Nov. 17, 1953

I. HARTER, JR., ET AL
APPARATUS FOR SEPARATING SLAG FROM
A SLAG CONTAINING MOLTEN METAL

2,659,120

Filed Feb. 2, 1951

2 Sheets-Sheet 1

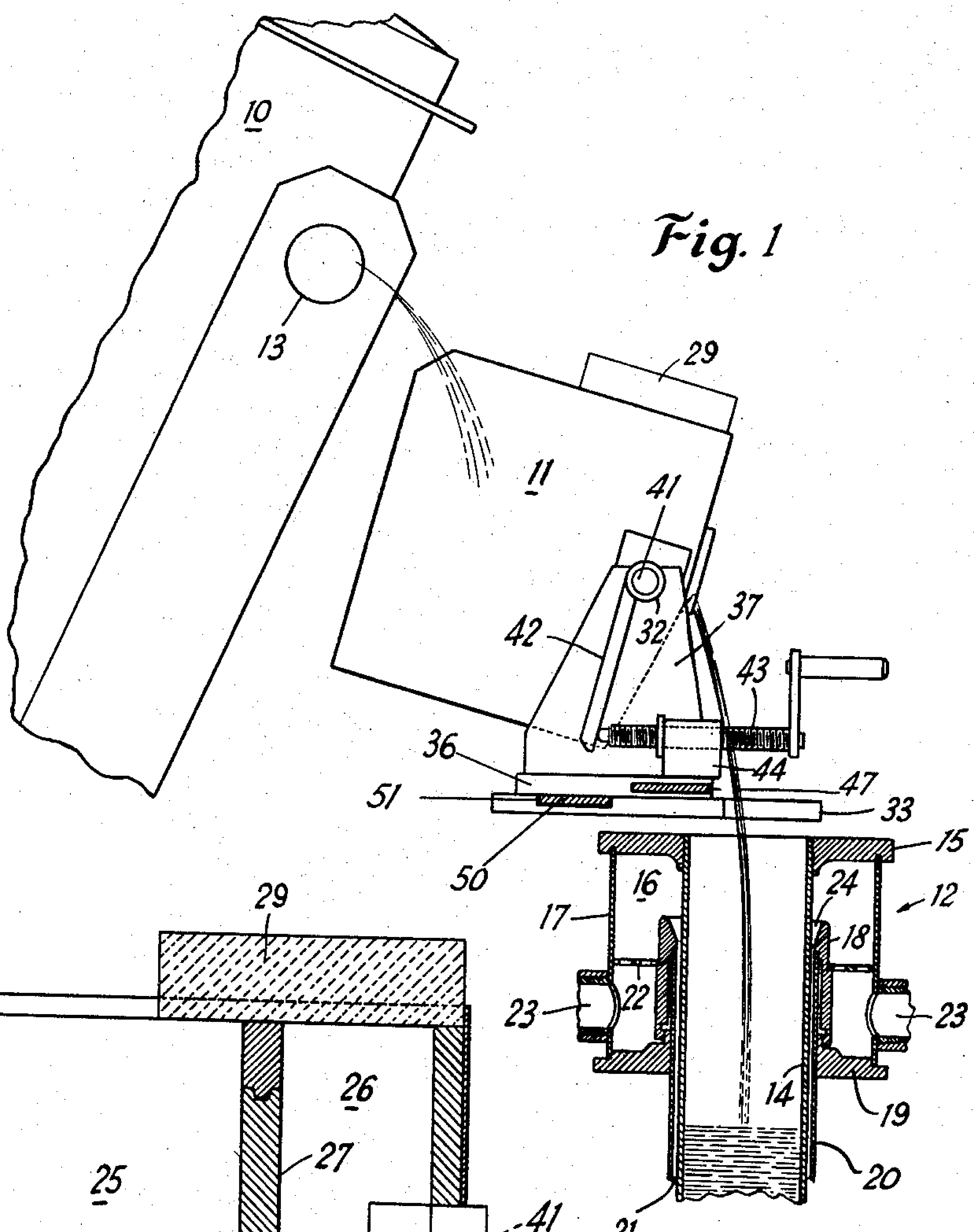

Fig. 1

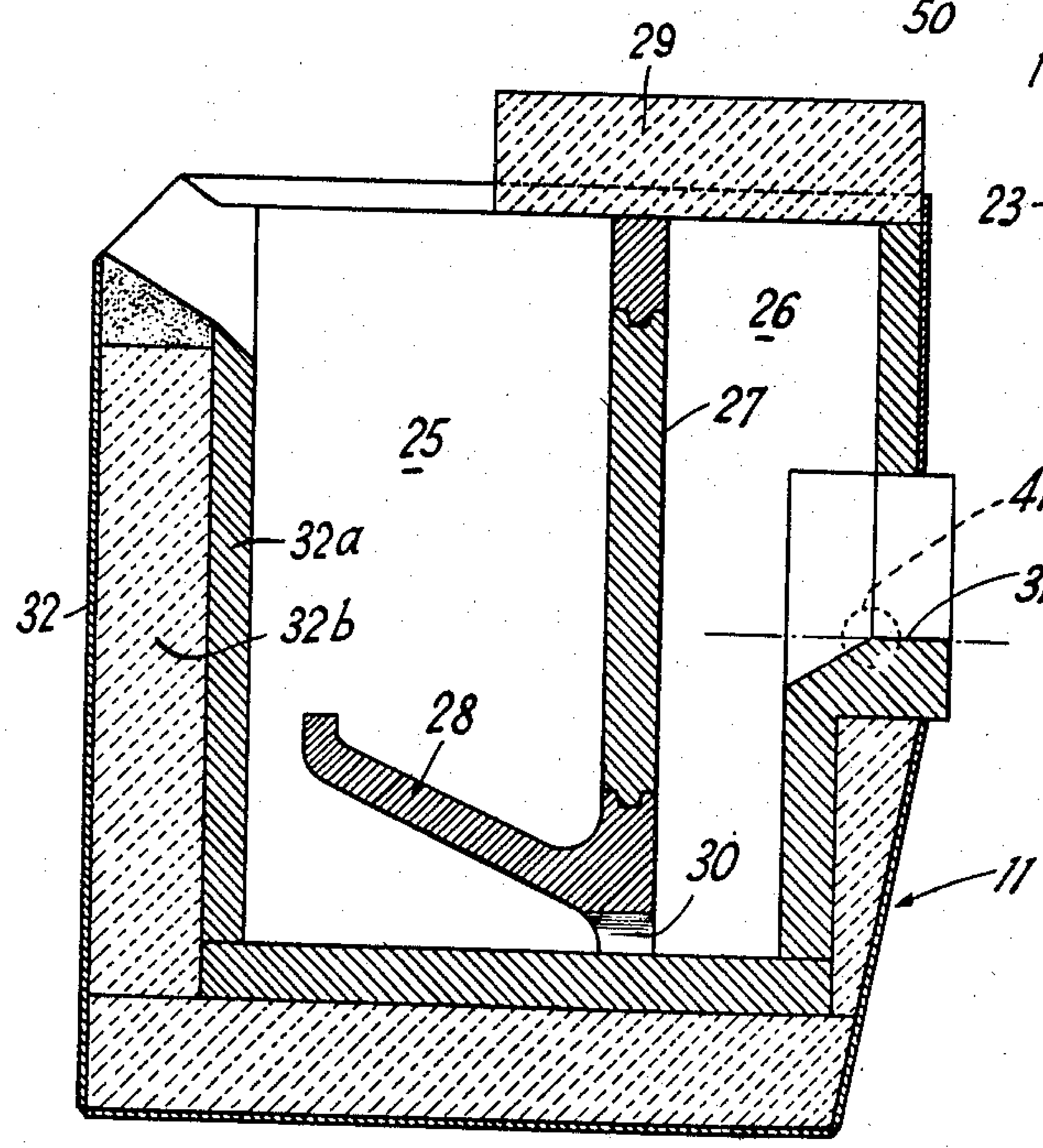

