

Aug. 2, 1966

M. ALLARD

3,263,283

CONTINUOUS CASTING PROCESS AND APPARATUS

Filed Aug. 26, 1963

2 Sheets-Sheet 1

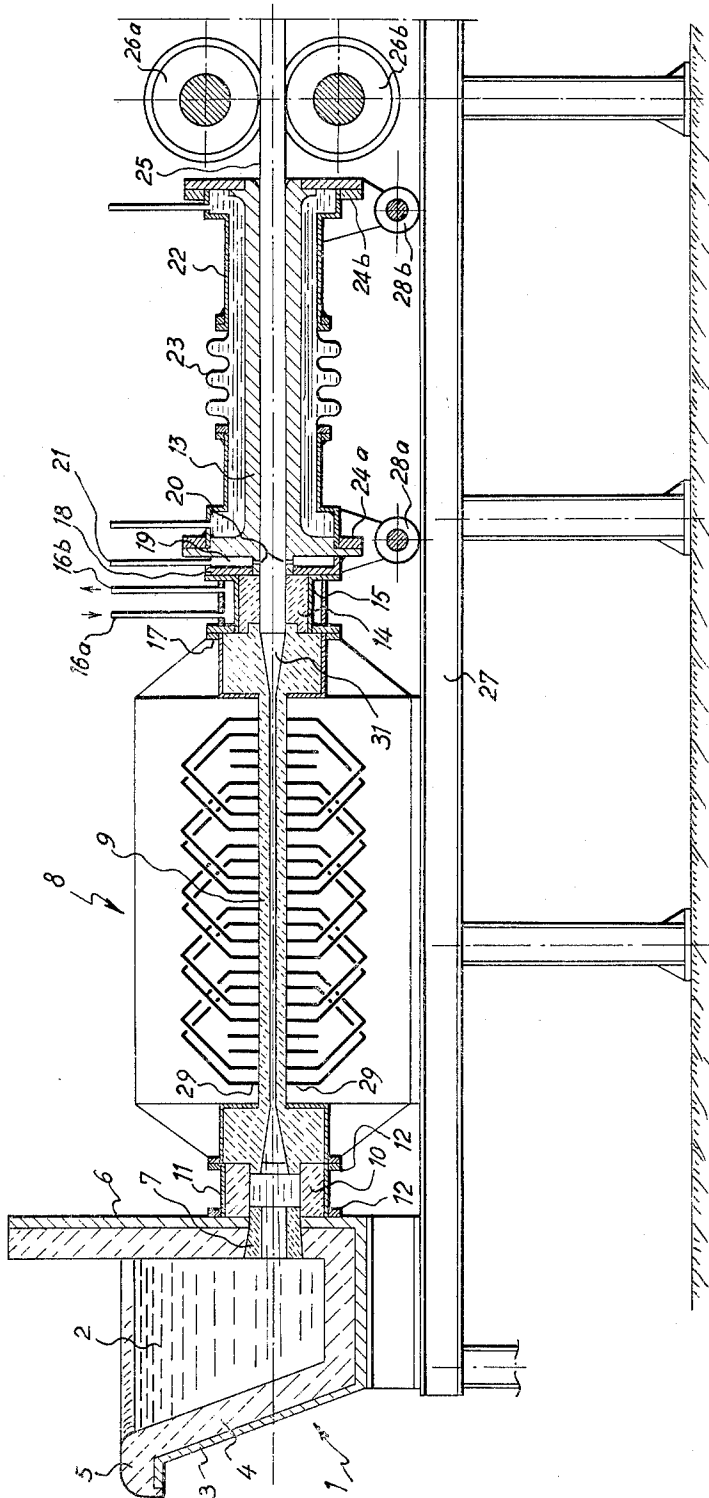


Fig. 1

INVENTOR
MARC ALLARD

Aug. 2, 1966

M. ALLARD

3,263,283

CONTINUOUS CASTING PROCESS AND APPARATUS

Filed Aug. 26, 1963

2 Sheets-Sheet 2

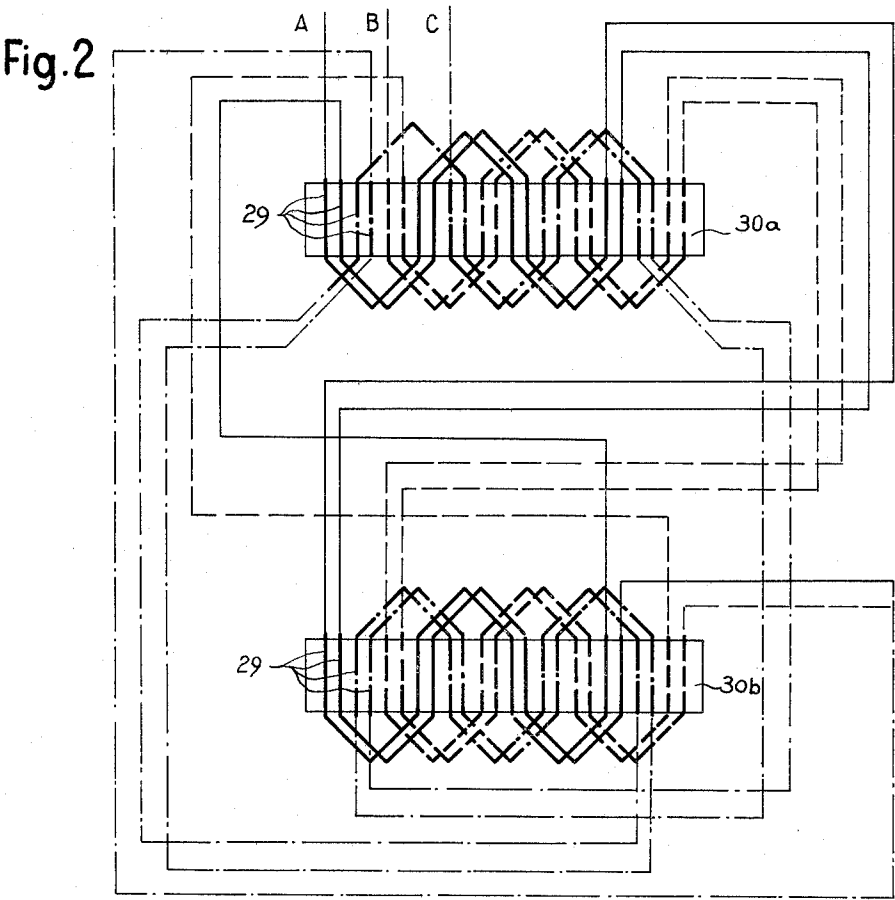
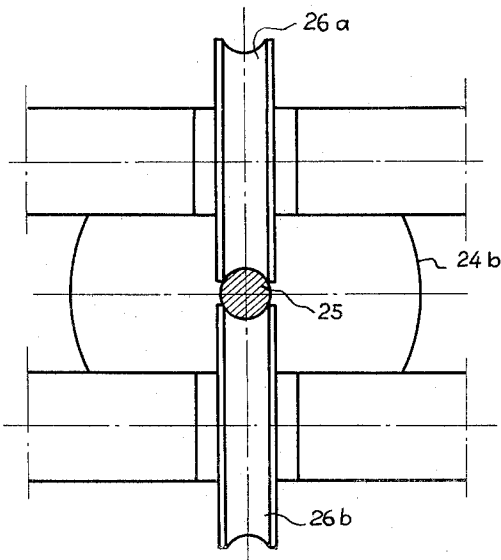


Fig. 3



Inventor
Marc Allard
by
Richard J. Striker
RJS

1

3,263,283 CONTINUOUS CASTING PROCESS AND APPARATUS

Marc Allard, Saint-Germain-en-Laye, France, assignor to
Institut de Recherches de la Siderurgie Francaise, Saint-
Germain-en-Laye, France

Filed Aug. 26, 1963, Ser. No. 304,324

Claims priority, application France, Sept. 4, 1962,
908,533, Patent 1,340,276

13 Claims. (Cl. 22—57.2)

The present invention relates to the casting of metals and in particular to the continuous casting of metals.

In general there are two basic types of machines and processes for continuously casting metals. In one type the metal is continuously cast in a vertical direction while in the other type the metal is continuously cast in a horizontal direction. While it is well known that metal can be continuously cast vertically, the structures for producing such continuous casting are undesirable from the standpoint that they must extend to enormous heights which are very undesirable, and the solution to the problem of the great height which vertical continuous casting of metals involves has never been satisfactorily provided. However, while the horizontal continuous casting of metals does not require an apparatus of extremely great height, the horizontal casting of metals has problems which are not present in the vertical casting of metals. For example, because of the natural tendency of metal to contract while it is solidifying there is produced in the horizontal continuous casting of metals unavoidable cavities or piping in the body of metal, and it is extremely difficult if not impossible to avoid this drawback of continuous casting of metals in a horizontal direction. Of course, this problem is not present in vertical casting because the molten metal always has in the mold such a pressure that it is impossible for any cavities to form due to contraction of the metal. However, this pressure is derived simply by the nature of the vertical casting apparatus where the molten metal has such a tremendous head above the mold that the molten metal provides in the mold at all times a pressure great enough for the metal to prevent formation of cavities due to contraction of the metal while it is solidifying. In horizontal casting apparatus, however, there is no such great head of metal providing a high pressure of the molten metal in the mold, so that the cavities resulting from contraction of the solidified metal are practically unavoidable. Of course, it might be possible to provide in connection with a horizontal mold a head of metal which is so great that the pressure in the mold will be great enough to prevent the formation of cavities, but in this case the inconvenience of the very great height of the apparatus will again be encountered, only with a horizontal mold, so that it is hardly worth while to use a horizontal molding apparatus where such a solution to the problem of the formation of cavities is relied upon.

