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3,408,059

APPARATUS FOR STREAM DEGASSING MOLTEN METAL

Filed June 2, 1965

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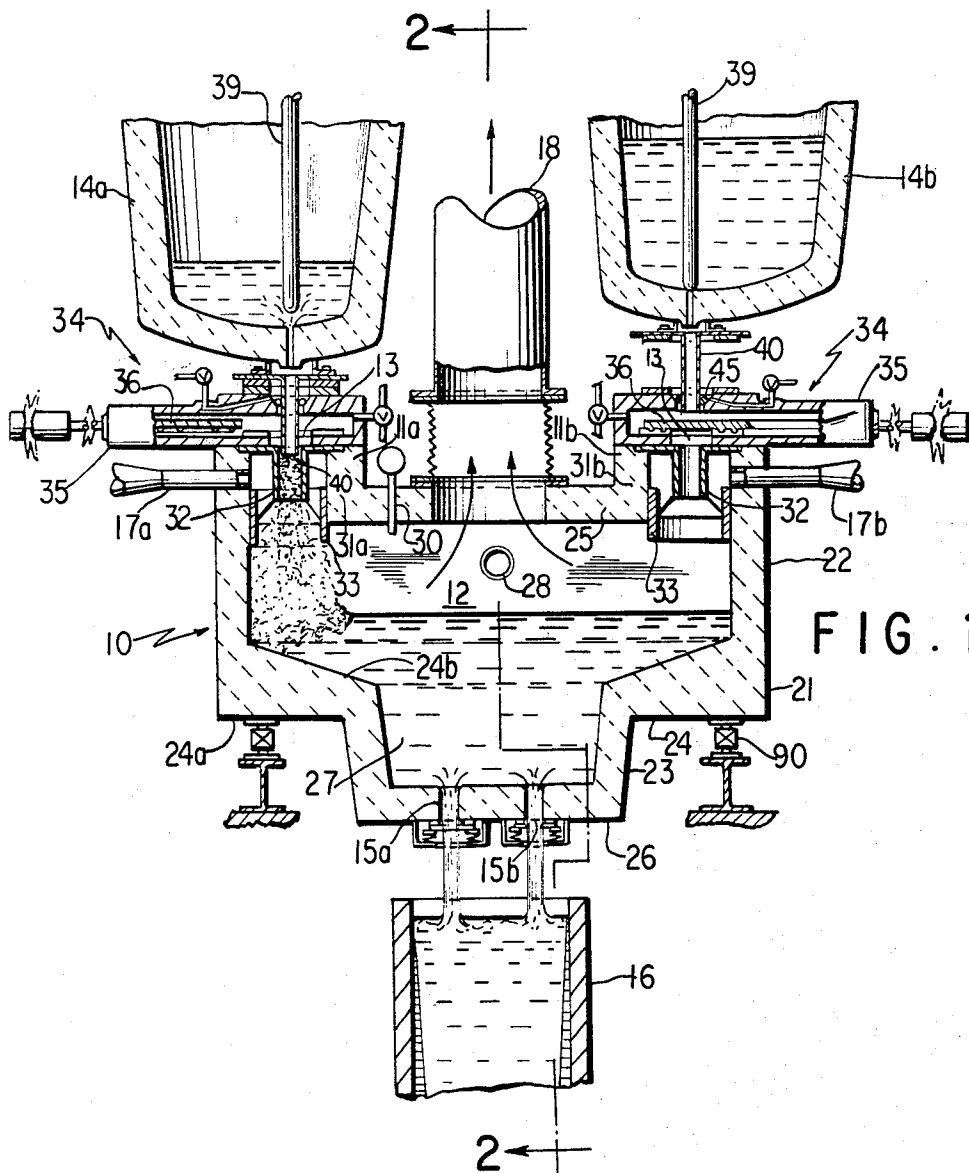


FIG. 1

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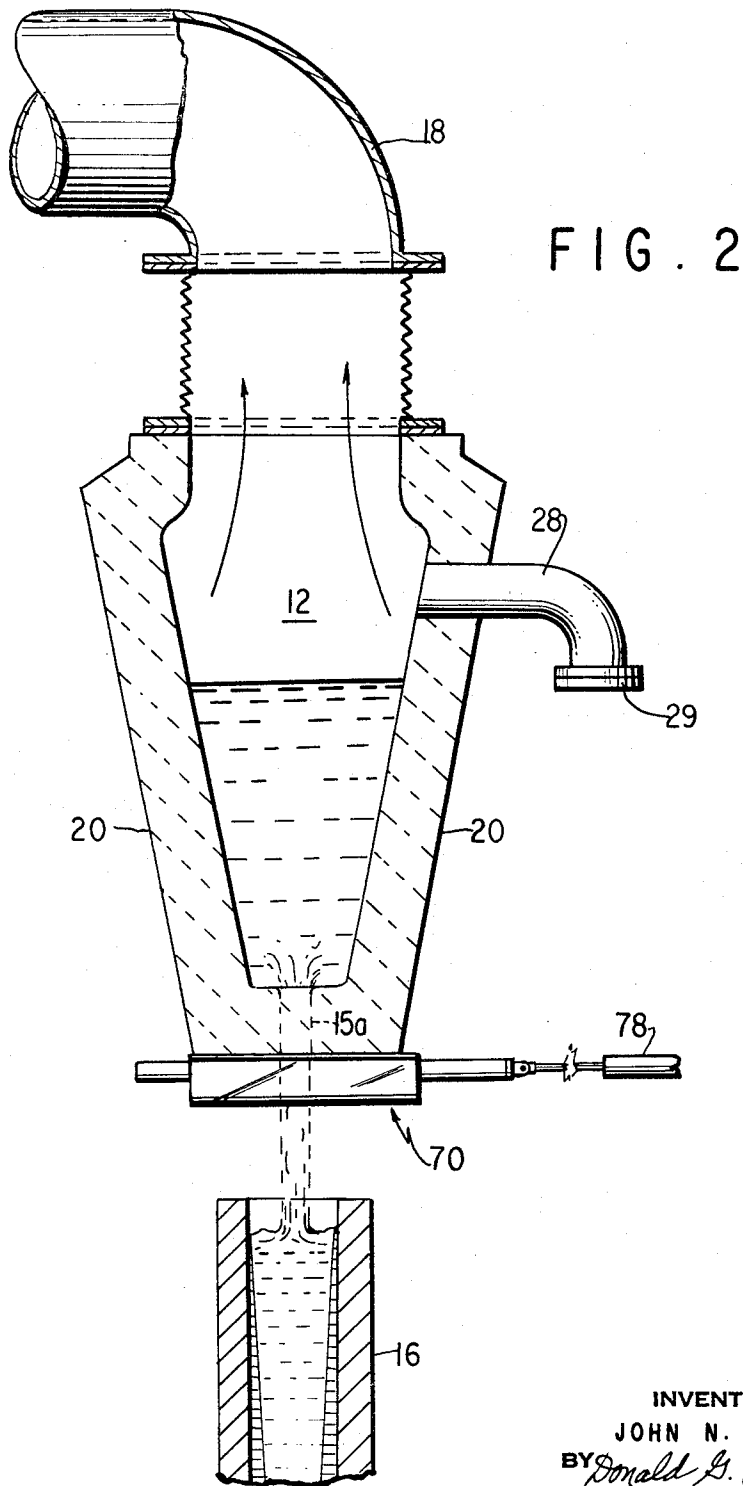
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APPARATUS FOR STREAM DEGASSING MOLTEN METAL