Fig. 2

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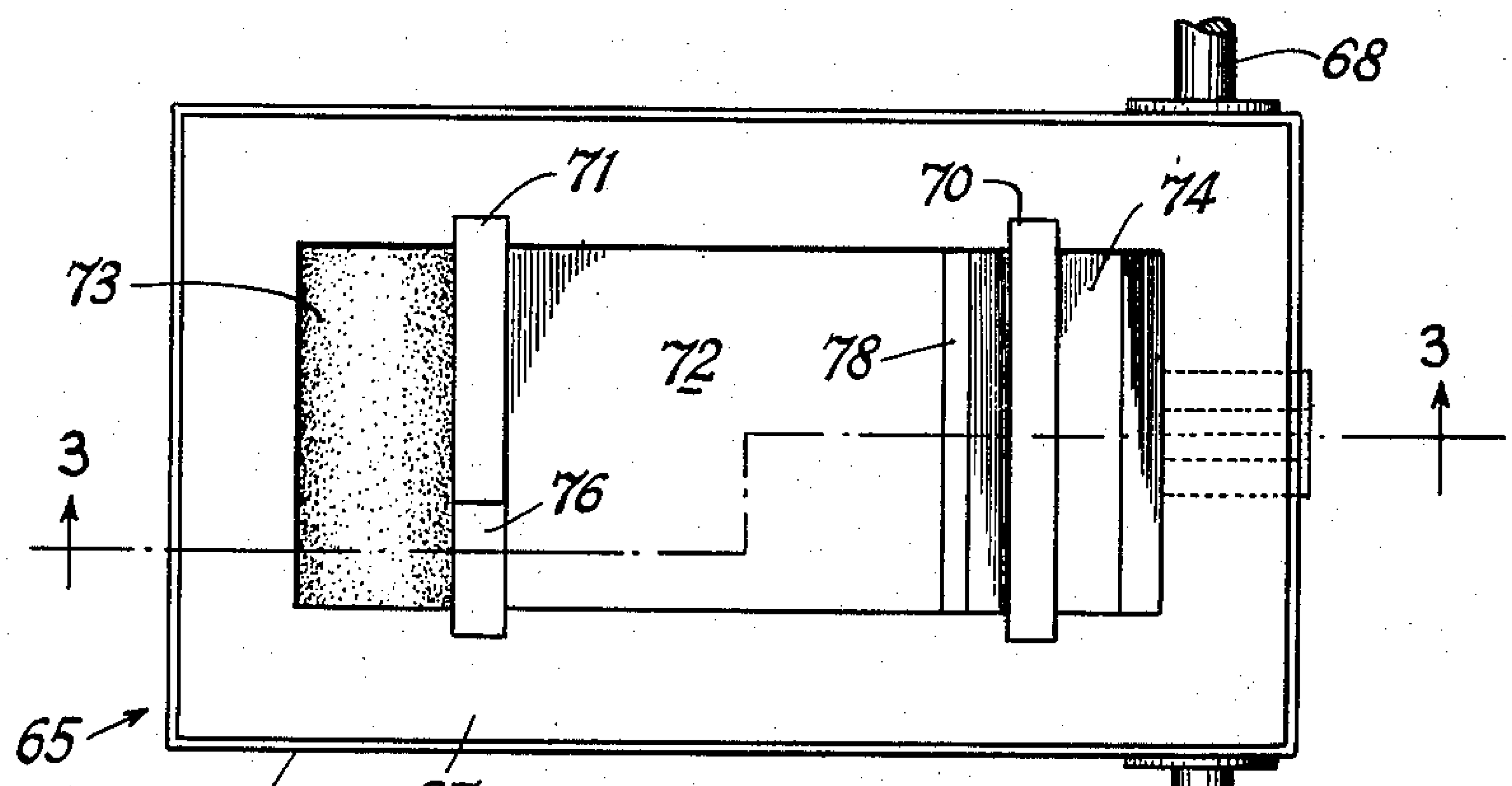

