

Jan. 4, 1955

V. TARQUINEE ET AL

2,698,467

METHOD AND APPARATUS FOR THE CONTINUOUS CASTING OF METAL

Filed June 5, 1950

3 Sheets-Sheet 1

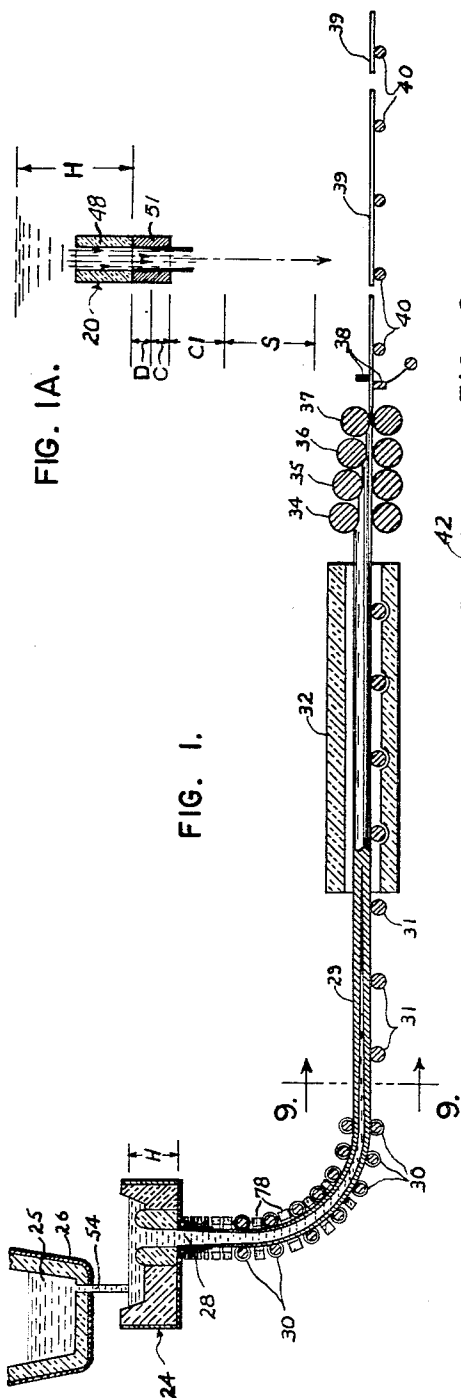


FIG. 1.

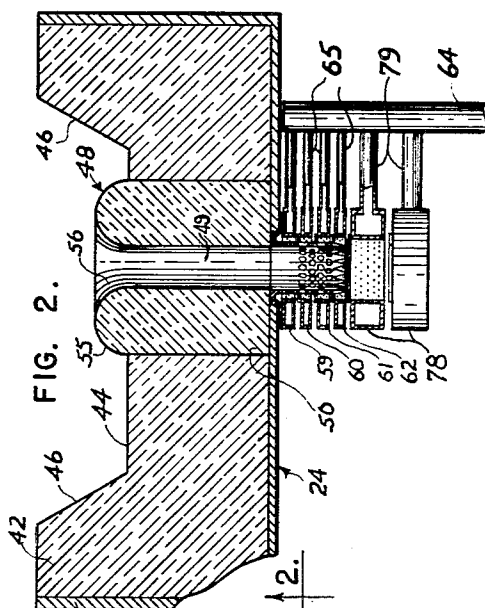


FIG. 2.

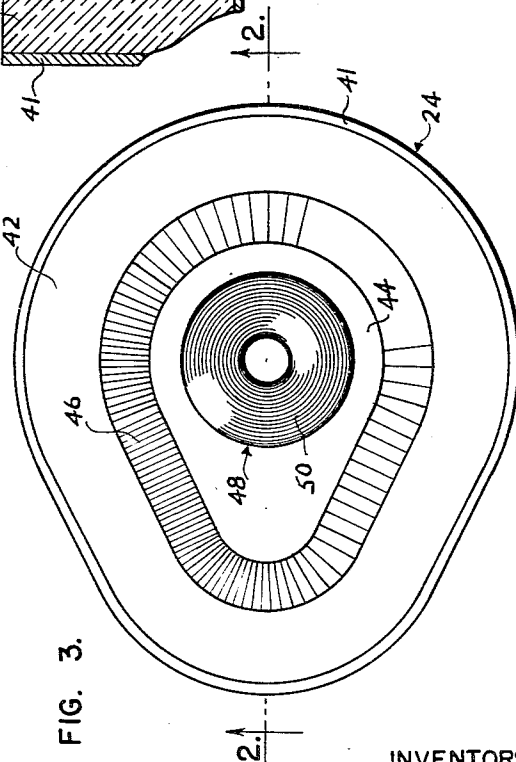


FIG. 3.

