

Feb. 27, 1962

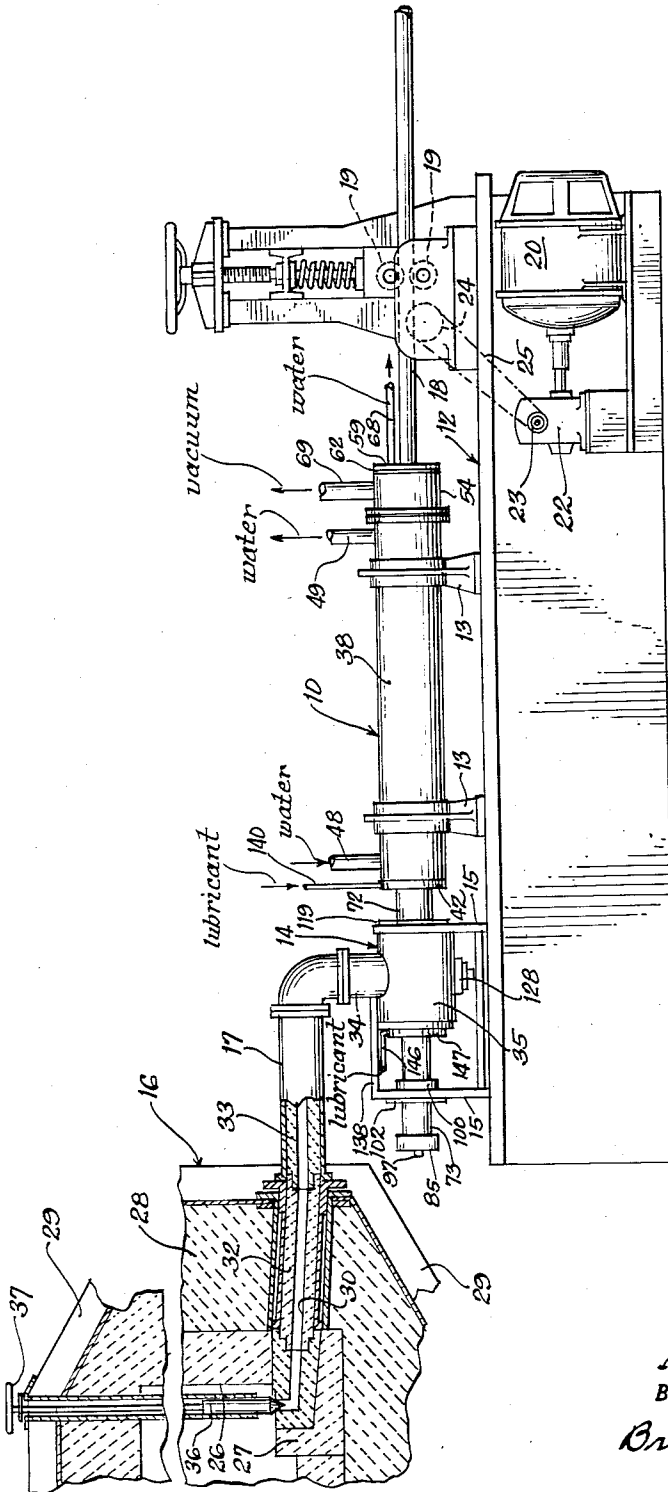
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3,022,552

CONTINUOUS CASTING APPARATUS

Filed Aug. 24, 1959

3 Sheets-Sheet 1



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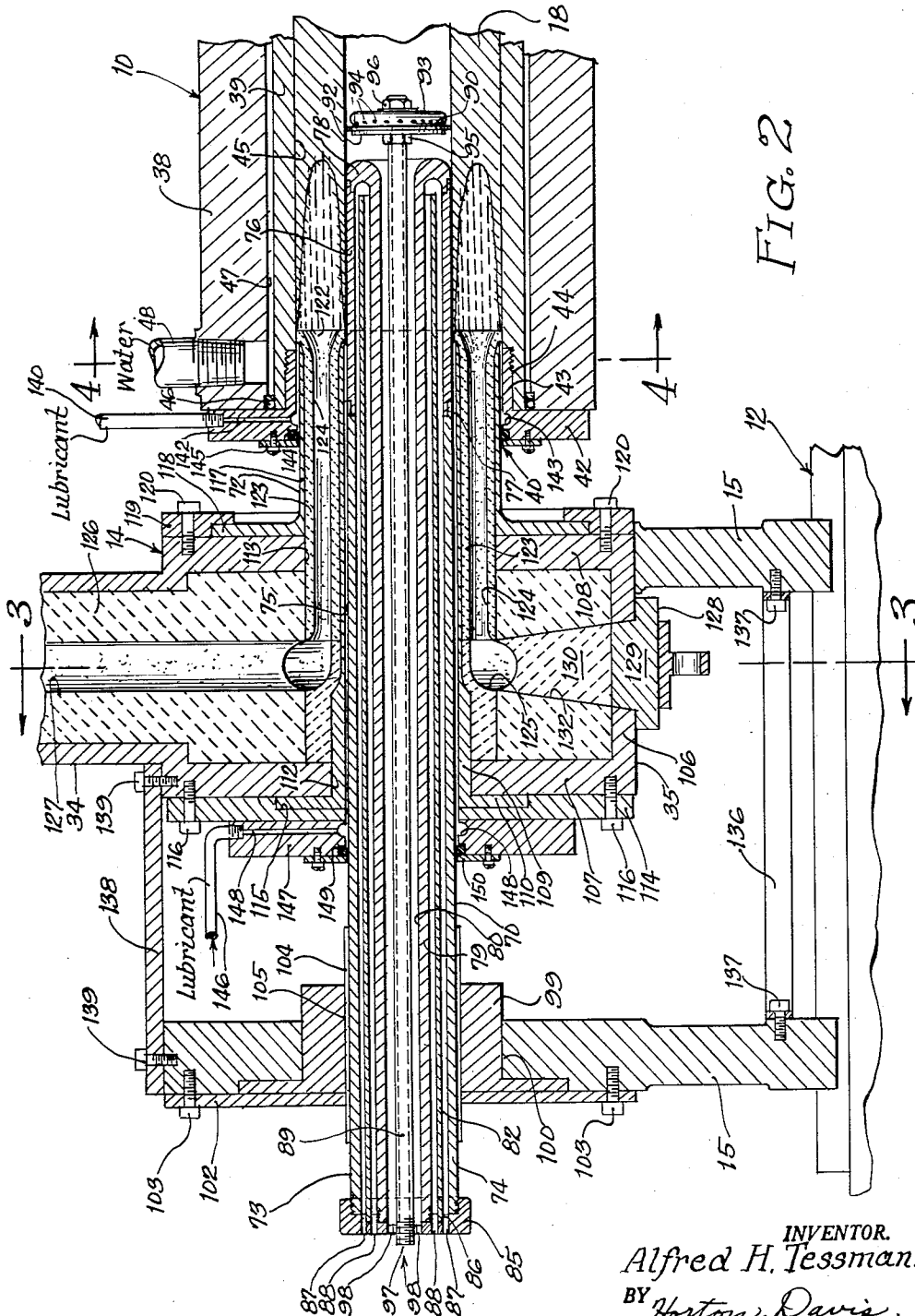
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CONTINUOUS CASTING APPARATUS

