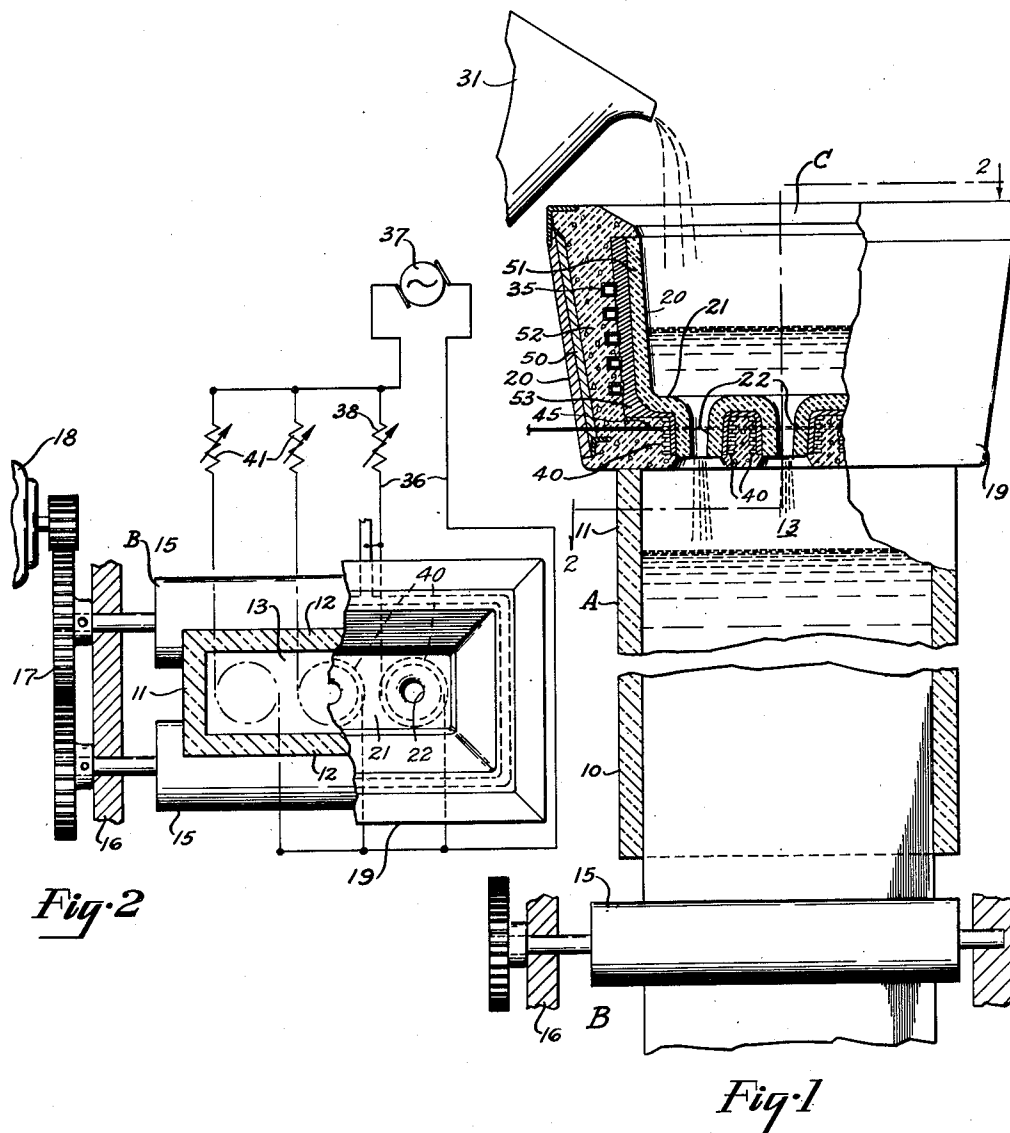


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RECEPTACLE FOR MOLTEN METAL

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RECEPTACLE FOR MOLTEN METAL

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1 Claim. (Cl. 22—79)

This invention pertains to the art of casting of metals and, more particularly, to the apparatus for holding the molten metal and feeding it into the mold or the like at a proper or desired temperature.

