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METHOD FOR VACUUM DEGASSING AND CASTING MOLTEN METAL WITH ELECTROMAGNETIC CONTROL

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Fig. 1.

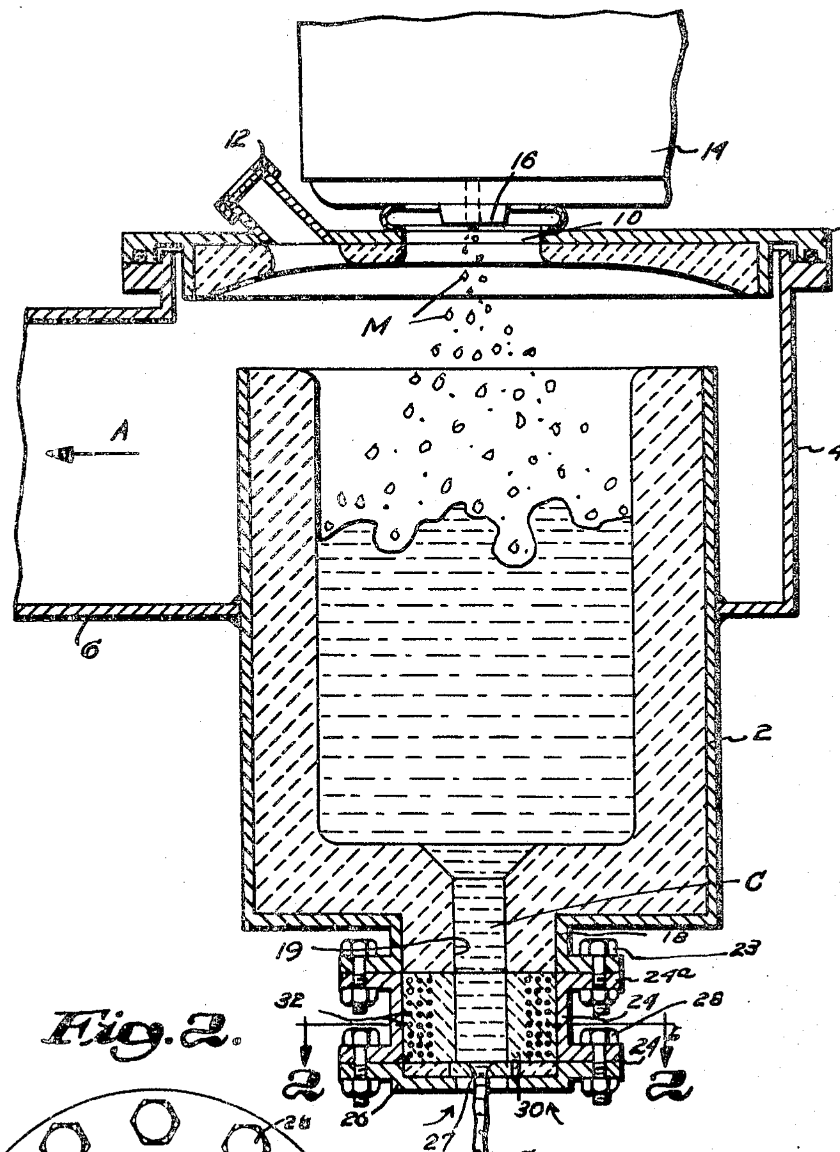
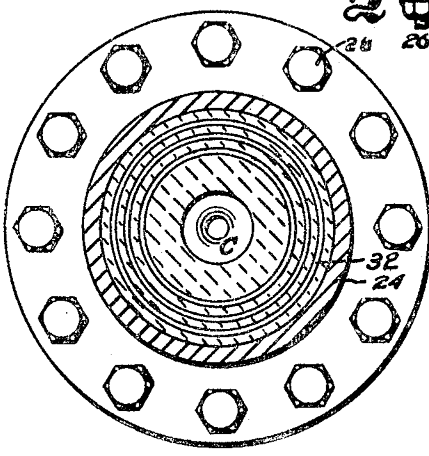


Fig. 2.