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3 Sheets-Sheet 2



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CONTINUOUS CASTING APPARATUS

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3 Sheets-Sheet 3

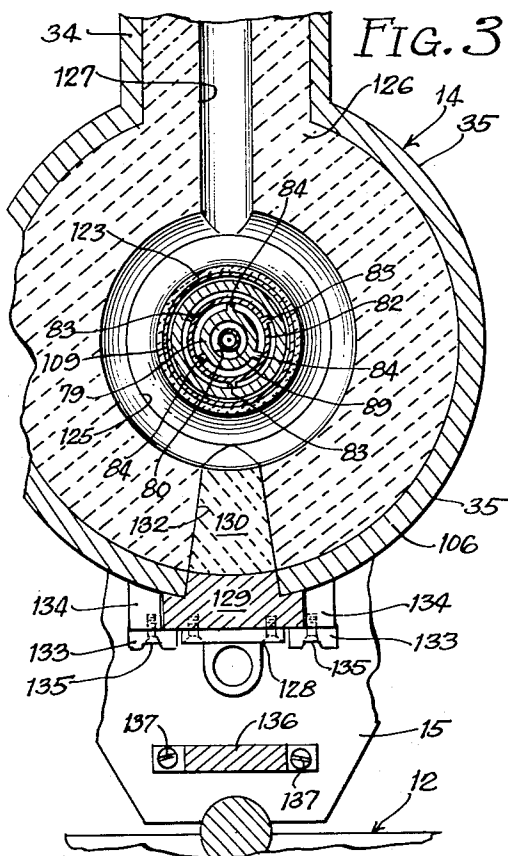


FIG. 3

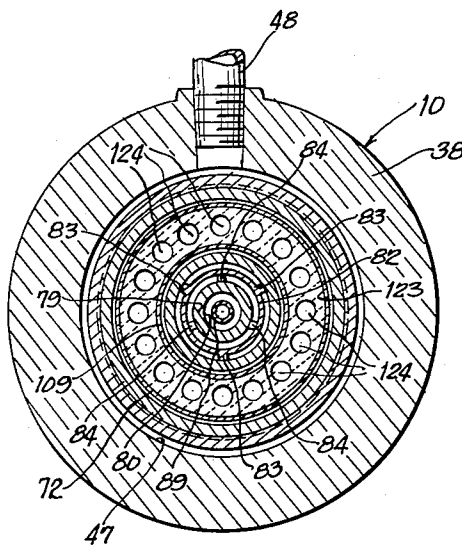


FIG. 4

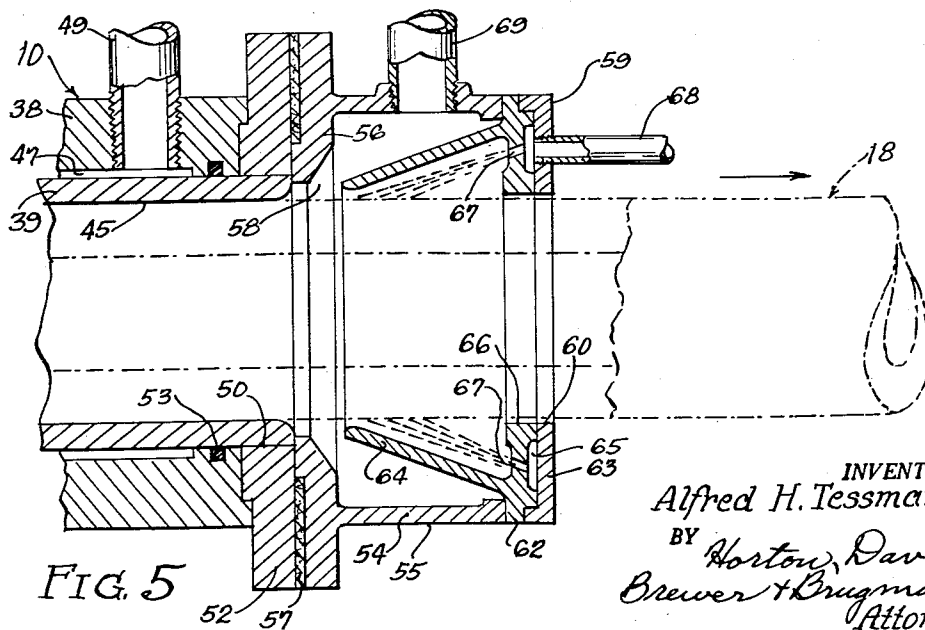


FIG. 5

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3,022,552
CONTINUOUS CASTING APPARATUS
 Alfred H. Tessmann, Chattanooga, Tenn.
 Filed Aug. 24, 1959, Ser. No. 835,634
 11 Claims. (Cl. 22—57.2)

This invention relates to apparatus for the continuous casting of metals, including apparatus which is adapted to the production of hollow sections, such as tubes and hollow ingots.