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APPARATUS FOR STREAM DEGASSING MOLTEN METAL

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FIG. 3

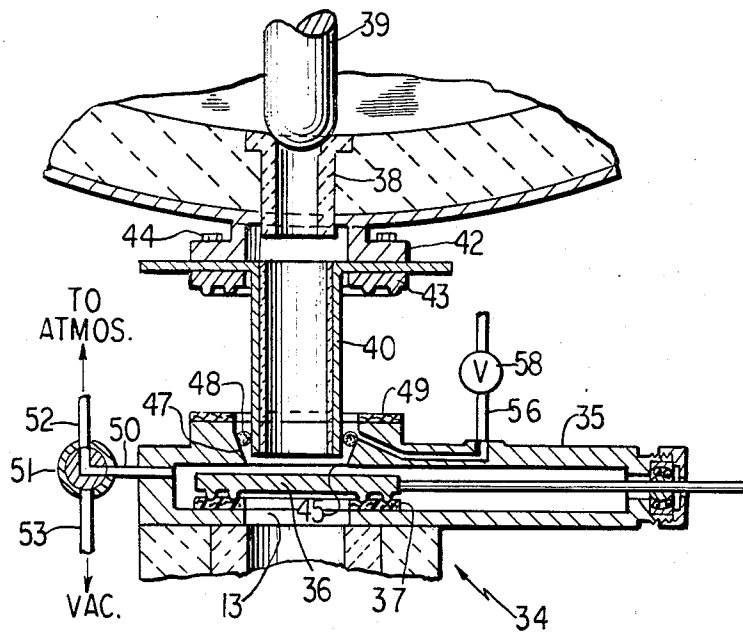
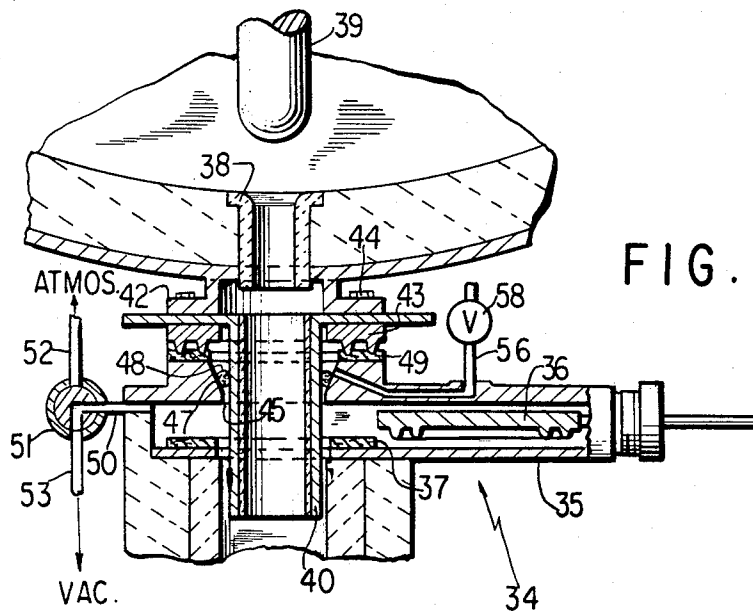