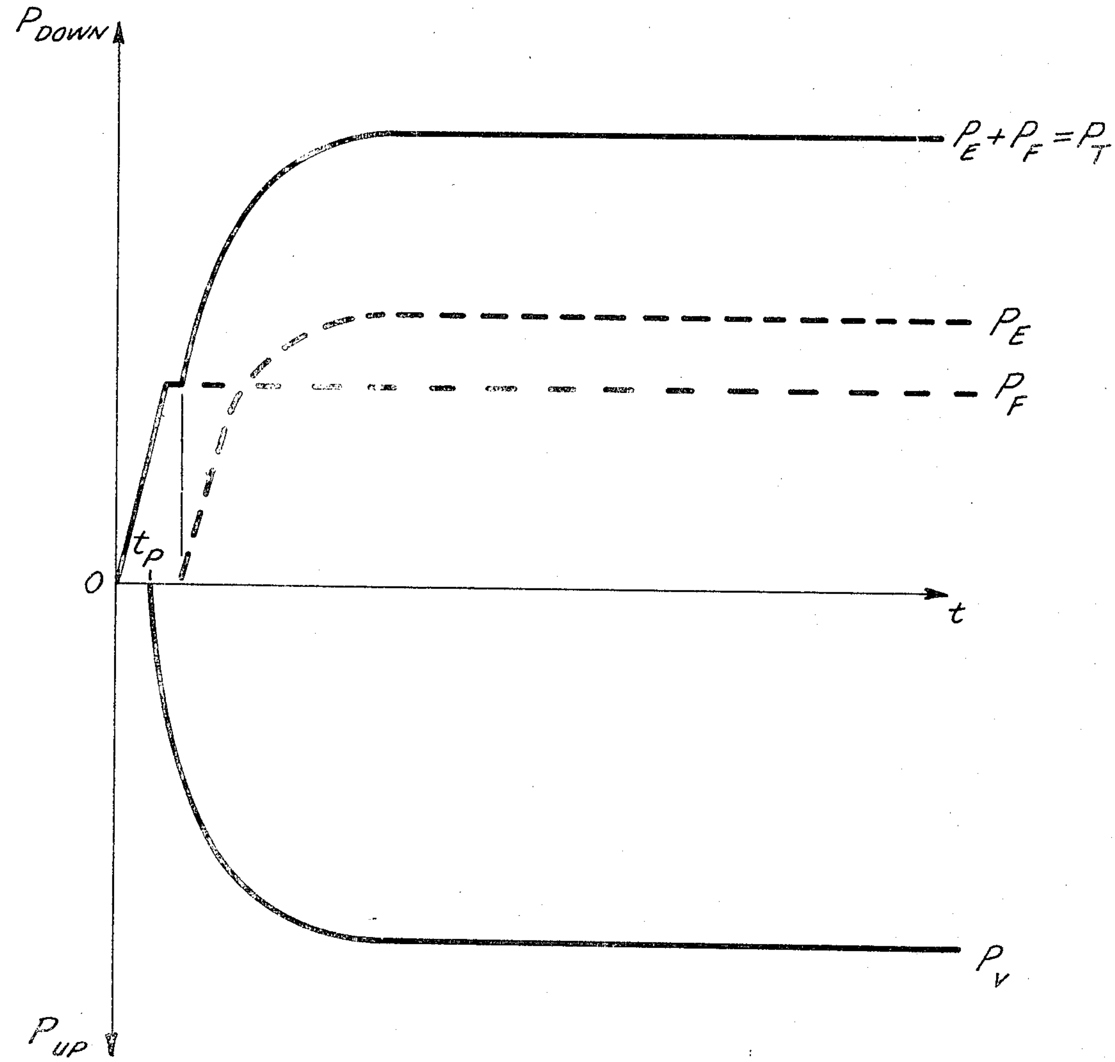


Fig. 3.

