

Aug. 19, 1958

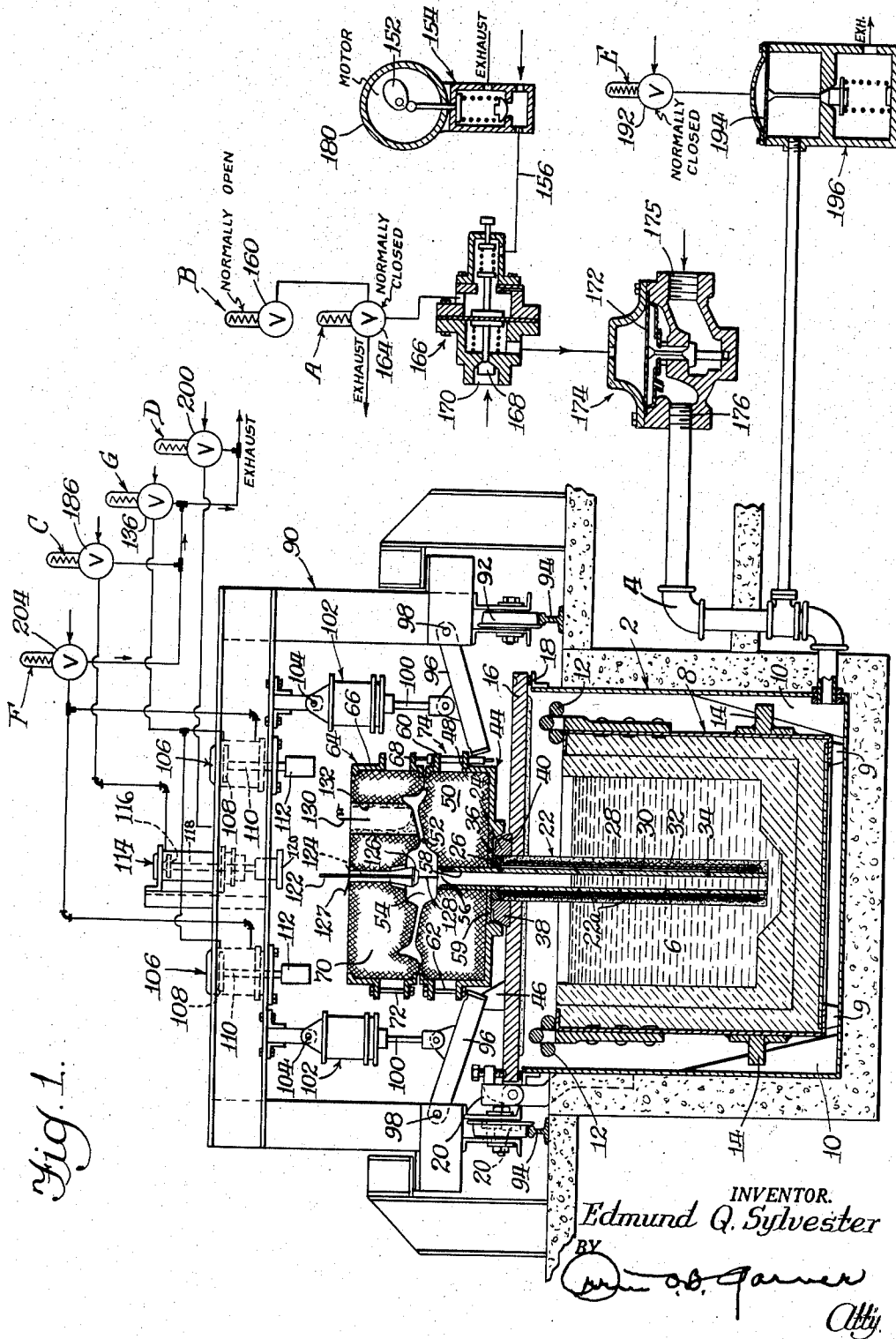
E. Q. SYLVESTER

2,847,739

CASTING APPARATUS

Filed July 12, 1951

3 Sheets-Sheet 1



Aug. 19, 1958

E. Q. SYLVESTER
CASTING APPARATUS

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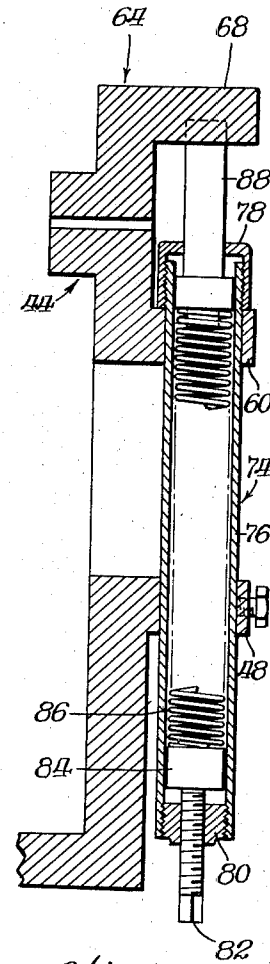