FIG. 4



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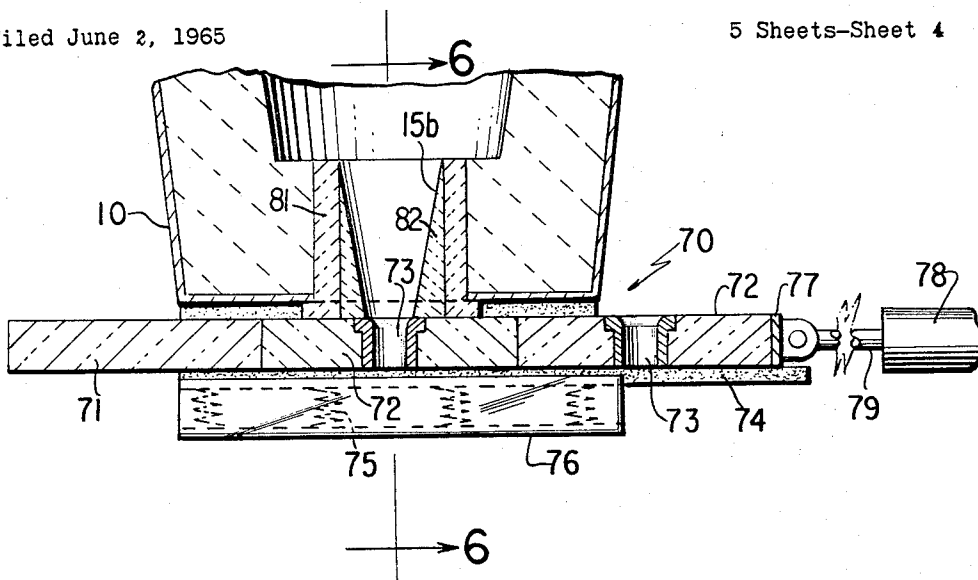


FIG. 5

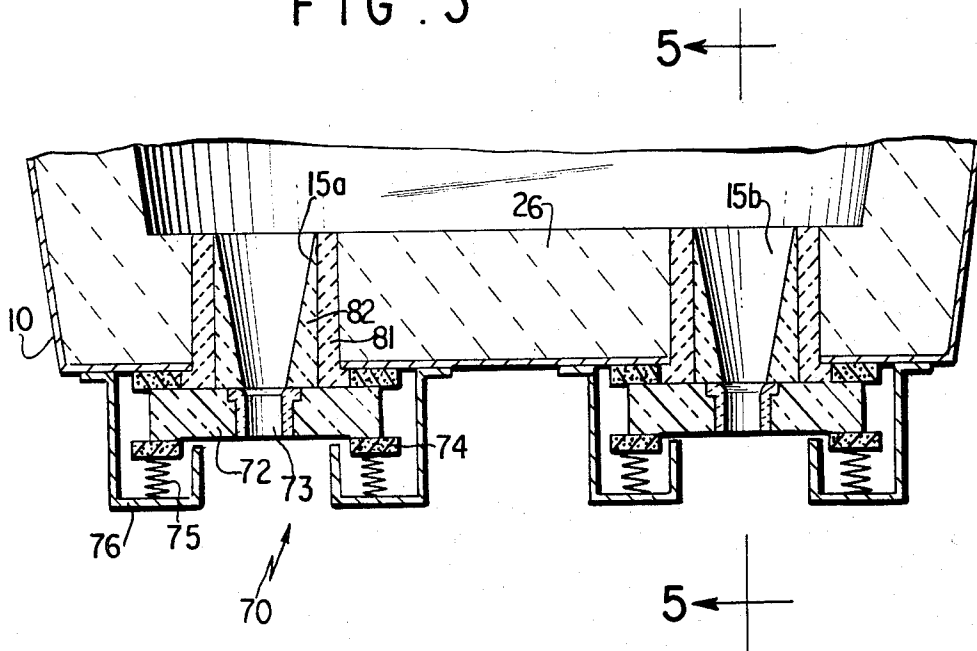


FIG. 6

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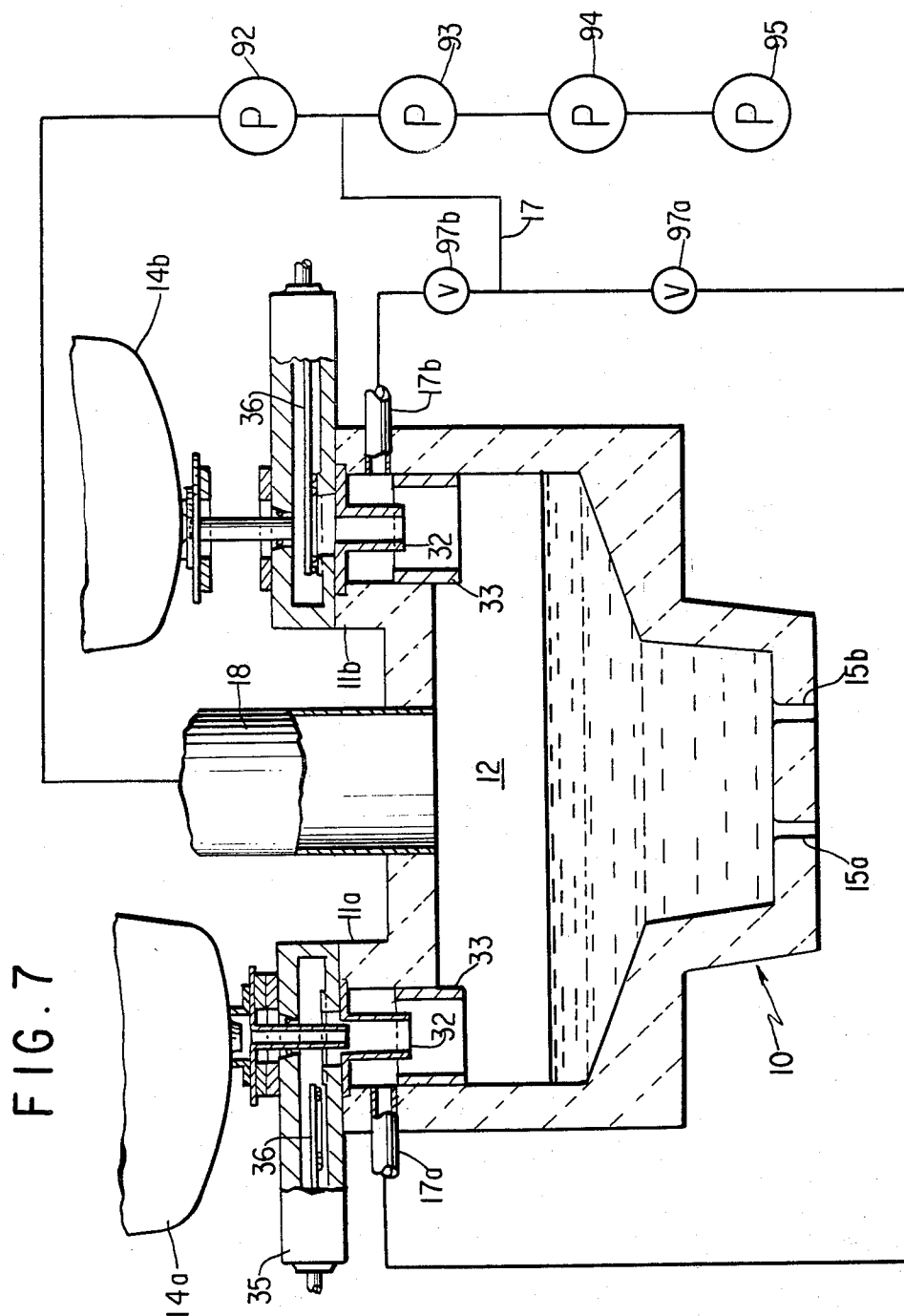
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APPARATUS FOR STREAM DEGASSING MOLTEN METAL