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METHOD FOR VACUUM DEGASSING AND CASTING MOLTEN METAL WITH ELECTROMAGNETIC CONTROL

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Continuation-in-part of application Ser. No. 498,363, Oct. 20, 1965. This application May 20, 1968, Ser. No. 730,383

Int. Cl. C21c *7/06*; B22d *37/00*

U.S. Cl. 75—12 9 Claims

ABSTRACT OF THE DISCLOSURE

Molten metal degassed in a vacuum chamber is released through a discharge conduit communicating with the atmosphere. The atmospheric pressure outside the chamber is much greater than the pressure therein and the pressure difference tends to prevent metal from flowing out of the vacuum chamber. To provide continuous flow, without requiring maintenance of a large head of metal within the chamber, electromagnetically induced forces act on the metal within the conduit, forcing it out of the chamber.

This application is a continuation-in-part of my copending application Ser. No. 498,363, filed Oct. 20, 1965, now abandoned and relates generally to improvements in casting molten metal for use in the steel-making industry. In one specific aspect, the invention is concerned with the type of casting operation in which molten metal to be cast is first subjected to a vacuum degassing process.

In carrying out methods of casting in which molten metal is first subjected to a vacuum degassing operation, problems arise in controlling the flow of molten metal in a satisfactory manner. This is especially the case when the stream of molten metal is discharged from the evacuated degassing enclosure into the much higher pressure atmosphere. Heretofore, in order to discharge molten metal from a degassing enclosure while maintaining the enclosure in an evacuated condition, it has been necessary to maintain a barometric head of molten metal (typically a column of four to five feet in height, the exact height depending on the pressure differential between the inside and outside of the degassing enclosure), plus an additional head of 18 to 24 inches to promote flow, within the enclosure in order to cause molten metal to flow outwardly through the bottom discharge outlet. The reason for this, of course, is that the higher atmospheric pressure outside the enclosure exerts a force continuously seeking to displace molten metal back into the vacuum chamber. To overcome this atmospheric-pressure-force, long, refractory-lined, heated barometric legs (such as those shown in U.S. Pats. Nos. 2,837,790, assigned to the Ford Motor Co., and 2,734,240 assigned to the Allegheny Ludlum Steel Corp., and my prior Pat. No. 3,146,288) have been provided between the outlet and the major portion of the degassing enclosure. Such barometric legs have provided the necessary downward discharge force, but at considerable cost. Such legs not only require large additional amounts of refractory and result in considerable heat loss but also make it impossible properly to vacuum degass the initial few tons of the batch of molten metal passed through the enclosure.

Accordingly, it is a principal object of the present invention to provide a method of controlling the flow of molten metal through the nozzle of a tundish or other vacuum casting member which eliminates the need for long barometric legs and, thereby, results in a simple and relatively inexpensive system which can be used for

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pouring in either air or vacuum without the use of extra pouring boxes, substantially eliminates the need of extra refractory, materially reduces heat loss, and permits vacuum degassing of all but a few pounds of the batch of molten metal passed through the enclosure.

The method of the present invention accomplishes these and other objects by exerting on the metal downward electromagnetic forces to create an electromagnetic head greater than the difference between the vacuum pressure head produced by the pressure differential without and within the enclosure and the ferrostatic head created by the molten metal within the enclosure. In preferred modes, this force is varied in accord with changes in the ambient discharge pressure and head of metal within the enclosure, and the force is further controlled in such a manner as to maintain metal within the nozzle to effectively seal the enclosure to keep it in an evacuated condition.

Other objects, features and advantages will appear from the following detailed description of a preferred embodiment of the invention, taken together with the attached drawings in which:

FIG. 1 is a cross-sectional view illustrating one form of casting apparatus and indicating diagrammatically continuous formation of molten metal into ingot material employing the method of the invention;

FIG. 2 is a plan cross section taken on the line 2—2 of FIG. 1; and

FIG. 3 is a schematic view illustrating the method of the invention.

Considering the preferred embodiment of the invention shown in FIGS. 1 and 2, numeral **2** denotes a standard continuous casting tundish having mounted around the upper end thereof in sealed relationship a vacuum enclosure or degassing hood **4**. A vacuum pump, not shown in the drawings, is connected at one side of the hood to an outlet **6** to remove gases in the direction indicated by arrow A.