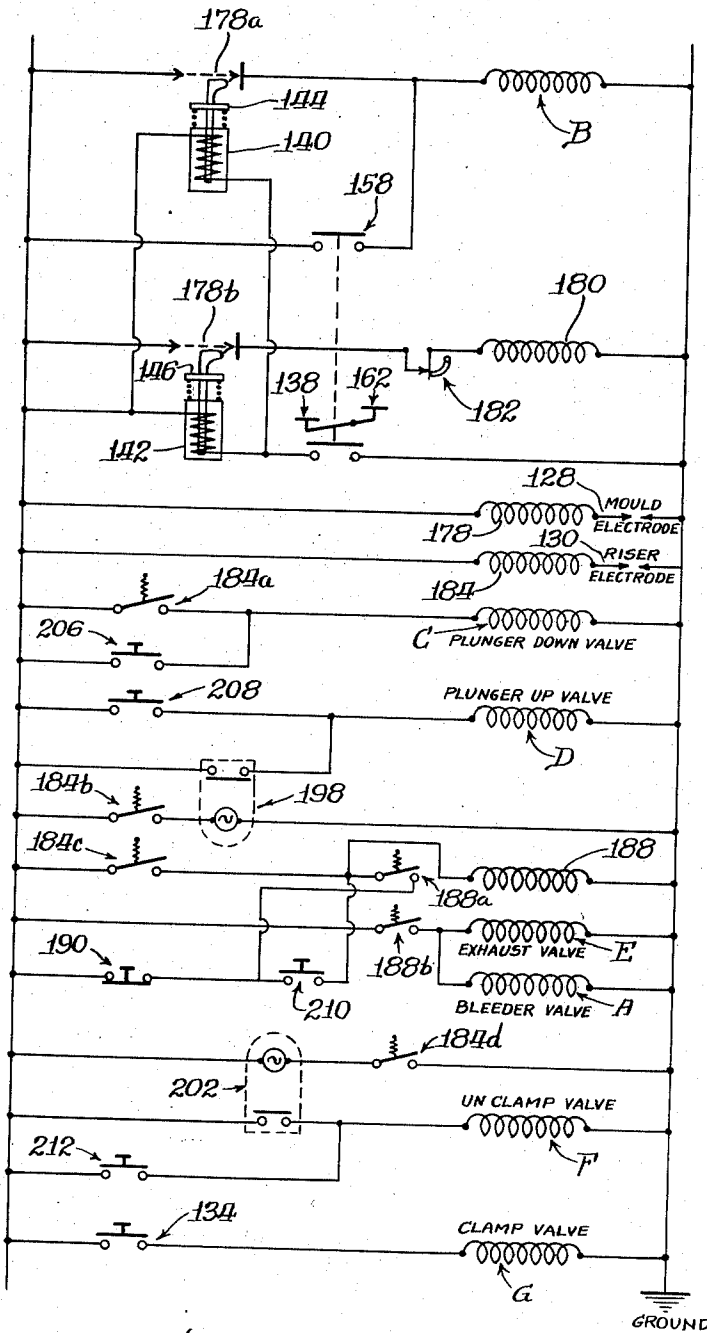


Fig. 2.

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3 Sheets-Sheet 3

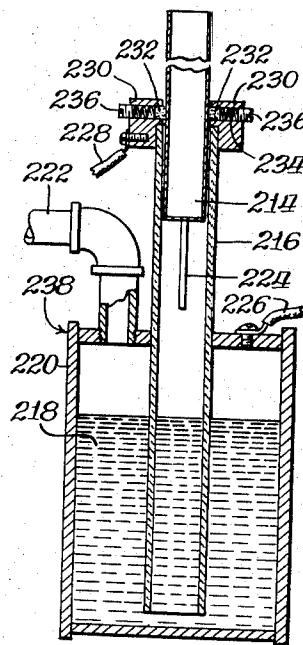
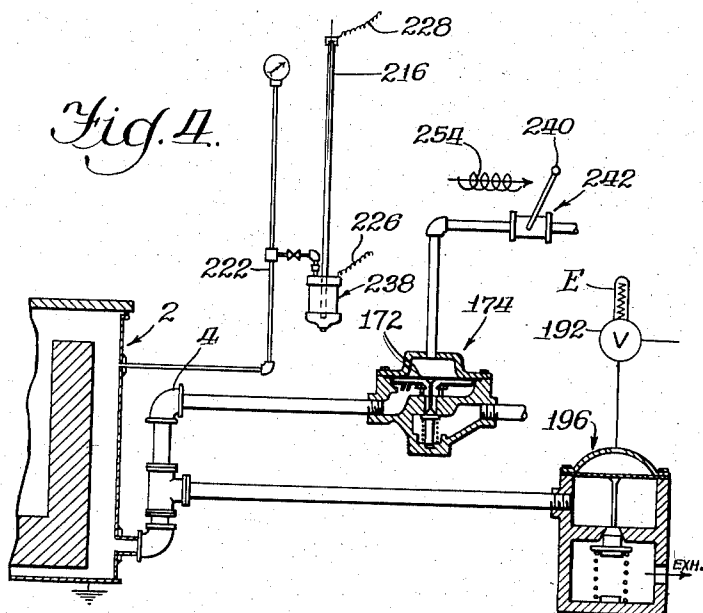


Fig. 5.

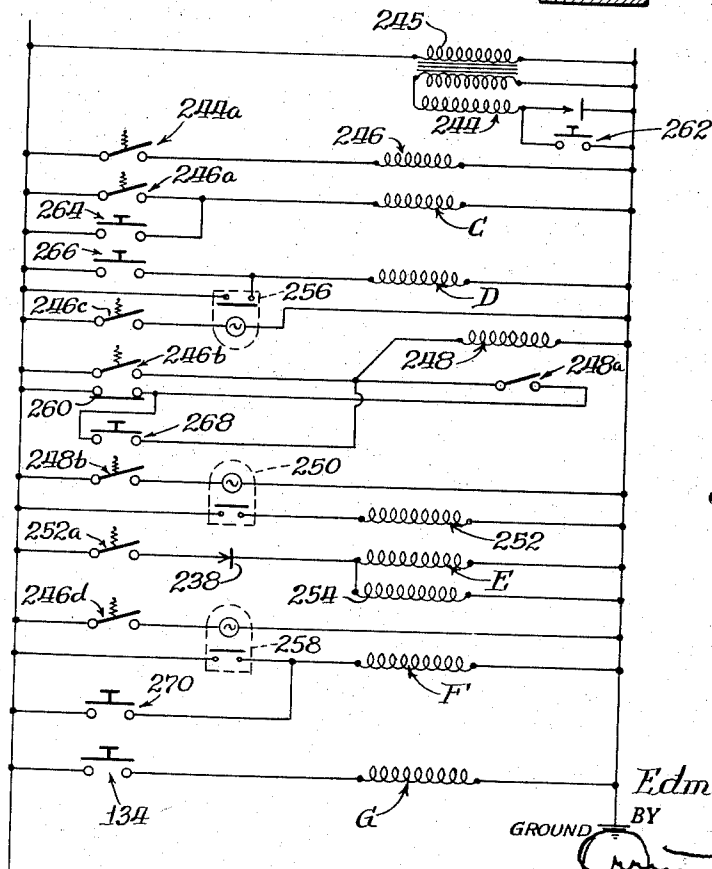


Fig. 6.

