Another object of the invention is to provide an ingot mold having one or more of the characteristics indicated above and which also draws the heat from the molten alumina at a rapid rate thus as quickly as may be to freeze the alumina into a solid ingot for use, after crushing and grading etc., as loose abrasive grain or for the manufacture of grinding wheels and coated abrasive products.

Another object of the invention is to provide an ingot mold of one or more of the characteristics indicated which shall not readily spall. Another object of the invention is to provide an ingot mold of one or more of the above characteristics which itself can be readily cast of cast iron. Another object of the invention is to provide an ingot mold of rugged characteristics which can stand rough handling. Another object of the invention is to provide an ingot mold for receiving molten refractory material of very high temperature which shall be safe so as not to endanger workmen nearby. Another object of the invention is to provide an ingot mold of the type indicated which can be used in several different positions so that the side exposed to the greatest heat during the pouring operation will not always be the same. Another object of the invention is to provide ingot molds of the type indicated which can contact each other along a line of each at the top thereof, whereby a plurality of such ingot molds may come in contact with each other without spilling the molten contents or fracturing the molds and whereby a continuous stream of molten material may fill a plurality of molds, one after

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the other, as they are slowly pushed under the stream. Another object of the invention is to produce an alumina ingot of coarse crystalline structure.

Other objects will be in part obvious or in part pointed out hereinafter.

In the accompanying drawings illustrating one of many possible embodiments of an ingot mold constructed in accordance with this invention,

Figure 1 is a plan view of my ingot mold in its now preferred form.

Figure 2 is a side elevation of the ingot mold.

Figure 3 is a vertical sectional view of the ingot mold taken along the line 3—3 of Figure 1.

Figure 4 is a vertical sectional view taken along the line 4—4 of Figure 1.

Figures 5, 6 and 7 are horizontal sectional views taken respectively along the lines 5—5, 6—6 and 7—7 of Figure 2.

The ingot mold 10 according to the invention is preferably an integral piece of cast iron or of cast steel. The choice between cast iron and cast steel is largely an economic choice as both of them are satisfactory. It may be of a size to hold 300 to 400 pounds of molten alumina when filled nearly to the top but the size, of course, can be varied and other sizes of molds may be preferred for the casting of other materials. In the case of an ingot mold having a capacity of 300 to 400 pounds, the wall thickness should be of the order of two inches.

The ingot mold 10 has four interior equilateral pyramidal surfaces 11 forming a truncated pyramidal angle with the apex below the bottom of the ingot mold. These surfaces 11 are tangent to and joined by four interior conical corners 12. These conical corners 12 end in four ledges 13 which in plan view have the shape of a new moon and are all at the same level. Extending downwardly from the four ledges 13 are four concave spheroidal surfaces 14 merging with the pyramidal surfaces 11 and into a spheroidal bottom surface 15 having a vertical axis and an apex at the center of the bottom. All of these interior surfaces are symmetrical about the vertical axis of the ingot mold 10 which vertical axis passes through the apex of the spheroidal bottom surface 15.

The four interior equilateral pyramidal surfaces 11 are tangent to and merge into convex cylindrical surfaces 16 while the four interior conical corners 12 are tangent to and merge into negative spheroidal surfaces 17 which are tangent to and merge into the convex cylindrical surfaces 16. By "negative spheroidal" I mean "saddleback,"

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in other words a surface which is convex in one section and concave in a section perpendicular to the first section. These negative spheroidal surfaces 17 are convex in diametral vertical section and concave in horizontal section.

Starting at the top, the ingot mold 10 has four exterior equilateral truncated pyramidal surfaces 20 which are tangent to and merge into four exterior truncated conical surfaces 21. The intersection of the surfaces 16 and 20 and of the surfaces 17 and 21 forms a continuous lip 22 for the ingot mold 10.

Continuing with the description of the exterior of the ingot mold 10, the four equilateral truncated pyramidal surfaces 20 merge into but are not tangent to four negative spheroidal surfaces 23 while the four exterior truncated conical surfaces 21 merge into but are not tangent to four negative spheroidal surfaces 24. The surfaces 23 are concave in all vertical sections with a small radius of concavity and are convex in all horizontal sections with a large radius of convexity. The surfaces 24 are concave in all vertical sections and convex in all horizontal sections and have a small radius of convexity as well as a small radius of concavity.

The surfaces 23 merge into exterior conical surfaces 25 of gentle curvature while the surfaces 24 merge into exterior conical surfaces 26 of sharp curvature and these surfaces 25 and 26 on the outside of the ingot mold 10 merge without break into each other. These surfaces 25 and 26 also merge into an exterior spheroidal bottom surface 27 having the same vertical axis as the surface 15 and having an apex right below the apex of the surface 15.