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APPARATUS FOR STREAM DEGASSING
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6 Claims. (Cl. 266-34)

ABSTRACT OF THE DISCLOSURE

A vessel for stream degassing molten metal comprising a refractory-lined chamber having a bottom discharge outlet and a roof. An inlet passage upstanding above the roof has a gate-valve housing thereon. The housing mounts a seal for a ladle bottom and a sleeve smaller than the passage extends downwardly thereinto from the housing. Gas-exhausts outlets open from the passage adjacent the sleeve and upwardly from the roof. Vacuum pumps maintain progressively lower pressures going from the passage to the chamber.

This invention relates to apparatus for stream degassing of molten metals and especially to degassing of steel.

Background of the invention

To produce steel of high quality by continuous casting, it is essential to cast slabs which are free from blow holes and non-metallic inclusions. Blow holes are formed by gases, principally oxygen and carbon monoxide, which are trapped in the steel slab as it solidifies. Carbon monoxide results from reaction of oxygen and carbon contained in the steel. Gas bubbles can escape from a conventional ingot but cannot escape from a continuously formed casting. The trapped gas bubbles form blow holes and voids throughout the casting. When such a casting is rolled into sheet, the resulting product has inferior mechanical properties and contains cracks. To avoid forming blow holes, it is necessary to reduce the oxygen content of the steel prior to its introduction into the mold.

The addition of conventional solid deoxidizers such as aluminum and silicon cannot be relied on to reduce the oxygen content of the steel to the desired level. These deoxidizers form alumina and silica respectively, which are insoluble in molten steel. These insoluble oxides may be concentrated near the surface of the casting, causing surface imperfections which must be removed, as for example by scarfing. They may also be dispersed in the casting as non-metallic inclusions, impairing the mechanical properties of the casting. It is therefore essential, for continuous casting, to remove oxygen from steel by means which will not result in the introduction of foreign impurities.

Vacuum degassing processes for steel are known in the art. However, the known processes have limitations which render them unsuitable for removal of oxygen in steel to be used in continuous casting. First of all, the presently known processes are intended primarily for the removal of hydrogen with only incidental removal of small quantities of oxygen. These processes are not well suited to the removal of large volumes of gas which results from vacuum deoxidization. To reduce the oxygen content of steel from the amount which the steel contains as it is tapped from the furnace to an amount acceptable for continuous casting, a volume of gas many times (e.g., 100) greater than that liberated in steel dehydrogenation must be removed. Presently known batch processes also require excessive times and do not allow enough time for pouring degassed steel into the mold unless the steel is tapped from the furnace at an excessively high temperature, which would shorten the life of refractory furnace

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and ladle linings. To avoid excessively high furnace temperatures, the maximum time from tapping the furnace to pouring molten metal into the mold is about one hour. Of this time, about 25 minutes is required in known batch degassing processes and about 15 minutes is needed to lift the tapping ladle from its tapping location to its teeming location above the mold, leaving only about 20 minutes for pouring which is insufficient.

Presently known continuous degassing processes fail to achieve the necessary oxygen removal for production of high quality continuously cast slabs. Continuous degassing in a single stage is known, but this does not give sufficient oxygen removal. Continuous plural stage degassing in which molten metal is dispersed into droplets in each stage and coalesced into a solid stream of molten metal between stages is also known, but this too fails to remove oxygen sufficiently for production of high quality continuously cast slabs.

It is an object of this invention to provide an improved plural stage vacuum degassing method and apparatus in which a solid stream of molten metal is shattered into a dispersed stream of high surface area as it enters the first degassing stage and remains in the form of a dispersed stream until the completion of the entire degassing operation.

A further object of this invention is to provide a continuous plural stage method and apparatus which is capable of removing large quantities of oxygen from steel so that the degassed steel has an oxygen content low enough to form high quality continuously cast slabs.