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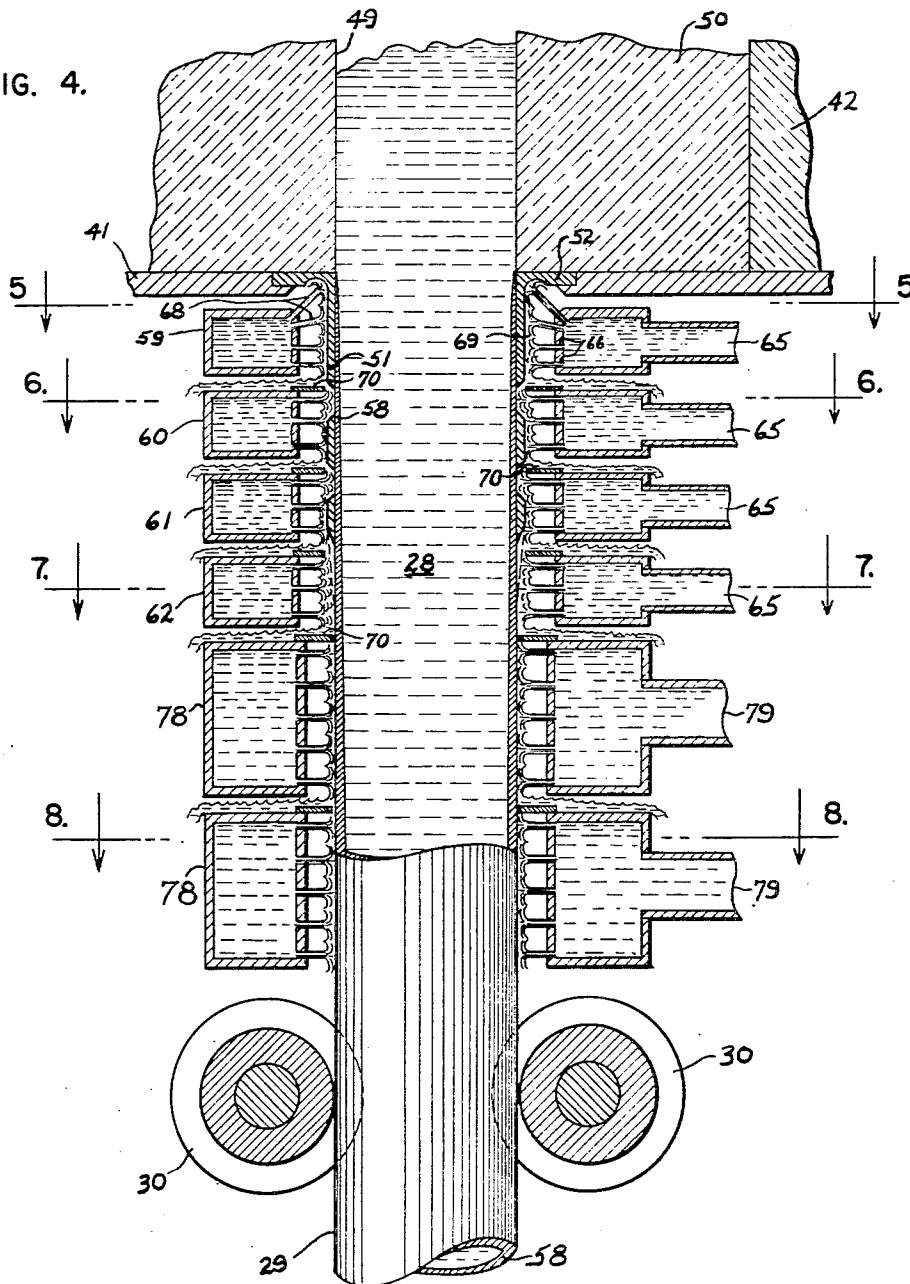
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FIG. 4.



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FIG. 5.

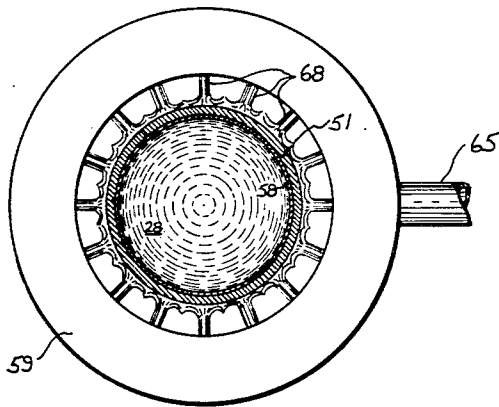


FIG. 6.

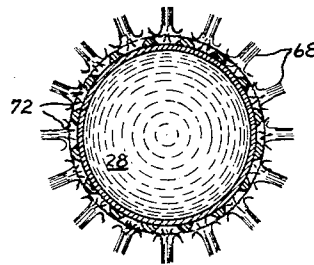


FIG. 7.

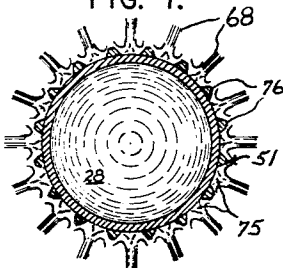


FIG. 8.

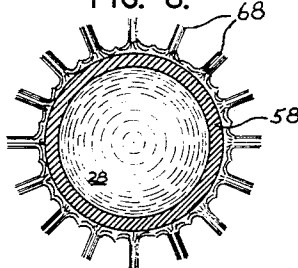


FIG. 13.