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2,847,739

CASTING APPARATUS

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Application July 12, 1951, Serial No. 236,324

14 Claims. (Cl. 22—68)

This invention relates to a novel method and means for producing castings, particularly castings of ferrous metal such as steel wheels.

A primary object of the invention is to devise a novel method and means for casting steel in a graphite mold without excessive erosion of the mold cavity defining the casting cavity.

Another object of the invention is to devise a novel method and means for casting annular objects in a graphite mold and to compensate for shrinkage of such annular castings, to prevent cracking thereof during cooling.

Another object of the invention is to devise a novel casting apparatus and control system therefor to automatically perform the steps required in a pressure casting operation.

Another object of the invention is to accommodate quick release of the pressure against the molten metal by closing the mold gate promptly after the mold has been filled.

Still a further object of the invention is to close the mold gate automatically in response to a predetermined level of molten metal within the mold.

Still another object of the invention is to devise a novel control system wherein the molten metal within the mold functions as an electrical conductor to energize certain elements of the system.

Still another object of the invention is to positively clamp the mold sections until the mold is filled with molten metal and to thereafter automatically unclamp the mold sections and relieve the weight of the top or cope section against the bottom or drag section to accommodate shrinking of the cast metal during cooling thereof.

Still another object of the invention is to devise a novel pressure pouring system whereby cooling of the molten metal in the ladle is reduced to a minimum so that a great number of molds may be poured successively in a continuous operation.

A more specific object of the invention is to devise a control system which relieves pressure against the molten metal after filling of each mold to a pressure value whereat the molten metal is lowered to a predetermined level beneath the upper end of the pouring tube preparatory to positioning a new mold in communication therewith.

A further object of the invention is to produce sound castings in a system such as above described by controlling the rate at which molten metal enters the mold.

Still another object of the invention is to facilitate rapid production of castings by forcing the molten metal under pressure at a relatively great flow rate until the metal reaches the gate of the mold and thereafter reducing the flow rate of the metal to a predetermined value until the mold is filled, thereby minimizing erosion of the mold during filling thereof.

The foregoing and other objects and advantages of the invention will become apparent from a consideration of the specification and the accompanying drawings, wherein:

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Figure 1 is an elevational view partly in central vertical section of a casting apparatus embodying the invention, in combination with a flow diagram of a novel pneumatic control circuit for said apparatus;

Figure 2 is an enlarged view of one of the cope floating devices, utilized in the mold shown in Figure 1;

Figure 3 is a wiring diagram of an electrical control system operatively associated with the pneumatic control system in Figure 1;

Figure 4 is a fragmentary view similar to Figure 1 but showing a modified control system for the casting apparatus;

Figure 5 is a central vertical sectional view of the mercury switch in Figure 4, and

Figure 6 is a wiring diagram of an electrical control system associated with the pneumatic system shown in Figure 4.

Describing the invention in detail and referring first to Figure 1, a pressure tank, generally designated 2, is connected to a pneumatic supply line 4 adapted to deliver pneumatic pressure fluid, such as compressed air, to act on molten metal 6 within a ladle, generally designated 8. The ladle is preferably provided with lugs or feet 9 seated on the bottom of the tank 2 and centered therein by guide plates 10 which are preferably spaced at approximately 90° about the perimeter of the ladle 8. The ladle comprises link means 12 for connection to an associated hoist (not shown) and also comprises trunnions 14 to tip the ladle when emptying it.

The pressure tank 2 is closed by a readily removable cover 16 which is releasably clamped against a sealing ring 18 by a plurality of clamps 20, one of which is shown in Figure 1 in solid lines at the applied position of the clamp and in phantom lines at the released position thereof. The cover 16 supports a composite pouring tube, generally indicated 22, the upper end of which is mounted within a collar 24 having a recessed sealing ring 26 clamped around the tube 22. The tube is preferably formed of segments 22a of ceramic tubing, bonded end to end and surrounded by a tube 28 of baked ceramic material such as, for example, foundry sand containing phenol resin binder. The tube 28 is in turn surrounded by a steel tube 30 supporting a layer 32 of wire mesh, around which is formed an outermost tube layer 34 of high temperature cement. The steel tube 30 is flanged as at 36 for support by the before mentioned collar 24, and the outermost tube layer 34 is tightly sleeved within a complementary opening of the collar 24.

The collar 24 is surrounded by a ring 38 having a conical outer perimeter received within a complementary opening 40 of the bottom wall 42 of a drag mold section 44. The drag section 44 is also aligned with the pouring tube 22 by means of a plurality of lugs 46 on the top of the cover 16.

The drag section 44 of the mold comprises a pan 48 containing a block 50 of ceramic material, such as graphite, having a mold surface 52 machined in the upper face thereof and defining the bottom side of a mold cavity 54. The mold cavity is provided with a gate 56, lined by a ceramic tube 58 adapted to mate with the upper segment 22a of the pouring tube 22, the tube 58 being surrounded at its lower end by a ceramic collar 59 which is adapted to compress the sealing ring 26, thereby affording an air tight seal between the tube 58 and the upper segment 22a. The drag section comprises a ring 60 in shouldered engagement with the graphite block 50 and clamped to the pan 38 as by bolt and nut assemblies 62, one of which is shown in Figure 1.

The mold also comprises a cope section, generally designated 64, having top and bottom rings 66 and 68 in shouldered engagement with the top and bottom of a graphite block 70 and clamped together by a plurality of

bolt and nut assemblies 72, one of which is shown in Figure 1.

