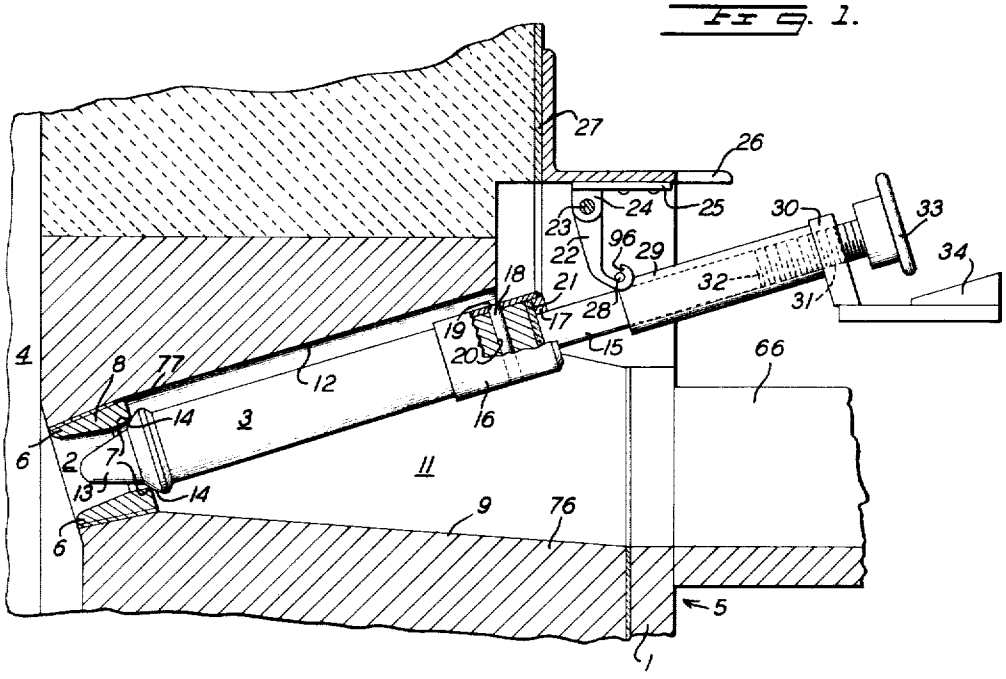
April 9, 1963 W. O. STAUFFER ETAL 3,084,925

APPARATUS FOR CONTROLLING THE FLOW OF MOLTEN METAL

Filed April 23, 1958 3 Sheets-Sheet 1

FIG. 1.



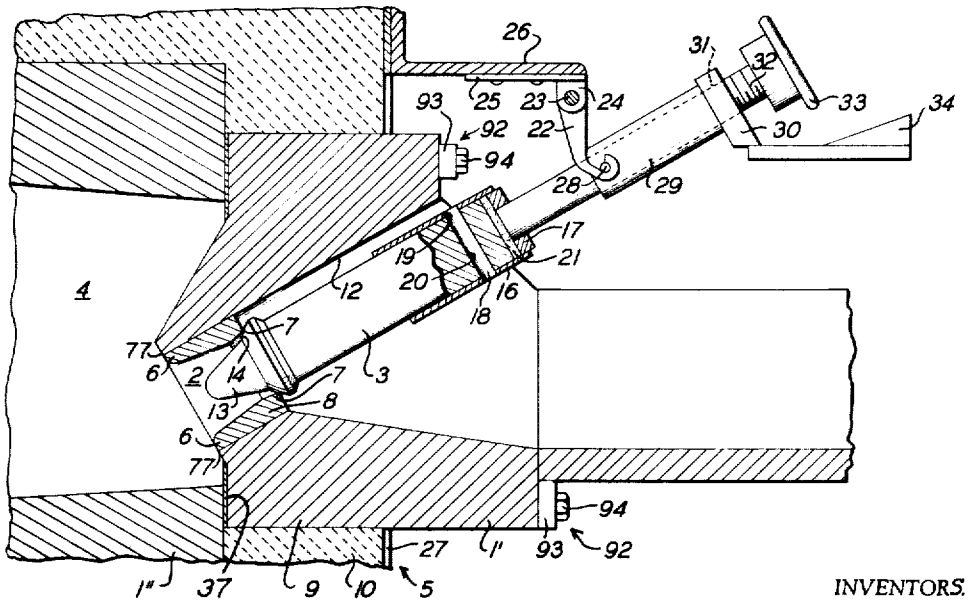


FIG. 2.

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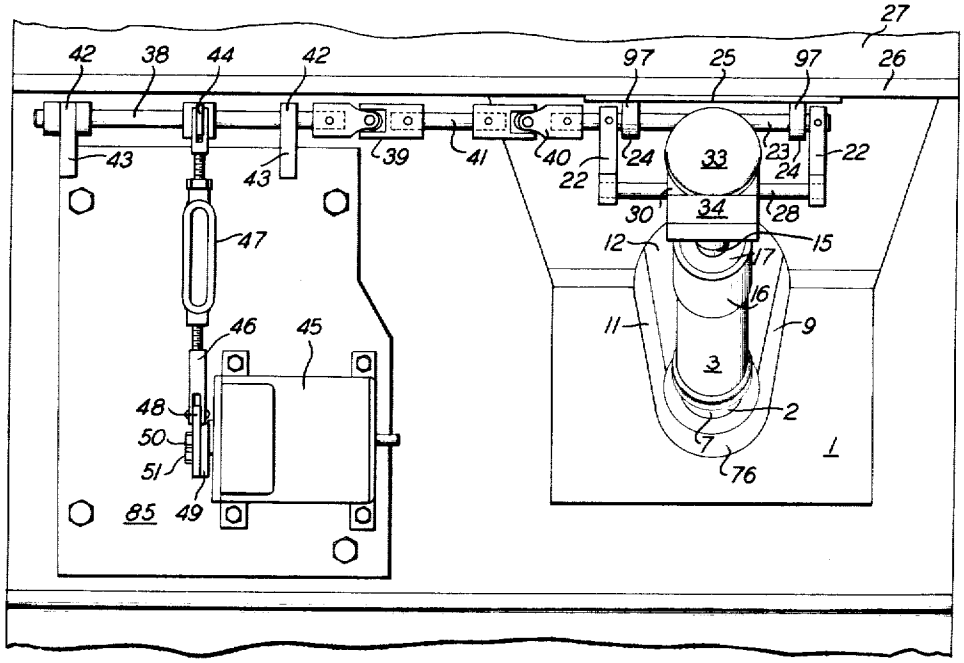


Fig. 3.

