METHOD AND APPARATUS FOR HANDLING MOLTEN, NON-FERROUS METALS

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I Claim. (Cl. 103—153)

This invention relates to a method and apparatus pertaining to the handling of certain molten, non-ferrous metals, and especially to a pump for effecting the movement of certain molten non-ferrous metal and to a process for making this pump. More particularly, the invention relates to a pump that can be submerged in a molten bath of a non-ferrous metal, to withdraw molten metal from beneath the surface of the bath.

This application is a continuation-in-part of my copending application, Serial No. 484,847, filed January 28, 1955, now U.S. Patent No. 2,897,572, dated August 4, 1959.

The pumping of molten aluminum and certain other non-ferrous metals, such as, for example, zinc and copper, from furnaces, cupolas, or molten baths of these metals, to other vessels and equipment has been difficult, costly and inefficient, because the molten metal exerts a corrosive and erosive action on pump parts that quickly destroys the pump. In the case of molten aluminum, for example, metal pump parts are unsatisfactory since even relatively high melting point metals, such as iron, dissolve in the molten aluminum and contaminate it.

In hot chamber die casting of aluminum, the molten metal is removed from the source of supply by suitable pumping means and conveyed to the machine chamber, where the molten metal is forced into and held in the cavity of the metallic mold or die under approximately 2000 to 4000 pounds pressure until solidification takes place. In cold chamber die casting the metal is fed by gravity or pumped to the machine with only enough pressure to lift the metal from its pot or container to the cold chamber machine cavity. It is then forced by a hydraulic ram into the die proper at pressures considerably greater than those used in hot chamber die casting. The pumps that are now available for handling molten aluminum are often unsatisfactory because of the difficulty involved in accomplishing the functions of transporting the molten metal, and metering it accurately, when the pump parts are attacked by the molten metal and become inaccurate dimensionally, and require replacement frequently.

One object of the present invention is to provide a practical pump for handling certain molten, non-ferrous metals.

Another object of the invention is to provide a practical pump for transporting and metering certain non-ferrous metals, such as aluminum and its alloys.

Another object of the invention is to provide a pump for transporting molten aluminum and its alloys, and other molten, non-ferrous metals, that will have a long life, and that will be simple to manufacture and relatively inexpensive.

Another object of the invention is to provide a pump that is made of a refractory material that is highly resistant to attack by various molten, non-ferrous metals, and that has a minimum number of moving parts.

Another object of the invention is to provide a practical pump for handling current molten non-ferrous metals that has a simple design so that it can fit any of the ordinary types of melting retorts.

Another object of the invention is to provide a pump for moving certain molten non-ferrous metals, to which discharge pipes having different size openings may be easily attached and detached.

A further object of the invention is to provide a relatively simple process for manufacturing pumps of the character described above.

Still another object of the invention is to provide a new process for transporting certain molten non-ferrous metals.

Other objects of the invention will be apparent hereinafter from the specification and from the recital of the appended claim.

In accordance with the present invention, molten aluminum and its alloys, and other non-ferrous metals, are moved by a pump, all of whose parts, that come in contact with the molten metal, are made from silicon nitride-bonded silicon carbide.

According to a preferred embodiment of the invention, a metering pump for die casting aluminum is made with a casing that has a chamber, inlet and outlet valves for admitting molten metal to the chamber and for discharging molten metal from the chamber, respectively, and impeller means, such as a piston that reciprocates in a cylinder that communicates with the chamber, disposed between the two valves, for alternately increasing and decreasing the pressure in the chamber to provide pumping action. The inlet and outlet valves include captive balls that can engage in valve seats in the casing to close their respective valves, and that can move predetermined distances away from their valve seats, to open the respective valves. Each of the two balls is restrained against movement more than a predetermined distance away from its respective valve seat by a guard pin that is integral with the casing. All parts of this pump are made of silicon nitride-bonded silicon carbide, and the casing is preferably a monolithic, fired casting.

In one preferred method of making the pump, the sludge casting techniques are employed that are described in my copending patent application, identified above. The casting, the guard pins, the piston, and the movable balls or valve members, are cast separately from a raw mixture that can be fired in a non-oxidizing, nitrogenous atmosphere to yield silicon nitride-bonded silicon carbide.

The castings of the balls are then inserted in operative position in the casting of the casing, and a refractory material or a fugitive, non-bonding coating is interposed between the balls and the surfaces with which they are in contact, so that they will not bond to any other part, during firing. The castings of the guard pins are then assembled in operative position in the casing casting. Thereafter, this assembly is fired, in a non-oxidizing, nitrogenous atmosphere, integrally to unite the guard pins and the casing. The piston casting is fired separately. Discharge piping of various sizes can also be cast and fired separately, for assembly to the pump.