Brief summary of the invention

The degassing apparatus of this invention comprises a plurality of degassing stages, an inlet passage in the first stage for introducing a solid stream of undegassed molten metal, a discharge opening in the last stage for withdrawing degassed molten metal, and a vacuum exhaust system including separate vacuum exhaust lines for each stage, so that the entire apparatus is under high vacuum with progressively lower absolute pressures in each successive stage. The high vacuum in the apparatus causes the stream of molten metal to be broken up into a dispersion of droplets of high surface area. The droplets fan out in a cone shaped zone from the mouth of the inlet opening, and pass from stage to stage without coalescence between stages. The expanded molten metal is dispersed throughout the outlet portion of each stage, making it possible to maintain a pressure gradient between stages. The inlet portion of each stage is of larger cross-sectional area than the outlet portion of the preceding stage to permit expansion of the dispersed molten metal as it passes from stage to stage. Preferably the outlet portion of each stage also is of greater cross-sectional area than the outlet portion of the preceding stage, in order to accommodate the successive expansions of the dispersion from stage to stage. The drop in pressure between successive stages causes a further break-up of the metal as it enters each stage, giving maximum degassing efficiency.

A preferred apparatus according to this invention is a two-stage apparatus comprising an inlet passage and a chamber of larger cross-sectional area than that of the inlet passage located therebelow. Molten steel is introduced from a ladle into the inlet passage where it is expanded into a dispersion of droplets of high surface area, which descends to the chamber below the inlet passage where it coalesces into a reservoir of degassed steel. Steel is continuously discharged from this reservoir into a suitable container, such as a continuous casting mold.

In an especially preferred embodiment of this invention, a pair of inlet passages are provided so that casting may be continued without interruption. A stream of molten metal is introduced into one of said inlet passages while

the other passage is closed by a gastight valve. When one tapping ladle is emptied, a second tapping ladle is positioned over the other inlet passage and the first inlet passage is then shut off. In this way the pouring of molten metal into the degassing vessel of this invention and thence into a continuous casting mold may continue indefinitely as long as no shutdown of the continuous casting apparatus for repairs is necessary.

Brief description of the drawings

In the drawings:

FIG. 1 is a vertical sectional view of a preferred apparatus according to this invention.

FIG. 2 is a vertical sectional view of the degassing vessel of this invention, taken along line 2—2 of FIG. 1.

FIG. 3 is a vertical sectional view of the inlet valve of this invention, showing the valve in closed position.

FIG. 4 is a vertical sectional view of the inlet valve of this invention, showing the valve in open position with the discharge nozzle of a tapping ladle in teeming position above the inlet opening of the degassing vessel.

FIG. 5 is a vertical sectional view of the discharge opening and associated discharge valve for a continuous degassing vessel according to this invention, taken along line 5—5 of FIG. 6.

FIG. 6 is a vertical sectional view taken along line 6—6 of FIG. 5.

FIG. 7 is a diagrammatic view of a degassing apparatus and vacuum pumping system therefor.

Detailed description of the preferred embodiment

Referring now to FIG. 1, 10 is a degassing vessel having a pair of identical restricted inlet passages 11a and 11b opening into the interior thereof and constituting the first stage of the apparatus and a chamber 12 located below said inlet passages and in communication therewith, constituting the second stage. The cross-sectional area of chamber 12 is larger than the cross-sectional areas of passages 11a and 11b. Each of the passages 11a and 11b has an opening 13 at its upper end for the introduction of a stream of undegassed molten steel. A stream of molten steel may be introduced into passage 11a from a suitable receptacle such as ladle 14a, and into passage 11b from ladle 14b. Molten steel is teemed into only one of the passages at a time. Vessel 10 also includes a pair of discharge openings 15a and 15b in the bottom thereof, for discharging degassed molten metal from the chamber 12 of vessel 10 into a suitable container such as continuous casting mold 16.

High vacuum is maintained in both passages 11a and 11b and in chamber 12 of vessel 10 by means of vacuum exhaust lines 17a and 17b communicating with the passages respectively, and vacuum exhaust line 18 communicating with degassing chamber 12. The vacuum maintained in vessel 10 is sufficient to cause a stream of molten metal being introduced into either passage 11a or 11b to be broken up into a dispersion of droplets having a high surface area as a result of the liberation of gas from said molten metal. The dispersed stream consists of at least in part of finely divided discrete particles or droplets of molten steel. It is believed that all or most of the dispersed stream is in the form of discrete particles or droplets, although possibly a substantial portion is in the form of a foam comprising thin films of molten metal surrounding bubbles of liberated gas. This dispersed stream is in the shape of a cone having a large apex angle, for example about 140°. The dispersed steel stream descends by gravity through the inlet passage into chamber 12. Most of the molten metal descends substantially vertically below the inlet opening 13. Thus the dispersed stream is most dense in the region directly below inlet opening 13, and is less dense in the remainder of the zone which the stream occupies. The stream is dispersed throughout the entire cross-sectional area of the outlet portion of the inlet passage 11a or 11b adjacent chamber 12. The down-

wardly flowing dispersed stream permits a slightly higher absolute pressure to be established in the first stage or inlet section than in the second stage degassing chamber. Only the passage 11a or 11b which is receiving molten metal has a pressure higher than that in chamber 12. The pressure in the passage not in use is the same as that in chamber 12.

The dispersed molten steel stream is expanded into a stream having a greater surface area with the removal of further quantities of gaseous impurities as it descends from either passage 11a or 11b into chamber 12. This results from the lower pressure in chamber 12 than in the inlet section.

The dispersed molten steel stream descends by gravity from the passage 11a or 11b into chamber 12 without coalescence. This gives more efficient degassing than previously known multiple stage degassing processes in which steel droplets are coalesced at the end of each stage and the steel introduced as a stream into the next stage. The dispersed steel stream coalesces and forms a reservoir of degassed molten steel at the bottom of chamber 12. The height of this reservoir above discharge openings 15a and 15b must be sufficient to maintain a barometric leg. An additional height is maintained in order to give the desired discharge rate, which is proportional to the difference between the height of the reservoir and the height necessary to maintain a barometric leg.