Projecting from the surfaces 25, 26 and 27 are six truncated prism projections 30 and at a lower level projecting from the bottom surface 27 are six truncated prism projections 31. The six truncated prism projections 30 have bottom surfaces 32 while the six truncated prism projections 31 have more or less vertical surfaces 33 which may be described as upstanding surfaces. The surfaces 32 and 33 form dihedral angles. As shown in Figure 7 the projections 30 and 31 are arranged in a 2, 2, 1, 1 order around the bottom of the ingot mold 10 for a purpose which will hereinafter appear.

The foregoing geometrical shapes are, in many cases, approximate shapes and can be modified somewhat without sacrificing the beneficial features of the invention. It will be seen that in plan view as shown in Figure 1 the ingot mold is approximately square and yet has rounded corners. These molds are intended to be mounted on small rail cars, three molds to a car being the usual arrangement and the lip 22 of one mold should contact the lips 22 of adjacent molds on opposite sides of the square. The cars are of such dimensions that an end mold of one car contacts an end mold of the next car. Thus, when pouring, a train of cars moves slowly past the pouring station carrying mold after mold under the stream of molten alumina and it will be noted that due to the contacting straight portions of the lip 22 when the axis of the stream of alumina passes through the line of contact between two lips 22 part of the stream will go into one mold and the rest of the stream will go into the other mold and practically none of the stream will be spilled.

The cars have spaced parallel angle irons extending in the direction of the length of the cars and the upstanding surfaces 33 contact the

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angle irons and lock the molds in position while the bottom surfaces 32 rest upon the angle irons and support the molds. It will be noted that no matter in which one of four possible positions a mold is placed on the angle irons of the cars, the mold has a three point support and therefore will not wobble as the car moves along the track. This is the reason for the 2, 2, 1, 1 arrangement of the projections 30 and 31 above mentioned.

When an ingot mold 10 is filled with molten alumina the alumina immediately starts to freeze being chilled by the cold iron. If this were not so the mold would melt because the molten alumina is at a temperature higher than the melting point of iron by hundreds of degrees. But iron is a good conductor of heat and the heat of the charge is quickly conducted away from the layers of alumina adjacent the inside surfaces of the mold. The ability of the mass of the mold to absorb heat is also involved because radiation outward is not fast enough quickly to form a skin on the pool of alumina. The poor conductivity of alumina is also involved because when the skin is formed, the conduction of heat through the skin of alumina is slow enough so that radiation from the outside of the ingot mold can take care of the heat being given off. It is important, therefore, that the ingot mold have enough capacity to absorb heat to form a skin on the pool of alumina almost immediately the mold is filled. A mold made of cast iron shaped as shown in the accompanying drawing has sufficient capacity for this purpose. By reason of the shape of the sides of the mold as above described, the sides of the square are thicker at the median portions thereof and where they are thicker the sides are closer to the center of the mold. This produces a nice balance of heat conduction and absorption because once the skin has started to form, those portions of the embryo ingot nearer to the center give out heat faster and it is precisely there that the metal of the mold should be the thickest. At the same time the construction provides somewhat thinner corners and this feature minimizes the strains due to thermal differentials.

It will be noticed from a comparison of Figures 5, 6 and 7 that the mold in cross section changes gradually from square to round and this is a highly desirable feature because, all things considered, a mold which must absorb and radiate heat and do so time and time again without cracking is best made round while in order that the pour stream may be split between molds, it is best made square or of other polygonal shape but a four-sided mold is best from all points of view taken together. Thus the gradual transition from square to round going from top to bottom of the mold proves to be the best shape.

It should now be noted that a vertical section of the mold taken anywhere at all will reveal a taper from top to bottom. An endless number of vertical sections can be made of this mold but every one of them will reveal this tapering from top to bottom. Furthermore in the bottom portion of the mold the tapering is fairly pronounced. This is important and permits the ingot which has solidified to be merely dumped out of the mold by partly inverting the mold. In molds where the ingot of refractory sticks to the metal not only is there a good deal of trouble in removing the ingot but some of the iron is usually torn away and the mold quickly deteriorates.

This result is achieved despite the provision of the ledges 13 by the shaping of the metal to form the four concave spheroidal surfaces 14. These four concave spheroidal surfaces provide broad bases for the ledges 13 thus distributing the loads upon the ledges over wide areas and furthermore they merge into the bottom 15 without any sharp angles and planes tangent to them form a wide polyhedral angle facilitating the removal of the ingot.