In some respects, the methods and apparatus disclosed herein are related to those disclosed and claimed in my United States Letters Patent No. 2,837,791 issued June 10, 1958, for Method and Apparatus for Continuous Casting.

One general object of this invention is to provide apparatus for the efficient and substantially continuous casting of metal in forms having hollow sections.

As another object, my invention has within its purview the provision of apparatus having cooled inner and outer molds for the substantially continuous casting of metal in hollow sectional forms, and wherein the inner mold is coextensive with the outer mold for a portion of the length of the outer mold which is sufficient to insure the formation of a substantial inner retaining shell of solidified metal near the end of the mold at which molten metal enters.

Another object of the invention is to provide apparatus of the type described for the substantially continuous casting of hollow metal sections, which apparatus embodies means affording conditions effective at both the outer and inner surfaces of the metal being cast for improving the quality and surface finish of the cast metal produced thereby.

My invention further comprehends the provision of casting apparatus having inner and outer molds for the substantially continuous production of hollow sections and wherein heat is removed from the metal along both the inner and outer surfaces by a flow of atmosphere longitudinally of the inner and outer molds.

It is another object of this invention to provide apparatus for the substantially continuous casting of metal in hollow sectional forms and utilizing inner and outer molds together with means for lubricating the surfaces of both molds and effecting the flow of lubricant longitudinally of the molds from the inlet to the outlet ends thereof.

This invention further has within its purview the provision of apparatus embodying inner and outer molds for the substantially continuous casting of metal in hollow sectional forms and including means for effecting a reduction of the atmospheric pressure at the discharge end of the inner mold to an extent sufficient to effect the flow of atmosphere along the inner mold between the metal and the mold.

As another object, my invention comprehends the provision of apparatus including a seal within a hollow casting mold and which is effective for use in connection with suitable pumping apparatus for effecting a reduction of atmospheric pressure and movement of atmosphere longitudinally of the mold between the mold and the metal being cast.

It is another object of this invention to provide apparatus for the substantially continuous casting of metal in hollow section, and which embodies means for effecting drainage of molten metal from the parts and conduits which feed molten metal to the mold when the supply of metal to the mold is stopped.

For effecting the accomplishment of the foregoing and other objects and advantages of this invention and to provide a definite example of a structure embodying and

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characterizing apparatus which affords an illustrative example of this invention, I have developed and disclosed the structure herein illustrated and described. Without making detailed reference to the accompanying drawings, it is first to be understood that the continuous casting of metals comprehends the uninterrupted flow of molten metal under pressure to one end of a casting mold, wherein the removal of heat from the metal effects the solidification thereof during the passage of the metal through the mold in which it is formed into a desired sectional shape. Before the metal leaves the shape determining mold, it is essential that a solidified outer shell shall be formed which has a thickness at least sufficient to continue its movement without material change of shape and withstand the hydrostatic pressure of any molten metal within the solidified outer shell.

Certain operating features and details of structure and arrangement of the disclosed apparatus are provided, not only to effect the continuous formation of molten metal into a casting of hollow section, but also to afford good surface finish, high quality and desirable crystal structure in the cast metal and freedom from porosity, as well as to accomplish the casting operation at a relatively high rate.

As herein depicted, a supply of molten metal flows by gravity from a source, such as a holding furnace, through a nozzle to a cavity between inner and outer casting molds having mold surfaces in spaced and opposed relationship to one another. The inner mold is coextensive with the outer mold for a distance sufficient to accomplish its shape determining purpose and to insure the formation of an inner shell of solidified metal of sufficient thickness to withstand the hydrostatic pressure of any molten metal which may remain within the cast piece beyond the end of that inner mold, while the outer mold extends beyond the inner mold for effecting the additional removal of heat and to provide support for the cast piece. The nozzle extends into the space between the molds and has surfaces in closely spaced relationship to the opposed surfaces of the inner and outer molds. However, there is sufficient space between the nozzle surfaces and those of the molds for the passage of films of lubricant and the passage of atmosphere into the mold and along the mold surfaces.

Lubricant is supplied at metered rates to the surfaces of the nozzle and thence to the mold surfaces. In the disclosed apparatus, the differential in atmospheric pressure between the inlet and discharge ends of the molds is sufficient to effect the flow of atmosphere between the cast metal and the mold surfaces and along the nozzle surfaces, thereby to induce the flow of lubricant longitudinally of the nozzle surfaces and mold surfaces. This movement of atmosphere not only effects the withdrawal of gases from the molten metal and from the vaporization of lubricant, but also prevents the formation of a static atmospheric barrier between the metal and the mold surfaces and effects the removal of both heat and carbonized lubricant. For effecting the stoppage of the casting operation for any reason without having metal solidify in the supply conduits and nozzle passages, a removable drain plug is provided at the bottom of the nozzle to provide for the drainage of metal therefrom as a supplement to the use of a valve for stopping the flow from the holding furnace.

Other objects and advantages of the invention will be apparent from the following description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a side elevational view of continuous casting apparatus embodying a preferred form of my invention and includes a fragmentary sectional illustration of a reservoir, such as a holding furnace, from which molten metal is supplied under a head pressure to the casting apparatus;

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FIG. 2 is a fragmentary side sectional view drawn to a larger scale than FIG. 1 and illustrating details of the internal structure of the continuous casting apparatus depicted in FIG. 1;

FIG. 3 is a fragmentary end sectional view taken substantially as indicated by a line 3--3 and accompanying arrows in FIG. 2;

FIG. 4 is a fragmentary end sectional view taken substantially at the position indicated by a line 4--4 in FIG. 2 and in the direction of the accompanying arrows; and

FIG. 5 is a fragmentary side sectional view similar to FIG. 2, but illustrating a different portion of the apparatus of FIG. 1.