Degassing vessel 10 is preferably an elongated vessel, wider at the top than at the bottom, having inwardly sloping side walls 20 and discontinuous end walls 21 comprising vertical upper portions 22 and lower portions 23 joined by horizontally extending walls 24. The lower portions 23 of walls 21 are closer together than the upper portions 22. Horizontally extending walls 24 are thicker at their outer ends than at their inner ends, and comprise horizontal outer surfaces 24a and sloping inner surfaces 24b. The lower portions 23 of walls 21 slope inwardly at a small angle to the vertical. Degassing vessel 10 also includes top wall or roof 25 and bottom wall 26. Bottom wall 26 together with side walls 20 and the lower portions 23 of end walls 21 define a well 27 of reduced cross-sectional area as compared to the upper portion of chamber 12. This well makes it possible to maintain the necessary height of molten steel which is required in order to provide a barometric leg and to establish the desired teeming rate without making it necessary to maintain large quantities of degassed molten metal in the degassing vessel 10. A refractory lined overflow outlet 28 is provided in one side wall 20 above the normal level of molten steel in chamber 12. This overflow outlet permits slag to run off, and also provides an emergency overflow outlet for molten steel in the event that vessel 10 is filled to too high a level. The outer end of overflow outlet 28 is capped with an aluminum cap 29. An inlet 30 for introducing a solid deoxidizer such as aluminum may be provided in top wall 25.

Passages 11a and 11b are structurally identical, and preferably of circular cross section having upstanding housing walls 31a and 31b respectively. Each passage has in addition to the circular opening 13, a flanged refractory sleeve 32 which is adapted to be supported by the housing walls 31a or 31b, and a removable insert sleeve 33 at the outlet end of the inlet passage. The lower end of each insert sleeve 33 may extend downwardly below the inside surface of top wall 25. In each inlet passage, sleeves 32 and 33 are coaxial with opening 13. The diameter of sleeve 33 is greater than the diameter of sleeve 32, so as to provide flow paths of progressively increasing diameter in passages 11a and 11b. The upper portion of chamber 12 adjacent sleeves 33 is of greater cross-sectional area than the sleeves to permit expansion of the descending metal stream. Sleeve 32 prevents the entrance of molten metal droplets into these vacuum lines.

The opening 13 in each inlet passage is controlled by a valve 34 actuated by a hydraulic cylinder and piston.

Valve 34 is shown in detail in FIGS. 3 and 4 in the closed and open positions respectively. Each valve 34 is opened for teeming of molten metal through the inlet opening 13 which it controls, and is kept closed at other times. As shown in FIG. 1, the valve 34 controlling inlet passage 11a is open to permit teeming of metal from ladle 14a, and the valve 34 controlling inlet passage 11b is closed while ladle 14b is in waiting position, ready to be lowered into teeming position and to commence teeming when ladle 14a is empty.

Referring now to FIGS. 3 and 4, valve 34 includes a laterally extending fluid tight valve housing 35 which is adapted to receive a sliding gate valve 36. Gate valve 36 seats on a resilient refractory seat 37 of asbestos or the like. Valve 36 is horizontally reciprocable in and out of seating engagement with seat 37. A cam track (not shown) may be provided so that gate valve 36 lifts slightly as it is moved to open position, in order to facilitate sliding movement.

Ladles 14a and 14b are identical conventional bottom pour ladles having refractory-lined metal shells with refractory nozzles 38 of restricted cross section for discharge of molten metal. The discharge of molten metal is controlled by means of conventional stopper rods 39. Pouring tubes 40 of larger diameter than the nozzle openings 38 are attached to the exteriors of ladles 14a and 14b beneath nozzles 38 in position to receive and direct molten steel discharged through the nozzles. These pouring tubes are refractory-lined flanged metal sleeves and may be secured to the exterior of ladles 14a and 14b in any convenient manner, as for example by means of attaching flanges 42. Clamping rings 43 and bolts 44 secure the pouring tube 40 to the attaching flange 42.

When ladle 14a is in teeming position, as shown in FIG. 1, its nozzle 38 and pouring tube 40 are axially aligned with sleeves 32 and 33 in inlet section 11a. These together provide a flow path of progressively increasing diameter for molten metal. A stream of molten metal is introduced through nozzle opening 38 into passage 11a. The high vacuum in the passage causes this stream to be expanded as gas is liberated. The expanded stream fans out so that some of the molten metal in it strikes the side walls of pouring tube 40 and sleeves 32 and 33. The stream thus occupies the entire cross-sectional area of the outlet portion of passage 11a. This entire cross-sectional area is believed to be filled with either molten metal or with liberated gas, so that communication between the evacuated space in passage 11a and chamber 12 is prevented. It is believed that this dispersal of the expanded metal stream throughout the entire cross section of passage 11a makes it possible to maintain a pressure differential between the first and second stages.

Valve housings 34 have round openings 45 in their upper walls to receive pouring tubes 40. Preferably the wall surface 47 surrounding opening 45 in each valve housing is beveled to provide a conical surface for a resilient refractory sealing ring 48 of asbestos or the like which provides a gastight seal between pouring tube 40 and the housing walls. A clamping ring 43, which may have beads for more effective sealing engagement, rests on asbestos ring 49 when the ladle 14a or 14b is in teeming position. In this way a high vacuum may be maintained inside valve housing 34.

Fluid conduits 50 are provided for alternately placing the interior of valve housings 34 under atmospheric pressure or under vacuum. Each of these conduits 50 includes a three-way valve 51 for placing conduit 50 alternately in communication with an atmospheric pressure line 52 or a high vacuum line 53 leading to a suitable high vacuum source such as a pump not shown.