Also supported in sealed relationship with the degassing hood **4** at its upper side is a vacuum cover **8** formed with an opening **10** and a sight tube **12**. Attached to this cover **8** is a bottom pouring stopper control ladle **14** having an adjustable stopper element **16** for opening and closing a discharge outlet in the bottom of the ladle **14** and regulating the flow of molten metal M from the ladle through the vacuum enclosure **4** and into the tundish **2**.

At its lower side, the tundish **2** is formed with a restricted nozzle portion **18** and nozzle extension **24**, defining a cylindrical passageway **19** in which a column C of molten metal is confined to seal the outlet. Nozzle extension **24** is formed with an upper flange portion **24***a* which may, for example, be secured by bolts at **23** to a correspondingly flanged part **25** of the tundish nozzle **18**. At its lower side the nozzle extension is formed with another flanged part **24***b* to which is secured by bolts **28** a bottom member **26**.

Received within the nozzle extension **24** is an annular body **30** of electrically insulated material and extending helically around the annular body **30** are a series of turns of an electrical conductor **32** which is connected to a suitable source of electrical power. As is well known in the art, the turns **32**, when electrically energized, constitute in effect a solenoid device producing an electromagnetic field which may induce a tractive or pulling force on a ferrous type body, e.g., the molten metal, extending through the turns. Other known devices capable of producing such a field may also be used.

Metal is continuously released through passageway **19** and a nozzle opening **27** in bottom member **26** into a relatively small stream of metal S and collects in a mold, for example, the illustrated continuous oscillating casting cylinder **17**, to form a partially hardened ingot **20**. The oscillating casting cylinder is provided with cooling coils **22** which regulate hardening of the molten metal in a manner well known in the art of continuous casting.

In practicing a preferred mode of the present invention, molten metal from ladle **14** is introduced into tundish **2** by opening stopper element **16** in the bottom of the ladle. As soon as the passageway **19** at the base of the tundish has been sealed, by a column C of molten metal, the vacuum pump is actuated to evacuate the degassing enclosure. An operator views the interior of tundish **2** through sight tube **12** and controls stopper element **16** to maintain the molten metal within the tundish at the desired level.

To prevent metal from freezing within passageway **19** and to provide the stability in the rate of flow of the stream S desired for continuous casting, it is necessary that there be a continuous, and preferably uniform, flow of molten metal through the passageway. The forces of gravity act on the metal within tundish **2** and create a ferrostatic pressure head which tends to move the molten metal downwardly through the passageway. At the same time, difference in pressure between the outside atmosphere and the evacuated interior of tundish **2** creates a vacuum pressure head which acts on the metal at the outlet of nozzle extension **24** and tends to move the molten metal upwardly. If metal is to flow from tundish **2** through passageway **19**, it is apparent that the total downward force acting on the molten metal must be greater than the upward force created by the vacuum pressure head. In the past, downward flow has been insured by providing a five to seven foot ferrostatic head. With the present invention, a ferrostatic head of, typically, less than 18 to 24 inches (measured from the bottom of passageway **19**) is combined with downwardly-acting electromagnetic head provided by coils **32** to force metal out of enclosure **2**.

The exact magnitude of the electromagnetic head required varies and depends, among other things, on the ferrostatic head within enclosure **2**, the vacuum pressure head caused by the difference in pressure within and without enclosure **2**, and the frictional and other forces required to cause flow within nozzle **18** and nozzle extension **24**. As shown in FIG. 3, the ferrostatic pressure head (P_F) within enclosure **2** rises rapidly as metal is initially poured into the tundish until the metal level reaches the predetermined level at which it is maintained. At the time (t_p) when the vacuum pump is first actuated, the ferrostatic head (P_F) may be sufficiently great to cause flow without requiring downward electromagnetic force. As the tundish is evacuated and the vacuum pressure head (P_V) rises, an electromagnetic head (P_E) must be induced by coils **32** so that the total downward force (P_T) is sufficiently great to force metal out of the enclosure at the desired rate. For the major portion of the casting operation, when the vacuum pressure head (P_V) is much greater than the ferrostatic head (P_F), the downward electromagnetic head (P_E) is required not only to provide downward flow but also to prevent the vacuum pressure head (P_V) from forcing the metal back into the tundish, thereby breaking the vacuum seal in passageway **19**. As indicated in FIG. 3, the total downward force (P_T), i.e., the sum (P_F+P_E) of the electromagnetic and ferrostatic heads, must at all times be greater than the vacuum head (P_V).