It is accordingly a primary object of the present invention to provide a process and apparatus for continuously casting metal in a horizontal direction while at the same time avoiding the above drawbacks, particularly the drawback of the presence of cavities in the metal resulting from the contraction thereof during solidification.

A further object of the present invention is to provide a horizontal continuous casting process and apparatus which will guarantee that the molten metal in the mold is at such a pressure that cavities or the like cannot form in the molten metal, while at the same time the use of structure providing a great head of metal is avoided.

It is furthermore an object of the present invention to provide a process and apparatus according to which the molten metal can be pumped into the mold which ex-

2

tends horizontally so as to maintain in the metal in this way the desired pressure.

It is furthermore an object of the present invention to provide a casting process and apparatus capable of regulating the speed with which the metal issues from the apparatus as well as guaranteeing the best possible casting while at the same time having a high output.

With the above objects in view the invention includes, in a process for continuously casting metal, the steps of continuously directing metal from a suitable source thereof in molten condition into the inlet end of an elongated horizontal mold the discharge end of which remains open so that the metal continuously discharges from the mold with at least the exterior surface of the metal solidified; and magnetically pumping the molten metal from the source thereof into the mold to maintain in the molten metal in the mold a pressure in excess of that which it would have without the pumping so that in this way it becomes possible to provide within the horizontal mold a pressure great enough to avoid the formation of cavities, as discussed above.

Also, in accordance with the present invention there is provided an apparatus which includes a tundish formed at a substantial distance below its top end with a discharge opening through which molten metal in the tundish can discharge therefrom. A magnetic pumping apparatus communicates with the opening of the tundish to receive molten metal therefrom and to pump the metal from the tundish so as to provide in the molten metal a pressure greater than that which it derives from the head of metal in the tundish, and the thus-pumped metal is delivered to the inlet end of an elongated horizontal mold through which the metal continuously moves to discharge therefrom continuously with at least the exterior surface of the metal solidified, and a means cooperates with the metal as it issues from the mold to guide the metal as well as to control the rate with which the metal issues from the mold so that this latter means can even retard the pushing of the metal from the mold by the pressure derived from the pump so as to provide the best possible treatment of the metal.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

FIG. 1 is a partly diagrammatic longitudinal sectional elevation of an apparatus according to the present invention;

FIG. 2 is a wiring diagram illustrating the manner in which the coils of the magnetic pump are electrically wound; and

FIG. 3 is a transverse sectional view of the structure of FIG. 1 as seen from the right end thereof, FIG. 3 showing the manner in which the solidified metal is treated upon issuing from the mold.

Referring now to FIG. 1, there is shown therein a tundish 1 containing molten metal 2, in a conventional manner, the tundish 1 including an outer steel casing 3 lined with a refractory lining material 4. The tundish receives the molten metal from one or more ladles which are emptied into the tundish, in a manner well known in the art and not illustrated. The slag which forms on the upper part of the molten metal can be removed over the portion 5 which takes the form of a lip or spout permitting the slag to discharge from an upper portion of the tundish 1.

A lower part of the tundish 1, situated at a substantial distance beneath the top end thereof, is formed with an