The upper walls of valve housings 34 include air bleed passages 56 which terminate above sealing rings 48. These passages 56 extend exteriorly of the valve housing and have manually operable valves 58 therein. By opening or closing valve 58, the space above sealing ring

48 may be opened to atmospheric air or shut off therefrom. When ladle 31a is in teeming position as shown in FIG. 4, a partial vacuum prevails in the space above sealing ring 48. When it is desired to remove the ladle, valve 58 is opened so as to place this space in communication with the atmosphere.

When it is desired to place the ladle 14a or 14b in teeming position, the ladle is first lowered so that its pouring tube 40 engages sealing ring 48 as shown in FIG. 3. Valve 51 is then rotated to the position shown in FIG. 4, placing the interior of housing 34 in communication with high vacuum exhaust line 53. This equalizes the pressure in valve housing 34 and inlet 11b. Valve 36 is then opened. Ladle 14 is then lowered to the teeming position shown in FIG. 4, in which pouring tube 40 extends downwardly into one of the passages 11a and 11b.

When the contents of the ladle 14a or 14b have been substantially exhausted and it is desired to remove this ladle from teeming position, air bleed valve 58 is opened in order to provide atmospheric pressure above sealing ring 48. The ladle is then lifted until the bottom of pouring tube 40 is above the plane of valve 36. The O-ring 48 maintains a pressure tight seal so that vacuum may be maintained therebelow. The pressure above sealing ring 48 and the vacuum below the sealing ring maintain the ring in seating engagement on beveled wall 47. When the bottom of pouring tube 40 is above the plane of valve 36, the valve is moved to closed position as shown in FIG. 3. Three-way valve 51 is then rotated to the position shown in FIG. 3, placing the interior of valve housing 34 in communication with the atmosphere. This equalizes the pressure on both sides of sealing ring 48. The ladle may then be withdrawn.

The discharge of molten metal from vessel 10 through discharge openings 15a and 15b is controlled by means of a pair of sliding gate valves 70 which are of identical construction. This valve is more fully described in the copending application of James T. Shapland, Ser. No. 453,730, filed May 6, 1965, now Patent No. 3,352,465. Two discharge openings 15a and 15b are provided to permit teeming into wide molds without an excessive concentration of heat and kinetic energy from hot molten metal at one location in the mold.

The structure of valve 70 may be seen best in FIGS. 5 and 6. Valve 70 includes a plurality of thin flat refractory plates of square or rectangular cross section. These refractory plates include at least one imperforate plate 71 and at least one plate 72 having a teeming opening 73. It is desirable to provide a plurality of plates 72 having teeming openings of different diameters so that the teeming rate may be varied. Provision of duplicate plates is also desirable to permit rapid replacement when a plate 72 is no longer usable. Plates 71 and 72 are held in engagement with bottom wall 13 of vessel 10 by means of spring pressed guide blocks 74, urged upwardly by compression springs 75 which are supported by spring retainer plates 76 secured to the exterior of vessel 10. A push bar 77, operatively connected to a fluid cylinder 78 through piston rod 79, pushes plates 71 and 72 in and out of position beneath the discharge nozzle of vessel 10. Plates 71 and 72 are placed in end to end engagement on guide 74 and are always pushed away from cylinder 78 by push bar 77. Cylinder 78 may be controlled by an operator through mechanisms known in the art. An imperforate plate 71 is placed beneath the discharge nozzle to prevent the discharge of molten metal from vessel 10. When it is desired to discharge molten metal from vessel 10, a plate 72 is placed beneath the discharge nozzle so that its teeming opening 73 is aligned with the discharge nozzle.

Discharge openings 15a and 15b of vessel 10 are formed by vertically extending cylindrical refractory nozzle inserts 81 and vertically extending conical inserts 82 located within cylindrical inserts 81. Both inserts 81 and 82 are located in the bottom wall 26.

The level of molten metal in degassing vessel 10 is continuously measured by a plurality of load cells 90 (FIG. 1) located beneath lower walls 26. The function of these load cells is to measure the weight of molten metal in vessel 10, which may be then translated into height, and to control the operations of discharge valves 12a and 12b in response to the level of molten metal within vessel 10. If the operator observes that the level of molten metal in vessel 10 is too high, he actuates the stopper rod of ladle 14a or 14b as the case may be to decrease the pouring rate. If the level of molten metal in vessel 10 is becoming too high and the level in continuous casting mold 16 is becoming too low at the same time, both conditions may be corrected by replacement of refractory plate 72 with another refractory plate 72 having a teeming opening 73 of larger diameter.

The pumping system for maintaining a high vacuum in vessel 10 is shown in FIG. 7.

This pumping system includes a plurality of vacuum pumps 92, 93, 94 and 95 constituting successive pumping stages. Four stages are illustrated herein, but any number of stages may be used as long as the number of pumping stages is not less than the number of degassing stages in degassing vessel 10. Pumping stages 92, 93, 94 and 95 are numbered in order of increasing absolute pressure. The inlet of pump 92 is the point at which the highest vacuum in the system is maintained. The outlet of pump 95 is to the atmosphere. Vacuum exhaust line 18 provides communication between chamber 12 and the inlet of pump 92. Chamber 12 constitutes the second and final stage in degassing vessel 10 as illustrated in this application. Vacuum exhaust lines 17a and 17b extend from passages 11a and 11b respectively to the inlet of pump 93. For convenience, exhaust lines 17a and 17b may merge into a single vacuum exhaust line 17. Check valves 97a and 97b are provided in vacuum exhaust line 17a and 17b to prevent cyclic gas flow from one line to the other due to the unequal pressure prevailing in passages 11a and 11b.