FIG. 4

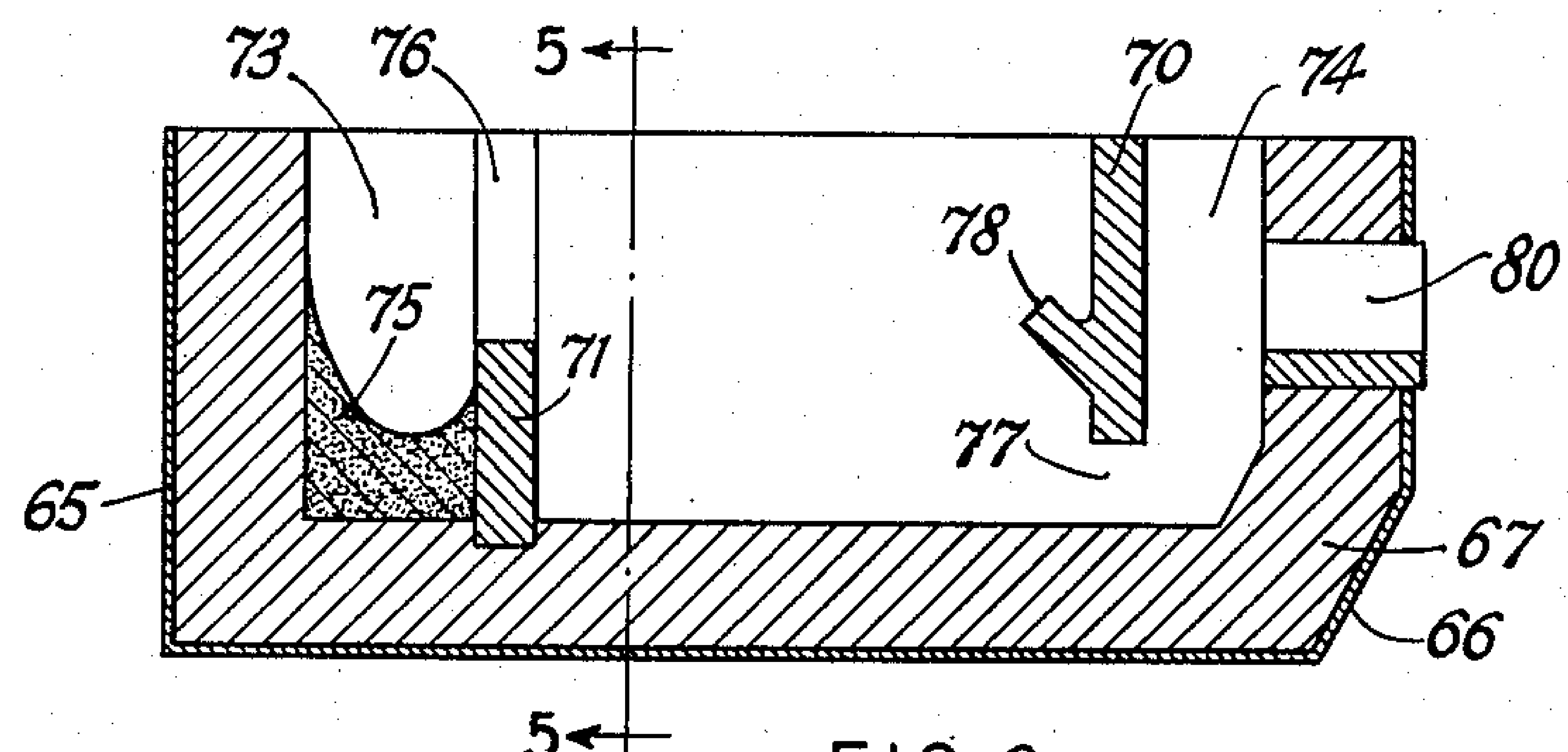

FIG. 3

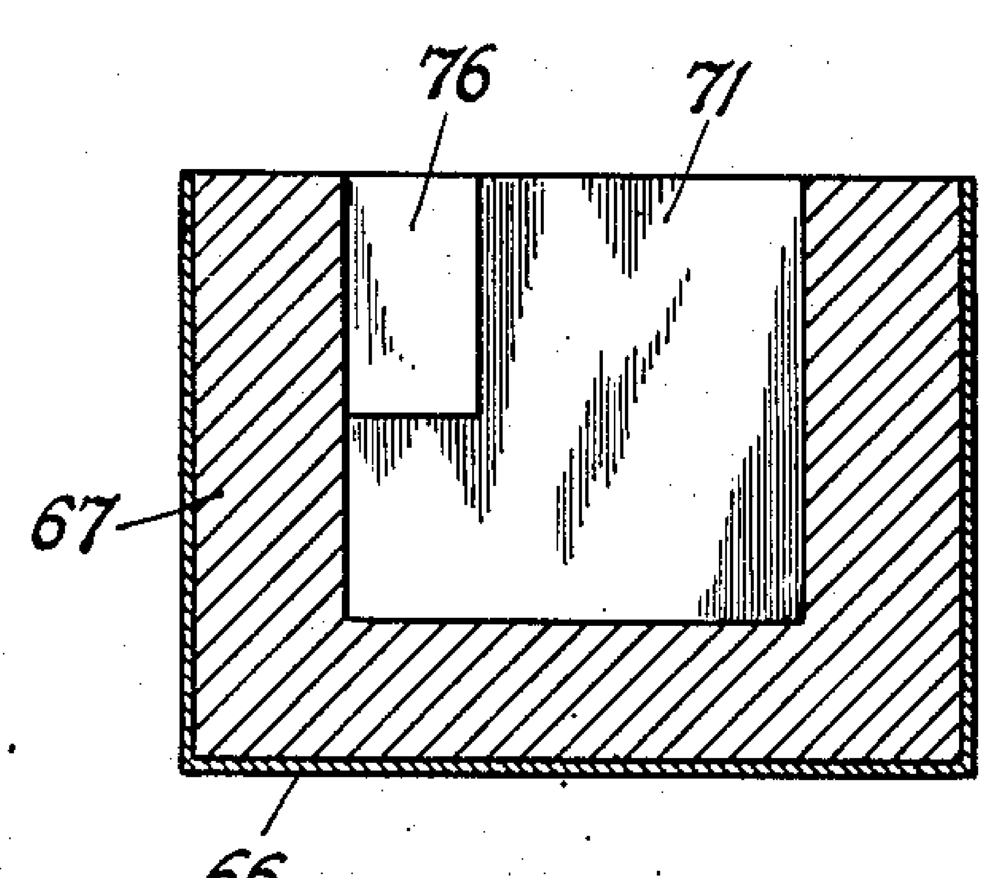

FIG. 5

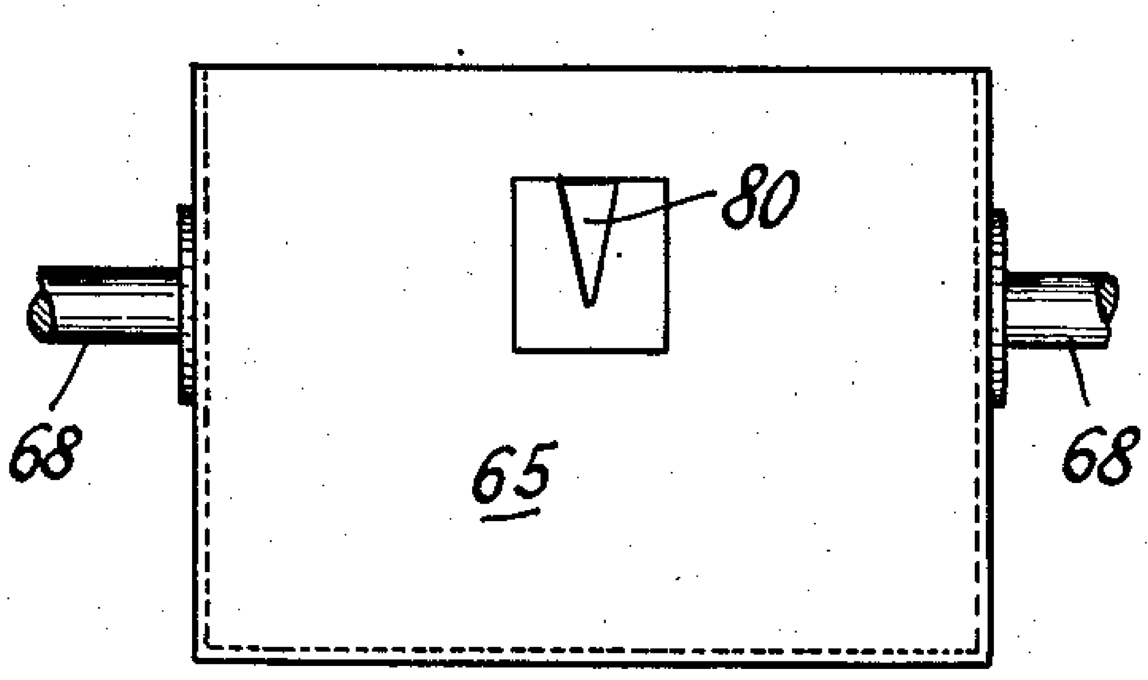

FIG. 6

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Patented Nov. 17, 1953

2,659,120

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2,659,120

APPARATUS FOR SEPARATING SLAG FROM A SLAG CONTAINING MOLTEN METAL

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Application February 2, 1951, Serial No. 209,164

3 Claims. (Cl. 22—79)

The present invention relates in general to the casting of metals, and more particularly to the pouring of molten slag-containing metals. This application is a continuation-in-part of our application filed January 13, 1948, Serial Number 2,114, now Patent No. 2,571,033.

In the casting of metals containing slag contaminants, it is desirable to eliminate or reduce the contaminants to the lowest degree possible before the delivery of the molten metal to a mold and the subsequent solidification of the casting. The presence of the slag contaminants in a casting is detrimental to its value and commercial acceptability, and while minor amounts of slag in or on an ingot are sometimes tolerated, the complete or partial elimination of the slag is highly desirable. Slag contaminants are particularly prevalent in the production of ferrous alloy castings such as steel. Ferrous metals are customarily melted under slagging conditions, and, as is also well known, the metals readily oxidize in contact with air at molten metal temperatures and chemically react with practically all of the known refractory materials in contact therewith, forming ferrous and ferric compounds collectively known as slag.