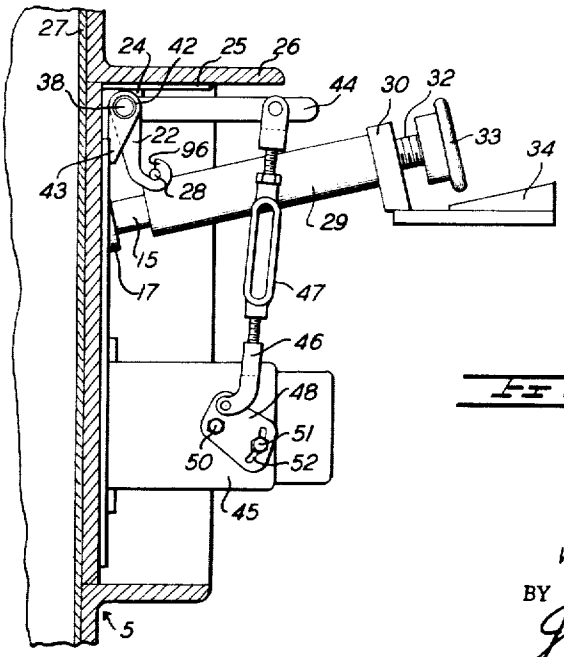


Fig. 4.

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Filed April 23, 1958 3 Sheets-Sheet 3

FIG. 4.

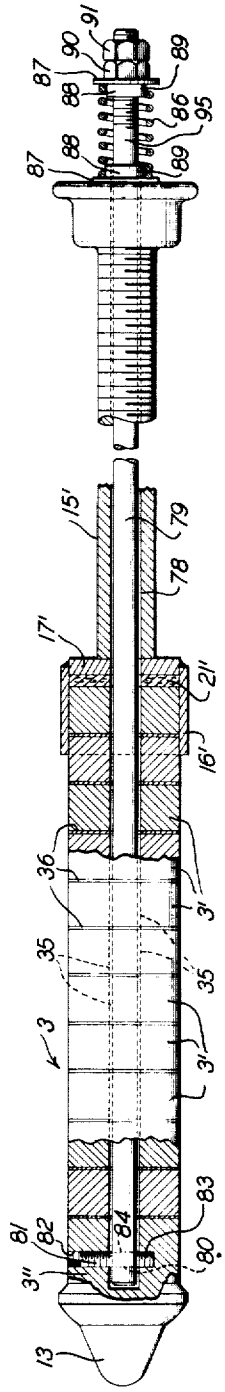
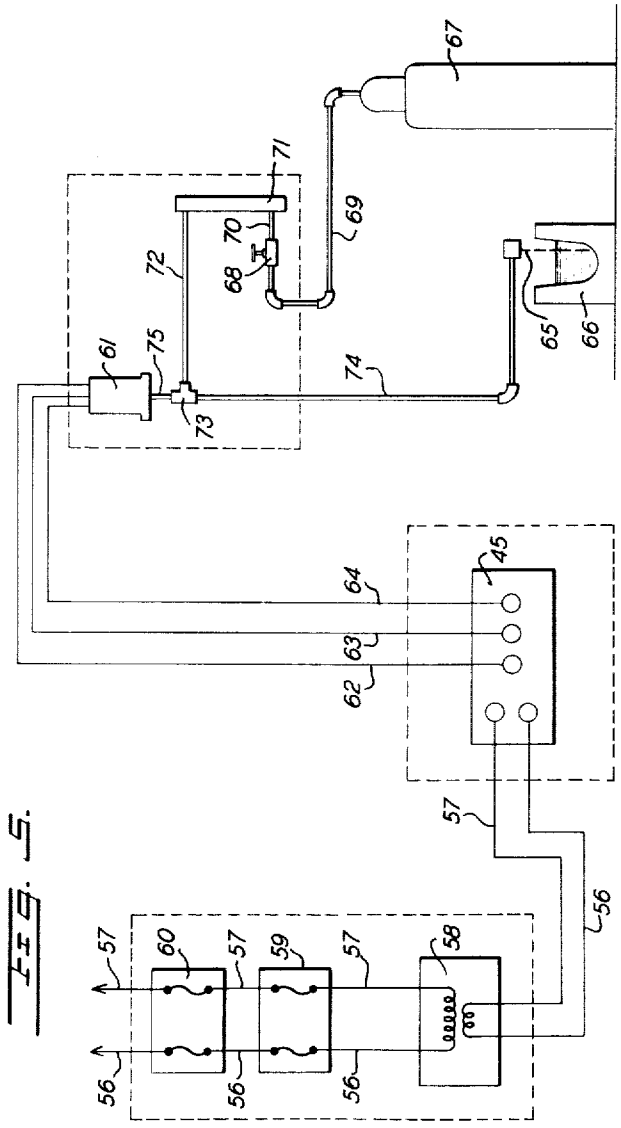


FIG. 5.



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United States Patent Office 3,084,925 Patented Apr. 9, 1963

3,084,925

APPARATUS FOR CONTROLLING THE FLOW OF MOLTEN METAL

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Filed Apr. 23, 1958, Ser. No. 730,427
9 Claims. (Cl. 266—42)

This invention relates to the handling and control of molten metal. More particularly this invention relates to a method and apparatus for releasing, controlling and stopping the flow of molten metal from a source thereof, e.g., a furnace or other molten metal receptacle.

In the casting of metal, e.g., aluminum and aluminum alloys, it is common practice to provide a body of molten metal in a suitable holding receptacle, e.g., an open hearth or reverberatory furnace, electrical resistance heated furnace or induction heated furnace. The open hearth furnace, which may be oil, gas, coal or coke fired, is commonly used for supplying molten metal for casting and may comprise a melting hearth and a holding hearth. In preparing the metal for casting the charge of metal and any desired alloying constituents to be melted are generally added in the melting hearth and thereafter the molten metal is transferred to the holding hearth where it is subjected to cleaning treatment and where control may be had of the composition and temperature of the molten bath. The treated molten metal may then be transferred from the holding hearth to the casting station by suitable means, e.g. a transfer trough. In handling the molten metal as above described it is necessary to provide means for releasing, controlling and stopping flow of molten metal from the holding hearth to the trough, casting station or ladle.