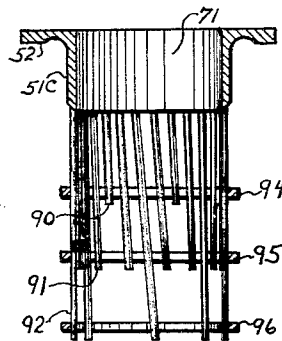


FIG. 10.

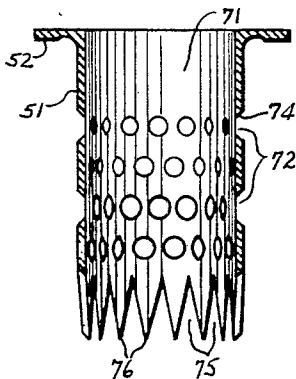


FIG. 11.

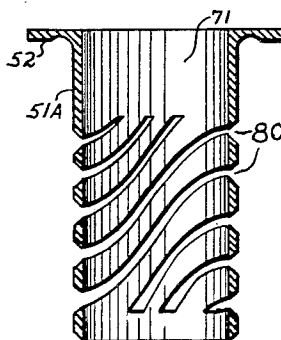


FIG. 12.

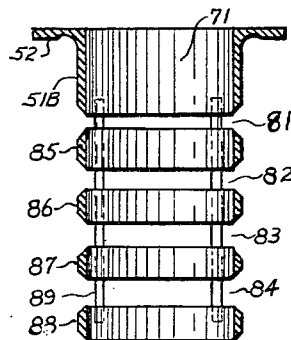
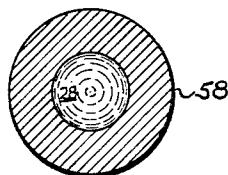


FIG. 9.



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METHOD AND APPARATUS FOR THE CONTINUOUS CASTING OF METAL

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Application June 5, 1950, Serial No. 166,198

14 Claims. (Cl. 22—57.2)

The present invention pertains generally to the art of continuous casting of metals and more specifically to a novel method and apparatus for casting an ingot of ferrous metal in a continuous length.

Since the time of Bessemer, the problem of casting ferrous metals continuously has received considerable attention. As a result, a number of methods and apparatus have been proposed in the past, meeting with varying degrees of success but all falling short of commercial feasibility for large scale mill production. Due to the high melting temperatures of ferrous metals, it is difficult to find suitable means for removing the large quantities of heat which must be removed at such temperatures to convert these metals from the liquid to the solid state. Heretofore, the severity of such operating conditions has precluded the development of a practical die or mold capable of handling any substantial amount of metal or of sustained operation over any considerable period of time.

Accordingly, it is a general object of the present invention to provide a novel method and apparatus for casting a high quality ingot of ferrous metal in a continuous length and at a rate which will be commercially feasible for large scale mill production. Such a rate may, for example, vary from approximately 96 tons per hour for a section of 4 inch diameter to 220 tons per hour for a section of 6 inch diameter.

A more specific object is to provide a method and apparatus of the character set forth and adapted for quantity production of a continuous length of ingot stock of appropriate size for rolling or other subsequent processing.

Another object is to provide a method and apparatus of the above type and which will permit the presentation of a continuous ingot directly to a rolling mill without the necessity for subsequent reheating other than light soaking to achieve uniformity of temperature within the ingot.

A further object is to improve the efficiency of rolling mill operation by eliminating the need for a number of steps in conventional practice, such as ingot stripping, soaking or heating, primary rolling, reheating and transportation, at the same time eliminating the apparatus associated with such steps. A related object is to devise a process of the character set forth having an over-all yield approaching 100 percent.

Other novel and advantageous features will become apparent upon consideration of the detailed description herein, taken in connection with the accompanying drawings, wherein:

Fig. 1 is a diagrammatic view exemplifying the practice of our invention by the use of one form of apparatus operatively associated with a rolling mill.

Fig. 1A is a diagrammatic view illustrating the broader aspects of our novel method.

Fig. 2 is an enlarged vertical sectional view through the ingot forming portion of the apparatus of Fig. 1.

Fig. 3 is an enlarged plan view of that portion of the apparatus shown in Fig. 2.

Fig. 4 is a further enlarged, fragmentary vertical sectional view detailing the ingot forming portion of the apparatus and its mode of operation.

Figs. 5 through 8 are enlarged, fragmentary horizontal sectional views taken through that portion of the apparatus shown in Fig. 4 and in the planes of the lines 5—5, 6—6, 7—7, and 8—8, respectively, and showing the sequential development of the ingot.

Fig. 9 is a transverse sectional view similar to Figs. 5

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through 8 but taken in the plane of the line 9—9 in Fig. 1. Figs. 10, 11, 12 and 13 are enlarged vertical sectional views detailing certain variants of the mold incorporated in the apparatus described herein.

While the invention is susceptible of various modifications and alternative constructions, certain preferred embodiments have been shown in the drawings and will be described below in considerable detail. It should be understood, however, that we do not intend to limit the invention to the specific forms disclosed but on the contrary, our intention is to cover all modifications and alternative constructions falling within the spirit and scope of the invention as expressed in the appended claims.