The presence of slag contaminants in the molten ferrous metals delivered to a continuous casting mold, as an example, is particularly deleterious due, in the main, to their insulating value. In the continuous casting process, any slag carried into the mold with the molten metal will tend to collect on the periphery of the casting. This will tend to insulate the contiguous portion of the casting wall from the heat removal effect of the adjacent mold, so that the shell strength of the casting may be insufficient to withstand the ferrostatic pressure imposed thereon, resulting in a rupture of the casting shell. It has also been observed that where the solidification of a portion of the casting is delayed, even though rupture of the wall does not occur, the subsequent solidification of the interior portion of the casting frequently results in an unequal circumferential cooling of the casting and the formation of shrinkage cracks or voids in a portion of the casting.

The art is well aware of the adverse effects of metal "splashing" in top pouring metal into a mold, but its deleterious effect is accentuated in the continuous casting of metals wherein the general cause of splashing is closely related to other problems more specific to a continuous casting process. Splashing is commonly caused by the improper delivery of metal from an excessive height above a mold and in an off-centered location with respect to the axis of the mold. In continuous casting, an off-center delivery of molten metal and/or an excessive height of metal fall to the level of the molten metal within the mold not only causes "splashing," but also encourages turbulence of metal within the mold which tends to prevent the formation of a circumferentially uniform wall thickness. It is also beneficial to reduce the length of all of the molten stream in order to reduce the chance of metal oxidation.