Means are provided for balancing substantially the entire weight of the cope section 64, said means comprising a plurality of balancing or floating devices 74 spaced around the perimeter of the sections. One of the devices 74 is shown in detail in Figure 2, wherein it will be seen that the device comprises a tube 76 sleeved within complementary openings of the ring 60 and pan 48. A cap 78 is threaded on the upper end of the tube 76, and a plug 80 is threaded into the lower end of the tube 76 in threaded engagement with a screw 82 adapted to adjustably position a spring support 84 for the lower end of a spring 86, the upper end of which supports a plunger 88 which supports the bottom ring 68 of the cope section 64.

The novel casting apparatus also comprises a gantry crane, generally indicated 90, which is supported by wheels 92 on rails 94 for movement to and from a position over the pressure tank. The crane 90 comprises a pair of levers 96 fulcrumed thereto as at 98 and actuated by piston rods 100 of power cylinder devices 102 pivotally mounted as at 104 on the crane 90. It will be noted that the levers 96 are adapted to support the drag section 44 of the mold until the gate 56 thereof is aligned with the pouring tube 22 whereupon the devices 102 are actuated to lower the levers 96, thereby lowering the mold gate 56 into communication with the pouring tube 22.

The crane 90 carries a pair of clamping cylinder devices 106, each comprising a piston 108 and a piston rod 110, carrying a clamp member 112 for engagement with the cope section 64 to clamp the mold sections tightly against the cover 16 during a pouring operation. The crane 90 also carries a plunger actuating power cylinder device 114 comprising a piston 116 and a piston rod 118 supporting an abutment 120 engageable with a plunger 122 sleeved within a ceramic bushing 124 extending through a complementary opening of the cope block 70, the lower end of the plunger being formed with a conical seat 126 adapted for engagement with a complementary seat at the upper end of the gate 56 to close the same, as hereinafter described in connection with the operation of the system.

The plunger 122 is releaseably held in its upper or open position by a readily deformable wire 127 sleeved through a complementary opening (not shown) in the plunger 122 and engaged at opposite sides thereof with the upper end of the bushing 124, to releaseably support the plunger 122 prior to actuation thereof by the device 114.

The plunger 122 is provided at its lower end with a mold electrode 128, and the mold cope section 64 is provided with another electrode 130 which projects into a riser hole 132 of the cope block 70 for a purpose hereinafter described in connection with the novel control system for the apparatus.

In order to avoid unnecessary repetition, the elements of the electrical and pneumatic control system, which are diagrammatically shown in Figures 1 and 3, will be described in connection with an operating cycle of the above described apparatus. With the mold sections 44 and 64 in the position shown in Figure 1, a normally open clamp push button 134 is momentarily depressed, thereby energizing a solenoid G which opens a normally closed pneumatic valve 136 (Figure 1) admitting pneumatic pressure fluid to the devices 106 urging their pistons 108 downwardly to clamp the mold sections against the cover 16. A reset push button 138 (Figure 3) is then depressed to energize solenoids 140 and 142 which release mechanical latches 144 and 146, respectively, of normally open relay switches 178a and 178b, whereupon these switches assume their normal open position. A cam 152 (Figure 1) of a time pattern transmitter valve 154 is then set to its zero position, at which pneumatic pressure delivered from its outlet

line 156 is at a negligible pressure value of, for example, the order of 3 pounds per square inch. It will be noted that, at this point in the cycle, switch 158 (Figure 3) has been closed by the before mentioned reset push button 138 thereby energizing a solenoid B to close a normally open pneumatic control valve 160 (Figure 1).

Pouring is initiated by depressing a starter button 162 (Figure 3), thereby opening switch 158 and de-energizing solenoids 140 and 142 as well as solenoid B of the normally open control valve which thus opens, permitting flow of pneumatic pressure fluid through a normally closed bleeder valve 164 (Figure 1) to a pressure equalizer valve 166. It will be noted that in the normally closed position of valve 164 flow of pneumatic fluid to the valve 166 is accommodated, and in the open position of the valve 164, as hereafter discussed, pressure fluid from the valve 166 is exhausted, to release pressure against a diaphragm 172 of a main air valve 174.

As pneumatic pressure fluid enters the valve 166, its stem 168 is actuated to open position accommodating flow of fluid from its high pressure port 170 to the diaphragm 172 of the normally closed balanced diaphragm main air valve 174, thereby permitting flow of pneumatic pressure fluid from an inlet port 175 thereof to an outlet port 176 thereof and thence to the line 4 developing pressure within the tank 2 to urge the molten steel 6 within the ladle 8 upwardly at a predetermined flow rate dependent upon the pressure of pneumatic fluid in the line 4 through the pouring tube 22. The molten steel is grounded through the mold sections and the pressure tank, as diagrammatically shown in Figure 3, and thus when the molten steel contacts the mold electrode 128, an electrical circuit is closed through a relay solenoid 178 (Figure 3), thereby closing its normally open switches 178a and 178b, which are latched in their closed position by the before mentioned latches 144 and 146. Closing of switch 178a energizes the before mentioned solenoid B, thereby closing the valve 160 and consequently trapping compressed air within the equalizer valve 166 at a pressure value sufficient to hold the molten metal at the upper end of the gate 56.

Closing of switch 178b energizes motor 180 (Figures 1 and 3) of the valve 154, increasing the pressure of pneumatic fluid delivered therefrom through its line 156 to the valve 166 and thereby actuating the stem 168 to its open position, accommodating increase of pressure delivered by the valve 174 to the line 4 in any determined time pressure pattern controlled by the cam 152 of the time pattern pressure valve 154 which is, of course, illustrated diagrammatically. The rise of pressure in the pipe 4, governed by the valve 154, urges the molten steel 6 upwardly at a predetermined flow rate substantially less than the flow rate of the molten steel prior to closing of the valve 160, as above described. The molten steel raises at this lesser flow rate through the gate 56, filling the mold cavity 54 as well as the riser hole 132 until the molten steel contacts the electrode 130. At this time, a pressure responsive switch which is responsive to pressure in the line 4 and is diagrammatically illustrated in Figure 3 as a Bourdon tube switch 182, opens to de-energize the motor 180, preventing further rise of molten metal within the mold.