As a preliminary to a discussion of our method, it might be helpful to outline certain observations which we have made in relation to the solidification of a ferrous metal such as open hearth steel. First of all, it is well known that steel can be cast in an open-ended cylindrical mold of metal having a lower melting point but a high rate of heat conductivity without melting the mold, provided heat is removed therefrom at a sufficiently high rate. We have observed that under quiet flow conditions, an initial skin of solidified steel having a thickness in the neighborhood of one sixteenth of an inch will form almost instantly upon contact between the molten steel and the inner peripheral wall of the mold. This skin is of high quality steel. If, while molten, the steel strikes the mold without splashing, the skin forms with a smooth, unbroken surface. With progressive cooling resulting from the transfer of heat to the mold at a high rate, the skin will tend to increase in thickness at an approximate rate which may be as high as one sixteenth of an inch in one tenth of a second.

A phenomenon of cardinal importance incident to solidification is the tendency of the skin to shrink out of contact with the mold. Such shrinkage is usually uneven, occurring in spots or patches due to local variations in heat distribution. These may be caused, for example, by turbulence within the molten metal behind the skin. This results in the formation at scattered intervals of gas pockets between the skin and the mold wall. Each of these gas pockets causes, immediately upon formation, a drastic reduction in the heat transfer rate between the mold and local area or patch of skin overlying the pocket. This, in turn, produces reheating of each such patch of skin by the molten metal behind it, reducing its strength and rendering it soft or plastic. The softened patch of skin then balloons out until it strikes the mold wall and solidification once more progresses. Because of the reheating action, the skin thickness and strength in the region of each of these patches is substantially less than in the regions between the patches.

Taking account of the foregoing, we have developed a novel method for casting an ingot of continuous length directly from a molten ferrous metal such as steel. Our method comprises flowing substantially without turbulence, a column of molten metal through a specially designed, transversely split mold pipe, the upstream portion of the pipe being formed of graphitic or refractory material having a relatively low heat conductivity and the remaining or downstream portion of the pipe being fashioned of material having a relatively high heat conductivity, such as copper. Other metals, alloys, or substances possessing sufficient physical strength and having ability to conduct heat rapidly would also be suitable for making the downstream portion of the pipe which can be termed the mold. Referring to Fig. 1A, there is shown an illustrative mold pipe 20 by means of which our method may be practiced and comprising an upstream portion 48 and a downstream portion or mold 51. Immediately upon entry into the mold 51, a thin peripheral skin or shell forms upon the column of molten metal. To insure a rapid and uniform thickening of this initially formed peripheral skin, we maintain a high rate of heat transfer between the latter and the mold. This is accomplished by the simple expedient of superimposing a predetermined head H of molten metal above the mold 51 so as to maintain firm contact between the peripheral skin and the mold wall.

After the metal column and its newly formed skin have traveled axially through a short distance D in direct

contact with the mold 51, the skin acquires sufficient strength to commence shrinking out of contact with the mold wall and to contain the molten metal in the core of the column which is subject to the hydrostatic pressure head H. Provision is made for preventing reheating and local bulging of the skin when such shrinking occurs by the direct application of coolant to the skin even before it has left the mold 51. This is accomplished, as the metal column passes through the region indicated at C in Fig. 1A, by exposing a progressively increasing portion of its peripheral area to direct contact with high velocity sprays or jets of coolant in what might be termed a "heat scrubbing" action. At the same time, the amount of radial support given the skin is progressively diminished. "Heat scrubbing" by direct contact with coolant is subsequently applied to the entire peripheral area of the solidifying column in the region indicated at C1 in Fig. 1A.

The cooling action resulting from the direct contact of the skin with the mold in the region D and from the direct application of coolant in the regions C and C1 continues to extract heat from the surface of the ingot. For certain applications, the cooling may be carried on in the manner described above until the overall heat content of the section is sufficient to soak the same to rolling temperature with the addition of little or no outside heat. Soaking may be carried out in the region S shown in Fig. 1A.

Having described our novel method, consideration may now be given to one form of apparatus by means of which the invention may be practiced. Referring more specifically to Fig. 1, such apparatus is shown comprising a pouring basket 24 adapted in this instance to receive molten steel 25 from a ladle 26 and to discharge the steel in a continuous column 28 of substantially circular cross section. After passing through certain heat extraction means, the column 28 becomes progressively solidified into an ingot 29 of continuous length which may conveniently be directed into a soaking furnace 32 by suitable guide and support rollers 30 and 31. From the furnace 32, the ingot 29 passes through a plurality of reduction rolls 34, 35, 36 and 37 which progressively reduce its cross sectional area, and thence to a flying shear 38 which severs it into lengths 39 as it passes on to table rollers 40.