opening which receives the discharge nozzle 7, this opening for the nozzle being arranged in the vertical wall 6 of the tundish 1. It will be noted that the exterior surface of the nozzle 7 mates with the surface of the opening formed in the wall 6 so that the nozzle 7, which has an exterior tapering surface is in this way fixed with the tundish 1 in the frustoconical opening thereof, and thus the molten metal will flow out of the tundish 1 through the nozzle 7 thereof. The metal which discharges from the tundish 1 through the opening or nozzle 7 has the pressure, which is already present due to the head of metal in the tundish 1, augmented by a magnetic pumping action provided with a magnetic pump assembly 8 which is further described below. The metal flows through the magnetic pumping means 8 in an elongated conduit 9 which is made of a refractory material of high electrical resistance, and the cross section of the conduit, particularly at its interior through which the metal flows, is substantially rectangular and very flat, which is to say the height or depth of the channel in the interior of the conduit 9 is extremely small with respect to the width thereof so that a wide film or ribbon of molten metal of small thickness flows continuously through the magnetic pumping means 8. The refractory conduit 9 may be made, for example, of fritted or chamotted alumina, or it may be made of zirconia, or from a mixture of these two refractory materials. The tundish 1 and the pumping device 8 are connected to each other in a fluid-tight manner by a refractory conduit 10 of circular cross section, and the conduit 10 is surrounded by a cylindrical casing 11 made of steel and fixed by flanges 12 to the other elements, the bolts which pass through the flanges 12 being omitted for the sake of clarity.

The electromagnetic pumping means 8 is designed so as to be capable of providing a flow of molten steel at the rate of 50 tons per hour under a pressure which at a maximum is ten atmospheres. The metal which is under pressure will be delivered to the elongated horizontal mold 13 which is cooled by circulating cooling water and to which the pump is connected by way of a refractory cylindrical conduit 14 housed within a metallic also cylindrical casing 15. The casing 15 has a double wall so that it is provided in its interior with an annular passage surrounding the conduit 14, and a pair of tubes 16a and 16b communicate with the inner annular space of the double-walled conduit 15, so that through these tubes it is possible to circulate cooling liquid which thus surrounds the conduit 14. The conduit 14 together with the casing 15 are fixed to the remainder of the assembly in the position shown in FIG. 1 by way of flanges 17 and unillustrated bolts passing therethrough. Between the conduit 14 and the inlet end of the mold 13 is arranged a ring 18 formed with an annular passage 19 which communicates through a circular row of small openings 20 with the interior of the mold 13 at the inlet end thereof, and a suitable lubricant is supplied through the pipe 21 to the space 19 to flow from the latter through the small openings 20 into the mold 13 together with the molten metal which penetrates into the mold from the pump 8. In this way a lubricant is provided to move along the inner surface of the mold 13, and this lubricant is supplied under pressure through the pipe 21 and can be a well known lubricant such as oil of colza in which pulverulent graphite is suspended.

The elongated mold 13 is circular in cross section and can be made of copper, and is cooled by a cooling liquid such as water circulating around the exterior of the mold.

For the purpose of cooling the elongated mold 13 it is surrounded by an elongated envelope 22 in the form of an elongated pipe having intermediate its ends a flexible portion 23 which has the construction of a bellows or the like and which is capable of expanding and contracting in a manner well known in the art so that in this way it is possible to compensate for the different rates of thermal expansion of the envelope 22 and the mold 13.

The elongated metallic tubular envelope 22 carries at its ends flanges 24a and 24b which by way of suitable bolts are fixed to flanges at the end of the mold 13 so that in this way it is possible to fix the ends of the envelope 22 to the end walls of the mold 13 in a fluid-tight manner enabling the envelope to define with the exterior surface of the mold an elongated hollow chamber through which a cooling liquid may be circulated in the manner indicated in FIG. 1. With this construction it is a simple matter to disconnect the envelope from the mold so as to enable the latter to be exchanged for another mold after the mold 13 becomes worn.

In the event that the lubricant which is introduced in the manner described above liberates a certain amount of undesirable gas in the interior of the mold, it is possible to provide a porous element through which the gas can escape. For example, there can be provided in the interior of the mold a casing of porous metal, made of bronze, for example, which is impermeable to the metal but through which the gas can pass so as to escape at the outlet end of the mold. A porous member of this type should have a relatively small thickness because the thermal conductivity thereof is not as favorable as that of the copper of the mold itself, and the cooling of the material will be undesirably effected by too great of a thickness of such a porous member. The cooling of such a porous casing can only be provided by way of contact with the copper of the mold 13. It is therefore important to see that there is a very good contact between the porous member and the mold. Inasmuch as it is necessary also to avoid any possible sliding of the porous member in the mold, one should use, for example, interchangeable molds in the same way as if they were made exclusively of copper and in which the porous casing is hopped in the mold, that is to say that the porous member is placed in the mold at a temperature substantially beneath that of the mold which has been preheated so that upon cooling the mold will shrink onto and be joined with the porous member tightly gripping the latter. Such a porous casing can be disposed only at a part of the mold, since it cannot extend along the entire length thereof, and care must be taken to see to it that there is not any unequal wear between the copper portion of the mold and the porous structure carried thereby, since such unequal wear would provide, in an undesirable manner, a shoulder or the like which would undesirably resist the movement of the molded metal continuously through the horizontal mold.