Contact of the molten metal with the riser electrode 130 energizes relay solenoid 184 (Figure 3), closing its normally open switches 184a, 184b, 184c and 184d.

Closing of switch 184a energizes a solenoid C which actuates a normally closed pneumatic valve 186 (Figure 1) directing pneumatic pressure fluid to the device 114 to actuate the piston 116 downwardly on advance stroke, thereby urging the plunger 122 to closed position, whereat its seat 126 engages the complementary seat at the upper end of gate 56, cutting off communication between the mold cavity 54 and the pouring tube 22.

Closing of switch 184c energizes relay solenoid 188

(Figure 3), thereby closing its normally open switches 188a and 188b. Closing of switch 188a establishes a holding circuit through solenoid 188a and through a normally closed push button 190. Closing of normally open switch 188b energizes a solenoid E, thereby opening a normally closed pneumatic valve 192 (Figure 1) to deliver pneumatic pressure fluid to a diaphragm 194 of an exhaust valve 196, thereby opening the line 4 to exhaust pressure in the tank 2, accommodating return of the molten steel 6 through the pouring tube 22 into the ladle 8. Closing of normally open switch 188b also energizes solenoid A of the before mentioned bleeder valve 164, thereby opening the bleeder valve to exhaust pressure in the equalizer valve 166, consequently closing the valve 174 and preventing further flow of pressure fluid to the line 4.

Closing of normally open switch 184b, in response to energization of its relay solenoid 184 as heretofore described, closes a circuit through a timer 198 which after a determined time delay of, for example, 10 seconds, closes an electrical circuit through a solenoid D, opening its normally closed valve 200 (Figure 1) to actuate piston 116 of the device 114 upwardly on return stroke, with the plunger 122 remaining in its closed position.

Closing of normally open switch 184d closes a circuit through a timer 202 (Figure 3) which after a predetermined time interval of, for example, 45 seconds, closes a circuit through solenoid F, energizing the latter to actuate its normally closed pneumatic valve 204 (Figure 1) to open position, whereat the pistons 108 of devices 106 are urged upwardly on return stroke to unclamp the mold sections 44 and 64, whereupon the devices 74 immediately balance substantially the entire weight of the top cope section 64 so that shrinkage of the casting within the mold cavity 54 upon cooling of said casting is readily accommodated without cracking of the casting due to the weight of the cope section 64. It will be noted that the casting cavity 54 is illustrated in the form of a conventional railway freight car truck wheel to which this feature is particularly applicable, however, it will be understood that the objects and advantages of the invention may be obtained in other types of castings.

Upon completion of the casting operation as above described, the devices 102 are actuated by a desired valve means (not shown) to lift the drag section 44 of the mold with the cope section 64 thereon, whereupon the mold may be removed by means of the gantry crane 90 in preparation for pouring of the next casting in the same or different mold. The push button 190 is also momentarily depressed to break the holding circuit through the relay solenoid 188, thereby accommodating opening of its normally open switches 188a and 188b and consequently de-energizing solenoids A and E to close their valves 164 and 192, thereby restoring the control system to its initial condition preparatory to another operating cycle.

It will be noted that normally open push buttons 206, 208, 210 and 212 are preferably provided for manually energizing solenoids C, D, 188 and F, respectively, as may be desired in adjusting or testing the apparatus.

Referring now to Figures 4 to 6 inclusive, which disclose a modified pneumatic and electrical control system for the casting apparatus, shown in Figure 1, the system will be described in connection with an operating cycle of the apparatus.

Elements of the modified control system which correspond to those shown in Figures 1 and 3, are identified by corresponding numerals in order to avoid unnecessary repetition.

With the mold in position on the pressure tank cover 16, as seen in Figure 1, the normally open push button 134 (Figure 6) is momentarily depressed to energize the solenoid G, thereby actuating devices 106 to clamp the mold sections 64 and 44 against the cover 16 as previously described.

Also, a float 214 (Figure 5) within a glass tube 216

immersed in a body of mercury 218 in a casing 220 connected by a tube 222 to the pressure tank 2 is pushed downwardly, until a contact rod 224 on the bottom of the float contacts the mercury 218 within the casing 220. The casing is grounded by a lead 226, and the float 214 is connected to another lead 228 by means of an electrically conductive block 230 containing carbon brushes 232, resiliently engaged with opposite sides of the float 214 by means of springs 234 adjustably compressed against the brushes 232 by screws threaded into the block 230. The springs are adapted to support the weight of the float 214 in any vertical position thereof as hereinafter described. The entire switch assembly, generally designated 238 in Figure 5, is diagrammatically shown in Figure 6 and designated by the numeral 238.

Pouring is initiated by manual actuation of a lever 240 of a control valve 242, thereby opening said valve and admitting pneumatic pressure fluid to the diaphragm 172 of the main pressure valve 174, admitting high pressure fluid to the line 4 and thence to pressure tank 2, forcing molten metal upwardly through the pouring tube 22 into the mold cavity 54. In this system, the mold electrode 128 is eliminated, and the molten steel under these conditions fills the mold cavity 54 and the riser hole 132 until the molten steel contacts the riser electrode 130, closing a circuit through a low voltage relay solenoid 244 (Figure 6) and a transformer 245. Relay solenoid 244, upon energization thereof, closes its normally open switch 244a, thereby energizing a relay solenoid 246, which upon energization thereof closes its normally open switches 246a, 246b, 246c and 246d.

Closing of switch 246a energizes relay C, thereby opening its valve 186 to actuate piston 116 of the device 114 on advance stroke thereof, urging the plunger 122 to its closed position.