Having detailed reference to the drawings, wherein an exemplary embodiment of the invention is shown for illustrative purposes, the continuous casting apparatus herein illustrated is adapted to horizontal disposition, although the invention comprehends either horizontally or vertically disposed apparatus. As depicted in FIG. 1, an outer mold assembly 10 is secured to a base structure 12 by supports 13. In aligned relationship to the outer mold assembly 10 and at one end thereof, a nozzle and inner mold assembly 14 is secured to the base structure 12 and supported relative thereto by supports 15. In the illustrated structure, molten metal is normally retained in a holding furnace 16 and flows from there to the continuous casting apparatus through a conduit 17. In passing through the casting apparatus, the molten metal solidifies and emerges therefrom as a continuous cast piece 18 of a desired hollow section. Withdrawing rolls 19 driven by a prime mover, such as a motor 20 through a speed reducing mechanism 22 and connected driving parts including elements such as sprockets 23 and 24 and a driving chain 25 aid in effecting the withdrawal of the cast piece from the casting apparatus; the speed of the withdrawing rolls being selected to effect the movement of the cast piece from the casting apparatus at a predetermined casting rate.

The holding furnace 16 has an internal reservoir 26 lined with a suitable refractory material 27 and has insulated walls 28 housed within a suitable retaining wall structure 29. A passage 30 through refractory material 32 extends from one end of the reservoir 26 to the exterior of the holding furnace wall and is there adjoined by the conduit 17 which has a refractory lining 33 and extends to a connecting conduit 34 on a housing 35 which comprises a part of the nozzle and inner mold assembly 14.

For effecting control of the flow of molten metal from the reservoir 26 of the holding furnace 16, a plug-type valve 36 is mounted for movement toward and from the end of the passage 30 within the holding furnace under the control of a manually operated valve actuator 37. In apparatus of the type illustrated, it is desirable that the passage 30 and conduit 17 shall have a downward slope from the interior of the holding furnace to the nozzle and inner mold assembly 14. This avoids the trapping of any molten metal at a position in which it might become solidified and hamper flow, and it also provides for the flow of molten metal away from the valve 36 through the passage 30 and conduit 17 and toward the nozzle and inner mold assembly 14 when the valve 36 is closed at the holding furnace to stop the operation of the casting apparatus.

As shown in FIG. 2, the outer mold assembly 10 includes a tubular outer jacket 38 which serves both as a housing and support for a mold tube 39 and as a jacket for the circulation of a coolant liquid, such as water, around and along the mold tube 39 during the operation of the apparatus. At its inlet end 40, as shown in FIG. 2, the outer mold tube 39 is secured to the tubular outer jacket 38 by a ring-type end plate 42 having a collar-type flange 43 thereon which is threaded into an internal recess 44 in the inlet end of the outer mold tube 39; the inner surface of the collar-type flange 43 being in substantially flush relationship to an inner sur-

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face 45 of the outer mold tube which defines the exterior surface of a mold cavity and determines the exterior sectional shape of the cast piece. Between the outer mold tube 39 and the tubular outer jacket 38 and adjacent the end plate 42, a seal in the form of a gasket 46 is provided to close a space 47 between the outer surface of the mold tube 39 and the inner surface of the outer jacket 38, through which coolant is circulated for cooling the mold tube during the operation of the apparatus. As shown in FIGS. 1 and 2, the coolant flows to the space 47 through a conduit 48 near the inlet end of the mold and flows from the space through a conduit 49 near the outlet end of the mold.

In order to provide desired heat conductivity in the mold tube 39, it is made of a highly heat conductive metal, such as copper with a wall thickness adequate to afford the required strength. The inner surface of this mold tube is reamed to a precise size and is then plated with a highly wear resistant metal, such as chromium, and is then highly polished to establish a very smooth and non-porous mold surface.

At the outlet or discharge end of the outer mold assembly 10, as shown in FIG. 5, the outer mold tube 39 fits into an opening 50 in an end closure plate 52, which closure plate is also adjoined to the end of the outer jacket 38. A gasket 53 provides a seal for the end of the coolant carrying space 47 and prevents the leakage of coolant therefrom adjacent the surfaces of the end cover plate 52. A housing 54 having a generally cylindrical side wall 55 and an end wall 56 is secured to the end closure plate 52 and a gasket 57 provides a seal between the end wall 56 and the end closure plate 52. An opening 58 is provided in the end wall 56 of the housing in alignment with the opening 50 in the end plate 52 for the passage of the cast piece 18 from the mold. At the end of the side wall 55 opposite the end wall 56, an end cap 59 is secured to the side wall 55 in spaced and opposed relationship to the end wall 56. The end cap 59 has an opening 60 which is aligned with the opening 58 for the passage of the cast piece 18 therethrough.

Between the end cap 59 and the side wall 55 a part 62 is provided which includes a mounting flange portion 63 and an inwardly projecting and substantially frusto-conical baffle 64, which baffle, in addition to projecting inwardly toward the end of the mold tube 39, is substantially concentric with respect to the openings 50 and 60. The flange portion 63 of the part 62 is secured to the housing 54 between the outer end of the side wall 55 and the end cap 59, and a channel 65 in the outer end surface of the part 62 extends around an opening 66 in the part 62 and provides a header passage communicating with a plurality of circumferentially spaced nozzle openings 67 which extend through the part 62 to the interior of the frusto-conical baffle 64. The channel 65 is closed by the end cap 59, and coolant is supplied thereto through a pipe 68 which is threaded into an opening in the end cap 59.