According to prior art practice releasing, controlling and stopping the flow of molten metal is accomplished by inserting a conical plug of a suitable molten metal resistant material, known in the art as a check-rod tip, in the molten metal outlet. It is customary to coat the conical plug with material such as a mixture comprising a suitable fiber material, such as asbestos shorts, flour and water. This material is known in the art as "dough" and the operation of sealing the tap hole by such means is referred to as "doughballing." This "dough" performs two functions. First, it fills any discontinuities in the outlet thus providing a tight seal and second, the carbonization of the flour provides a bond which although weak, prevents the metal head in the furnace from forcing the plug out of the orifice.

Such practice possesses many inherent disadvantages, particularly with regard to casting aluminum where it is desired to produce high quality metal with a minimum of porosity and inclusions. As mentioned hereinabove, the bond formed by the carbonization of the flour is quite weak. This makes it difficult to obtain a leak proof seal when "doughballing" against relatively high metal heads, particularly with large tap holes. The trend in present day practice is to employ higher and higher heads in molten metal receptacles. When employing "doughballing" the maximum head which may be employed is very limited. With such practice high heads result in leaky seals which may cause hazards to safety, production delays and damage to casting equipment. Even in the plastic stage the "doughball" material possesses very little strength. This makes closures of the tap hole difficult at high metal velocities because of the washing action of the metal.

Further, when a furnace is tapped a portion of the "doughball" remains in the outlet. If this material is not removed regularly, buildup in the outlet occurs

thereby restricting the metal flow from the outlet. The "doughball" material contains water, inert filler material and carbonaceous matter which latter represents a potential source for gassing the metal resulting in porosity in the ultimate cast body. The "doughball" material is quite friable and breaks up into pieces when the furnace is tapped. These fragments represent a potential source of non-metallic inclusions.

In addition, when tapping a furnace employing the methods and apparatus of the prior art turbulence and cascading generally occur in the tap hole area which results in regassing and entrapment of oxide films in the metal. These conditions affect the quality of the ingot being cast. Further, conventional "doughballing" methods result in solidification of metal and metallic oxides at the entrance to the tap hole. As a result, tapping or starting metal flow frequently requires the use of an oxygen lance to open the tap hole area. The use of an oxygen lance delays the casting operation and results in damage to the tapping block. Also, the apparatus of the prior art merely provides means for releasing and stopping metal flow and fails to provide means for controlling the rate of flow of molten metal. In addition, doughballing operations require an excessive amount of labor.

Accordingly, the primary purpose and object of this invention is to provide an improved method and apparatus for releasing, controlling and stopping flow of molten metal from molten metal receptacles which eliminates or substantially reduces many of the disadvantages of the prior art techniques.

Another object of this invention is to provide a novel method and apparatus for releasing, controlling and stopping flow of molten aluminum metal from a receptacle for molten aluminum wherein such defects as porosity and inclusions may be eliminated or substantially reduced in the ultimate cast body.

Another object of this invention is to provide a novel method and apparatus for releasing, controlling and stopping molten metal flow from a molten metal receptacle whereby the problem of buildup of material in the outlet is eliminated or substantially reduced and adequate metal delivery is assured.

Another object of this invention is to provide a novel apparatus for use in conjunction with the transfer of molten metal from a molten metal receptacle whereby the molten metal flow may not only be released and stopped but the rate of flow may be controlled.

Another object of this invention is to provide a novel apparatus for releasing, controlling, and stopping molten metal flow from a molten metal receptacle with a minimum expenditure of labor.

Another object of this invention is to provide a novel apparatus for releasing, controlling and stopping the flow of molten metal from a molten metal receptacle including a tapping block provided with an orifice, a plug adapted to be disposed at least partially within said orifice having a spherical segment seating surface whereby a line of contact may be made between said spherical segment seating surface and the inner periphery of said orifice when said spherical segment contacts said orifice.

In accordance with this invention, releasing, controlling and stopping the flow of molten metal from a molten metal holding receptacle is accomplished by the combination of a tapping block provided with an orifice for the passage of the molten metal, a flow channel on the outlet side of said orifice and a plug of novel configuration adapted to be disposed at least partially within said orifice.

The orifice embodying the principles of this invention has a rounded inlet edge and a rounded outlet edge, the radius of curvature of said outlet edge being relatively small. The orifice is inclined at an angle to the horizon-

tal with the outlet end at a higher position than the inlet end. The lower surface of the flow channel has a downward pitch away from the orifice while the upper surface has an upward pitch away from the orifice. It is preferred that the upper surface have a curvature such that a transverse cross section defines a segment of a circle, e.g. a cylindrical segment surface or a conical segment surface. The center line of such curvature preferably is parallel to the center line of said orifice.

The plug configuration is characterized by a spherical segment seating surface whereby a line of contact may be made between the spherical segment seating surface and the outlet edge of the orifice and an elongated end portion extending from the spherical segment surface into the orifice. This elongated portion is adapted to control the rate of flow of molten metal passing through the orifice whereby the rate of flow increases as the plug is withdrawn from the orifice.

Suitable means are provided for moving the plug into and out of the orifice and for maintaining the plug in tight contact with the orifice. This actuating mechanism is provided with counterweight means whereby the end of the plug when withdrawn from the orifice is maintained against the upper surface of the flow channel. Since the upper surface of the flow channel preferably takes the form of a cylindrical segment or a conical segment it guides the plug into the orifice as the plug is moved toward the orifice. The angle of inclination of the center line of the orifice and of the center line of the curvature of the upper surface of the flow channel is such that the plug may be moved in a straight line into and out of the orifice.

For purposes of more detailed discussion, this invention will be specifically described with reference to the embodiment shown in the accompanying drawings wherein:

FIGURE 1 is an elevational view in cross-section, with parts removed for purposes of clarity, of a portion of a molten metal receptacle illustrating the novel tapping block, plug and actuating mechanism of this invention.

