ABSTRACT: An apparatus for casting a molten metal has a lower melt chamber holding a bath of molten metal, an upper mold chamber containing a mold having a mold cavity and a vent orifice, and a conduit extending up from the melt chamber to the cavity for filling same with the molten metal. A port is formed either in the conduit or in the mold to open the interior of the conduit and the cavity to one of the chambers. Both chambers are pressurized to the same extent with the port open so that the mold cavity is also pressurized. Then the port is closed and the pressure in the mold chamber is reduced, while still maintaining same superatmospheric, so that the pressure differential between the melt chamber and the interior of the conduit and the mold cavity forces the metal up through the conduit and into this cavity.
METHOD AND APPARATUS FOR CASTING UTILIZING FLUID PRESSURE DIFFERENTIALS

Our present invention relates to a device for casting molten metals under the action of a gas-pressure differential and gas counterpressure built up ahead of the flowing metal; the invention also relates to a method of operating such apparatus.

The controlled casting of metals by inducing the flow of molten metal from a vessel containing a bath of metal to a mold under the influence of a pressure differential has already been proposed. A system of this type regulates the bath of metal flow by controlling the pressure differential applied between the mold chamber and the liquid-metal chamber to permit more or less rapid filling of the mold, but yet prevent the speed of the flowing metal from exceeding that at which turbulence occurs. Such apparatus is, moreover, designed to prevent a counterpressure to the flow of gas. In these systems, the mold chamber is generally separate from the liquid-metal chamber while the interior of the mold is connected to the latter via a duct through which the metal is induced to flow under the pressure differential. A preliminary period commonly precedes the casting step in which both chambers are brought to a supersaturated pressure which, however, is different in the two chambers and arranged to drive the liquid bath into the mold. After solidification of the metal in the mold, the pressure in both chambers is restored to the ambient (usually atmospheric pressure) to permit the removal of the casting from the mold.

It has been found to be undesirable to have pressure variations in the different parts of the system such as the tendency to cause premature rise of the melt in the mold or ducts or penetration of air into the melt container through the feeding pipe or duct. Prior-art devices for casting metals under gas counterpressure are characterized by this disadvantage and create problems which, although solvable by increasing the processing time, have not proved to be satisfactory because of the accompanying decrease in the production rate. We have now found that the basic cause of these problems is the variation in pressure within the mold and duct system, the system (hereinafter referred to as the metal-flow path) being usually filled with gas at normal atmospheric pressure. When the mold and melt chambers are subjected to pressurization, albeit with the aforementioned pressure differential, the ducting from the duct system or flow path and the mold increase to the working level; as the melt rises in the flow path, it drives the gas therein out through the vent orifices provided in the mold at some distance from the metal increase thereof until the pressure is eliminated. The walls of the mold progressively contact the gases and the melt while the level of the liquid metal is constantly advancing toward the vent orifices. In conventional mold designs, the vent orifices are of relatively small diameter and permit the escape of gases while retaining the metal. We have now found that this arrangement causes the vent orifices to act as check valves or constrictions which may delay the rise of pressure in the mold despite equal pressure in the mold chamber and the liquid-metal chamber, which delay results in an accelerated filling of the mold with the molten metal. If one attempts to eliminate this disadvantage by decreasing the pressure in the melt chamber, there is the possibility that gas will be drawn into the bath in this chamber through the duct and increase the length of time required for casting and the danger of turbulence and impurities inclusion.

It is, therefore, the principal object of the present invention to provide an improved method of and apparatus for casting metals under the influence of a pressure differential and against a gas counterpressure.

Still another object of our invention is to provide an improved apparatus for the casting of metals under pressure differential wherein the pressure variations in the flow path can be eliminated or avoided.