As previously mentioned, an operator controls stopper element **16** to maintain the molten metal within tundish at the desired level at which the ferrostatic head (P_F) is far less than the vacuum pressure head (P_V). The electromagnetic tractive force required for continuous and uniform flow is controlled either automatically or by a second operator, such as the operator who normally controls the speed at which the continuously formed ingot is withdrawn from oscillating casting cylinder **17**.

When the operator controlling stopper element **16** sees that the last metal in ladle **14** has passed into evacuated tundish **2** and thereby been completely degassed, the vacuum pump is deactivated and a valve, schematically shown as valve **34** in the side of tundish **2**, opened to permit the pressure within the tundish to return to atmospheric. The second operator continues to apply such electromagnetic tractive force as is required to pump all the molten metal out of the tundish.

With the above-described method of the present invention, it is possible, for the first time, to maintain both a high vacuum and continuous and uniform metal flow though the ferrostatic head of the metal within the enclosure is always, except for a brief initial moment, far less than the vacuum pressure head. The method, in addition, reduces the amount of un-degassed metal at the beginning of each batch from several tons to a few hundred pounds, and provides for a greatly increased stability in the rate of flow into the ingot pouring mold or cylinder.

It will be understood also that in the apparatus of FIGS. 1 and 2, various other means for producing an electromagnetic head may be utilized. For example, a plurality of separately energized wires or other electromagnet devices may be used in the nozzle extension or even in conjunction with the oscillating sleeve **17**. In addition, current regulating means may be employed and operated in some desired relationship with respect to the rate of formation of an ingot or the rate of solidifying of the molten metal.

Various other embodiments within the scope of the appended claims will occur to those skilled in the art.

I claim:

1. In a method of casting molten metal in which molten metal is introduced into an enclosure body and released from said enclosure body through a discharge conduit, the steps including:

sealing said body;

evacuating said body to create a vacuum pressure head caused by the difference in pressure outside and within said enclosure body;

maintaining molten metal within said enclosure body to create a ferrostatic pressure head of said molten metal;

exerting on molten metal within said discharge conduit electromagnetic forces to create an electromagnetic head; and

maintaining the sum of said electromagnetic and ferrostatic heads greater than said vacuum pressure head, said vacuum pressure head being greater than said ferrostatic head.

2. The method of claim **1** including the step of continuously maintaining molten metal within said enclosure at a level such that said ferrostatic head is less than said vacuum pressure head.

3. The method of claim **1** including the step of varying said electromagnetic head in accordance with changes in said ferrostatic head.

4. The method of claim **1** including the step of varying said electromagnetic head to maintain the movement of metal from said discharge conduit at a substantially constant rate.

5. A method of removing molten metal from an evacuated degassing enclosure through a discharge conduit therein having its outlet end exposed to an ambient discharge pressure higher than that pressure within said enclosure, said difference in pressure creating a vacuum pressure head and molten metal within said enclosure creating a ferrostatic pressure head, said vacuum pressure head being greater than said ferrostatic head, comprising the steps of:

exerting on molten metal within said discharge conduit electromagnetic forces to create an electromagnetic head; and

maintaining the sum of said electromagnetic and ferrostatic heads greater than said vacuum pressure head.

6. The method of claim **5** including the step of introducing molten metal into said enclosure to continuously maintain a predetermined level of molten metal therein.

7. The method of claim 5 wherein molten metal is introduced into said enclosure to seal said discharge conduit prior to evacuating said enclosure.

8. The method of claim 7 including the steps of evacuating said enclosure subsequent to sealing said discharge conduit and raising the pressure within said enclosure to a pressure substantially equal to said ambient discharge pressure prior to removing all of said molten metal from said enclosure.

9. The method of claim 8 wherein said ambient discharge pressure is atmospheric pressure.

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