In the particular apparatus shown herein, the pouring basket 24 comprises a trough-like steel shell 41 lined with a heavy body of refractory material 42. Defined in the upper face of the material 42 is a pear-shaped recess 44 having outwardly flaring side walls 46. Centered in the wider portion of the recess 44 is an upright pipe 48 defining a column forming passage 49 for the molten steel leaving the pouring basket 24. The recess 44 is made with sufficient depth to permit impurities to float free of the steel entering the passage 49. In the apparatus illustrated, the pipe 48 comprises an upper portion in the form of a massive graphite sleeve 50 and a lower portion in the form of a relatively thin sleeve or mold 51 of copper or some other substance having a comparatively high rate of heat conductivity. The mold 51 projects through an opening in the bottom of the shell 41, being dependably supported therefrom by a peripheral end flange 52. To insure quiet and substantially non-turbulent flow of molten steel through the passage 49, the latter is located in offset relation with the pouring opening 54 of the ladle 26 and the narrow end of the recess 44 is disposed in underlying relation with the pouring opening 54. Thus any disturbance in the puddle of steel within the basin 24 due to its fall from the ladle occurs in a region remote from the passage 49. In addition, turbulence is further minimized and smoothness of flow facilitated by rounding off the upwardly projecting end of the graphite sleeve 50 as at 55 and by flaring out as at 56 the entrance to the passage 49.

Starting of the molten metal through the mold pipe may be effected in any convenient manner. For example, we may employ a relatively short plunger of appropriate diameter to make a comfortable sliding fit within the mold and initially block the passage 49. The plunger may be mounted at the end of a flexible metallic tubular member leading upwardly through the various guide and support rollers. Thus upon the exertion of a downward pull on the tubular member, the plunger is drawn down through the passage 49 and followed by a column of molten metal having a partially solidified lower end.

Provision is made for cooling the mold 51 at a sufficiently high rate to preclude melting thereof and at the same time to create about the smoothly flowing molten steel column 28 an even peripheral skin 58 which progressively thickens as the column 28 passes through the mold. This is accomplished by directing against the outer periphery of the mold a large volume of coolant in the form of high velocity fluid jets which effect a "heat scrubbing" action thereon. Accordingly in the present instance there are disposed in axially spaced, encircling relation with the mold 51 a plurality of hollow annular cooling heads 59, 60, 61 and 62 each supplied with pressurized cooling water from cooling main 64 as by means of branch conduits 65. Each such cooling head has formed in its inner peripheral wall a series of orifices or nozzles 66 and which are adapted to project a series of high velocity jets 68 generally radially of the exterior of the mold. The jets 68 blast away the film of steam which tends to hug the exterior of the mold, blanketing the latter with an ever changing sleeve of cooling water 69 which virtually "washes" away the heat transmitted to the exterior of the mold. For the purpose of avoiding distortion of the jets of the lower cooling heads by a cascade of spent cooling water from above, a series of separator baffles 70 may be interposed between successive ones of the cooling heads. To insure rapid and uniform thickening of the skin 58 during the initial stages of its formation, a high rate of heat transfer is maintained by direct contact between the skin 58 and the inside surface of the upstream end portion of the mold 51. In furtherance of such objective, steel is maintained in the pouring basket at a predetermined level, thereby superimposing a substantially constant head H on the steel within the mold 51.

After a certain amount of axial travel by the column 28 with its skin 58 in direct contact with the inner periphery of the mold, the skin 58 develops sufficient strength to commence shrinking out of contact with the wall of the mold containing the molten column 28 in opposition to the pressure resulting from the head H. Means is accordingly provided for maintaining progressive thickening of the skin and at the same time for preventing reheating and bulging of the newly formed skin as an incident to such shrinkage. To this end, provision is made for exposing the entire peripheral area of the skin in increments to the direct application of coolant even before it has left the mold 51 and while giving the skin sufficient radial support to prevent excessive bulging or rupture at any exposed increment or increments. Referring more specifically to Figs. 4 and 10, it will be perceived that the upper end portion of the mold is formed with solid walls which define a zone 71 of initial skin formation and direct contact between the skin 58 and the mold. On the downstream side of the zone 71, the mold walls are mutilated as by means of a large number of circumferentially spaced, axially staggered perforations 72. Each of the latter is adapted to permit at least one of the coolant jets 68 from the heads 60, 61 to pass through and impinge directly upon a given increment of skin surface area, as shown in Fig. 6. If desired, interference with the jets may be minimized by outwardly flaring the side surface 74 of each of the perforations 72. Those portions of the mold wall between the perforations 72 are cooled from the cooling heads by jets other than those which enter the perforations 72. By reason of the foregoing structure, each increment of surface area of a given transverse portion of the column 28 will be subjected to "heat scrubbing" by direct application of coolant before it leaves the mold.

Provision is also made in the mold 51 for progressively diminishing the amount of radial support given the skin 58 and at the same time progressively increasing the area exposed to direct cooling. Turning once more to Figs. 2, 4, 7 and 10, it will be noted that the downstream end portion of the mold is formed with a series of circumferentially spaced, axially extending serrations 75 defining a series of prongs 76. The side walls of the serrations, like those of the perforations 72, may taper outwardly. As shown clearly in Figs. 4 and 7, jets of coolant from the cooling head 62 are projected through the serrations 75 and between the prongs 76 to impinge directly upon the thickening skin 58. Some of the jets of course strike against the prongs 76 and cool the same.