During the movement of the metal through the mold it gives up its heat to the wall of the mold 13 and it becomes solidified so as to issue from the discharge end of the mold in the form of a bar 25 of circular cross section which is received and guided in its speed of issue from the mold by a pair of externally grooved rollers 26a and 26b (FIGS. 1 and 3). FIG. 3 in particular shows the section of the bar 25 which is continuously molded, and it will be seen that this bar is of circular cross section, and in addition FIG. 3 shows the curvature of the peripheral grooves of the rolls 26a and 26b. Also there is seen in FIG. 3 the flange 24b at the end of the cooling envelope 22 and connected to the end of the mold 13. It will be seen that the rolls 26a and 26b have a structure similar to pulleys.

The entire assembly is carried by suitable framework 27 on which rollers 28a and 28b rest, and these rollers permit the envelope to move freely with respect to the receptacle 1 so as to automatically compensate for expansion and contraction of the elements during heating and cooling thereof and this compensation takes place through the free rolling contact of the rollers 28a and 28b on the frame 27 without any undesirable restraint on the parts. The extent of elongation of the parts during operation can be on the order of a few tens of millimeters, and this elongation is easily taken care of by the rolling of the rollers 28a and 28b on the frame 27.

5

With respect to the electromagnetic pump means 8, it will be seen from FIG. 1 that it is traversed by the refractory conduit 9 which passes, therethrough, as described above. There is provided above and below the refractory conduit 9 a plurality of electrically conductive bars 29 which extend horizontally, perpendicularly to the conduit 9 and to the plane of FIG. 1, so that these bars 29 also extend perpendicularly with respect to the direction of flow of the molten metal. These electrically conductive, transversely extending bars 29 are situated in slots which are formed in the magnetic, laminated masses which are not shown in FIG. 1 and which are situated above and below the conduit 9, and the active surfaces of these magnetic masses are illustrated diagrammatically at 30a and 30b in FIG. 2. FIG. 2 also clearly illustrates how the several electrically conductive bars 29 extend across the magnetic laminated masses. The structure situated above the conduit 9 and the structure situated below the conduit 9 are shown separately in FIG. 2 displaced from each other so as to clearly illustrate the manner in which the parts are electrically connected to each other, but it is to be understood that in the actual construction the two sections shown in FIG. 2 are placed one above the other.

Referring to FIG. 2 it will be seen that the several bars 29 are electrically connected so as to form the series-connected imbricated, three-phase windings similar to the windings of the field of an induction motor and supplied with current from a three-phase source of electricity A, B, C. The entire construction is the same as that of the stator of an asynchronous three-phase motor which has been unrolled from its cylindrical configuration into a flat configuration. The rotating field of such an asynchronous motor is thus replaced in the magnetic pump by a longitudinally shifting field whose lines of force extend perpendicularly to the plane of FIG. 2 while the field itself shifts in its own plane in a direction parallel to the axis of the refractory conduit 9, this shifting field inducing in the molten metal flowing through the conduit 9 currents on which the field exercises forces which drive the metal in the direction in which the field shifts, and of course the field shifts from left to right, as viewed in FIGS. 1 and 2, so that in this way the molten metal itself is pumped away from the tundish 1 into the inlet end of the mold 13.

In order to be able to obtain a magnetic field which is as intense as possible, the vertical thickness of the refractory conduit is made as small as possible, and in an actual construction the molten metal flowing through the conduit 9 has the form of a ribbon or sheet of metal having a thickness of approximately 1 cm. and a width of approximately 20 cm.

In the example illustrated in the drawing and described above the pump 8 is designed to provide a maximum flow of molten steel at the rate of 50 tons per hour under a pressure in the neighbourhood of 10 bars. The structure includes sixty electrically conductive bars 29 above the conduit 9 and also sixty bars 29 below the conduit 9, and the current which flows through these bars is on the order of 3,000 amperes, and the power required for the pump is on the order of 150-200 kw. The electrical windings are clearly shown in FIG. 2. Thus, it will be seen that those windings which cooperate with phase A are all shown in solid lines, while the phase B windings are shown in dotted lines, and the phase C windings are shown in dot-dash lines, so that the manner in which the bars 29 are interconnected is clearly apparent from FIG. 2.