FIGURE 2 illustrates a second embodiment of the plug and control rod of this invention wherein the plug is segmented.

FIGURE 3 is an elevational view in cross-section with parts removed for purposes of clarity, of a portion of a molten metal receptacle, tapping block, plug and actuating mechanism of this invention illustrating a second embodiment of the tapping block of this invention wherein the tapping block is segmented.

FIGURE 4 is an elevational view partially in cross-section, with parts removed for purposes of clarity, of the molten metal receptacle of FIGURE 1 illustrating an automatic control means for controlling the position of the plug during tapping of the molten metal.

FIGURE 5 is an elevational view of the molten metal receptacle and automatic control means of FIGURE 2 taken along a plane transverse to that of FIGURE 2.

FIGURE 6 is an electrical and pneumatic diagram of the control means of FIGURES 4 and 5.

Referring now more particularly to the drawings in which the same reference numerals have been applied to various corresponding parts and with particular reference to FIGURE 1, the present invention involves the use of a tapping block **1** provided with a tap hole or orifice **2** and a plug **3**. A molten metal body **4** is contained in a suitable holding receptacle **5**.

The edge **6** of the inlet end of the orifice **2** is rounded off thereby eliminating stagnant flow areas and reducing accumulation of dross and other materials at the orifice **2** while casting. It is preferred that the ratio of the radius of curvature of the edge **6** to the minimum inside diameter of the orifice **2** range from 0.25 to 1.0. Further it is preferred that the minimum inside diameter of orifice **2** should be not greater than 4½ inches. It has been found that the minimum diameter whereby plugging would be avoided is ¼ of an inch. In order to avoid

chipping of the outlet edge **7** of orifice **2**, edge **7** should be either chamfered or rounded. For best contact with plug **3** it is preferred that edge **7** be rounded with a radius of curvature ranging from 0.125 to 0.475 inch and an arc length ranging from 30° to 120°. With the exception of the rounded inlet edge **6** and the rounded or chamfered outlet edge **7**, the inside surface of orifice **2** may be any of several contours. The most simple surface is a hollow cylinder of uniform inside diameter. However, the inside surface may also be formed to the contour of one or two frustrums of right circular cones, one or two segments of circular parabolic or free curved tori, and any combination thereof including combinations with or without a right circular cylinder. A preferred inside surface is the one illustrated in FIGURES 1 and 2 which is made up of a segment of a torus, and two right circular cones. The orifice **2** is inclined whereby the center line is at an angle to the horizontal ranging from 10° to 60°, preferably from 20° to 45°, with the outlet end at a higher position than the inlet end.

The internal configuration of the tapping block should be such that a flow channel **11** is defined therein on the outlet side of orifice **2**. The lower surface **76** of flow channel **11** should have a downward pitch away from the orifice **2** ranging from about 10° and 30° to the horizontal to allow the metal to drain away from the orifice **2**. A pitch less than 10° would not provide sufficient drainage to prevent buildup around orifice **2** while a pitch greater than 30° would result in excessive turbulence which tends to result in oxide inclusions and regassing of the metal. The upper surface **12** of the flow channel **11** has an upward pitch away from orifice **2**, and takes the form of either a segment of a cylinder or a segment of a cone. As will be described in greater detail hereinafter, by maintaining the end of plug **3** in contact with the upper surface **12**, the upper surface will serve as a guide whereby plug **3** may be guided into orifice **2**.

The center line of the segment of a cylinder or cone forming upper surface **12** is parallel to the center line of orifice **2**. By having the center lines of the orifice **2** and the upper surface of the flow channel **11** at an angle to the horizontal, a straight line valving action for inserting and withdrawing plug **3** is made possible wherein the actuating mechanism is out of the molten metal and line of contact seating is permitted. It has been found preferable that the length of the tapping block **1** should range from 1.1 to 1.5 times the thickness of the refractory wall **10** of holding receptacle **5** in which the tapping block is placed. This eliminates the need of a short transfer trough which is employed in conventional metal transfer equipment and the problems encountered in the use of a short transfer trough such as expansion cracks and a friable unfired refractory lining. The configurations of the outlet of flow channel **11** may take the shape of the internal contour of a transfer trough where a transfer trough **66** is employed, as in most conventional transfer operations.

Plug **3** has a compound configuration whereby said plug is adapted for both closing orifice **2** and controlling the flow of molten metal when plug **3** is withdrawn from orifice **2**. This compound configuration comprises a spherical segment seating surface **14**, whereby a line of contact may be made between seating surface **14** and the outlet edge **7** of orifice **2**, and an elongated end portion **13** extending from surface **14** into orifice **2** when surface **14** contacts edge **7**. The elongated end portion **13** of the plug has a shape substantially conical or other shape suitable for controlling metal flow by movement of said plug into or out of orifice **2**. While a frustrum of a cone having a rounded end is shown in FIGURE 1, the surface of end portion **13** could be curved. It is preferred that the radius of curvature of the seating surface **14** range from 0.6 to 1.2 times the exit diameter of the orifice. When the curvature of seating surface **14** is spherical a line of contact seal in the form of a true circle is ob-

tained regardless of small differences in angularity between the center line of plug 3 and the center line of orifice 2. If seating surface 14 had any curvature other than spherical perfect straight line valving action would be essential requiring expensive valving mechanisms of great precision.

The phrase, "line of contact seating" as used herein may be defined by reference to FIGURE 1. From FIGURE 1 it can been seen that the spherical segment seating surface 14 of plug 3 contacts the rounded outlet edge 7 at two points in the plane shown in FIGURE 1. By rotating this plane 180° about the center line of the orifice 2, the locus of the points of contact would generate a circular line. This circular line is the line of contact as used herein. Line of contact seating has many advantages over the plane of contact seating employed in the prior art, i.e. contact over a zone of appreciable breadth rather than a line. For example, fouling of the seating surface on the valve plug and/or tap hole is minimized. A particle or obstruction must lodge along the line of contact to prevent mating and closure of the valve. Positive seating action is obtained and the seating areas on the valve plug and orifice insert are self-cleaning in nature. All of the force applied to the valve plug during the seating operation is concentrated at the line of contact between the valve plug and the orifice insert. Since this contact area is very small (e.g., a line several thousandths of an inch wide), the load per unit area is extremely high and this generally dislodges or removes any obstruction of a non-metallic nature which has fouled the seat.