The principal object of the present invention is to provide apparatus for the controlled delivery of molten metal to a casting mold. A further and more specific object is to provide apparatus of the character described for the separation of slag contaminants from molten ferrous alloys and the delivery of clean metal to a casting mold. An additional specific object is to provide apparatus of the character described capable of delivering a stream of substantially slag-free molten metal to a continuous casting mold under regulated conditions of delivery position and a substantially uniform molten metal delivery velocity.

The various features of novelty which characterize our invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which we have illustrated and described an embodiment of our invention.

Of the drawings:

Fig. 1 is an elevation, partly in section, of a tun dish and its operating mechanism constructed in accordance with the present invention as interposed between a tilting ladle source of molten metal and a continuous casting mold;

Fig. 2 is an elevation, in section, of the tun dish;

Fig. 3 is an elevation, in section, of a modified form of tun dish taken on line 3—3 of Fig. 4;

Fig. 4 is a plan view of the tun dish shown in Fig. 3;

Fig. 5 is a section taken on the line 5—5 of Fig. 3; and

Fig. 6 is an end elevation, as viewed from the right of Fig. 3.

While various features of the present invention are adapted for use in the casting of metals, the apparatus herein described is particularly advantageous for use in the continuous casting of carbon and alloy steels and other slag-forming metals.

In the continuous casting of metal, the molten metal, such as steel or other metal or alloy is introduced into the upper end of an upright mold, solidified therein by heat exchange with a cooling fluid and withdrawn from the opposite lower end of the mold. The molten metal is delivered to a holding and pouring ladle 10 from which it is poured at a selected rate and an optimum temperature through a pouring lip in one side thereof into a tun dish 11 for delivery into a continuous casting mold assembly 12. The ladle 10 is shown schematically in Fig. 1 in its relationship with the tun dish and the mold assembly. The ladle is arranged for tilting motion about a horizontally disposed axis of rotation defined by trunnions 13 projecting outwardly on opposite sides of the ladle body. The position of the ladle 10 is also adjustable in a horizontal direction so that the stream of metal discharged from the ladle may be selectively positioned while the rate of discharge therefrom is regulated by the angle of ladle tilt.

The tun dish 11 of the present invention is arranged to receive the molten metal from the ladle 10 and to discharge the metal into the open end of the mold assembly 12. The mold assembly includes, in general, a vertically elongated molding tube 14 encircled by a horizontally disposed flange member 15 at its upper end. An annular fluid chamber 16 surrounds the upper end of the tube 14 as defined by the flange 15, a transverse plate member 19 and an outer cylindrical wall 17. An inner cylindrical sleeve 18 is spaced from the outer surface of the tube 14 and extends upwardly from the member 16 to a position spaced from the flange 15. A cylindrical skirt 20 extends downwardly from a position adjacent the upper end of the sleeve 18 in closely spaced relationship with the molding tube 14 to define an annular cooling fluid flow passageway 21 therebetween substantially the length of the mold. An annular perforated distributing plate 22 is positioned intermediate the height of the chamber 18 between a plurality of cooling fluid inlets 23 and a flared inlet 24 of the passageway 21. With this construction the molten metal is solidified in the mold assembly by heat exchange through the tube 14 to a high velocity stream of cooling fluid passing through the passageway 21.

Experience has shown that the most satisfactory casting results are attained by the delivery of molten metal to the center of a pool of molten metal maintained in the upper portion of the molding tube in a substantially slag-free condition and under substantially uniform flow conditions. Best casting results are obtained with a low velocity of molten metal delivery. The temperature of the metal and the rate of its delivery is obtained by proper control of the pouring ladle 10, but the accurate regulation of optimum metal delivery position within the mold is determined by adjustment of the tun dish 11. The tun dish is also constructed and operated to minimize the inclusion of slag in the continuous casting and to provide a maximum visibility of the metal within the mold.

The tun dish 11 is shown in detail in Fig. 2 and consists of a metallic outer casing 32 having an inner refractory lining 32*a* and a layer of insulating material 32*b* interposed between a major portion of the lining and the casing. The tun dish 11 is divided into an inlet chamber 25 and a smaller outlet chamber 26 by a transverse vertical refractory baffle or partition 27. The chamber 26 and part of the chamber 25 is covered by a movable refractory top 29. A transverse inclined refractory baffle section 28 is located in the inlet chamber 25 and extends upward at an angle of approximately 20°–30°, with its lower end merging into the vertical partition 27. The lining and baffles are made of any suitable high temperature refractory material. Holes 30 in the bottom of the vertical partition 27 below its junction with the inclined baffle 28 form a plurality of separate passages, or in some cases a single passage, through which the molten metal can flow from the inlet to the outlet chamber of the tun dish. A V-notch refractory weir 31 is formed in the end wall of the tun dish for the discharge of molten metal. In operation, the tun dish is preheated to a high temperature, normally tilted forwardly about 10° and positioned so that the stream of molten metal from the ladle 10 falls into the inlet chamber 25 and strikes the vertical partition 27 below the normal molten metal level therein at such an angle that the stream continues to descend until it strikes the inclined baffle 28, which deflects the metal entrapped slag to the surface. The rising impetus given to the molten stream and the entrapped slag is most important because the slag being lighter endeavors to separate from the heavier metal and also readily adheres to other slag that has previously come to the surface. The slag-free metal then flows over the end of the inclined baffle 28 and through the passages 30 in the vertical baffle to the outlet chamber 26, from which it flows over the V-notch weir 31.