In the apparatus thus far described, the length of the mold 51, the cooling rate and the speed of travel of the

ingot are so correlated that upon exit from the mold, the solidified skin 58 has acquired a large amount of strength and no longer needs radial support. The molten core 28 of the ingot introduces further problems, however, and these are given special consideration in the construction of the remaining portion of our apparatus. Since the peripheral or solidifying portion of the molten core 28 is at a relatively constant temperature, the temperature of the surface of the ingot is determined by the rate at which heat is extracted therefrom. If this rate is too low, the dispersion of heat into the skin from the molten core will raise the skin surface temperature to a point where the skin will lose its strength, bulging out and possibly rupturing.

To avoid the adverse effects of loss of strength, we subject the ingot 29 to further "heat scrubbing" by the direct application of coolant after the ingot 29 emerges from the mold. This direct cooling is maintained until the possibility of bulging or rupturing of the skin has passed. In the present instance, we accomplish the foregoing by mounting a plurality of additional cooling heads 78 in axially spaced relation with the ingot 29 and below the mold 51, the heads 78 alternating with the guide and support rolls 30. Like the cooling heads 59, 60, 61 and 62, the heads 78 project fluid coolant in the form of radial jets 68, the coolant being conducted from the main 64 via supply conduits 79 (Figs. 2 and 4). Unlike the others, the entire output of each of the cooling heads 78 is projected against the skin 58 of the ingot without interference from supporting elements, as clearly indicated in Fig. 8. Thus the jets 68 of the additional cooling heads 78 impinge directly upon the skin of the ingot, blanketing the entire peripheral surface of the ingot with an ever-changing sleeve of fluid coolant and thereby continuing the "heat scrubbing" action earlier described. This sleeve initially protects the ingot from oxidation. However, as the ingot travels away from the mold and its surface temperature is reduced oxidation becomes less severe. For this reason and also because the skin has acquired sufficient thickness, the maintenance of an unbroken blanket of coolant about the ingot becomes unnecessary. Consequently, the additional cooling heads 78 subsequently encountered by the ingot are disposed in axially spaced relation and are alternately located with respect to various groups of the guide rollers 30. The cooling action set up by the heads 78 is maintained until the skin 58 changes from the thickness indicated in Fig. 8 to a thickness approaching that indicated in Fig. 9. By the time the skin reaches a thickness comparable to that of Fig. 9, the molten core 28 has become so small in diameter that it no longer contains enough heat to cause deformation and rupture of the frozen skin 58. Thus with further longitudinal movement, solidification of the core 28 may be completed at a reduced rate of heat extraction in any desired manner.

In certain installations, it might be desirable to sever the ingot 29 into predetermined lengths, as by means of a flying shear, shortly after solidification. To obtain maximum economy from operation of the apparatus described above, however, it is preferable to feed the ingot 29 into a continuous type rolling mill having a series of reduction rolls such as rolls 34, 35, 36 and 37.

The total heat content of the ingot 29 upon solidification could, if evenly distributed, maintain the ingot 29 at a temperature suitable for rolling. However, the very nature of the preceding cooling process has produced a relatively steep temperature gradient between the center and the skin of the ingot 29. It is usually desirable to effect a substantially uniform distribution of heat transversely of the ingot just prior to rolling. In this instance it is run through the soaking furnace 32. By drastically reducing the loss of heat from the surface of the ingot, the furnace 32 permits the temperature gradient between the center of the ingot and the skin to approach a level attitude. By properly regulating the overall heat content of the ingot prior to its entry into the soaking furnace 32, this leveling off of the temperature gradient, or in other words soaking, may bring the ingot to a suitable rolling temperature with the addition of little or no outside heat.

Synopsis of operation

While the operation of the apparatus described above will no doubt be readily apparent to those skilled in the art, a brief summary thereof might be appropriate at

this point. Referring again to Fig. 1, molten steel is poured from the ladle 26 into the basket 24 and drained from the latter at its quiet end. The column of molten steel enters the pipe 48, passing under substantially laminar flow conditions from the graphite sleeve 50 into the mold 51 which is cooled by fluid jets from the cooling heads 59, 60, 61 and 62. Flow through the pipe 48 may of course be started in any suitable manner, as by means of the plunger and flexible metallic tube arrangement referred to earlier herein. A progressively thickening skin 58 forms in the zone 71 in the initial portion of the mold, contact with the mold wall being maintained by means of the hydrostatic pressure head H. Such contact causes the skin to form with substantially uniform radial thickness in any given cross sectional plane. As soon as the skin acquires sufficient strength to withstand the internal pressure due to the head H, it leaves the zone 71 and a progressively increasing portion of its surface is subjected to direct application of fluid coolant from the cooling heads 59, 60, 61 and 62 while a progressively decreasing portion of its surface receives radial support. Upon exit from the mold, the partially solidified portion of the ingot is subjected to further direct application of coolant by jets from the axially spaced cooling heads 78, but now about its entire periphery. This results in still further thickening of the skin 58 until the diameter of the molten core becomes so small that it will solidify without deformation of, or other adverse effects upon, the previously solidified portion of the ingot. Due primarily to the fact that the solidifying core 28 has constantly superimposed thereon a supply of molten metal represented by the unsolidified upstream portion of the core, solidification occurs substantially without the formation of pipe. The solidified portion of the ingot is thereupon passed into the soaking furnace 32 so as to level off its transverse temperature gradient. From the furnace 32, the ingot enters the reduction rolls 34, 35, 36 and 37 and after rolling is severed into predetermined lengths by means of the flying shear 38.