The molten metal issues from the outlet 31 of the pump 8, and thus it is introduced under pressure into the mold 13 where it starts to solidify at the inner surface of the mold 13. The pressure of the molten metal acts on the skin of solidified metal which forms at the inner surface of the mold and this pressure of the molten metal tends to keep the solidifying exterior skin of metal in contact

6

with the mold wall so that in this way the tendency of the solidifying metal to contract away from and fail to engage the inner surface of the mold is negated and also in this way the poor heat exchange which would result from separation of the exterior surface of the molten metal from the inner surface of the mold is also eliminated. Moreover, any cavities which always tend to form during the cooling of an ingot or a bar or the like because of contraction of the metal after the exterior skin of the metal has already solidified is prevented from forming with the process and apparatus of the invention by the continuous permanent supply of metal under pressure which acts in the interior of the mold 13 so as to prevent the formation of cavities, piping, or the like.

In order to improve the engagement between the steel or other molten material which starts to solidify and the mold itself it is possible to provide a slight taper in the mold so that its inner surface has a slight conicity and converges toward the discharge end, this conicity being on the order of 1%, for example. However, it is difficult to provide precisely the best conicity for each operation since the extent of contraction of the metal can vary to a substantial extent from one casting to another and even in the course of the same casting.

At the discharge end of the mold 13 an additional intense cooling can be provided on the bar 25 issuing from the mold by spraying or sprinkling the bar with water in a manner well known and not shown, and if desired the bar can even be passed through a suitable bath of cooling liquid so that it is immersed in the liquid.

The rollers 26 situated at the discharge of the mold 13 guarantee proper guiding of the mold material and extraction of the bar 25 from the mold in a uniform manner. The rolls 26a and 26b are driven at a constant speed which can be adjusted, by way of an electric motor, in a manner well known. However, it is not generally necessary to draw the bar from the mold by application of a substantial pull thereon in order to provoke discharge of the bar since the pressure of the molten metal entering into the mold is sufficient for this purpose. The speed with which the bar issues from the mold is controlled by controlling the speed of rotation of the rollers 26a and 26b as well as by controlling the electrical current in the windings of the magnetic pump, and of course this adjustment or of the current in the windings of the magnetic pump 8 is also controlled so as to automatically compensate for variations in the head of molten metal in the tundish 1, so that in this way metal at a substantially constant pressure will be supplied to the mold 13. The turning rollers 26a and 26b guarantee a uniform advance of the bar 25 and they may apply a very slight tension tending to pull the bar 25 from the mold. On the other hand, in many cases it is desirable to turn the rollers 26a and 26b at such a slow rate that they resist the speed of issue of the bar 25 from the mold and retard the issue of the bar so as to guarantee that the bar remains in the mold for a predetermined length of time which greatly improves the structure of the molded bar issuing from the mold.

Of course, the circular cross section of the bar 25 is not essential and it is possible to produce with the process and apparatus of the invention bars of square or rectangular cross section or of any other desired profile. The process and apparatus of the invention are of particular advantage for the casting of products of relatively small cross section, because the process and apparatus of the invention enable the speed of casting to be increased considerably, as compared to known casting processes. The pressure of ten bars referred to above is not essential and the advantages of the invention can of course be obtained with other pressures, in particular lower pressures which might be used under other conditions.

Thus, with the process and apparatus of the invention the molten metal will at all times be introduced into the

mold 13 at a pressure which is sufficiently high to guarantee that the mold 13 is at all times completely filled and to avoid or at least reduce to a very great extent the possibility of the formation of cavities or piping in the body of the molten material. Moreover, the fact that the pressure of the molten metal entering into the mold 13 guarantees the complete filling thereof at all times serves to maintain the exterior surface of the material entering the mold in engagement with the interior surface of the mold so as to very greatly improve the heat exchange between the material which is being molded and the mold itself, so that in this way also the solidification of the metal is greatly facilitated. The fact that the pressure of the molten metal itself continuously urges the metal out of the mold is of particular advantage since in this way the pulling of metal out of the mold can be avoided to a very great extent. When it is remembered that the metal issuing from the mold in a continuous casting apparatus is still in liquid or pasty form in the interior of the molded material and is only solidified at its exterior, then it is clear that the pulling of such metal may often be to such an extent that the metal is incapable of remaining stable under the tension which is applied to it in order to withdraw it from the mold, and thus the metal issuing from the mold is often unable to resist the tension and will be undesirably deformed. However, this undesirable result is very reliably avoided with the process and apparatus of the present invention which very often even requires the speed of issue of the metal from the mold to be retarded as described above, and such retarding is easily provided by applying brakes to the rotating rolls 26a and 26b so as to reduce the extent to which they rotate and thus reduce the rate of withdrawal of the bar 25 from the mold.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of continuous casting process and apparatus differing from the types described above.