The inner end of the frusto-conical baffle 64, in addition to extending toward the outlet end of the mold tube 39, has an inner surface which terminates in close proximity to the surface of the cast metal 18 at its position of emergence from the mold tube, whereupon coolant supplied through the pipe 68 and header passage 65 and sprayed onto the outer surface of the cast metal through the nozzle openings 67 within the baffle 64 also provides an effective seal between the cast metal and the end of the baffle.

A conduit 69 is secured to and communicates with the upper portion of the side wall 55 of the housing 54 and is connected to a vacuum pump (not shown) for reducing the pressure at the outlet end of the mold tube 39 and within the housing 54 to a value well below normal atmospheric pressure. The coolant and the coolant vapors which are caused by the contact of the coolant with the

cast metal within the baffle 64 are withdrawn from the interior of the housing 54 through the conduit 69 and are separated from the atmosphere in the vacuum line. This avoids the escape of coolant and vapors through the openings 60 and 66 at the end of the housing 54. The reduced pressure within the housing 54 also, in addition to preventing the movement of coolant into the outlet end of the mold tube 39 between the cast metal and the mold, effects a movement of atmosphere longitudinally of the mold tube 39 between the metal and the mold from the inlet end of the mold tube 39.

In the nozzle and inner mold assembly, as illustrated in FIG. 2, an inner mold assembly 70 extends through the interior of a nozzle 72 to a position well within the inlet end of the mold cavity of the outer mold tube 39 for defining the inner surface of the cast piece 13 of hollow section. This inner mold assembly 70, in addition to being supported with the nozzle 72, at the inlet end of the outer mold, also has a projecting outer end portion 73 which is supported by one of the supports 15 at a position spaced from the nozzle. The outer end portion of the inner mold includes an outer metal support tube 74 which is longitudinally straight and of uniform section, which outer metal support tube extends into a longitudinal inner opening in the nozzle 72 and there adjoins an inner metal mold tube 76 at a joint 77 providing snugly fitting overlapping portions on the adjoined ends of the tube and from which the tubes extend in coaxial relationship to one another with their outer surfaces in flush relationship. The outer support tube 74 may be made of a metal such as steel, while the inner metal mold tube 76, like the outer mold tube 39, is made of a highly heat conductive metal such as copper plated on its exterior surface with a wear resistant metal such as chromium having a highly polished outer surface ground accurately to size to establish the proper wall thickness in the cast metal and provide a surface to which the metal will not adhere unduly during the casting operation.

At its inner end, the inner mold tube 76 adjoins a flared end 78 on an inner metal tube 79 which extends through the inner mold tube and outer metal support tube 74 in substantially coaxial and concentric relationship thereto. The inner metal tube 79 has an opening 80 which extends longitudinally therethrough from end to end.

Between the inner metal tube 79 and the outer metal support tube 74, a metal tube 82 extends from the outer end of the inner metal tube 79 to a position within the inner mold tube 76 and near the flared end portion 78 of the inner metal tube. As shown in FIGS. 3 and 4, the metal tube 82 has peripherally spaced metal ribs 83 extending longitudinally of the outer surface thereof, which ribs engage the inner surface of the outer support tube 74 and the inner surface of the inner mold tube 76 to afford support between the adjacent tubes and to provide passages therebetween for the flow of coolant to the inner surface of the inner mold tube 76. Similarly, the inner metal tube 79 has peripherally spaced ribs 84 extending longitudinally thereof and engaging the inner surface of the metal tube 82 to provide supporting spacers therebetween while leaving passages for the flow of coolant from the inner end of the inner mold tube 76 to the outer end of the inner mold assembly. A cap 85 is threaded onto the outer end of the outer support tube 74 and has threaded engagement with the inner metal tube 79, as shown in FIG. 9, as well as having a groove 86 therein for supporting the outer end of the metal tube 82. Passages 87 extend through the cap 85 and communicate with the space between the metal tube 82 and the outer support tube 74 for making connections to a suitable source of a liquid coolant, such as water, to supply such coolant to the inner surface of the mold tube 76. Passages 88 in the cap 85 communicate with the space between the inner metal tube 79 and the metal

tube 82 to provide for the flow of coolant from the inner mold assembly.

A pipe 89 extends through a central opening in the cap 85 and extends through the longitudinal opening 80 in the inner metal tube 79 to a position beyond the inner end of the inner mold tube 76 and the flared end portion 78 on the inner metal tube. At its inner end and in spaced relationship to the inner end of the inner mold tube and the flared end portion 78 of the inner metal tube, the pipe 89 has a disc 90 of a wear and heat resistant material and a supporting metal disc 92 secured thereto in spaced and opposed relationship to the flared end portion 78 of the inner metal tube; the diameter or peripheral size of the disc 90 being only slightly smaller than the normal inside dimension or dimensions of the hollow portion of the cast piece 13. Also secured to the inner end of the pipe 89 adjacent the surface of the disc 90 which is opposite the inner mold tube 76 is a hollow housing 93, the interior of which is in communication with the interior of the pipe 89 and which has therein a plurality of peripherally spaced openings 94 for directing liquid coolant, such as water conducted thereto through the pipe 89 to the peripheral surface of the disc 90. The discs 90 and 92 and the housing 93 are secured in place on the pipe 89 by means such as a nut 95 and an end closure cap 96 for the pipe 89.