The described construction of the tun dish is effective in separating slag from the molten metal delivered thereto, and is also effective in maintaining an essentially uniform velocity in the stream of metal delivered to the mold assembly. This is largely accomplished by the baffles 27 and 28, in that the stream of metal entering the chamber 25 contacts a pool of molten metal therein which absorbs a major share of the velocity of the entering metal stream, with the stream thereafter reversing its direction of flow as directed by the baffles. The reversal in the direction of metal flow tends to absorb the remaining velocity of the entering metal stream. The flow of molten metal over the upper end of and beneath the baffle 28 toward the passages 30 consequently moves substantially under the influence of the difference in metal head between the pools of metal in the inlet and outlet chambers. In this manner, the velocity of the stream of metal entering the mold assembly 12 from the tun dish is at a minimum and is not appreciably influenced by changes in the metal velocity as delivered to the tun dish.

In operation, the molten metal is lip-poured from the ladle 10 to enter the previously described entrance and of the tun dish 11 and to discharge from the opposite end thereof into the mold 12. The rate of molten flow into the mold is ordinarily regulated by controlling the ladle 10 with the angle of tilt of the tun dish maintained at an adjusted value during the pouring period. The partition 27 and the inclined baffle 28 cooperate to divert the flow direction of the entering stream of metal so as to absorb the velocity head thereof in the pool of metal maintained in the tun dish and to encourage the separation of slag from the molten metal. The molten metal thereafter passes beneath the inclined baffle and through a plurality of submerged passageways 30 in the lower portion of the partition into the outlet chamber of the tun dish. In this manner slag is separated from the metal and the metal will discharge from the pouring lip of the tun dish under substantially uniform velocity flow conditions into the mold. It will be observed that the velocity of the molten metal stream delivered to the mold will be maintained at a generally uniform low velocity head which is substantially independent of the stream velocity entering the tun dish. Such flow velocity conditions are particularly important in a continuous casting process, in that turbulence within the mold is largely avoided and optimum circumferential uniformity of metal cooling is encouraged.

A modified form of tun dish is shown in Figs. 3–6. Such a modified construction can be used to advantage under certain conditions of operation, as for example when the pouring rate therethrough is relatively high and an increased volume of molten metal can be advantageously maintained therein to provide time for effective slag and metal separation. As illustrated, the tun dish 65 includes an outer metallic casing 66 having a refractory lining 67, and is provided with trunnions 68 attached to and extending outwardly from opposite sides thereof. The tun dish is divided into three connected chambers by spaced transverse substantially upright partitions 70 and 71, with the intermediate chamber 72, between the baffles 70 and 71, having more volume than the chambers 73 and 74 at the inlet and outlet end portions, respectively.

The inlet chamber 73 is provided with a rammed refractory bottom 75, as shown in Fig. 3, where the upper surface is curved to receive a downwardly directed incoming stream of molten metal and to direct the stream upwardly and longitudinally toward the discharge end of the tun dish. The partition 71 is provided with an opening 76 in the upper portion thereof adjacent one longitudinal side of the tun dish. The opening 76 is restricted in cross-section flow area so that the stream of metal passing therethrough from the inlet chamber 73 into the intermediate chamber 72 will have sufficient velocity to cause the entrained slag to rise to the surface of the molten metal pool maintained in chamber 72. Locating the opening 76 adjacent one longitudinal wall of the tun dish also encourages the maintenance of a relatively quiescent pool of metal in the chamber 72 adjacent the partition 71 removed from the opening 76.

The partition 70 is provided with one or more port openings 77 therein between the chambers 72 and 74 adjoining the bottom of the tun dish. An inclined baffle 78, similar in location and function to the baffle 28 of the tun dish 11 shown in Fig. 2, is positioned on the chamber 72 side of the partition 70 and extends transversely across the full width of the chamber. The baffle 78 is upwardly inclined and merges with the partition 70 at a position upwardly adjacent the port openings 77, to redirect the metal flowing downwardly along the partition 70 toward the upper surface of the molten metal pool therein so as to encourage further slag separation. The molten metal passing through the port 77 into the chamber 74 must pass around the end of the baffle 78, and in its movement separation of entrained slag is encouraged. As a result, the metal discharging from the chamber 74 through the V-notch weir is substantially slag free.