Closing of normally open switch 246b energizes the relay solenoid 248 which closes its normally open switches 248a and 248b. Closing of switch 248a closes a holding circuit through the solenoid 248, and closing of switch 248b energizes a timer 250 which after a predetermined time delay of, for example, one second, closes a circuit through a relay solenoid 252. Energization of relay 252 closes its normally open switch 252a, thereby closing a circuit through solenoid E, opening its valve 192 and consequently opening exhaust valve 196 which thus opens the line 4 to exhaust. Closing of switch 252a also establishes a circuit through a solenoid 254 (Figures 4 and 6) which actuates the lever 240 to close its control valve 242 thereby closing the main pressure valve 242, cutting off further flow of pneumatic pressure fluid to the line 4 substantially simultaneously with opening of the exhaust valve 196 whereby molten steel falls within the pressure tube 22, and the mercury in the tube 216 falls therein until the molten steel in the pouring tube 22 is at a predetermined level below the gate 258 at which level mercury in its tube 216 falls below the level of the contact 224, thereby opening the mercury switch 238 and de-energizing solenoid E accommodating return of the exhaust valve 196 to its normally closed position. Under these conditions, the molten steel in the pouring tube 22 is maintained at a predetermined level therein preferably immediately below the gate tube 58. If air pressure within the tank 2 increases due to increase of temperature so that metal in the pouring tube 22 rises above said level, the switch 238 again opens to automatically open the exhaust valve 196 until the molten steel in the pouring tube 22 again falls to said level, whereupon the switch 238 automatically is opened as above described to close the exhaust valve 196. It will be noted in this connection that the pressure of the springs 234 against the mercury float 214 is effective to prevent dropping thereof due to gravity but readily accommodates upward movement of the float whenever the mercury 218 is forced against the bottom of the float by pressure within the tank 2.

Closing of relay switch 246c energizes a timer 256 which, after a predetermined time delay of, for example, 5 seconds, closes a circuit through solenoid D, energizing the latter to open its valve 200, thereby actuating piston 116 of the device 114 upwardly on return stroke, with the plunger 122 remaining in its closed position, preventing flow of molten steel from the mold.

Closing of relay switch 246d energizes a timer 258 which, after a predetermined time interval of, for example, 10 seconds, closes a circuit through solenoid F, energizing the latter to open its valve 204, thereby actuating pistons 108 of the clamping devices 106 upwardly on return stroke to unclamp the cope and drag sections 64 and 44, respectively, whereupon the devices 74 are effective to balance the weight of the cope 64 accommodating shrinkage of casting within the cavity 54 as previously described.

A normally closed push button 260 is then depressed momentarily to de-energize solenoid relay 248, thereby breaking the holding surface through its normally open switch 248a and restoring the electrical system to its initial condition preparatory to another pouring cycle as previously described.

It will be noted that upon succeeding cycles, progressively greater pressure within the tank 2 is required inasmuch as the metal 6 must be lifted at each pouring to a high level in order to fill the casting cavity 54 and riser cavity 132 of the mold. Thus the mercury 218 of the switch 238 pushes the float 214 to a higher position during the pouring of each mold; however, during the intervals between pouring the molten steel within the tube 22 is held at the same level, preferably immediately below that of the gate tube 58, due to the above described action of the mercury switch 238 in closing the exhaust valve 196 whenever the molten steel and mercury fall in unison to a predetermined level below that at which the mercury engages the contact 224. It will be understood that the mercury tube 216 or the contact 224, or both, may be proportioned in length to hold the molten steel within the tube 22 at any predetermined level between pouring cycles.

Referring again to Figure 6, it will be noted that preferably normally open push buttons 262, 264, 266, 268 and 270 are provided for manually energizing solenoids 244, C, D, 248 and F, respectively, as may be desired during adjustment or testing of the apparatus.

I claim:

1. Pressure casting apparatus comprising a mold having a mold cavity, a gate through said mold communicating with said cavity, means for forcing molten metal into said gate at a certain flow rate, means responsive to entrance of said molten metal into said cavity from said gate for automatically reducing said rate to a lesser substantially constant flow rate, and means rendering the first mentioned means effective.

2. Pressure casting apparatus comprising a mold having a mold cavity with a bottom gate, means for forcing molten metal into said gate at a certain flow rate, means responsive to initial entrance of said molten metal into said cavity from said gate for automatically reducing said rate to a lesser substantially constant flow rate, means rendering the first mentioned means ineffective, and means for closing the gate to prevent flow of said metal therefrom.

3. Pressure casting apparatus comprising a closed chamber containing molten metal, a mold formed of erodible refractory material, said mold having a bottom gate communicating with said molten metal, a movable member having a seat within said mold spaced from an engageable with said gate to close the latter, said movable member comprising electrically conductive means positioned approximately at the top of said gate, control valve means for admitting superatmospheric pneumatic pressure to said chamber and for increasing said pressure at a certain rate to urge said metal into said gate, electri-

cally operated control means energized by contact of said molten metal with said electrically conductive means for controlling said valve means to automatically decrease the rate at which pneumatic pressure is increased within said chamber until the mold has been filled with said molten metal, whereby erosion of the mold by flow of said molten metal into the mold is minimized, and means for actuating said movable member to urge its seat against said gate.

4. Pressure casting apparatus comprising a substantially air tight sealed chamber containing molten steel, a graphite mold having a mold cavity with a bottom gate, a pouring tube removably connected to said gate, said tube having its lower end immersed in said steel and being affixed to the top of said chamber, an opening through the top of said mold extending into said cavity and aligned with the top of said gate, a plunger movable in said opening toward said gate and having a downwardly facing seat spaced from and engageable with a complementary area defining the top of the gate to close the latter when the mold cavity has been filled with molten steel, said plunger comprising electrically conductive means positioned above the top of said gate, means for developing superatmospheric pressure in said chamber and for increasing said pressure at a certain rate until the molten steel reaches the top of said gate, electrically operated means responsive to contact of said molten steel with said electrically conductive means for automatically increasing pressure in said chamber at a rate less than the first mentioned rate until the mold cavity has been filled with molten steel, means for actuating said plunger to urge its seat against said area, thereby closing the top of the gate against flow of the molten steel therethrough, and means for releasing pressure in said chamber to accommodate disconnection of said mold gate from said tube and connection of another mold gate thereto.