These objects and others which will become apparent hereinafter are attained, in accordance with our present invention, by providing an apparatus for casting molten metal which has a melt chamber and a mold chamber, conduit means connecting the melt-containing vessel of the melt chamber with the interior of the vented mold for leading molten metal from a bath thereof into the mold and having walls progressively contacted by the molten metal as it passes into the mold, means for applying supersaturated gas pressure to said chambers and a gas pressure differential thereacross to drive the molten metal from the bath into the mold, and in accordance with an essential feature of this invention, a controlled pneumatic connection between the mold and duct (i.e., between the melt feed path) and the melt chamber, the pneumatic connection forming a valve port of adjustable flow cross-section.

Advantageously, a closable port is provided in a wall of this path traversed by the melt whereby checking effects of the vent orifices are obviated and the reduced rate of pressure buildup in the mold is avoided without decreasing the pressure within the melt chamber so as to draw gas through the duct into the bath.

The above and other objects, features and advantages of the present invention will become more readily apparent from the following description, reference being made to the accompanying drawings in which:

FIG. 1 is a diagram, representing a vertical elevational cross section, showing schematically the apparatus of the present invention provided with closable pneumatic connection between the duct or siphon tube and the melt chamber;

FIG. 2 is a view similar to FIG. 1 of an apparatus wherein the pneumatic connection of the present invention is provided directly, i.e., between the mold and the mold chamber with a further connection between the mold chamber and the melt chamber;

FIG. 3 is an axial cross-sectional view of a casting apparatus operating in accordance with the technique illustrated schematically in FIG. 1;

FIG. 4 is an axial cross-sectional view of an apparatus embodying the same principles as those of FIG. 3 but having another valve structure; and

FIG. 5 is an axial cross-sectional view of an apparatus embodying the principles of FIG. 2.

In FIG. 1 we show an apparatus which comprises generally a housing 100 subdivided by a partition 120 into a mold chamber 112 receiving through the duct 109 melt metal, and a mold chamber 103 in which the melt-containing vessel 104 is disposed. From the mold 102, a siphon tube 109 extends downwardly into the bath of metal 121 contained in vessel 104, i.e., below the level 122 of this bath. Chamber 103 thus constitutes a thermal protection chamber for the bath of molten metal. The mold 102 is provided with vent orifices of conventional type which are represented diamentrically at 111 and communicate with the mold cavity and the surrounding mold chamber 112 while a valve 110 in a line 123 is provided between the interior of chamber 112 and the ambient atmosphere. A compressor or a compressed-gas cylinder 105 (e.g., of nitrogen) has an outlet line 124 whose pressure-reducing valve 106 determines the maximum pressure delivered to the housing while the valves 107 and 108 in conduits 127 and 128 determine the pressure in the chambers 103 and 112, respectively, and thus the pressure differential across these chambers. The interior of the duct 109 and the cavity of mold 102 constitute the "flow path" for the molten metal and form the walls progressively traversed by the melt. According to this invention, a port 101 is formed in one of these walls and is controlledly closable, e.g., by a valve member 132 adapted to engage the seat 130 surrounding the port 101. A rod 131 connected to the valve plate 129 has a handle 132 projecting externally from chamber 103 and slidably mounted at 133 in the wall of the housing. When the valve plate 129 is drawn to the right (FIG. 1), communication is established between the flow path (i.e., duct 109) and the melt chamber 103. When
port 101 is open as shown in FIG. 1, the compressed gas from cylinder 105 flows through valve 106, valves 107 and 108 into the chambers 103 and 112. In spite of the checking effect at the vent orifices 111 and the fact that the siphon tube penetrates the bath 121 of molten metal so that, in the absence of port 101, the pressure built up in the interior of the mold 102 will be less rapid than in chamber 112, there may be a spontaneous rise in duct 109; port 101 communicates between the siphon tube and melt chamber 103, thus cancelling the checking effect of the vent orifices 111, the difference of flow resistances, volumes, temperatures, etc. The presence of port 101 prevents the melt from passing into the mold through duct 109 and prevents gas from being drawn into the melt-containing vessel 104. When, however, the desirable pressure is obtained, port 101 is closed by plate 129 and the desirable pressure differential regulated by the valves 107, 108 and 110. The melt rises in the siphon tube 109 into the mold at a rate controlled by the gas-pressure differential with the compressed gas in the mold being gradually pushed through the vent orifices 111 into the chamber 112 surrounding mold 102.