It has been found that for the direct valving action of this invention it is desirable to have a wet or mushy seal at the line of contact between the seating surface 14 of plug 3 and the orifice 2. If a small amount of metal were permitted to freeze at this line of contact, withdrawal of the plug from the orifice would be difficult and damage to the edge 7 of the orifice 2 may result. Damage to the edge 7 would make sealing of orifice 2 with plug 3 impossible. Accordingly, the materials of construction for the plug 3 and the material surrounding the orifice 2 should have high thermal conductivity such that the heat from the body of molten metal 4 is conducted to the line of contact between edge 7 and surface 14 whereby freezing is prevented. Further, the shape of plug 3 is such that the molten metal at the line of contact is sufficiently thick to avoid easy freezing. Other important properties for the material surrounding orifice 2 and the plug 3 are abrasion resistance, metal attack resistance, hardness and good thermal shock resistance. The principal material prerequisites for the main portion of tap-pink block 1 are high strength, thermal shock resistance, abrasion resistance and a relatively low thermal conductivity as compared to that of the material immediately surrounding the orifice 2. Accordingly, it is preferred that the orifice 2 be provided in an insert 8 of a different material than that of the body 9 of tapping block 1.

In order to facilitate insertion and removal of insert 8 and to avoid undue stresses due to differential expansion, a layer of resilient refractory material 77 may be provided between insert 8 and tapping block body 9. Examples of refractory materials that are suitable for the body 9 of the tapping block 1 include a 90% alumina composition, mullite, stabilized zirconia, magnesium-aluminate spinel, zircon and combinations thereof. Preferred materials of construction for the valve plug 3 and the insert 8 include silicon-nitride, silicon-nitride bonded silicon carbide, pure silicon carbide (self bonded or recrystalized silicon carbide) and the refractory hard metal borides, carbides and nitrides of metals such as titanium, zirconium, chromium, etc. or mixtures thereof.

Suitable means are provided for moving plug 3 into and out of orifice 2 and for maintaining plug 3 in tight contact with orifice 2. One such means is shown in FIGURE 1 and comprises a control rod 15 on which plug 3 is mounted by means of a sleeve 16 of a suitable material such as steel. Sleeve 16 is affixed by suitable means, such as welding, to a collar 17 which in turn is welded to control rod 15. Sleeve 16 has an internal diameter slightly larger than the outside diameter of plug 3 whereby it may fit over the end of plug 3 opposite the end portion 13. Plug 3 is affixed within sleeve 16 by means of a pin 18 passing through openings 19 in sleeve 16 and a matching opening 20 in the end of plug 3. Since the refractory material of which plug 3 is fabricated is generally somewhat brittle, a suitable resilient refractory material 21 is provided between the end of plug 3 and collar 17 to avoid undue physical stress being imparted to plug 3 by the valve actuating mechanism. It has been found that aluminum silicate fiber materials are suitable for the resilient refractory material 21. By the term "aluminum silicate fiber materials" is meant materials obtained by melting and fiberizing mixtures of alumina and silicon with or without modifying agents such as borax, glass, zirconium, and soda ash. One example of an available commercial material of this type suitable for this application comprises 51.2% Al_2O_3, 47.5% SiO_2, 0.6% B_2O_3, 0.6% Na_2O, balance MgO, CaO, Fe_2O_3 and impurities in minor amounts. Control rod 15 is pivotally suspended from a pair of hook members 22 by means of a shaft 28 affixed to a cylinder 29 by suitable means such as welding.

In order to prevent accidental dislodging of shaft 28 from hooks 22 when plug 3 is in contact with edge 7 of orifice 2 to prevent flow through orifice 2, hooks 22 are fabricated as shown in FIGURES 1, 3 and 4 whereby the end portions 96 overlap the upper surface of shaft 28. Thus shaft 28 cannot be forced upwardly out of hooks 22 unless hooks 22 are rotated about shaft 23 a sufficient amount to release the pressure imparted by hooks 22 on shaft 28 whereby shaft 28 may be moved to the left and then upwardly out of hooks 22. Cylinder 29 has an interior cylindrical surface of a diameter larger than the diameter of control rod 15. At the end of cylinder 29 furthest removed from shaft 28 a plate 30 is affixed by suitable means such as welding. Plate 30 has a threaded opening 31, the center line of which coincides with the center line of cylinder 29 and is adapted to engage suitable threads 32 on the end of control rod 15.

The end of control rod 15 opposite the end affixed to plug 3 is provided with a handle 33 whereby control rod 15 may be moved longitudinally through cylinder 29 by rotation of handle 33. Affixed to plate 30 by suitable means such as welding is a counter weight 34 which has sufficient weight such that when plug 3 is withdrawn from orifice 2 while mounted in hook members 22, the counterweight 34 will cause plug 3 to be maintained against the upper surface 12 of flow channel 11. Thus with counterweight 34 maintaining the plug 3 against the upper surface 12 of flow channel 11 the upper surface 12 acts as a guide whereby when the plug is moved towards the orifice 2, said upper surface 12 guides the plug into the orifice 2. Further, maintaining plug 3 against upper surface 12 where upper surface 12 has an upward pitch away from orifice 2 forces the metal leaving orifice 2 to flow under plug 3 thereby minimizing turbulence and regassing of the molten metal.