These ledges 13 have a special function which will now be described. In spite of the excellent characteristics of the mold shape generally the molds would not have such a very long life if it were not for these ledges 13. This is because, despite the tapering characteristics already pointed out and the wide polyhedral angle of the surfaces 14 and the generally rounded nature of the spheroidal bottom surface 15, the alumina ingot has a tendency to stick to the ingot mold 10. In order to minimize this tendency the inside of the mold 10 is preferably painted with aluminum paint just prior to its use, but even this does not completely eliminate the sticking. However the combination of all these features with the ledges 13 does definitely end sticking and permits the ingot to be dumped from the ingot mold and none of the metal of the mold is torn away when the ingot is removed from it.

After the molten alumina has acquired a skin and when this skin has thickened somewhat to produce what may be called a crust of frozen alumina, this crust starts to shrink as it cools. This shrinkage, not very pronounced at first, becomes greater as the temperature of the crust becomes lower and now the ingot being formed rests upon the four ledges 13 which it nicely fits and the bottom of the ingot shrinks upwardly from the surface 15 as well as inwardly from portions of the surface 15 and inwardly from the concave spheroidal surfaces 14 to provide a clearance, more pronounced near the apex of the bottom surface 15, between the ingot and the ingot mold 10. This shrinkage also takes place above the ledges 13 and causes a clearance to be established between the ingot and the pyramidal surfaces 11 and the conical surfaces 12. If it were not for the ledges 13 the ingot would simply subside upon cooling and then would make firm contact with the metal of the ingot mold over practically the entire outer surface of the ingot. This is necessarily so because of the tapering shape of an ingot mold which is important for reasons hereinbefore pointed out. But to avoid the disadvantages of the tapering interior of the ingot mold, I have provided these ledges 13 which in effect lift the ingot as it cools and give a clearance between the ingot and the inside of the ingot mold practically everywhere except at the ledges 13 themselves. This clearance all around the ingot being formed not only prevents sticking of the ingot to the mold and permits easy dumping of the ingot from the mold but also reduces or even substantially eliminates heat transference by conduction from the ingot to the mold 10 after shrinkage has proceeded sufficiently to establish the clearances. Radiation of course still transfers heat from the ingot to the mold but the elimination of conduction reduces the outflow of heat from the ingot to the mold. This results in a drop in temperature of the mold as the mold radiates heat outwardly and also loses heat by convection circulation, etc. This is beneficial to the mold inasmuch as the useful life of the mold is limited by the length of time at which

it is at very high temperatures as well as the number of cycles of heating and cooling. But this reduction in heat transference also slows down the solidification of the alumina inside of the shell of already frozen alumina and this has beneficial results in the crystallization of the alumina or of other refractory compounds or mixtures such as of other oxides, for the slower crystallization results in larger crystal growth which especially in the case of alumina produces a better abrasive product.

It will be noted that the ledges 13 now receive the greatest heat transference and consequently become hotter than any other part of the ingot mold and furthermore once the clearances have been established these ledges 13 bear practically the entire weight of the ingot of alumina and the combination of great heat and pressure subjects them to the greatest amount of strain, but due to their broad curvature and due to their location in the corners where the metal of the mold is relatively thin between the conical corners 12 and the exterior conical surfaces 26 and more especially due to their broad supporting bases comprising the metal back of the spheroidal surfaces 14 and the merging of these surfaces 14 with the bottom surface 15 it has been found that these ledges 13 are well able to withstand the extra strains and indeed ingot molds constructed exactly as described herein have withstood hundreds of cycles of use, each cycle involving the painting of the mold, the filling of the mold with molten alumina, the cooling of the molten alumina to form the ingot and the subsequent dumping of the ingot out of the mold and finally the cooling of the mold close to outdoor temperature. It has been found that supporting ledges such as those illustrated herein in four separate unconnected ledges last longer than does a continuous ledge all the way around the inside of the mold.

It will be noted that the ledges 13 are located in the lower part of the ingot mold where the taper commences to be sharp and this permits them to be supported by metal back of the surfaces 14 which still have a pronounced taper. This approximate location and geometry is believed to be the best combination for the purpose in view of all the factors.

The four exterior conical surfaces of gentle curvature 25 are the result of the plan that the molds should not vary a great deal in thickness from one place to another and furthermore have the function of keeping exterior surfaces of adjacent molds reasonably far apart so that circulation of air between adjacent molds is permitted and will carry off heat. It may be said that the pouring is intended to be done under cover but the molds are intended reasonably promptly to move outdoors and of course outdoors there is usually some wind and furthermore convection currents will cause a draft of air. It may be stated then that the ingot mold 10 tapers on the exterior from top to bottom as well as that it tapers on the interior from top to bottom.