This pump can be used most advantageously when completely submerged in a bath of the molten, non-ferrous
metal that is to be moved by the pump. The pump can be employed advantageously as a metering pump, to withdraw, at each stroke of the piston, a predetermined increment of molten metal from the bath, beneath the surface of the bath, and for injecting the molten metal increment into a die casting mold under pressure.

In the drawing:
The sole FIGURE of the drawing is a view partly in elevation and partly in section of a pump constructed according to one embodiment of this invention.

Referring now to the drawing, 10 denotes a pump casing that is formed with a chamber 11 therein. At one end of the casing 11, the casing is formed with an aperture 12 that constitutes an inlet port for admitting molten metal to the chamber. The bottom wall of the chamber 11 is sloped upwardly adjacent the inlet port 12 toward the inlet port, as denoted at 14, and the casing 10 is formed with a valve seat 15 about the inlet port 12. A ball 16 is disposed in the chamber 11 adjacent the inlet port 12, to engage in the seat 15 to close the inlet port, and to move away from the seat 15 to open the inlet port. A pin 17 is disposed transversely of the chamber 11 to limit the distance that the ball 16 may travel into the chamber 11, away from its seat 15.

At its other end, the casing 10 is formed with a discharge passage 20 that is disposed at right angles to the chamber 11. The discharge passage 20 communicates with the chamber 11 through an orifice 21 in a web portion 22 that is integral with the casing. The upper part of the web portion 22 is formed as a valve seat 24, and a ball 25 is disposed in the discharge passage 20 for engagement in the valve seat 24 to close the orifice 21. A pin 26 is disposed transversely of the discharge passage 20 above the web 22, to limit the movement of the ball check 25 away from the seat 24. The guard pins 17 and 26 are integral with the casing.

The casing 10 is also formed with a cylindrical passage 27 that communicates with the chamber 11 intermediate the inlet port 12 and the orifice 21. The axis of the passage 27 intersects the axis of the chamber 11 at a right angle, and is in parallelism with the axis of the discharge passage 20. A piston 30 is mounted for reciprocatory movement in the cylindrical passage 27. At its lower end, the piston 30 is formed with a conical working face 31. The upper end of the piston 30 is cast with a threaded recess 32, for attachment to a reciprocatory drive rod (not shown).

The upper end of the discharge passage 20 is cast with an enlarged diameter and threads to receive the threaded end of a discharge pipe 34 that has a bore 35 that is the same size as the discharge passage 20. At its upper end, the discharge pipe 34 is formed with a radially-directed passage 36 that communicates with the bore 35. The end portion 37 of an offtake pipe 38 is inserted in the passage 36. The offtake pipe 38 has a bore 40 that communicates with the bore 35 of the discharge pipe. The discharge pipe is shown with a downwardly directed discharge duct 41, that communicates with its bore 40, to discharge molten metal downwardly. However, the offtake pipe 35 can be formed for connection to other pipes, and alternatively, other pipes can be directly connected to the casing instead of the discharge pipe 34 and the offtake pipe 38.

I have found that silicon nitride-bonded silicon carbide is not wet by molten aluminum and its alloys and many other molten, non-ferrous metals. Metal that is allowed to solidify on exposed areas of the pump is easily stripped off. When the pump is at operating temperature, this property, coupled with good strength characteristics, and great resistance to heat, thermal shock, and chemical attack, make silicon nitride-bonded silicon carbide an ideal material from which to construct my pump.

The preferred process for making the parts for the pump employs the sludge-casting process described in my copending application, identified above. In this process, a mixture having the following composition is made:

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Amount (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon carbide, 10 mesh and finer</td>
<td>70</td>
</tr>
<tr>
<td>Silicon carbide fines</td>
<td>10</td>
</tr>
<tr>
<td>Ferromanganese silicate, 200 mesh</td>
<td>10</td>
</tr>
<tr>
<td>Silicon, 200 mesh</td>
<td>10</td>
</tr>
<tr>
<td>Bentonite</td>
<td>0.5</td>
</tr>
<tr>
<td>Water</td>
<td>4800</td>
</tr>
<tr>
<td>Dextrose</td>
<td>0.24</td>
</tr>
<tr>
<td>Lithium citrate, 20% aqueous solution</td>
<td>320</td>
</tr>
</tbody>
</table>

Other, similar mixes can also be employed, as described in greater detail in my aforesaid copending patent application.

All of these ingredients except the water and lithium citrate are mixed dry to form an intimate mixture, after which the water and lithium citrate are added, either separately or together, and the whole is mixed for approximately 10 minutes. The resulting wet mix is then left in the mixer or transferred to a container and covered over with a wet burlap cloth, or otherwise protected against undue evaporation of water from the mixture, and the mixture is then allowed to age for between 2 and 8 days, before use.