While the invention has been illustrated and described as embodied in horizontal continuous casting process and apparatus, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. In a process for continuously casting metal, the steps of continuously directing molten metal from a source thereof into an elongated horizontal mold which is open at its opposite ends so that the metal continuously moves into the mold to be shaped therein and continuously issues from the mold with at least a solid exterior surface; and magnetically pumping the molten metal from the source thereof into the mold to provide the metal with a pressure above that which it would have without the pumping thereof.

2. In a process for continuously casting a metal, the steps of continuously directing molten metal from a suitable source thereof into one end of an elongated horizontal mold whose opposite end is open so that the metal will move continuously through the mold and will issue therefrom continuously with at least a solid exterior surface; and applying to the molten metal between the source thereof and the mold a magnetic field which acts on the molten metal with a force having at least one component which is directed toward the said one end of said mold

so that the metal will be magnetically pumped into the mold with a pressure in excess of that which would obtain without magnetic pumping.

3. In a process for continuously casting metal, the steps of continuously directing molten metal from a suitable source thereof into an open end of an elongated horizontal mold the opposite end of which is also open and through which the metal moves continuously with the metal issuing from said opposite end of said mold with at least a solid exterior surface; and magnetically pumping the metal from the source to the mold by applying to the metal a magnetic field which traverses the molten metal and which itself moves continuously in the direction of flow of the molten metal toward the mold.

4. In a process for continuously casting metal, the steps of directing metal from a lower portion of a tundish which contains molten metal into one end of an elongated horizontal mold through which the metal continuously moves while issuing from an opposite end of the mold, so that the head of molten metal in said tundish provides in the metal a pressure urging it from the tundish into the mold and providing the metal in the mold also with a certain pressure influenced by the head of molten metal in said tundish; and magnetically pumping the metal between the tundish and the mold from the tundish toward the mold to provide the metal with a pressure in addition to that which it derives from the head of molten metal in the tundish.

5. In a process for continuously casting metal, the steps of directing metal from a lower portion of a tundish which contains molten metal into one end of an elongated horizontal mold through which the metal continuously moves while issuing from an opposite end of the mold, so that the head of molten metal in said tundish provides in the metal a pressure urging it from the tundish into the mold and providing the metal in the mold also with a certain pressure influenced by the head of molten metal in said tundish; magnetically pumping the metal between the tundish and the mold from the tundish toward the mold to provide the metal with a pressure in addition to that which it derives from the head of molten metal in the tundish; and adjusting the magnetic force with which the metal is magnetically pumped to the mold to compensate for variations in the head of the molten metal in the tundish.

6. In a process for continuously casting metal, the steps of continuously directing molten metal from a source thereof into an inlet end of an elongated hollow mold which extends substantially horizontally, the metal solidifying at least partially within the horizontal mold and issuing from an open discharge end thereof continuously; magnetically pumping the metal from the source thereof into the inlet end of the mold so as to provide the metal with a pressure greater than that which it would have without the pumping thereof; and retarding the rate with which the metal issues from said discharge end of said mold so as to retain the metal within the mold for a period longer than the period it would have remained in the mold were it not retarded.

7. In an apparatus for continuously casting metal, in combination, a tundish adapted to contain molten metal, said tundish being formed at a substantial distance beneath the top thereof with a discharge opening through which the molten metal can flow from the interior of the tundish; magnetic pump means communicating with said opening of said tundish to receive molten metal from said tundish and to pump the molten metal magnetically so as to provide the metal with a pressure greater than that which it would have from the head of metal in the tundish; and an elongated hollow substantially horizontal mold having an inlet end communicating with the outlet of said magnetic pump means for receiving molten metal therefrom, said mold having distant from said inlet end an open discharge end through which the metal continuously issues so as to be horizontally passed with a pressure greater

than that which would be provided from the head of metal in the tundish alone.

8. In an apparatus for continuously casting metal, in combination, a tundish adapted to contain molten metal, said tundish being formed at a substantial distance beneath the top thereof with a discharge opening through which the molten metal can flow from the interior of the tundish; magnetic pump means communicating with said opening of said tundish to receive molten metal from said tundish and to pump the molten metal magnetically so as to provide the metal with a pressure greater than that which it would have from the head of metal in the tundish; and an elongated hollow substantially horizontal mold having an inlet end communicating with the outlet of said magnetic pump means for receiving molten metal therefrom, said mold having distant from said inlet end an open discharge end through which the metal continuously issues so as to be horizontally passed with a pressure greater than that which would be provided from the head of metal in the tundish alone; and roller means located adjacent the discharge end of said mold for receiving the metal issuing therefrom and guiding it for movement beyond the mold.