Each degassing stage has its individual vacuum exhaust line. As herein illustrated, the first stage or passages 11a and 11b have exhaust lines 17a and 17b respectively, while the second stage or chamber 12 has its vacuum exhaust line 18. Each vacuum line terminates at the inlet of a lower pressure pumping stage than the vacuum exhaust line from the preceding degassing stage. The vacuum line from the final degassing stage terminates at the inlet of the pump providing the lowest absolute pressure.

The operation of the degassing device of this invention will now be described. The interior of vessel 10 is evacuated with both discharge valves 70 and both inlet valves 36 closed. A teeming ladle 14a is brought into position above opening 13 of passage 11a, and lowered so that pouring tube 40 forms a sealing engagement with sealing ring 48. Inlet valve 36 is then opened and the ladle 14a is lowered into position as shown in FIG. 1. Stopper rod 39 is then opened permitting a stream of molten steel to enter inlet section 11a. This stream is expanded into a dispersion or spray of fine droplets, which descend through passage 11a, being spread over the entire cross-sectional area of the outlet end of the passage in the vicinity of sleeve 33. As the spray of molten metal droplets descends from passage 11a into degassing chamber 12, where the absolute pressure is slightly lower than in passage 11a, the droplets of steel are further broken up into finer droplets as additional degassing takes place. A reservoir of molten metal is collected in the bottom of degassing chamber 12, the discharge openings 15a and 15b remaining closed until the desired height teeming into mold 16, as indicated, by load cell 90, has been attained. These discharge openings, which are controlled by valve 70, are then opened, permitting molten metal to flow into continuous casting mold 16. When ladle 14a is exhausted, a second ladle 14b is brought into place over passage

11b, and teeming from this second ladle 14b is commenced at the same time that ladle 14a is shut off. Ladle 14a is then withdrawn and passage valve 36 controlling inlet 11a is closed. When ladle 14b is empty, a new ladle 14a may be brought into place for teeming of additional metal. In this way teeming can be continued indefinitely without interruption, until it is necessary to shut down vessel 10 or some other part of the continuous casting line for repairs.

When it is desired to shut down vessel 10, an inert gas such as argon is admitted to degassing chamber 12. The pressure of this gas is progressively increased as the level of molten metal drops, so that the total pressure at discharge openings 15a and 15b remains constant. In this way a constant rate of discharge of molten metal from vessel 10 may be achieved.

By way of illustration of a specific embodiment of this process, using a degassing vessel having a single inlet passage and a degassing chamber therebelow, a solid stream of molten steel having an initial oxygen content of 195 parts per million is continuously introduced into a degassing vessel in which the pressure in the passage is 1.60 mm. of mercury and the pressure in the degassing chamber therebelow is 0.44 mm. of mercury. The solid stream of molten steel is dispersed as aforesaid, and is then collected at the bottom of the degassing chamber and discharged therefrom. The degassed molten steel has an oxygen content of 75 parts per million, and a carbon content 0.02% less than that of the undegassed steel.

The foregoing example is merely illustrative, and variations can be made over wide limits without departing from the invention. For example, the inlet passage pressure may vary from about 1 mm. up to as high as about 30 mm. of mercury, and the pressure in the degassing chamber may vary from less than 0.5 mm. of mercury up to about 5 mm. of mercury. The pressure in the degassing chamber is always less than in the inlet passage; the pressure difference may vary depending upon the absolute pressures in each chamber, but is generally in the order of about 1 to 2 mm. of mercury.

I have found that superior degassing is attained according to my invention by providing a plurality of stages in a vessel in which the molten steel remains in dispersed form without coalescence from the time it is first introduced in the initial stage until it is collected as a body of degassed molten metal in the final stage. Although the degassing vessel has two stages, it will be understood that more degassing stages may be provided if desired. Various other modifications will also be apparent to those skilled in the art.

What is claimed is:

1. Apparatus for degassing molten metal comprising a bottom-pour teeming ladle having a nozzle-extension tube extending downwardly therefrom, a vacuum chamber having a roof with a restricted inlet upstanding therefrom adapted to receive said tube, a horizontally movable gate valve effective to close said inlet when said tube is withdrawn therefrom, a sleeve in said inlet below said valve having a cross-sectional area smaller than that of said inlet and greater than that of said tube, a gas-exhaust outlet from the space around said sleeve, a gas-exhaust outlet from said top wall and a molten-metal discharge outlet in the bottom of said chamber.

2. Apparatus as defined in claim 1, characterized by sealing elements on said ladle and on said inlet, the sealing element on said ladle engaging the sealing element on said inlet when said ladle is connected to said inlet.

3. Apparatus as defined in claim 1, characterized by an additional removable insert sleeve in said passage having a cross-sectional area greater than that of said first-mentioned sleeve and being arranged generally therebelow.

4. A degassing vessel comprising a refractory lined chamber having a roof and an outlet in the bottom thereof, an inlet passage upstanding above said roof and being

of smaller cross-sectional area than said chamber, a valve housing on said inlet passage having an opening there-through aligned with said inlet passage, a valve reciprocable in said housing for closing said passage, ladle-sealing means on said housing, a sleeve extending downwardly from said housing into said passage, said sleeve being smaller in cross-sectional area than said passage to provide space for flow of gas between said sleeve and said passage, a first gas-exhaust outlet opening outwardly from said passage, means connected to said first gas-exhaust outlet for exhausting gas from said passage, a second gas-exhaust outlet opening upwardly from said roof, and means connected to said second gas-exhaust outlet for exhausting gas from said chamber to a lower pressure than said passage.

5. Apparatus as defined in claim 4, in combination with a bottom-pour teeming ladle having a nozzle-extension tube projecting downwardly therefrom adapted to enter said opening when said valve is retracted, and means for sealing said tube to said housing.

6. Apparatus as defined in claim 4, characterized by said vessel having substantially plane opposed side walls converging downwardly.

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