A coolant liquid, such as water, is supplied to the pipe 89 through a projecting end 97 thereof which is exterior to the cap 85 at the outer end of the inner mold assembly 70. Also, passages such as 98 are provided in the cap 85 at the outer end of the inner mold assembly for connection to a vacuum pump, so that the inner metal tube 79 serves as a conduit for obtaining sub-normal atmospheric pressure at the discharge end of the inner mold tube, while the disc 90 and the coolant supplied thereto through the pipe 89 and housing 93 serve as an effective seal within the cast metal piece at the position spaced from the end of the inner mold. The pressure reduction at the inner end of the inner mold is sufficient to exhaust the liquid coolant and vapor from around the disc 90 and also to effect the movement of atmosphere and vapors longitudinally of the inner mold assembly between the mold and the metal being cast. This flow of atmosphere along the mold not only cools the metal and removes vapor and gases therefrom, but also prevents the movement of any moisture from the region of the seal to the space between the inner mold and the metal being cast.

At the outer end of the inner mold assembly 70, a flanged bearing 99 fits into an opening 100 in the support 15 and is held in place by an end plate 102 which is secured to the support 15 by fastening means, such as cap screws 103. A shim 104 is used in the disclosed structure between the outer surface of the outer support tube 74 and an opening 105 in the bearing 99 to insure accurate positioning and firm support for the outer end of the inner mold assembly.

The nozzle 72 constitutes an assembly of parts encompassing the mid-portion of the inner mold assembly and which has a portion extending into the cavity of the outer mold for conducting molten metal from a source, such as the holding furnace 16 to the space between the inner mold tube 76 and the outer mold tube 39. That space between the inner and outer mold tubes, of course, defines the sectional shape and dimensions of the hollow cast section. It may be understood that although the inner mold tube does not extend through the full length of the outer mold tube, it does extend for a sufficient distance within the mold cavity to insure the formation of an adequate inner solidified metal shell in the cast piece to withstand the hydrostatic pressure of any molten metal which may possibly be left within the section of the cast piece. The extent of the inner mold into the mold cavity depends upon factors including the kind of metal being cast, the thickness of the cast wall of the

metal and the cooling effected by the flow of coolant through the inner mold assembly, as well as the cooling accomplished by the flow of atmosphere between the cast metal and the molds, and also the cooling effected by the coolant which is used for sealing purposes at a position spaced from the discharge end of the inner mold.

Considering the structure of the nozzle 72, as shown in FIGS. 2, 3 and 4, the housing 35 is of generally cylindrical structure, having an outer wall 106 and end walls 107 and 108. The conduit 34 adjoins and extends from the upper portion of the outer wall 106 for making connection to the conduit 17 through which molten metal is conducted to the nozzle from the holding furnace or other source of supply. A tubular metal inner shell 109 having an outwardly projecting flange 110 at its outer end extends through aligned openings 112 and 113 in the end walls 107 and 108 of the housing 35; the tubular portion of the shell fitting snugly into the opening 112 in the end wall 107 and extending through the opening 113 in spaced relationship to the end wall 108 to a position such that it projects beyond the end wall 108, while the flange 110 engages the outer surface of the end wall 107. This tubular metal shell 109 is secured in place relative to the end wall 107 by a removable covering plate 114 having a recess 115 therein which fits over the flange 110 and is secured to the end wall 107 by fastening means such as cap screws 116.

An outer tubular metal shell 117 has an outwardly projecting flange 118 thereon and is secured to the end wall 108 by a flanged holding ring 119 held in place against the end wall 108 by fastening means, such as cap screws 120. The inner opening of the outer metal shell 117 is substantially equal in size to the size of the opening 113 in the end wall 108. Also, the lengths of the inner metal shell 109 and the outer metal shell 117 are such that in addition to being disposed in substantially coaxial and concentric relationships to one another, the ends of the shells remote from the housing 35 terminate in substantially coplanar relationship to one another and define the exterior surfaces of a ring-type nozzle portion 122 which extends into the cavity of the outer mold tube in closely spaced relationship thereto, as well as encompassing the inner mold tube 76 and its support tube 74 in closely spaced relationship thereto.

Between the inner and outer shells 109 and 117 a lining 123 of a heat insulating refractory material is provided and has a plurality of circumferentially spaced and axially extending openings 124 therein which extend to and open into the space between the inner and outer mold tubes from a circumferential header passage 125 which encompasses the inner mold assembly 70 at the longitudinal mid-portion of the housing 35. The remainder of the housing 35 and the conduit 34 are lined with a heat insulating refractory material 126 which has a passage 127 therein affording communication between the header passage 125 and the passage 30 in the conduit 17. To provide for a downward flow of molten metal from the supply in the holding furnace to the header passage 125, for supplying molten metal to the mold cavity under a head pressure, the passage 127 is located at the top portion of the housing 35.

For effecting the drainage of molten metal from the nozzle passages 124, the header passage 125 and the metal feed passages 127 and 30, a removable plug 128 is provided at the bottom portion of the housing 35 and includes a cap portion 129 to which is secured a refractory plug element 130 for closing a tapered opening 132 in the lower portion of the refractory lining 126 in the housing 35, which opening 132 communicates with the lower portion of the header passage 125. As depicted in FIG. 3, the plug 128 is normally held in place in the opening 132 by manually rotatable holding elements 133 secured to blocks 134 on the lower surface of the housing 35 by fastening means, such as screws 135.

For bracing the structure of the nozzle and inner mold

assembly, a brace 136 extends between the lower portions of the supports 15 and is secured thereto by fastening means, such as cap screws 137. Also, a top brace 138 extends between the top of the outer support 15 and the top portion of the end wall 107 of the housing 35, and is secured thereto by fastening means, such as cap screws 139.

For aiding in the prevention of sticking of the metal being cast to the surfaces of either of the mold tubes 39 or 76, provision is made for the supply of a metered quantity of lubricant to the surfaces of each of the mold tubes from the spaces between each mold tube surface and the nozzle 72. For supplying the lubricant to the inner surface of the outer mold tube 39, a conduit 140 is threaded into the edge of the ring-type end plate 42 and communicates with a passage 142 in the end plate for the flow of lubricant to a peripheral groove 143 in the inner surface of the end plate, which groove encompasses the outer shell 117 of the nozzle. The leakage of lubricant between the nozzle and the outer end of the end plate 42 is prevented by a gasket 144 secured in place between the groove 143 and the outer surface of the end plate by a retaining ring 145. From the conduit 140 and passages 142, lubricant flows around the nozzle in the groove 143 and then moves longitudinally of the inner surface of the mold in the space between the nozzle and the mold tube and then moves along the mold surface between the metal and the mold as a result of the reduction of the atmospheric pressure at the outlet end of the mold.