The invention is particularly applicable to apparatus for holding the molten metal for a continuous-casting process and will be particularly described with reference to this ultimate use, although it will be appreciated that the invention is not so limited and has other applications.

In the art of continuous casting of metals, it is customary to continuously feed molten metal into the upper end of an elongated water-cooled mold open also at the bottom, which mold cools the metal as it moves downwardly through the mold so that solidified metal is continuously drawn from the bottom end of the mold.

One of the problems in this art has been one of maintaining an accurate control of the temperature of the molten metal being fed into the inlet end of the mold. If the temperature of the molten metal is either too hot or too cold, poor castings result. If it is too hot, solidification is not accomplished by the time the metal has reached the bottom of the mold and rupturing occurs of the thin solidified skin which first forms, allowing the molten metal to flow through, thus resulting in defective molded articles. If it is too cold, a non-homogeneous casting results.

The problem is particularly acute where it is desired to continuously cast shapes other than round shapes, such as flat bars or the like. With such a shaped bar, improper variations in the temperatures of the metal while molten in the upper end of the mold result in non-uniform castings which are not commercially saleable. Normally, in rectangular molds, cooling tends to take place at a greater rate adjacent the narrow edges of the mold than across the wider face, which nonuniform cooling rate on a body of molten metal having an initially uniform temperature across the entire top has been found to produce poor castings.

Heretofore, molten metal was first poured from the melting furnace into a retainer called a "tundish" from which the molten metal flows through a pouring spout into the upper end of the mold. This tundish serves the function of a settling chamber where slags can float to the top and where the metal can be brought to the desired temperature before pouring.

This tundish normally has been comprised of a steel shell with a refractory liner. Once the molten metal is in this tundish, it can only be heated if it has reached too low a temperature by pouring in hotter molten metal; or, if it is too hot, by pouring in metal which is somewhat cooled or by simply allowing the molten metal in the tundish to cool by radiation or the like. Because of the difficulty of controlling the temperature being poured into the tundish from the melting furnace and because of the inherent variations in the temperature from batch to batch, it is extremely important that some means be provided for very quickly and rapidly either adding heat to or removing heat from the molten metal in the tundish.

Various methods have been proposed for heating the metal while in the tundish, such as high-frequency induction heating of the metal itself, but heretofore such heat-

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ing has only been successful to a small degree. While induction heating enables heat to be very rapidly added to the molten metal, no means have heretofore been provided for rapidly removing heat from the molten metal to reduce the temperature in the batch in the event that the metal from the melting furnace, when poured into the tundish, is over the desired temperature.

The present invention contemplates means and method for providing an extremely accurate and rapid-acting temperature control for the molten metal in the tundish and for the metal flowing into the continuous mold. The present invention also contemplates an extremely accurate means and method for providing a variation in the temperature of the metal flowing into an irregular shaped mold, such as a rectangular mold, to enable the obtaining of more perfect continuously casted rectangular slabs.

In accordance with the present invention, a holding receptacle or tundish, together with its pouring spout, is provided which is formed from a refractory material having a substantial heat conductivity and this tundish, including the receptacle and the pouring spout, is surrounded by one or more high-frequency induction-heating coils which are water cooled and which are disposed in heat-conducting relationship with the refractory material of the tundish. Cooling water is continuously circulated through these coils. Thus, if it is desired to raise the temperature of the metal in the tundish, high-frequency currents may be flowed through the coils to induce high-frequency currents to flow either in the molten metal in the tundish or in the refractory material of the tundish itself which is generally somewhat electrically conductive at the temperature of the molten metal to actually heat the metal in the tundish to any desired amount. However, if it becomes necessary to lower the temperature of the metal in the tundish, the high-frequency currents flowing in the coil are turned off and the heat of the molten metal then flows through the heat-conductive refractory material to the induction-heating coils where it is carried away by the cooling water. Normally, if the temperature of the metal in the tundish is correct, then high-frequency currents will be flowed in the coil in an amount to just offset the amount of heat being conducted to the coils through the refractory material.

Temperature-sensitive apparatus may be placed in the molten metal stream as it flows into the open-ended mold, which apparatus may be operatively associated with the power input to the high-frequency induction-heating coils so that the temperature may be automatically varied and maintained at any desired value.