Modifications

Turning once more to the drawings, there are shown in Figs. 11, 12 and 13, respectively, certain modified mold forms 51A, 51B, and 51C which are susceptible of use in the apparatus described herein. All of the molds are broadly similar to the mold 51, being mutilated so as to expose all increments of surface area of the skin 58 to the direct application of coolant while providing sufficient radial support to prevent rupture of the exposed area increments. Each of the modified molds also includes an initial skin formation zone 71. Extending downstream from the zone 71 of the mold 51A (Fig. 11) are a plurality of helical slots 80 in its side wall, each terminating just short of the downstream end of the mold. These slots all widen out in the downstream direction and expose increasing amounts of ingot skin area to direct blasts of coolant from the cooling heads 60, 61 and 62.

Considering next mold 51B (Fig. 12), it will be noted that its upstream end portion is similar in form to those already described, defining an initial skin formation zone 71. Downstream from the zone 71, the mold 51B has a series of axially spaced transverse slots 81, 82, 83 and 84 for exposing the ingot skin to direct contact with coolant. Of this group, the upstream slot 81 is the narrowest, each of the remaining ones being of greater width than the one upstream therefrom. These slots divide that portion of the mold below the zone 71 into a corresponding series of rings 85, 86, 87 and 88 which may be mechanically fixed together as by means of longitudinal outside struts 89.

Turning now to Fig. 13, it will be perceived that modified mold 51C has an upstream end portion similar to the other molds, including the initial skin formation zone 71. That portion of the mold 51C downstream from the zone 71 is of cage-like form, being defined by a plurality of substantially axially extending bars 90, 91 and 92 of varying lengths. Preferably, each of the bars is of round cross section and has some degree of helical twist. In the present instance, the bars are grouped according to length in three alternate, circumferentially spaced series. Their free ends are provided with external support in the form of peripheral hoops 94, 95 and 96. This construction permits exposure of progressively increasing portions of skin surface area to

direct application of coolant and at the same time progressively decreases the amount of radial support. One of its principal advantages is the fact that the entrapment of coolant between the mold wall and the skin is positively precluded.

Upon reflection, it will be appreciated that our novel method and apparatus described above adequately fulfill the objectives set forth earlier herein and possess numerous advantages in addition to those already discussed.

We claim as our invention:

1. A method of continuously casting molten metal and comprising quietly flowing the molten metal through an open ended mold, applying fluid coolant continuously to the exterior of the mold to initiate solidification of a peripheral skin on the molten metal therein, projecting said fluid coolant directly against a progressively increasing portion of the surface of said solidifying peripheral skin within said mold while at the same time progressively decreasing the amount of radial support afforded said skin by said mold.

2. A method of casting molten metal in a continuous length and comprising flowing said metal without turbulence through an open ended chilled mold so as to freeze instantaneously a solidified peripheral skin about said molten metal, superimposing a head of fluid pressure upon the molten metal in the mold to facilitate formation and thickening of said peripheral skin, applying fluid coolant continuously to the mold, applying coolant directly to a progressively increasing portion of the surface of said peripheral skin within the mold while at the same time progressively decreasing the degree of radial support afforded said peripheral skin by said mold.

3. A method of casting ferrous metal in a solid cross section of continuous length and comprising the steps of initially forming a peripheral skin of solidified metal, said skin being formed instantaneously by contact with a chilled radial supporting surface, progressively thickening the skin by applying a coolant directly to the same while gradually decreasing to zero the radial support afforded the skin by said surface, and maintaining the application of coolant until the peripheral skin has built up sufficient thickness to absorb the heat from the molten core and solidify the same without undergoing deformation.

4. A method of casting ferrous metal in a solid cross section of continuous length and comprising the steps of initially forming a peripheral skin of solidified metal about the molten metal by flowing the same along a chilled radial supporting surface, superimposing a head of fluid pressure upon the molten metal in contact with said supporting surface to facilitate formation of said skin, progressively thickening the skin by heat scrubbing the same with fluid coolant in directly applied jet form while gradually decreasing to zero the radial support afforded the skin by said surface, and maintaining the heat scrubbing action of the coolant jets until the peripheral skin has built up sufficient thickness to absorb the heat from the molten core so as to solidify the same without undergoing appreciable deformation, and soaking the section to level off the transverse temperature gradient of the same preparatory to reduction rolling.