For providing a metered quantity of lubricant to the outer surface of the inner mold tube 76, lubricant is supplied through a conduit 146 which is threaded into an edge of an end plate 147 and flows through a passage 148 in the end plate 147 to a groove 143 in the inner edge surface of the end plate 147, which latter groove encompasses the outer surface of the outer support tube 74. Leakage of lubricant past the outer end surface of the end plate 147 is prevented by a gasket 149 held in place between the end plate and the outer support tube by a ring 150 secured to the end surface of the end support plate 147. From the conduit 146 and passage 148, lubricant flows around the outer surface of the outer support tube 74 in the groove 143, and then flows between the inner shell 109 of the nozzle and both the outer support tube and the inner mold tube 76 to provide lubrication between the inner mold tube and the metal being cast; the flow of lubricant being induced by the reduction of atmospheric pressure at the discharge end of the inner mold tube.

To start the operation of the disclosed apparatus, a metal piece having the sectional shape of the metal to be cast and a length sufficient to extend from the withdrawing rolls 19 to a position between the inner and outer mold tubes near the discharge end of the nozzle 72 is placed in the mold cavity and in engagement with the withdrawing rolls. This piece is desirably threaded on its end, so that it can be detached from the cast metal by unscrewing it therefrom after the casting operation is under way. With the starting piece in place, the flow of coolant to the inner and outer molds and to the vacuum seals for the inner and outer molds is started. Also, the metered flow of lubricant is started through conduits 140 and 146, and the vacuum pumps are turned on for effecting the reductions of air pressure at the discharge ends of the inner and outer molds so that the molds are cooled and lubricated and the reduced atmospheric pressures at the discharge ends of both the inner and outer molds are effective from the commencement of the operation thereof. Then, with the plug 128 in place, the flow of molten metal is started by opening the valve 36 at the holding furnace. The flow of metal and the continuous casting of metal in a hollow sectional shape may be continued for any desired period of time. When the cast metal has reached the withdrawing rolls and is being withdrawn

thereby at a predetermined rate, the starting piece is disconnected from the cast metal for another use in starting the operation of the apparatus.

During the continuous casting of metal, the reduced atmospheric pressure within the housing 54 effects the movement of lubricant and atmosphere longitudinally of the inner surface of the outer mold tube 39 between the metal and the mold, and atmosphere, vapors and gases from the metal and lubricant, as well as carbonized lubricant and the vaporized coolant sprayed on the outer surface of the cast metal for cooling and sealing purposes within the housing 54 are removed by the action of the vacuum pump through the conduit 69. A considerable amount of heat is removed by the air and atmosphere which moves through the mold as a result of the reduced pressure at the outlet end thereof and the removal of vapors and gases from the metal, as it is cast, improves the quality of the cast metal and aids in eliminating surface indentations and internal blow holes in the cast metal.

Similar functions are accomplished by the reduction of pressure and cooling which is effected by the reduction of the atmospheric pressure at the discharge end of the inner mold and between the inner mold and the seal provided by the disc 90 and the coolant which is applied to the surface thereof for cooling and sealing purposes. Since the inner and outer molds are both cooled by a flow of coolant and that cooling is aided by the movements of air and atmosphere along the molds, as well as by the coolant applied directly to the inner and outer surfaces of the cast piece adjacent the discharge ends of the molds, the casting rate may be relatively high and internal structure and grain of the cast metal afford high quality in the cast piece. Furthermore, the finish of both the inner and outer surfaces of the cast metal is smooth and devoid of scale.

When the operation of the apparatus is to be stopped for any reason, the valve 36 at the holding furnace is closed, and the plug 128 at the bottom of the housing 35 is promptly removed, so that the molten metal from within the passages 30 and 127, as well as from the nozzle passages 124 and the header passage 125 flows outwardly through the opening 132 without solidifying in the passages. The operation of the withdrawing rolls 19 is continued until the end of the cast piece is removed from the mold cavity, after which the various coolant supplies, the vacuum pumps and the lubricant are shut off.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent of the United States is:

1. In apparatus for the substantially continuous casting of metal in the form of a hollow section having inner and outer surfaces, the combination comprising an outer metal mold having an opening therethrough which defines the outer surface of a mold cavity having inlet and outlet ends, a metal inner mold extending into the inlet end of said mold cavity in the outer mold and having an outer mold surface in spaced and opposed relationship to said surface of the outer mold, said inner mold terminating at an inner end within the mold cavity in the outer mold, a ring-type nozzle encompassing the inner mold and having a portion extending into the inlet end of the mold cavity, said nozzle having inner and outer surfaces in closely spaced relationship to portions of said surfaces of the inner and outer molds and having a passage therein for the flow of molten metal to the mold cavity, means for cooling the molds, means providing an effective closure for the hollow section of cast metal and an effective seal with the inner surface thereof at a position within the outer mold and spaced from the inner end of the inner mold, and means for effecting a reduction of the atmospheric pressure to a value below normal atmospheric pressure within the space between the inner mold and the closure providing means.

2. In apparatus for the substantially continuous casting of metal as defined in claim 1, said means for cooling the inner mold including passages in the inner mold for the flow of coolant longitudinally of the inner mold toward and from the inner end thereof.

3. In apparatus for the substantially continuous casting of metal as defined in claim 1, said inner mold having an opening extending longitudinally therethrough, and means extending through said opening in the inner mold and serving as a support for the closure providing means.