Another feature is that the four exterior equilateral truncated pyramidal surfaces 20 result in spacing adjacent molds from each other except for line contact and this is also for the purpose of providing a clearance to promote cooling and furthermore keeps adjacent molds from welding to each other.

While distinct and discontinuous ledges 13 are preferred, nevertheless many of the objects of the invention can be achieved using a continuous ledge that is to say as though the ledges 13 were

joined by straight shelves and consequently in the claims where the ledges are not stated to be separate, a continuous ledge is included thereby.

It will thus be seen that there has been provided by this invention an ingot mold in which the various objects hereinabove set forth together with many thoroughly practical advantages are successfully achieved. As many possible embodiments may be made of the above invention and as many changes might be made in the embodiment above set forth, it will be understood that all matter hereinbefore set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

I claim:

1. An ingot mold having a flaring top with a continuous lip which top is generally square but has rounded corners, horizontal cross sections of said mold from top to bottom gradually changing from square with rounded corners to round, the bottom of the mold being spheroidal inside and outside except for projections on the outside for holding the mold in position and except for four concave spheroidal surfaces of different curvature from and intersecting said spheroidal bottom on the inside, the mold having four interior pyramidal surfaces above the spheroidal bottom, the mold having separate ledges in the inside corners adjacent the spheroidal bottom and above and terminating the four concave spheroidal surfaces of different curvature and the mold being of one integral piece of metal.

2. An ingot mold having a flaring top with a continuous lip which top is generally square but has rounded corners, horizontal cross sections of said mold from top to bottom gradually changing from square with rounded corners to round, the bottom of the mold being spheroidal inside except for four concave spheroidal surfaces of different curvature from and intersecting said spheroidal bottom on the inside, the mold having four interior pyramidal surfaces above the spheroidal bottom, the mold having ledges in the inside corners adjacent the spheroidal bottom and above and terminating the four concave spheroidal surfaces of different curvature and the mold being of one integral piece of metal.

3. An ingot mold having a flaring top with a continuous lip which top is generally square but has rounded corners, the bottom of the mold being spheroidal inside except for four concave spheroidal surfaces of different curvature from and intersecting said spheroidal bottom on the inside, the mold having ledges in the inside corners adjacent the spheroidal bottom and above and terminating the four concave spheroidal surfaces of different curvature and the mold being of one integral piece of metal.

4. An ingot mold having a flaring top with a continuous lip which top is generally square but has rounded corners, horizontal cross sections of said mold from top to bottom gradually changing from square with rounded corners to round the bottom of the mold being spheroidal inside, the mold having four interior pyramidal surfaces above the spheroidal bottom, the mold

having ledges in the inside corners adjacent the spheroidal bottom and the mold being of one integral piece of metal.

5. An ingot mold having a shape such that horizontal cross sections of said mold from top to bottom gradually change from square with rounded corners to round, the bottom of the mold being spheroidal inside except for four concave spheroidal surfaces of different curvature from and intersecting said spheroidal bottom on the inside, the mold having four interior pyramidal surfaces above the spheroidal bottom, the mold having ledges in the inside corners above and terminating the four concave spheroidal surfaces of different curvature and the mold being of one integral piece of metal.

6. An ingot mold with a bottom which is spheroidal inside except for four concave spheroidal surfaces of different curvature from and intersecting said spheroidal bottom on the inside, the mold having ledges adjacent the spheroidal bottom and above and terminating the four concave spheroidal surfaces of different curvature and the mold being of one integral piece of metal.

7. An ingot mold having a spheroidal bottom and having a shape such that horizontal cross sections of said mold from top to bottom gradually change from square with rounded corners to round except for four concave spheroidal surfaces of different curvature from and intersecting said spheroidal bottom on the inside, the mold having four interior pyramidal surfaces above the spheroidal bottom, the mold having ledges in the inside corners above and terminating the four concave spheroidal surfaces of different curvature and the mold being of one integral piece of metal.

8. An ingot mold having a shape such that horizontal cross sections of said mold from top to bottom gradually change from square with rounded corners to round, the bottom of the mold being spheroidal inside and the mold having four interior pyramidal surfaces above the spheroidal bottom, the mold having ledges in the inside corners adjacent the spheroidal bottom and the mold being of one integral piece of metal.

9. An ingot mold having a shape such that horizontal cross sections of said mold from top to bottom gradually change from square with rounded corners to round, the mold having four interior pyramidal surfaces above its bottom, the mold having separate ledges above its bottom and the mold being of one integral piece of metal.

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