5. Apparatus for casting molten metal in a continuous length and comprising in combination, a mold pipe having a relatively thin walled portion possessing a relatively high coefficient of heat transfer radially thereof, means for quietly channeling a flow of molten metal through said mold pipe, a plurality of axially spaced cooling heads each adapted to direct fluid coolant in a series of radial jets against said thin walled portion of said mold pipe to initiate solidification of a peripheral skin upon the molten metal within the same, said thin walled portion having openings therein for exposing to the coolant jets portions of the area of the peripheral skin therein, the areas of said openings increasing progressively in the downstream direction.

6. Apparatus for casting molten metal into an ingot of continuous length and comprising the combination of a mold pipe terminating in a relatively thin walled mold having a relatively high coefficient of heat transfer radially thereof, means for quietly flowing molten metal through said mold, a plurality of axially spaced cooling heads each adapted to direct fluid coolant in radial jets against said mold to initiate solidification of a peripheral skin upon the molten metal within the same, said mold

having openings in the walls thereof exposing certain portions of the peripheral skin, said cooling heads also being adapted to direct jets of coolant against the exposed portions of solidified peripheral skin within the downstream from said mold, and a plurality of transverse baffles disposed in alternate series relation with said cooling heads to preclude deflection of the radial jets by spent coolant cascading along said mold and the solidified peripheral skin.

7. An apparatus for casting a ferrous metal ingot in a continuous length of generally circular cross section and comprising in combination, a refractory pouring basket having an oblong recess therein for receiving a supply of molten metal at one end thereof, a graphite sleeve located at the opposite end of the recess for tapping molten metal from the same, said graphite sleeve having an upright passage with an outwardly flared mouth for quietly guiding molten metal into such passage, a relatively short thin walled copper sleeve mounted in depending relation with said graphite sleeve and axially aligned with the passage therein, said sleeve being of substantially circular cross section and having an out-turned mounting flange at its upper end, said sleeve having an unbroken wall portion and a broken wall portion situated downstream therefrom, said broken wall portion having openings therein progressively increasing in area toward the lower end of said sleeve, a plurality of annular cooling heads mounted in axially spaced surrounding relation with said sleeve, additional cooling heads mounted in axially spaced relation below said sleeve, all of said heads being adapted to project fluid coolant inwardly in radial jets, said cooling heads being alternately spaced with a plurality of annular separator baffles.

8. In an apparatus for the casting of molten metal in continuous lengths and wherein such metal is flowed with substantially no turbulence into a cooled mold pipe, an open ended mold comprising an upstream portion having a solid wall and a downstream portion having openings increasing in size progressively toward the downstream end of the mold.

9. In an apparatus of the character set forth for casting molten metal in continuous lengths by quietly flowing the metal through a cooled mold pipe, an open ended mold comprising an upstream portion having a solid wall for initially forming a solidified peripheral skin about the molten metal, said mold also comprising a downstream portion having openings increasing in size toward the downstream end of the mold and staggered to expose every portion of the circumference of the peripheral skin.

10. In an apparatus of the type set forth for casting molten metal in continuous lengths by flowing the same quietly through a chilled mold pipe, an open ended mold of material having a relatively higher heat conductivity than the molten metal and comprising, in combination, an unbroken upstream end portion having a solid wall, an intermediate portion having a plurality of circumferentially spaced and outwardly flaring openings in the walls thereof, said openings increasing in size in a downstream direction, and a downstream end portion terminating in a series of relatively sharp outwardly flaring serrations defining a plurality of teeth tapering axially toward the downstream end of said mold.

11. In an apparatus of the character set forth for casting molten metal in continuous lengths by flowing the metal through a chilled mold pipe substantially without turbulence, an open ended mold comprising, in combination, an upstream end portion having an unbroken wall, an intermediate portion having a plurality of circumferentially spaced and staggered openings in the wall thereof, and a downstream end portion having gashed wall defining a plurality of circumferentially spaced tapered teeth.

12. In an apparatus of the type set forth for casting molten metal in continuous lengths by flowing the metal through a chilled mold pipe substantially without turbulence, an open ended mold comprising the combination of an upstream end portion having an unbroken wall, an intermediate portion having a plurality of circumferentially spaced spiral slots in the wall thereof, each of the slots being of progressively increasing width in the downstream direction, and a downstream end portion also having an unbroken wall.

13. In an apparatus of the character set forth for casting molten metal in continuous lengths by quietly

flowing the metal through a chilled mold pipe, an open ended mold comprising, in combination, an upstream end portion having an unbroken wall, a main body portion situated downstream from said upstream end portion and including a plurality of annular collars axially spaced at intervals which progressively increase in length in the downstream direction, and means for rigidly securing said collars in spaced relation with said upstream end portion.

14. In an apparatus of the character set forth for casting molten metal in continuous lengths by quietly flowing the metal through a fluid cooled mold pipe, an open ended mold comprising, in combination, an upstream end portion having an unbroken wall, a plurality of circumferentially spaced rod members each extending from said upstream end portion in a downstream and slightly spiraled direction, certain ones of said rods being of different lengths so that their ends define a serrated pattern, and means for holding the

free end portions of said rods in rigidly fixed relation, the inner sides of said rods forming an extension of the inner surface of said mold.

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