A plurality of molds are prepared, one for each of the different components in the pump. Thus, separate molds are required, respectively, for the casing of the pump, for the balls, for the guard pins, the piston, and the discharge piping. Each of these molds is made of a combination of plaster and graphite, with or without the use of other filler material such as, for example, sand, crushed mold residue, or walnut shells. Gypsum cement can also be employed as a part, at least, of the binder. Satisfactory molds and cores have been made from the following compositions:

<table>
<thead>
<tr>
<th>Mold Ingredients</th>
<th>Mold Mix Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pottery plaster</td>
<td>1</td>
</tr>
<tr>
<td>Percent by Weight</td>
<td>50</td>
</tr>
<tr>
<td>Powdered graphite</td>
<td>50</td>
</tr>
<tr>
<td>Ball...</td>
<td>30</td>
</tr>
<tr>
<td>Walnut Shells...</td>
<td>5</td>
</tr>
<tr>
<td>Gypsum cement...</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>40</td>
</tr>
</tbody>
</table>

The amount of water will depend on the grade of plaster that is used, but in general a mixture in the neighborhood of 50% water and 50% plaster and graphite mixture by weight is satisfactory. The mixture of plaster and graphite is sprinkled and gradually stirred into the water, and after all of the dry mixture has been added to the water, the moist mass is agitated with a high speed mixer. The mixture is then immediately poured into patterns or molds to form the desired molds. The plaster sets rapidly and the mold is ready for use as soon as the plaster sets. The moisture contained in the mold body serves a useful purpose in molding, since it prevents excessively rapid extraction of moisture from the casting mixture when the mold is used.

Before the aged mix is cast, it is vibrated for a short time, such as one half hour, and it is continuously mixed, preferably by troweling, as it is vibrated. When the molds and the mix are ready, the molds are clamped together as necessary, and are placed on the vibrating table, and then the mix is fed into the mold cavity by means of a filling chute. The filling chute is rested upon a block or other support that will transmit vibrations to the mix passing from the chute to the mold. Preferably, the entire mix container is placed on the vibrating table as the molds are filled, so that the mix is subjected to vibration continuously throughout the casting process.

After the molds have been filled with a slight surplus of mix, to allow for shrinkage, the molds are left on the vibrator and are subjected to vibration for an additional
short period, during which period any necessary additional small increments of mix can be added to the mold cavities in order to fill voids and replace water that is absorbed by the molds. When no more material is required in the molds, they are struck off with a trowel and the molds are placed in a drier and dried at 140° F. over night. After drying, the molds can be removed from the cast shapes desired. This is done by tapping the mold lightly, just enough to break the contact between the mold and the piece.

The castings for the balls 16 and 26 respectively are then sprinkled with a parting agent, such as, for example, pulverized graphite, which will prevent bonding of the balls to the casting and pin points during firing. Alternatively, a fugitive, non-bonding coating can be used to cover the balls. The balls are then positioned in the casting adjacent their respective seats. Thereafter, the castings of the pins 17 and 26 are mounted in their respective positions in the casing 10. Preferably, the casting of the casing 10 is made with apertures to receive the ends of the pins, but alternatively, if the walls are solid, appropriate apertures can be drilled carefully. Cement is not necessary to hold the pins in place, but a small amount of a carbonizing cement can be used advantageously to bond the ends of the pins in their respective apertures, so that the pins will not become dislodged when the casing 10 is handled prior to firing. The cement can be a resins cement, for example, that will carbonize during firing.

This assembly, together with the assembled castings for the discharge pipe 34 and the off-take pipe 36, and the separate castings of the piston 30, is then placed separately in a suitable kiln or furnace chamber, and the products of combustion are fired in a non-oxidizing nitrogenous atmosphere at a temperature of 1400° C. to 1500° C. The furnace is held at peak temperature for a period of several hours, in order to allow time for completion of the reaction between the nitrogen introduced, and the silicon carbide, to form a silicon nitride, silicon carbide containing bond for the silicon carbide. The piston 30 is then assembled to the casing, and the pump is ready for use.

The sludge-casting process for silicon nitride-bonded silicon carbide produces pump parts that have an extremely smooth, dense surface appearance that is characteristic of articles formed by wet casting, and they also have extremely uniform, dense body structures throughout. There is virtually no shrinkage or warpage. Fired parts are as accurate in size and finish as the molds in which they are made. Tolerances can be kept extremely close, with 0.003 inch. The parts have a fine inter-crystalline structure that results in high strength and rigidity even at elevated temperatures. The modulus of rupture is about 2½ times as high as ordinary bonded silicon carbide, and may be as high as 10,000 p.s.i. at 2450° F. The density of the parts is about 40% of that of chrome-nickel steel. Thermal conductivity is about 70% that of heat-resistant alloys. Moreover, these parts have excellent resistance to heat shock and are highly resistant to fracture even when subjected to extreme fluctuations in temperature.