5. Casting apparatus comprising a closed pressure chamber containing molten steel, a pouring tube sealed within an opening of said chamber and extending downwardly from said opening into said steel, said tube having a seat at the upper end thereof, a graphite mold comprising a graphite drag having a seat in complementary substantially air tight engagement with the first mentioned seat, a gate through the drag connected to the upper end of the tube when the seats are mated, an upwardly facing surface in said drag defining the upper end of said gate, a graphite cope seated on the drag and defining therewith a casting cavity communicating with the gate, an opening through said cope aligned with the gate, a plunger in said opening yieldingly held therein in spaced relationship to said surface, said plunger having a downwardly facing seat engageable with said surface to close the gate against flow of molten steel therethrough when the cavity has been filled with molten steel, said plunger having a portion projecting upwardly from said opening, means for developing superatmospheric pressure in said chamber to urge said steel upwardly through the tube and gate into the cavity, a structure horizontally movable to a position above said tube and horizontally movable to another position remote therefrom, a power device carried by said structure and comprising means for urging said portion downwardly to engage the plunger seat with said surface, another power device carried by said structure and comprising means engageable with the top of the cope to clamp the latter against the top of the drag and thereby clamp the drag seat against the tube seat, power means carried by said structure for lowering the drag to engage its seat with the tube seat and for lifting the drag to disengage its seat from the tube seat when the cavity has been filled with molten steel whereby said structure may carry the mold to a position remote from said tube and may deposit said mold at said last mentioned position whereupon said last mentioned means may then lift another mold for carriage by said structure to the tube.

6. Pressure casting apparatus comprising a chamber, a ladle of molten steel in said chamber insertable into and removable from the top thereof, a readily removable cover having a substantially fluid tight sealed connection to the top of said chamber, a pouring tube carried by said cover, the lower end of said tube being immersed in said steel, said tube having a substantially fluid tight sealed fit within an opening of said cover, a mold comprising a drag with a bottom gate having a removable connection to the top of said tube, said mold also comprising a cope with an opening extending through the top thereof and aligned with said gate, a plunger in said opening having a downwardly facing seat and having a portion projecting upwardly through said opening and extending above the top of the cope, an upwardly facing seat around the top of said gate formed and arranged for engagement by said plunger seat to close the gate when the mold has been filled with molten steel, yielding means carried by the cope having a connection with the plunger for holding the plunger with its seat spaced above the second mentioned seat, and means for developing superatmospheric pressure in said chamber to force said steel upwardly through said tube and gate into said mold to fill the latter, a power device supported above said cope, said device being operatively associated with said portion for urging the plunger downwardly to engage its seat with the upwardly facing seat when the mold has been filled with molten metal, and remote control means operatively connected to said power device for actuation thereof.

7. Pressure casting apparatus comprising a chamber containing molten metal, a readily removable cover on said chamber having a substantially air tight connection to the top thereof, a pouring tube carried by the cover and extending downwardly therefrom into said molten metal, a mold having a drag removably supported by said cover, said drag having a bottom gate communicating with the top of said tube, said mold having a cope seated on top of said drag, said cope and drag being formed of erodible refractory material defining a casting cavity in the mold, releasable clamp means engageable with the top of said cope for urging the cope downwardly against the drag and thereby clamping the drag against the cover, a plunger extending through an opening of the cope and having a seat spaced above and engageable with the gate to close the latter, electrically conductive means on said plunger beneath its seat, control valve means for admitting superatmospheric pneumatic pressure to said chamber at a predetermined rate of pressure increase therein to urge said metal upwardly through the tube into the gate, electrically operated control means energized by contact of said molten metal with said electrically conductive means for controlling said valve means to increase said pressure in said chamber at a predetermined rate lower than the first mentioned rate until the mold cavity has been filled with said molten metal, means for actuating said plunger to urge its seat against the gate, and means for releasing said pressure in said chamber.

8. Pressure casting apparatus comprising a chamber, a ladle of molten steel in said chamber insertable into and removable from the top thereof, a readily removable cover having substantially air tight sealed connection to the top of said chamber, a pouring tube immersed in said steel and having a substantially fluid tight fit within an opening of said cover, a mold comprising a drag with a bottom gate having a readily removable connection to said tube, said mold also comprising a cope with an opening aligned with said gate, an upwardly facing seat in said cope around the top of said gate, a plunger in said opening having a downwardly facing seat spaced from and engageable with the first mentioned seat to close the gate when the mold has been filled with molten steel, yielding means for holding the plunger with its seat spaced from the first mentioned seat, said plunger com-

prising electrically conductive means below its seat and spaced from the first mentioned seat, said last mentioned means being disposed above the top of the gate, means for developing superatmospheric pressure in said chamber and for increasing said pressure until the molten steel reaches the top of said gate, electrically operated means responsive to contact of the molten steel with said electrically conductive means for automatically increasing pressure in said chamber at a rate less than the first mentioned rate until the mold has been filled with molten steel, and means for actuating the plunger to urge its seat against the first mentioned seat when the mold has been filled with molten steel.

9. Pressure casting apparatus comprising a pressure tank, an open container of molten metal therein, a pouring tube carried by said tank and immersed in said metal, a mold having a bottom gate connected to the tube, means for delivering pneumatic pressure fluid to said tank for forcing said metal through said tube and gate into said mold, valve means for exhausting said tank, means for rendering said delivering means ineffective and for opening said valve means, and means responsive to rendering of said delivering means ineffective and to the volume of metal in said tube for automatically closing said valve means when said metal is at a predetermined level in said tube above the top of said container and below said gate, and for automatically opening said valve means when said metal rises above said level.