While the tapping block 1 and the plug 3 are shown in FIGURE 1 as being of one-piece construction, it is within the scope of this invention to fabricate plug 3, of a plurality of segments 3' and 3'' as shown in FIGURE 6. With this construction it is preferable to separate segments 3' and 3'' from each other by suitable resilient refractory material 36 such as an aluminum silicate material, as previously described. Plug 3 and segments 3' and 3'' may be mounted on a modified control rod 15', as shown in FIGURE 6. Control rod 15' is provided with a hollow center 78 adapted to permit passage of a tie rod 79. One end of tie rod 79 is provided with an opening 80 whereby end segment 3'' of plug 3 may be affixed by means of a pin 81 of suitable material such as stainless steel

passing through an opening **82** in segment **3''** and opening **80** in tie rod **79**. In order to maintain pin **81** in position external threads **83** may be provided on pin **81** which are adapted to engage internal threads **84** in opening **80**. Thus pin **81** may be threaded into and through opening **80** to the position shown in FIGURE 6, the engagement of threads **83** and **84** maintaining pin **81** in position. Pin **81** may be provided with a slot or socket (not shown) whereby a suitable tool such as a screw driver or socket wrench can be employed for threading pin **81** into opening **80**. Opening **82** may be plugged at either end with a mortar **98** of a material similiar to that of plug **3**, to avoid contact between molten metal leaving orifice **2** with pin **81**.

The segments **3'** of plug **3** are all provided with axial openings **35** which have a diameter slightly larger than the diameter of tie rod **79** and are mounted thereon as shown in FIGURE 6. A suitable sleeve **16'** affixed to a collar **17'** by suitable means such as welding is provided over the end of plug **3** opposite the end portion **13**. Collar **17'** in turn is suitably affixed as by welding to control rod **15**. As in the embodiment shown in FIGURE 1, a suitable resilient refractory material such as an aluminum silicate material, is provided between the segment **3'** and the collar **17'**. The segments **3'** and **3''** are maintained in compression by means of a suitable spring **86** provided at the end of tie rod **79** opposite the end provided with opening **80**. This end of tie rod **79** extends beyond the end of control rod **15'** and handle **33** a sufficient distance to allow for spring **86**. Suitable washers **87** provided with extensions **88** of a diameter slightly smaller than the inside diameter of spring **86** are provided at each end of spring **86** and have central openings **89** adapted to fit over tie rod **79**. Tie rod **79** is provided with suitable threads **95** on the end opposite the end having opening **80** which threads are adapted to engage the internal threads of nuts **90** and **91**. Spring **86** and washers **87** are placed over the end of tie rod **79**. Nuts **90** and **91** are threaded onto the end of tie rod **79** up against one of the washers **87** and moved in a direction to compress spring **86** whereby control rod **15'** is urged toward plug **3** and tie rod **79** is urged away from plug **3**. This compresses segments **3'** between resilient refractory material **21'** and segment **3''** since the action of spring **86** tends to move plug segment **3''** to the right and collar **17'** and resilient refractory material **21'** to the left.

While tapping block **1** is indicated as one-piece construction it may be fabricated from a plurality of sections for example, two sections **1'** and **1''** as shown in FIGURE 2. In such an instance generally the sections would be separated by a suitable resilient refractory material **37**, such as an aluminum silicate material as described above. Segments **1'** and **1''** are held together by means of suitable clamps **92**. Clamps **92** comprise bars **93** which are affixed to shell **27** of holding receptacle **5** by means of bolts **94** which can be threaded into openings (not shown) in shell **27** of holding receptacle **5** having internal threads which can be engaged by external threads (not shown) on bolts **94**. With a tapping block fabricated as shown in FIGURE 3, section **1'** may be easily removed from **1''** whereby the tap hole insert **8** may be easily removed without dismantling the wall **10** of receptacle **5**.

With the actuating means shown in FIGURES 1 and 3, valve plug **3** may be positioned relative to orifice **2** by either turning handle **33** or by rotation of shaft **23**, to which hook members **22** are affixed. The actuating mechanism of this invention is well adapted to automatic control through the actuation of shaft **23** by automatic control means. Such automatic control means may be either electrical or pneumatic and may be a type whereby plug **3** automatically closes orifice **2** in the event of failure of the automatic control device.

One form of automatic control means is illustrated in

FIGURES 4, 5 and 6. With reference at this time more particularly to FIGURES 4 and 5, it will be seen that shaft **23** is supported within bearings **97** mounted on support members **24** and connected to a second shaft **38** through universal joints **39** and **40** and a coupling shaft **41**. Shaft **38** is supported within bearings **42** mounted on support members **43**. Support members **43** are in turn suitably affixed to the shell **27** of holding receptacle **5**. A crank arm **44** is suitably affixed to shaft **38**. Crank arm **44** may be moved upward or downward by a suitable control motor **45** through linkage means **46**, employing a turn buckle adjustment means **47**. Linkage means **46** is pivotally attached at one end to crank arm **44** and pivotally attached at its other end to a plate **48** which in turn is adjustably affixed to a crank arm **49** by means of bolts **50** and **51**. Bolt **51** passes through a slot **52** in plate **48** and is threaded into the end of crank arm **49**. Bolt **50** passes through an opening in plate **48** of substantially the same diameter as bolt **50**. Thus the radial position of plate **48** may be adjusted relative to the radial position of crank **49** by loosening the bolts **50** and **51** and moving plate **48** to any new position permitted by slot **52** and retightening bolts **50** and **51**.

Control motor **45** is a suitable conventional electrically operated valve control motor. One example of such a valve control motor is the Minneapolis-Honeywell Modutrol Motor M 904E. In a preferred embodiment of this invention a Modutrol Motor M 904E employing 15 second timing was used.

With reference more particularly to FIGURE 6, it will be seen that the control motor **45** is electrically connected to a suitable power source such as 110 volt alternating current supply by means of conductors **56** and **57** through a suitable transformer **58**, fuse box **59** and a double pole single throw switch **60**. The position of the crank arm **49** of motor **45** is controlled by a pressure actuated control device **61** through conventional electrical connections by means of conductors **62**, **63** and **64**. One example of a suitable pressure actuated control device **61** is the Minneapolis-Honeywell Pressuretrol Model L91A1X2. Pressure actuated control device **61** is in turn actuated by the molten metal level at a convenient location on the outlet side of orifice **2**. Since in most conventional molten metal transfer systems a trough is employed, the molten metal level in such a trough may be used for purposes of control. If the molten metal is discharged directly into a casting mold the level in said casting mold may be employed for such control. The operation of this pressure actuated control device is effected by passing a suitable gas such as nitrogen which is inert to the molten metal through a tube **65**, immersed in the molten metal. For purposes of description, it will be presumed that the tube **65** is immersed in the molten metal in a transfer trough **66**. As shown in FIGURE 6, the nitrogen gas passes from a conventional gas cylinder **67** through a flow control valve **68** which insures a constant rate of flow of nitrogen through the system, the gas passing from the cylinder **67** to the valve **68** through a suitable conduit **69**. From the valve **68** the gas passes through a conduit **70** to a suitable metering device **71** such as a Fisher and Porter rota meter 132G which indicates the rate of flow of gas. From the metering device **71** the gas passes through a suitable conduit **72** to a **T 73** and then through a conduit **74** to tube **65**. Also connected to **T 73** is a conduit **75** connected to pressure actuated control device **61**.