With the construction described, molten metal delivered thereto follows an "over and under" flow path in moving through the tun dish. The stream of molten metal entering the tun dish 65 from the ladle 10 strikes the curved surface of the bottom 75 in the inlet chamber 73 and is directed in an upward direction through the restricted opening 76 in the baffle 71. The molten metal stream rises to the surface of the pool of metal maintained within the chamber 72 and with the reduction in flow velocity in passing therethrough slag will separate and accumulate on the pool surface. The separated slag will tend to move toward the partition 70 due to the impetus of the entering metal, and the flow of metal downwardly along the surface of the partition would entrain some minor portion of the accumulated slag with the downwardly moving metal. However, the baffle 78 redirects the downwardly moving metal stream in an upward direction, so that any entrained slag will be again directed toward the surface of the pool and the metal passing around the end of the baffle 78 toward the port 77 and the chamber 74 will be substantially slag free.

As disclosed and claimed in our co-pending application, Serial Number 2,114, filed January 13, 1948, the tun dish 11 or 65 is supported at a predetermined elevation above the mold assembly 12 by an arm 33. The arm is pivotally arranged for movement in a horizontal plane so that the tun dish can be generally positioned relative to the mold, and when not in use the arm and tun dish may be swung away from the vicinity of the mold. A more accurate positioning of the tun dish relative to the mold is obtained by a plurality of adjusting movements of the tun dish relative to the arm 33. These movements include tilting the tun dish about a horizontal axis intersecting the crest of the weir 31; angular movement of the tun dish in a horizontal plane about a vertical axis; and a straight line lineal movement of the tun dish in a horizontal plane. These motions are primarily for the purpose of correcting any misalignment of the metal stream which may be caused by frozen metal on the discharge lip of the tun dish or on the weir of the pouring ladle 10, and thus enable the operator to accurately direct the stream of metal into the center of the molten pool in the mold.

A metal platform or plate 36 is pivotally attached to the arm 33 and directly supports the tun dish by means of pedestals 37 carrying the trunnion bearings 32. The pivotal connection between the arm and the plate is provided by a pivot pin closely fitted through the plate 36 and extending through a slotted opening in the arm 33. The pivot maintains the arm and plate in vertical relationship while permitting a horizontal rotational movement of the plate relative to the arm. The tun dish is supported by trunnions 41 extending outwardly from opposite sides thereof and resting in the bearings 32 to provide an axis of tilting rotation intersecting the crest of the V-notch weir. One of the trunnions 41 is provided with a depending lever arm 42 keyed thereon which is contacted by a crank screw 43. The screw 43 is threaded through a block 44 fastened to the plate 36 so that the lever arm can be moved through an arc to regulate the angle of tilt of the tun dish.

While in accordance with the provisions of the statutes we have illustrated and described herein the best form and mode of operation of the invention now known to us, those skilled in the art will understand that changes may be made in the form of the apparatus disclosed without departing from the spirit of the invention covered by our claims, and that certain features of our invention may sometimes be used to advantage without a corresponding use of other features.

We claim:

1. A tun dish comprising refractory walls defining a vessel having a discharge weir in an end wall thereof, at least one transverse partition spaced from said weir and extending across said vessel and having at least one port therethrough positioned adjacent the bottom of said vessel, and an inclined baffle merging into the side of said partition remote from said weir and above said port, said baffle projecting away from said partition at an acuate angle to the portion of the partition above the baffle, said baffle extending far enough toward the wall of the vessel opposite the wall having the discharge weir to intercept and deflect upwardly the stream of molten metal entering the tun dish.

2. A tun dish comprising refractory walls defining an open top vessel having a discharge opening in one end thereof, a transverse partition in said vessel having a plurality of passageways therethrough positioned intermediate the ends of its lower portion, and an inclined transverse baffle merging into the side of said partition remote from said end discharge opening and above said passageways, said baffle projecting from said partition at an acute angle to the portion of the partition above the baffle, said baffle extending far enough toward the wall of the vessel opposite the wall having the discharge

opening to intercept and deflect upwardly the stream of molten metal entering the tun dish.

3. A tun dish comprising refractory walls defining a vessel having a V-notch weir in one end wall thereof, a transverse substantially upright partition spaced from said weir and extending across said vessel and having at least one port therethrough positioned adjacent the bottom of said vessel, an inclined baffle merging with said partition above said port and projecting away from the weir end of said vessel at an acute angle to said partition, and a second transverse partition extending across said vessel at a position spaced from said weir and said first transverse partition, said second partition having an opening in the upper portion thereof adjacent one of the side walls of said vessel.

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