In FIG. 2 we show another apparatus providing substantially the same effect. In this embodiment, the mold 202 has a port 201 in a wall traversed by the melt communicating between the mold cavity and the melt chamber 212. In this system, a further valve is provided for pressure equalization at 213 in the partition 220 between the mold chamber 212 and melt chamber 203. The port 201 can be closed by valve plate 229 which is connected with the rod 231 slidably extending to 232 outwardly from the housing 200. From the mold 202, a siphon tube 209 extends downwardly into molten metal vessel 204 in the chamber 203 supplied with valve 207 with the gas from cylinder 205. This cylinder, provided with a pressure-controlling valve 206, also feeds the branch valve 208 and chamber 212 which is connected via a valve 210 with the atmosphere and is connected with the mold cavity via the vent orifices 211. Even when the equalizing valve 213 is not employed, communication exists between the port 201 and the melt chamber 203 via lines 207 and 208 so that the checking effect of the vent orifices 211, if the only outlet for the rapidly movable gas, can be eliminated. The pipes and valves 207 and 208 are in this case so regulated as to balance the gas flow resistances. The necessity of regulating valves 207 and 208 is eliminated by using an equalizing valve 213 which directly connects chamber 212 with chamber 203 in parallel with the piping system containing valves 207 and 208.

FIG. 3 represents an apparatus wherein the mold 302 has a mold cavity 302a formed by the upwardly open mold member 302b and a vertically movable upper mold member 302c defining the vent orifices 311 on the open side of cavity 302a remote from the siphon tube 309. Valves 307 and 308 control the gas pressures developed in the chambers 312 and 303 together with valves 310 and 306 as previously described. The melt chamber 303 is here shown to have a steel jacket 303a lined at 303b with refractory material and supporting an upwardly open vessel 304 containing the melt. The refractory dip tube 309 has an upwardly widening throat portion 309a whose wall is traversed by the metal as it rises to the inlet opening 302d of the mold cavity. The port 301 of the siphon tube is here closed by a plug 329 guided in the ring 301a surrounding the orifices 301. The plug 329 is carried by a head 329a of a rod 331 whose handle is shown at 332. The device of FIG. 3 operates identically to that of FIG. 1.

While the embodiment of FIG. 4 is functionally similar to that of FIG. 3, the valve is here formed by raising and lowering the vessel 404 containing the melt 421. The mold 402 has a mold cavity 402a supplied with the molten metal through an opening 402d at the base of this cavity while relatively narrow vent orifices 411 are provided at the upper end of the cavity. The siphon tube 409 rests with its shoulder 409a upon the partition 420 between the mold chamber 412 and the melt chamber 403 which were shown to be constituted of refractory material. The lower and 409c of the siphon tube 409 is provided with ports 401 which are controlledly blocked by the level 429 of the melt as the latter is raised or lowered with vessel 404 by jack 414 which may be hydraulically or mechanically actuated. The jack 414 is supported at 414a and has a head 414b adapted to lift the container 404 until the liquid level 429 extends above the ports 401. It may be understood that the same result can be obtained by raising and lowering the chamber 403 relative to partition 420 and tube 409 or by lowering this partition, the mold 402 and tube 409 into the melt. Electromagnetic pumping may be used to raise the level 429 of the melt. Thus the port 401 communicates between the mold and the melt chamber 403 as the gases are supplied to the system via valves 406, 407, 408 and 410 whose functions are similar to the corresponding numbered valves previously discussed. When the level of the melt blocks the ports 401, it is as if the port 101, 201 or 301 had been closed.