10. Casting apparatus comprising a closed pressure chamber containing molten steel, a pouring tube having an air tight seal within an opening of said chamber and extending downwardly from said opening into said steel, said tube having a seat at its upper end, a mold comprising a drag having a seat in frictional substantially fluid tight engagement with the first mentioned seat to accommodate quick disengagement from the tube seat by upward movement of the drag therefrom, a gate through the drag connected to the upper end of the tube when the seats are mated, an upwardly facing surface in said drag defining the upper end of said gate, a cope seated on top of the drag and defining therewith a casting cavity communicating with the gate, an opening through said cope aligned with the gate, a plunger in said opening yieldingly held therein in spaced relationship to said gate, said plunger having a downwardly facing seat engageable with said surface to close the gate against flow of molten steel therethrough when the cavity has been filled with molten steel, said plunger having an electrically conductive part below its seat, said part extending approximately above the upper end of the gate, and said plunger having a portion projecting upwardly from said opening, means for developing superatmospheric pressure in said chamber and for increasing said pressure at a certain rate to urge the molten steel upwardly through the tube and the gate, a structure horizontally movable to a position above said tube and horizontally movable to a position remote therefrom, a fluid pressure device carried by said structure and comprising means for urging said portion downwardly to urge the plunger seat against said surface, another fluid pressure device carried by said structure and comprising means engageable with the top of the cope to clamp the latter against the top of the drag and thereby clamp the drag seat against the tube seat, power means carried by said structure and engageable with the drag for lowering the drag toward the tube to engage the drag seat with the tube seat and for lifting the drag from said tube when the cavity has been filled with molten steel and the plunger seat has been engaged with said surface, whereby said structure may move horizontally to a position remote from said tube and may deposit said mold at said last mentioned position to accommodate lifting of another mold by said power means for carriage by said structure to the tube, and means responsive to contact of the molten steel with said part for automatically decreasing

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the rate at which said pressure is increased within said chamber.

11. Pressure casting apparatus comprising top and bottom mold sections defining a casting cavity, a gate through the bottom section communicating with said cavity approximately centrally thereof, said gate terminating at its upper end in an upwardly facing seat, a plunger sleeved through an opening in the top section and having a downwardly tapering conical seat aligned with the first mentioned seat and engageable therewith to close the gate when the casting cavity has been filled, yielding means connected to the plunger and top mold section for yieldingly supporting the plunger with its seat spaced above the first mentioned seat, said means being ineffective to urge the plunger upwardly when its seat is engaged with the first mentioned seat, and means for forcing molten metal upwardly through said gate into said casting cavity.

12. A method of filling a permanent mold formed of erodible mold sections defining a mold cavity and having a gate extending downwardly through at least one of said sections communicating with the cavity and connected to an elongated tube extending downwardly from the gate into a reservoir of molten metal, said method comprising developing superatmospheric pressure in the reservoir and increasing said pressure at a certain rate, which forces the molten metal through the tube at a certain flow rate, which would cause turbulent flow of the molten metal in said cavity, until the molten metal flows upwardly through the gate, and then, when the molten metal flows from the gate into the cavity, reducing the rate at which pressure is increased in said reservoir to a rate at which the molten metal is forced through said gate into said mold cavity at a flow rate at which turbulent flow of molten metal in the cavity is prevented until the cavity is filled.

13. Pressure casting apparatus comprising a substantially air-tight sealed chamber containing molten metal, a mold having a mold cavity with a bottom gate, a pouring tube removably connected to said gate, said tube having its lower end immersed in said metal, an opening through the top of said mold extending into said cavity and aligned with the top of said gate, a plunger movable in said opening toward said gate and having a seat spaced from and engageable with a complementary seat in said mold at the top of the gate to close the latter when the mold cavity has been filled with molten metal, said plunger comprising electrically conductive means positioned above the top of said gate, means for developing superatmospheric pressure in said chamber and for increasing said pressure at a certain rate until the molten metal reaches the top of said gate, electrically operated means responsive to contact of said molten metal with said electrically conductive means for automatically increasing pressure in said chamber at a rate less than the first mentioned rate until the mold cavity has been filled with molten metal, means for actuating said plunger to urge its seat against said seat in the mold, thereby closing the gate against flow of the molten metal therethrough, and means for releasing pressure in said chamber to accommodate disconnection of said mold gate from said tube and connection of another mold gate thereto.

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14. Casting apparatus comprising a closed pressure chamber containing molten metal, a pouring tube sealed within an opening of said chamber and extending downwardly from said opening into said metal, said tube having a seat at the upper end thereof, a mold comprising a drag having a seat in complementary substantially air-tight engagement with the first mentioned seat, a gate through the drag connected to the upper end of the tube when the seats are mated, a seat in said drag at the upper end of said gate, a cope seated on the drag and defining therewith a casting cavity communicating with the gate, an opening through said cope aligned with the gate, a plunger in said opening in spaced relationship to said seat, said plunger having a seat engageable with said first mentioned seat to close the gate against flow of molten metal therethrough when the cavity has been filled with molten metal, means for developing superatmospheric pressure in said chamber to urge said metal upwardly through the tube and gate into the cavity, a structure horizontally movable to a position above said tube and horizontally movable to another position remote therefrom, a power device carried by said structure and comprising means for urging said plunger downwardly to engage the plunger seat with said first mentioned seat, another power device carried by said structure and comprising means engageable with the top of the cope to clamp the latter against the top of the drag and thereby clamp the drag seat against the tube seat, power means carried by said structure for lowering the drag to engage its seat with the tube seat and for lifting the drag to disengage its seat from the tube seat when the cavity has been filled with molten metal whereby said structure may carry the mold to a position remote from said tube and may deposit said mold at said last mentioned position whereupon said last mentioned means may then lift another mold for carriage by said structure to the tube.

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