This pump is particularly useful for pumping molten aluminum and aluminum alloys for use in making die castings. These alloys include, for example, alloys of aluminum and copper containing 4% to 14% by weight of copper; alloys of aluminum and silicon containing 5% to 13% by weight of silicon; alloys containing aluminum, silicon, and copper; alloys containing aluminum, silicon, and copper; alloys containing aluminum, silicon, copper, nickel, and cobalt; also useful in pumps containing molten copper and Zinc, and many of their alloys. Moreover, corrosion resistance is exceptionally high, and the pump can be used advantageously for handling acids and acidic salts, mixed chlorides and sulfates, corrosive slags, and other highly reactive materials.

In the preferred method of using the pump, the pump is first submerged in a molten bath of the metal that is to be moved. To operate the pump, the piston 30 is reciprocated. When the piston 30 is drawn up in its cylinder 27, the outlet ball check 25 is drawn down against its seat 24 to close the outlet orifice 21; and the inlet ball check 16 is drawn into the chamber 11 until it engages against the pin 17. Molten metal enters the chamber 11 through the inlet port 12, flowing around the inlet ball check 16, until the piston 30 reaches the upper limit of its stroke. When the piston 30 is on its down stroke, the pressure that is exerted on the molten metal in the chamber 11 forces the inlet ball check 16 back against its seat 15 to close the inlet port 12, and forces the outlet ball check 25 off its seat 24 until it engages against its retaining pin 26. The molten metal is forced up through the orifice 21 and the discharge passage 20, around the ball check 25, through the bore 35 of the discharge pipe 34, and thence through the off-take pipe 38.

By controlling the length of stroke of the piston 30, and the number of strokes in a given time interval, the amount of molten metal that is discharged from the pump can be metered.

The pump can operate only partly immersed in molten metal, so long as the inlet port 12 is always completely covered by molten metal; but it is preferred that the entire pump be submerged to decrease thermal shock and heat loss, and so that the metal that is withdrawn is free from any impurities that might be floating at the surface of the metal.

In operation of the pump, it is preferred that the piston be extended above the top of the bath of molten metal at all times. However, a connecting rod of other refractory material may be secured to the tapped bore 32 at the top of the piston, if necessary, and it can extend into the bath.

While the foregoing description relates to a piston pump construction, it will be understood that the techniques described herein can be employed for the manufacture of other pumps, sintered rolls, and other equipment for handling, transferring, castings, etc., and for use in contact with molten non-ferrous metal. For example, for transferring large volumes of molten, non-ferrous metal rapidly, a centrifugal pump can be constructed according to the process described above. The mix that is employed to make the various castings can be altered from the specific mix disclosed above, following in general the teachings of my aforesaid copending patent application.

In making the valves for any type of pump, it is preferred that the ball checks be made from the same material as the pump casing. Instead of pins, removable bolts can be used to hold the ball checks in place. These bolts will be of sufficient length to extend through the body of the pump, and they can be secured in place by nuts threaded on their ends against the outside surface of the pump body. This facilitates replacement of the ball checks if necessary. These nuts and bolts also should be made from the same material as the pump casing.

To eliminate freezing, it is preferred that the pipes on the discharge side of the pump have large diameter bores; and in some cases, the use of heating elements, that are secured to the discharge pipes, may be necessary or helpful.

Pumps that are made and operated according to my invention withstand temperatures up to about 3000° F., and exhibit excellent resistance to corrosion, erosion, and abrasion. The silicon nitride-bonded silicon carbide is not affected by molten aluminum, zinc, copper, or the alloys described above, and pumps made from this material have long life.

My piston pump can also be made by any other suitable process, but the sludge-casting method is preferred because it produces castings of highly desirable characteristics, as pointed out above.

While the invention has been described in connection with a specific embodiment thereof, it will be understood that it is capable of further modification, and this application is intended to cover any variations, uses, or adaptations of the invention following, in general, the
principles of the invention and including such departures from the present disclosure as come within known or customary practice in the art to which the invention pertains and as may be applied to the essential features hereinbefore set forth, and as fall within the scope of the invention, or the limits of the appended claim.

I claim:

A pump for transferring a molten, non-ferrous metal without contamination thereof and which is highly resistant to thermal shock and corrosion by such metal which comprises a casing including an inlet and an outlet therefor, and impeller means within said casing, both said casing and said impeller means being formed of sludge-cast silicon nitride-bonded silicon carbide and having working faces for contact with a molten metal which are not wettable by said molten metal and which have a smooth, dense surface.

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