In the embodiment of FIG. 5, the port 501 is formed in the mold 502 as a movable wall of the mold cavity 502a preferably at the distributing inlet 502d from which the molten metal is distributed to the individual mold compartments 502e. Conventional means represented at 531 (e.g., a hydraulic cylinder, solenoid or electrical motor) may be used to raise or lower the plug 529 which forms the valve member shown in its closed position in FIG. 5. In this embodiment, the upper mold member 502c is affixed to the cover 512a of the mold chamber 512 and can be lifted with it from the wall 512b to afford access to the interior of the mold. The chamber 512 is separated from the mold cavity 502a by a partition 520 through which the siphon tube 509 extends downwardly into liquid-metal vessel 504. Valves 506, 507, 508 and 510 control the gas pressures and chambers 503 and 512 while vents 511 connect the mold cavity 502a with the chamber 512. In general, an equalizing valve will be provided in the partition 520 as shown at 213 in FIG. 2. The valve 501, 529 is open during charging of the system with gas under pressure, thereby insuring equalization between gas pressure in the mold chamber, the gas pressure in the melt chamber and the gas pressure along the flow path. When the casting process is about to begin and the pressure head created, the valve 501, 529 is closed to permit casting. The movable mold portion forming the valve may, according to this invention, be the whole upper portion of the valve which is opened by lifting it away from the lower portion, or the valve may be the mold which can be lifted away from the feed pipe 509.

We claim:
1. An apparatus for casting a molten metal comprising:
a housing;
a partition in said housing defining therein a closed mold chamber and a closed mold chamber adapted to hold a bath of said molten metal;
mold means in said mold chamber having a mold cavity and at least one orifice for discharging a gas from said cavity into said mold chamber during filling of said cavity with said molten metal;
conduct means forming a molten-metal-flow path between opposite sides of said partition and having one end opening into said cavity and another end opening in said mold chamber, said flow path being in part defined by a wall along which molten metal is adapted to flow;
a port formed in said wall and in one of said means and defining a passage in said wall extending between said flow path and one of said chambers;
means for selectively blocking and unblocking gas flow through said passage;
means for pressurizing said chambers to a superatmospheric pressure; and
means for controllingly venting said mold chamber to the atmosphere and thereby reducing pressure therein while nevertheless maintaining the mold-chamber pressure above atmospheric pressure.
2. The apparatus defined in claim 1 wherein said conduit means extends at least partly through said mold chamber and said other end thereof projects into said bath, said means for
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5 blocking gas flow through said passage including a valve member sealingly engageable with said port and actuating means external of said housing and operatively connected with said valve member for shifting same.

3. The apparatus defined in claim 2 wherein said port is formed in said conduit means in said melt chamber with said passage opening thereinto.

4. The apparatus defined in claim 2 wherein said port is formed in said mold means with said passage opening into said mold chamber.

5. The apparatus defined in claim 1, further comprising a valve in said partition for equalizing the pressures in said chambers.

6. The apparatus defined in claim 1 wherein said conduit means is an upright pipe formed at said other end with said port, said other end being adjacent said bath of molten metal, said means for blocking gas flow through said port including means for shifting said bath such that said bath covers and blocks said port.

7. The apparatus defined in claim 1 wherein said housing is upright and said partition subdivides said housing into a bottom portion forming said melt chamber and a top portion forming said mold chamber, said conduit means being a generally upright pipe depending from said mold chamber into said melt chamber and adapted to project into said bath.

8. A method of casting a molten metal in an apparatus having a melt chamber for holding said molten metal, a mold chamber containing a mold with a mold cavity and at least one vent orifice, and a conduit between said melt chamber and said mold cavity for filling said cavity with said molten metal, said method comprising the steps of:

pressurizing both of said chambers to the same super-atmospheric pressure while permitting free gas flow from one of said chambers into said mold cavity so that both of said chambers and said cavity are equally pressurized;

thereafter blocking said gas flow from said one of said chambers into said cavity;

reducing pressure in said mold chamber to a lower pressure above atmospheric pressure while maintaining the super-atmospheric pressure in said melt chamber to force said molten metal through said conduit and into said mold cavity by the pressure differential between said chambers transmitted to said cavity through said orifice;

hardening said molten metal in said cavity to form a casting;

depressurizing said chambers; and

removing said casting from said mold.