In embodiments of the invention, the refractory material may be of a graphitic material or the like which has a definite electrical conductivity so that the high-frequency currents will also be induced directly in the graphitic material so as to heat this material along with the molten metal.

Where rectangular bars or the like are to be continuously cast, the tundish is provided with a plurality of pouring spouts of the same material as referred to above, each spout having a high-frequency, induction-heating coil associated therewith in heat-conductive relationship with the refractory material for the purpose of either heating or cooling the molten metal as it flows through the pouring spouts.

Further, in accordance with the invention, it is contemplated to so adjust the temperature of the pouring spouts to heat the metal flowing into the mold adjacent the narrow edges of the rectangular mold to a temperature hotter than that of the metal being fed to the middle of the rectangular mold.

An object of the invention is to provide new and improved means for feeding molten metal to a continuous-casting process which is simple in construction, positive

in operation and permits of an extremely accurate and rapid temperature control over the temperature of the molten metal flowing into the mold.

Another object of the invention is the provision of a tundish for use in metal casting which has a relatively high conductivity, at least at the temperature to which the molten metal will be poured, in combination with high-frequency induction-heating coils surrounding the tundish for the purpose of inducing high-frequency currents to flow in the conductive material of the tundish to directly heat same to the desired temperature at which the metal is to be poured.

Another object of the invention is the provision of new and improved means for feeding molten metal into a rectangular mold for a continuous-casting process, the means including a tundish having a plurality of spouts adapted to feed molten metal into different parts of the mold; namely, adjacent the narrow edges of the rectangular mold and adjacent the middle of the mold, the tundish comprising means for heating the spouts for feeding the mold adjacent the edges to a temperature higher than those feeding the middle of the mold.

Still another object of the invention is the provision of new and improved means for rapidly effecting temperature changes of molten metal in a tundish or the like comprising providing a tundish made of a refractory material having a relatively high heat conductivity and placing a water-cooled high-frequency induction-heating coil in heat-conductive relationship with the material whereby heat of the molten metal may be directly conducted away to the cooling water of the coil, the coil being energized from an alternating-current power source in amounts sufficient to offset the heat being conducted to the cooling water of the coil in desired amounts.

Still another object of the invention is the provision of a new and improved method of either rapidly increasing or decreasing the temperature of molten metal in a tundish or the like comprising providing a tundish made from a heat-conductive material and positioning a water-cooled high-frequency induction-heating coil in heat-conducting relationship with the material and supplying electrical energy to the coil in amounts either greater or less than the rate of heat conduction to the coil to either increase or decrease the temperature of the metal in the tundish.

The invention may take physical form in certain parts and arrangements of parts, a preferred embodiment of which will be described in this specification and illustrated in the accompanying drawing which forms a part hereof, and wherein:

Figure 1 is a side sectional view somewhat schematically showing a continuous-casting machine, together with a tundish, for feeding molten metal therinto embodying the present invention, and

Figure 2 is a cross-sectional view of Figure 1 taken approximately on the line 2—2 thereof.

Referring now to the drawing wherein the showings are for the purpose of illustration only and not for the purposes of limiting the invention, the figures show a continuous-casting machine comprised of a mold A open at both ends, drive rolls B adjacent the bottom end of the mold A for drawing solidified bars from the mold A and a tundish arrangement C embodying the present invention for feeding molten metal into the mold A. The continuous-casting mold A forms no part of the present invention but, for the purposes of this description, may be said to include a generally rectangular, artificially cooled shell 10 having narrow walls or edges 11 and wider side walls 12 defining a vertically extending through opening 13, at the top end of which molten metal is adapted to be poured and from the bottom end of which substantially solidified metal bars are adapted to be continuously withdrawn. In a like manner, the rolls B form no part of the present invention and may comprise a pair of rolls 15 disposed on opposite sides of the center line of the shell 10 adjacent the bottom end thereof and

mounted for rotation in suitable bearing supports 16. The rolls 15 may be driven through a suitable gearing 17 and an electric motor 18.