The operation of this system is as follows: As the molten metal level rises in trough **66** (or the casting mold as the case may be) the nitrogen pressure in conduits **72**, **74** and **75** increases thus actuating the pressure actuated control device **61**. The pressure actuated control device **61** then actuates the control motor **45** whereby plate **48** is rotated causing crank arm **44** to be moved downward. This rotates shafts **38**, **41** and **23** in a counterclockwise direction thus moving the lower portion of hook mem-

bers 22 toward orifice 2. This in turn moves cylinder 29, control rod 15 and plug 3 toward orifice 2 thus restricting the flow of metal between plug 3 and orifice 2. With the flow of metal restricted the level of molten metal in trough 66 will drop. As the molten metal level drops the pressure in conduit 75 is decreased whereby pressure actuated control device 61 is actuated. Control device 61 in turn actuates control motor 45 to raise crank arm 44 thereby rotating shafts 38 and 23 in a counterclockwise direction, thus moving the lower portion of hooks 22 away from orifice 2. This in turn moves shaft 28, control rod 15 and plug 3 away from orifice 2 permitting more metal to flow through orifice 2. Through such action the system reaches equilibrium whereby the molten metal level in the trough 66, mold or other receiver is maintained constant.

An example of the invention, involving apparatus as shown in FIGURES 1, 4, 5 and 6 and applied to an aluminum melting and holding furnace, pertains to the casting of three 20 inch diameter 7075 aluminum alloy round ingots having a length on the order of 100 inches. Approximately 10,000 pounds of 7075 aluminum alloy were charged and melted in an oil fired open hearth furnace. The molten metal was stirred for about 5 minutes and sampled by spectographic analysis. Upon receipt of the analysis, the alloy composition was corrected to the exact 7075 alloy composition desired by adding the necessary alloying constituents. The composition of the melt was approximately 0.14% silicon, 0.22% iron, 1.89% copper, 2.58% magnesium, 0.24% chromium, 5.69% zinc, 0.03% titanium, balance aluminum. The molten metal was fluxed by a suitable method and means. The temperature of the metal was on the order of 1330° F.

The molten metal was level poured from the furnace through an orifice and a flow channel on the outlet side of said orifice embodying the principles of this invention into a transfer trough containing one outlet and into the casting mold. The orifice 2 had a configuration as shown in FIGURE 1 with a minimum diameter of 1⅞ inches and a length of 2¾ inches. The radius of curvature of the inlet edge 6 was 7/16 inch and the radius of curvature of the outlet edge 7 was ⅛ inch with an arc length of 45°. The orifice was inclined whereby the center line was at an angle to the horizontal of 20°, with the outlet end at a higher position than the inlet end. The upper surface 12 of the flow channel 11 was hemicylindrical and had an upward pitch away from the orifice with the center line of said upper surface parallel to the center line of said orifice. The lower surface of the flow channel had a downward pitch away from the orifice of 10° to the horizontal. The end portion 13 of plug 3 had the form of a frustrum of a cone with a rounded end portion while the spherical segment seating surface 14 had a radius of curvature of 1½ inches. The body of the tapping block 1 was fabricated from phosphate bonded 90% alumina while the orifice insert 8 was fabricated from silicon nitride. The plug 3 was fabricated from silicon-nitride bonded silicon carbide.

The three aluminum alloy ingots were cast successively in the casting apparatus. This necessitated stopping the flow of molten metal when the casting of each ingot was completed in order to remove the ingot and prepare to cast the next ingot. Thus it was necessary to release and stop the flow of molten metal three times during the casting of the three ingots. With the apparatus of this invention, releasing and stopping the flow of molten metal was accomplished with ease and a minimum expenditure of labor. Further during the casting operation, the molten metal flow was easily controlled through the use of this apparatus. The 7075 aluminum alloy ingots produced had excellent metallurgical quality and were satisfactory for the production of high quality products by rolling, forging or extrusion operations. The ingots were subjected to reflectoscope tests and evidence of inclusions or porosity was found to be within the maximum limits set by sonic standards for 7075 plate.

As used herein the term "aluminum" is meant to cover high purity aluminum, commercial purity aluminum and aluminum alloys.

It is to be understood that various changes and modifications may be made in the foregoing apparatus and method and substitution of equivalent mechanism effected without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. An apparatus for releasing, controlling and stopping the flow of molten metal from a molten metal holding receptacle comprising in combination a tapping block provided with an orifice for the passage of said molten metal and a plug adapted to be disposed at least partially within said orifice, said orifice having a rounded outlet edge, said plug having a spherical segment seating surface whereby a line of contact is made between said spherical segment seating surface and the outlet edge of said orifice, said plug also being provided with an elongated end portion extending from said spherical segment seating surface into said orifice and adapted to control the flow of molten metal passing through said orifice.

2. An apparatus for releasing, controlling and stopping the flow of molten metal from a molten metal holding receptacle comprising in combination a tapping block provided with an orifice having a rounded inlet edge, a rounded outlet edge, and a flow channel at the outlet edge of said orifice having a downward pitch away from said orifice, a plug adapted to be disposed at least partially within said orifice characterized by a spherical segment seating surface whereby a line of contact is made between said spherical segment seating surface and the outlet edge of said orifice, said plug also being provided with an elongated end portion extending from said spherical segment seating surface into said orifice and adapted to control the flow of molten metal passing through said orifice.

3. The apparatus of claim 2 wherein said plug is formed from a plurality of segments and a resilient refractory material is provided between said segments.