4. In apparatus for the substantially continuous casting of metal as defined in claim 1, said passage in the ring-type nozzle for the flow of molten metal to the mold cavity including a header passage extending circumferentially of the nozzle, and a plurality of passages spaced circumferentially of the nozzle and extending longitudinally thereof from the header passage through said portion which extends into the mold cavity.

5. In apparatus for the substantially continuous casting of metal as defined in claim 1, the combination being further characterized by means for introducing lubricant between the nozzle and the inner mold at a position external to the mold cavity, means for effecting distribution of the lubricant peripherally of the surface of the inner mold, and said reduction of atmospheric pressure in the space between the inner mold and the closure providing means effecting the flow of said lubricant longitudinally of the inner mold between the inner mold and the nozzle.

6. In apparatus for the substantially continuous casting of metal as defined in claim 3, said opening through the inner mold serving as a conduit for connection to the pressure reducing means, and said means extending through said opening comprising a conduit for the flow of liquid to the means providing an effective seal with the inner surface of the cast metal.

7. In apparatus for the substantially continuous casting of metal as defined in claim 4, said nozzle also having an openable and closeable passage therein for the drainage of molten metal from the header passage.

8. In apparatus for the substantially continuous casting of metal in the form of a hollow section having inner and outer surfaces, the combination comprising an outer mold having an opening therethrough which defines an outer mold surface having an inlet end for the introduction of molten metal and a discharge end for the ejection of solidified metal, an inner mold supported within the inlet end of the outer mold surface and having a mold surface in spaced and opposed relationship to said outer mold surface to define a mold cavity between the outer and inner molds, nozzle means extending into the mold cavity between the inner and outer molds at the inlet end of the outer mold surface, said nozzle having a passage therein for the flow of molten metal into the mold cavity between the molds, said inner mold having an end at which solidified metal emerges, means for introducing lubricant to each of the mold surfaces between the nozzle and each mold, and means including a conduit extending through the inner mold, a chamber at one end of the outer mold, and parts providing effective pressure seals with the metal being cast at positions spaced from one end of the inner mold and also within said chamber for effecting atmospheric pressure differentials between the ends of each of the molds which is sufficient to move lubricant and atmosphere longitudinally of each mold toward the discharge end thereof.

9. In apparatus for the substantially continuous casting of metal to form a casting of hollow section, the combination comprising an outer metal mold having an elongated opening therethrough which defines an outer mold surface and has an inlet end to which molten metal is supplied and an outlet end from which a solidified metal casting is ejected, a metal inner mold extending into the inlet end of said opening within said outer mold surface and having a mold surface in spaced and opposed relationship to said outer mold surface to define a mold cavity be-

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tween the outer and inner molds, a ring-type nozzle extending into the mold cavity at the inlet end of said opening and having outer and inner surfaces in closely spaced relationship to portions of said mold surfaces of the outer and inner molds and having a passage therein for the flow of molten metal to the cavity between the molds, means for supplying molten metal to said passage, means for cooling the inner and outer molds, means for introducing lubricant between the nozzle surfaces and the mold surfaces of each of the molds, and separate means for effecting reductions of the atmospheric pressures at the ends of the outer and inner molds remote from the nozzle to values below normal atmospheric pressure, thereby to effect movements of the lubricant along the nozzle and between each mold surface and the metal being cast, said means for effecting reduction of the atmospheric pressure at the end of the inner mold including means spaced from said end of the inner mold and providing a seal within the hollow casting and a conduit extending longitudinally through the inner mold.

10. In apparatus for the substantially continuous casting of metal in the form of a hollow section having inner and outer surfaces, the combination comprising an outer mold having an opening therethrough which defines an outer mold surface having an inlet end for the introduction of molten metal and a discharge end for the ejection of solidified metal, an inner mold supported within the inlet end of the outer mold surface and having a mold surface in spaced and opposed relationship to said outer mold surface to define a mold cavity between the outer and inner molds, a ring-type nozzle extending into the mold cavity and having surfaces in closely spaced relationship to said mold surfaces of the inner and outer molds, said nozzle having a passage therein for the flow of molten metal to the mold cavity between the molds, means providing an effective seal with the solidified metal at a position spaced from the discharge end of the inner mold, and means for effecting a reduction of the atmospheric pressure to a value below normal atmospheric pressure between the discharge end of the inner mold and the last mentioned means, said means providing an effective seal with the solidified metal comprising a metal plate mounted in a plane transverse to the mold surface of the inner mold and having its periphery in

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closely spaced relationship to the solidified metal, and means for providing a flow of liquid to the surface of said metal plate remote from the inner mold and directed to the periphery of the metal plate to provide a liquid seal between the periphery of the metal plate and the solidified metal.

11. In apparatus for the substantially continuous casting of metal to form a casting of hollow section, the combination comprising an outer metal mold having an elongated opening therethrough which defines an outer mold surface and has an inlet end to which molten metal is supplied and an outlet end from which a solidified metal casting emerges, a metal inner mold extending into the inlet end of said opening within said outer mold surface and having a mold surface in spaced and opposed relationship to said surface of the outer mold to define a mold cavity between the outer and inner molds, a ring-type nozzle extending into the mold cavity at the inlet end of said opening and having outer and inner surfaces in closely spaced relationship to portions of said mold surfaces of the outer and inner molds and having a passage therein for the flow of molten metal to the cavity between the molds, means for supplying molten metal to said passage, means for cooling the inner and outer molds, said casting having inner and outer surfaces produced by the spaced mold surfaces, and separate means including parts providing seals with the inner and outer surfaces of the casting and spaced from the ends of the respective molds, and conduits extending to the spaces between said seals and the ends of the molds for effecting reductions of atmospheric pressure at the ends of the inner and outer molds remote from said nozzle and in amounts for effecting movements of atmosphere along the nozzle between each mold and the metal being cast.

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