The tundish C comprises a generally large receptacle 19 disposed above the mold A having side walls 20 and a bottom 21, the latter having a plurality of openings therethrough forming pouring spouts 22. These pouring spouts extend downwardly from the bottom of the side 21 into the upper end of the molding shell 10. In the embodiment shown, there are three pouring spouts in a row, the outermost spouts 22 being adapted to feed molten metal adjacent the narrow sides 11 of the shell while the center spout is adapted to feed metal at the center of the sides 12. If desired, a cover (not shown) having openings through which the pouring spout 22 extends may be positioned across the upper end of the shell to exclude oxygen from the upper end of the shell and prevent undesirable oxidation of the heated molten metal, or the tundish may rest directly on top of shell 10 as shown to perform the same function.

A ladle 31 is shown pouring molten metal into the open end of the tundish C. The molten metal is pooled in the tundish until all slag has floated to the top and until it has reached a desired uniform temperature throughout the entire mass when it then flows through the pouring spouts into the shell 10.

The tundish C, together with its pouring spouts, must normally be made of a refractory material and, in accordance with the invention, a refractory material is chosen which has a substantial heat and/or electrical conductivity at least at the temperature at which the metal will be poured. Graphite has proven quite satisfactory for this purpose for nonferrous metals. Other materials may be used for steel.

In the embodiment of the invention shown, the tundish C is comprised of an outer cylindrical steel shell 50 having centrally positioned therein a crucible 51 of a graphitic material molded to the desired shape with the pouring spouts 22. The space between the outer surface of the crucible 51 and the inner surface of the steel shell 50 is packed with a standard refractory material 52 which preferably has a relatively low heat conductivity. In a like manner, the inner surface of the crucible 51 has a packed liner 53 of a refractory material preferably having a relatively high heat conductivity. It will be noted that the refractory material 52, 53 also extends into the pouring spouts 22, completely enclosing the graphitic material which forms this spout.

Further, in accordance with the invention, means are provided for directly heating or cooling the entire tundish or the metal in the tundish to a temperature approaching that desired at which the metal should be poured so that a desired uniform temperature throughout the metal may be obtained and so that desired variations in the pouring temperature between the various spouts 22 may be quickly obtained.

Thus, in accordance with the invention, a multiturn coil 35 of hollow water-cooled copper tubing surrounds the outer surfaces of the crucible 51 and the turns are in thermal contact with the material of this crucible. The coil is connected to a source of preferably high-frequency electrical energy 37 through wires 36. A variable reactance 38 may be placed in series with one of the wires 36 so as to control the energization of the coil 35.

In a like manner, each pouring spout 22 is surrounded with a multiturn coil 40 of hollow water-cooled copper tubing, each connected through means shown schematically as a variable resistance 41 to the source of high-frequency electrical energy 37. Each coil is shown as being connected to the same source of electrical energy. It will be appreciated that separate sources of electrical energy could be employed if desired. Any desired means for varying the energization of the coils 35 and 40 may be employed if desired.

The coils 40 surrounding each pouring spout 22 are also in thermal conducting relationship with the outer

surface of the crucible forming the pouring spout so that heat in the crucible itself can be rapidly conducted away through the cooling water in the high-frequency induction-heating coil.

With the tundish, together with its pouring spouts 22, being formed with a lined graphitic material which has a substantial heat and electrical conductivity, it will be appreciated that high-frequency currents flowing through the high-frequency coils 35 and 40 will induce high-frequency currents to flow within the graphitic material, which currents will rapidly heat the graphitic material to any desired temperature, which temperature may be below that of the metal in the tundish so as to cause a cooling effect thereon or about that of the metal in the tundish so as to provide a heating effect therefor.

It will be appreciated that the cooling water in both the coils 35 and the coils 40 will be continuously conducting heat away from the crucible and, thus, away from the molten metal in the tundish C. If it be assumed that the temperature of the molten metal in the tundish is just at exactly the correct temperature, then in order for this temperature to remain without change, it will be necessary to supply a sufficient amount of high-frequency energy to the heating coil to just offset the amount of heat being removed in the cooling water of the coil. If the temperature of the molten metal should drop to too low a value, then the amount of power in the coils should be increased so as to effect an over-all heating of the crucible and the molten metal.