4. An apparatus for releasing, controlling and stopping the flow of molten metal from a molten metal holding receptacle comprising in combination a tapping block provided with an orifice having a rounded inlet edge, a rounded outlet edge, and a flow channel at the outlet edge of said orifice having a downward pitch away from said orifice, a plug adapted to be disposed at least partially within said orifice and characterized by a spherical segment seating surface whereby a line of contact is made between said spherical segment seating surface and the outlet edge of said orifice, said plug also being provided with an elongated end portion extending from said spherical segment seating surface and adapted to extend into said orifice to control the flow of molten metal passing through said orifice and means for moving said plug into and out of said orifice and for maintaining said plug in tight contact with said orifice.

5. An apparatus for releasing, controlling and stopping the flow of molten metal from a molten metal holding receptacle comprising in combination a tapping block provided with an orifice and a flow channel on the outlet side of said orifice, said orifice having a rounded inlet edge, a rounded outlet edge, and being inclined at an angle to the horizontal with the outlet end at a higher position than the inlet end, the lower surface of said flow channel having a downward pitch away from said orifice, the upper surface of said flow channel having an upward pitch away from said orifice, said upper surface having a curvature such that a transverse cross-section thereof defines a segment of a circle, the center line of said curvature and the center line of said orifice being parallel, a plug adapted to be disposed at least partially within said orifice and having a configuration characterized by a

spherical segment seating surface whereby a line of contact is made between said spherical segment seating surface and the outlet edge of said orifice, and an elongated end portion adapted to extend from said spherical segment surface into said orifice to control the rate of flow of molten metal passing therethrough.

6. An apparatus for releasing, controlling and stopping the flow of molten metal from a molten metal holding receptacle comprising in combination a tapping block provided with an orifice and a flow channel at the outlet of said orifice, said orifice having a rounded inlet edge and a rounded outlet edge, the minimum diameter of said orifice ranging from ¼ to 4½ inches, the ratio of the radius of curvature of the inlet edge of said orifice to the diameter of said orifice ranging from 0.25 to 1.0, said orifice being inclined whereby the center line is at an angle to the horizontal ranging from 10° to 60° with the outlet end at a higher position than the inlet end, the lower surface of said flow channel having a downward pitch of from 10° to 30° relative to the horizontal, the upper surface of said flow channel having an upward pitch away from said orifice, said upper surface having a curvature such that a transverse cross section defines a segment of a circle, the center line of said curvature and the center line of said orifice being parallel, a plug adapted to be disposed at least partially within said orifice and characterized by a spherical segment seating surface having a radius ranging from 0.6 to 1.2 times the exit diameter of said orifice whereby a line of contact is made between said spherical segment seating surface and said orifice, said plug having an elongated end portion extending from said spherical segment seating surface and into said orifice and adapted to control the flow of the molten metal passing through said orifice.

7. An apparatus for releasing, controlling and stopping the flow of molten metal from a molten metal holding receptacle comprising in combination a tapping block provided with an orifice and a flow channel on the outlet side of said orifice, said orifice having a rounded inlet edge and being inclined at an angle to the horizontal with the outlet end at a higher position than the inlet end, the lower surface of said flow channel having a downward pitch away from said orifice, the upper surface of said flow channel having an upward pitch away from said orifice, said upper surface having a curvature such that a transverse cross-section thereof defines a segment of a circle, the center line of said curvature and the center line of said orifice being parallel, a plug adapted to be disposed at least partially within said orifice and having a configuration characterized by a spherical segment seating surface whereby a line of contact may be made between said spherical segment seating surface and the outlet edge of said orifice, and an elongated end portion adapted to extend from said spherical segment surface into said orifice to control the rate of flow of molten metal passing therethrough, means for moving said plug into and out of said orifice during discharge of molten metal to automatically control the flow of said molten metal issuing from said orifice comprising an externally threaded control rod on one end of which said plug is mounted, a pivotally mounted internally threaded supporting member adapted to engage the threads of said control rod, said supporting member being provided with a counterweight means whereby the end of said plug when withdrawn from said orifice is maintained against the upper surface of said flow channel, said control rod being provided with a handle on the end opposite the end affixed to said plug whereby said control rod and said plug may be moved longitudinally by rotation of said handle, a pair of hook members wherein said supporting member is pivotally mounted, said hook members being affixed to a shaft member whereby rotation of said shaft member causes the ends of said hook members within which said supporting member is supported to move toward or away from said orifice thus moving said control rod and said plug toward or away from said orifice, a pressure actuated control device, linkage means between said shaft member and said control device, said pressure actuated control device being connected to a gas conduit which discharges gas from a source under pressure into the molten metal issuing from said flow channel whereby raising of the level of said molten metal increases pressure in said conduit causing said control device to actuate said motor to move said control rod and plug toward said orifice while lowering of the molten metal level decreases the pressure whereby said control device actuates said motor to move said control rod and plug away from said orifice.

8. An apparatus for releasing, controlling and stopping the flow of molten metal from a molten metal holding receptacle comprising in combination a tapping block provided with an orifice and a flow channel on the outlet side of said orifice, said orifice having a rounded inlet edge, a rounded outlet edge, and being inclined at an angle to the horizontal with the outlet end at a higher position than the inlet end, the lower surface of said flow channel having a downward pitch away from said orifice, the upper surface of said flow channel having an upward pitch away from said orifice, said upper surface having a curvature such that a transverse cross-section thereof defines a segment of a circle, the center line of said curvature and the center line of said orifice being parallel, a plug adapted to be disposed at least partially within said orifice and having a configuration characterized by a spherical segment seating surface whereby a line of contact is made between said spherical segment seating surface and the outlet edge of said orifice, and an elongated end portion adapted to extend from said spherical segment surface into said orifice to control the rate of flow of molten metal passing therethrough, means for moving said plug into and out of said orifice comprising an externally threaded control rod on one end of which said plug is mounted, a pivotally mounted internally threaded supporting member adapted to engage the threads of said control rod, said supporting member being provided with counterweight means whereby the end of said plug when withdrawn from said orifice is maintained against the upper surface of said flow channel, said control rod being provided with a handle on the end opposite the end affixed to said plug whereby said control rod and said plug may be moved longitudinally by rotation of said handle.

9. The apparatus of claim 8 including means for positioning said plug relative to said orifice during discharge of molten metal to automatically control the flow of said molten metal issuing from said orifice.

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