9. In an apparatus for continuously casting metal, in combination, a tundish adapted to contain molten metal, said tundish being formed at a substantial distance beneath the top thereof with a discharge opening through which the molten metal can flow from the interior of the tundish; magnetic pump means communicating with said opening of said tundish to receive molten metal from said tundish and to pump the molten metal magnetically so as to provide the metal with a pressure greater than that which it would have from the head of metal in the tundish; an elongated hollow substantially horizontal mold having an inlet end communicating with the outlet of said magnetic pump means for receiving molten metal therefrom, said mold having distant from said inlet end an open discharge end through which the metal continuously issues so as to be horizontally passed with a pressure greater than that which would be provided from the head of metal in the tundish alone; and connecting means located between said magnetic pump means and said inlet end of said mold for connecting the outlet of the magnetic pump means to the inlet of the mold, and said connecting means having an outer annular passage extending therearound and through which a cooling liquid may flow for cooling said connecting means.

10. Apparatus for continuously casting metal, comprising, in combination, a tundish formed with an opening at a distance substantially lower than the top end of the tundish so that when the latter contains molten metal the molten metal will flow out through said opening; elongated magnetic pump means communicating with said opening for receiving metal therefrom and magnetically pumping the same; elongated substantially horizontal mold means having an inlet end communicating with said magnetic pump means to receive the molten metal therefrom and an opposite discharge end through which the metal continuously discharges from the mold; and means located adjacent the inlet end of said mold for introducing into the latter a lubricant for lubricating the metal as it moves through the mold.

11. In an apparatus for continuously casting metal, in combination, a tundish for molten metal, said tundish having at a distance substantially beneath the top end thereof an opening through which the molten metal dis-

charges from the tundish; magnetic pump means communicating with said tundish for receiving molten metal therefrom and for pumping the metal away from the tundish; elongated hollow substantially horizontal mold means having an inlet end communicating with said magnetic pump means to receive the molten metal therefrom, said mold means having distant from said inlet end thereof a discharge end through which the metal continuously discharges so that the metal is continuously cast in a horizontal direction; and cooling means surrounding said mold for cooling the same.

12. In an apparatus for continuously casting metal, in combination, a tundish for molten metal, said tundish having at a distance substantially beneath the top end thereof an opening through which the molten metal discharges from the tundish; magnetic pump means communicating with said tundish for receiving molten metal therefrom and for pumping the metal away from the tundish; elongated hollow substantially horizontal mold means having an inlet end communicating with said magnetic pump means to receive the molten metal therefrom, said mold means having distant from said inlet end thereof a discharge end through which the metal continuously discharges so that the metal is continuously cast in a horizontal direction; and cooling means surrounding said mold for cooling the same, said cooling means including an outer wall surrounding and spaced from said mold to define with the latter a chamber in which cooling liquid is adapted to be located, and said outer wall including an expandible and contractable portion so that the outer wall can compensate for different rates of thermal expansion of said wall and said mold.

13. In an apparatus for continuously casting metal, in combination, a tundish for molten metal, said tundish having at a distance substantially beneath the top end thereof an opening through which the molten metal discharges from the tundish; magnetic pump means communicating with said tundish for receiving molten metal therefrom and for pumping the metal away from the tundish; elongated hollow substantially horizontal mold means having an inlet end communicating with said magnetic pump means to receive the molten metal therefrom, said mold means having distant from said inlet end thereof a discharge end through which the metal continuously discharges so that the metal is continuously cast in a horizontal direction; cooling means surrounding said mold for cooling the same, said cooling means including an outer wall surrounding and spaced from said mold to define with the latter a chamber in which cooling liquid is adapted to be located, and said outer wall including an expandible and contractable portion so that the outer wall can compensate for different rates of thermal expansion of said wall and said mold; and support means supporting said outer wall for free longitudinal movement in a direction parallel to the axis of said mold.

References Cited by the Examiner

UNITED STATES PATENTS

60	2,224,982	12/1940	Morin	22—70
	2,837,791	6/1958	Tessmann	22—57.2
	2,865,291	12/1958	Watt	103—1
	2,996,771	8/1961	Armand et al.	22—57.2

65 J. SPENCER OVERHOLSER, *Primary Examiner*.

R. S. ANNEAR, *Assistant Examiner*.