On the other hand, if the molten metal is at too high a temperature, then the electrical energy supplied to the coils must be decreased; in which case, an extremely rapid cooling of the molten metal can be obtained by allowing the heat to be conducted away through the cooling water in the coils. This cooling action is much more rapid than anything which so far as I know has ever been obtained and is particularly important in enabling the accurate temperature control necessary for continuous-casting operations. The accelerated cooling effect is particularly of importance in pouring spouts where desired differences in the temperature of the metal flowing from the various spouts can be easily obtained, although all of the metal in the main part of the tundish is at a uniform temperature.

So far as I know, I am the first to employ a tundish made of electrically conductive material in which heating may be directly induced so as to control the pouring temperature of the metal into the continuous mold. Also, so far as I know, I am the first to employ the cooling effect of the cooling water in high-frequency induction-heating coils for providing a cooling action on molten metal in a ladle, tundish or melting pot.

Further, in accordance with the invention, each pouring spout 22 and the holding receptacle are provided with temperature-sensitive means such as thermocouple 45, which thermocouples are, in turn, connected through suitable amplifying apparatus well known and not shown to the power controls for the coils associated with the particular thermocouple, the arrangement being such that the energization of each coil 35 and 40 will be so controlled and adjusted to maintain the temperature of the metal either in the receptacle or flowing through the pouring spouts at a predetermined temperature necessary to give the desired results in the continuous-casting process.

As heretofore stated, one of the problems in the continuous casting of rectangular shapes of metal has been in the uneven cooling of the rectangular bar due to the greater cooling area per unit of volume adjacent the edges 11 of the bar. In accordance with the present invention, the outer pouring spouts 22 feed metal adjacent the edges 11 and the energization of the coils 40 for these pouring spouts is so adjusted that the temperature of the metal emerging therefrom will be higher than the metal coming from the central pouring spouts which, as shown, feed generally the central portion of the rectangular mold. With this arrangement, the more rapid cooling

adjacent the thin edges of the ingot will be compensated for by hotter metal being fed into this point and a highly uniform ingot will move continuously from the lower end of the shell 10. If desired, valve members (not shown) may be provided for controlling the rate of flow of the molten metal through the various spouts. Such valves are known in the art.

The invention is useable with any of the known metals such as iron, steel, aluminum, copper, bronze, brass or the like, although it is of particular value with aluminum, steel and copper or brass.

An additional feature of the invention is the effect of the high-frequency magnetic fields about the pouring spouts. It has been found in practice that by providing the coils about the pouring spouts of the tundish that an action results, particularly with aluminum, wherein splashing and the like appears to a large extent to be eliminated, such splashing normally occurring when the metal from the spout reaches the pool of molten metal in the mold.

It will be appreciated that a preferred embodiment of the invention only has been described and that variations will occur to others upon a reading and understanding of this specification, all of which will differ radically from the preferred embodiment shown. It is my intention to include all such modifications and variations insofar as they come within the scope of the appended claim.

Having thus described my invention, I claim:

A tundish for holding molten metal and continuously feeding the same to a continuous casting machine of the type which casts rectangular bars of metal by means of a rectangularly-shaped mold open at the upper end and having narrow ends and relatively wide sides, said tundish comprising, receptacle having a wall extending therearound and a bottom, a plurality of pouring spouts in said bottom and aligned in a row with the spouts at the end of the row adapted to be positioned near the ends of the mold and with at least a spout therebetween positioned towards the center of the mold, said tundish wall having a lining of a refractory material having substantial electrical and heat conductivity, a high frequency induction heating coil around said refractory, means for flowing cooling water through said coil to conduct heat from the molten metal away from said wall and means for energizing said coil with electrical energy to either equal, exceed or be less than the amount of energy conducted away by said cooling water, each of said spouts being comprised of an electrical and heat conductive refractory, a high frequency induction heating coil around each spout, means for energizing each coil at each spout, and means for controlling the energization of the coil around each spout independently of the coils around the other spouts whereby the spouts at the end of the row may be heater to a higher temperature than the intermediate spout so that the metal flowing through the spouts at the end of the row and next adjacent the narrow ends of the mold will be heated to an elevated temperature relative to the metal flowing through the intermediate spout near the center of the mold.

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