Nov. 25, 1958 K. E. MANN ET AL 2,861,302

APPARATUS FOR CONTINUOUS CASTING

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Fig. 1

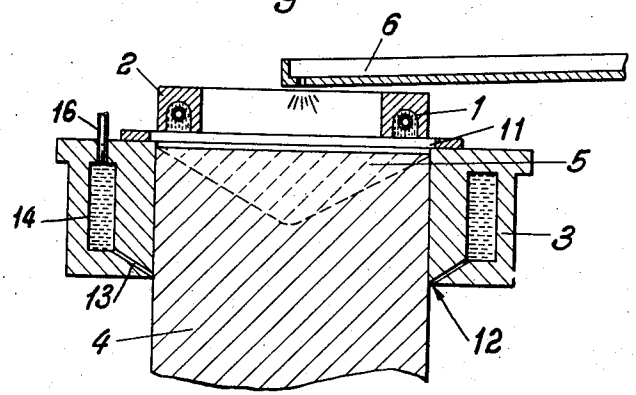
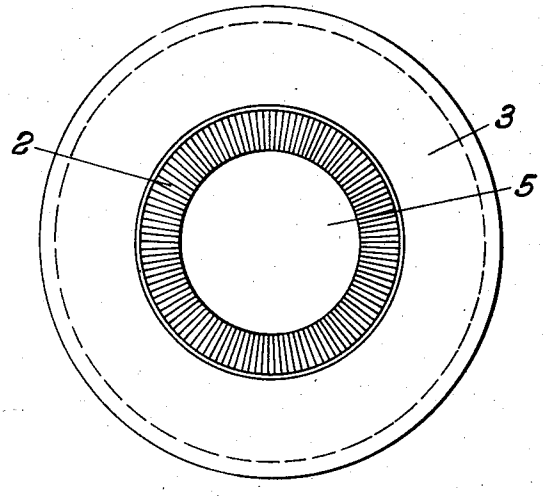


Fig. 2



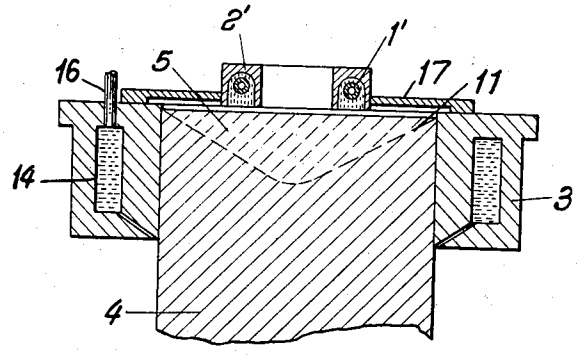
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APPARATUS FOR CONTINUOUS CASTING

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Fig. 3



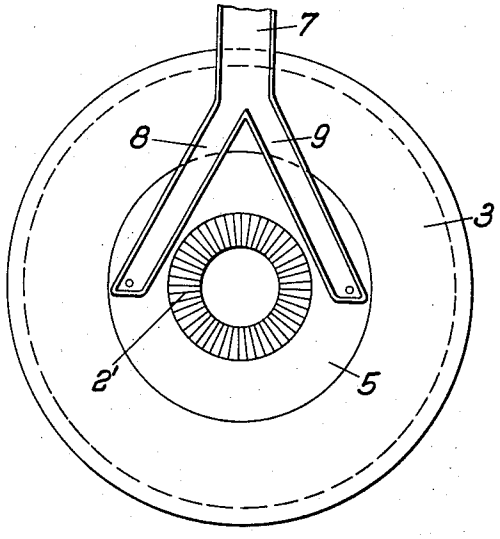


Fig. 4

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APPARATUS FOR CONTINUOUS CASTING

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Application August 14, 1956, Serial No. 603,915

5 Claims. (Cl. 22—57.2)

The present invention relates to a new and improved method and apparatus for the continuous casting of molten metal. More particularly the present invention relates to a new and improved apparatus for the continuous casting of molten metal to form a casting having a homogeneous and uniform structure.

The present application is a continuation-in-part of our copending application, now abandoned, Serial No. 544,786, filed on November 3, 1955 and entitled "Continuous Casting Improvement."

There are conventional casting processes of molten metal known in the art which are identified as continuous casting processes wherein the molten material is poured into a mold in which it is solidified and the solidified material is continuously withdrawn from the mold. Therefore, there is always a portion of the material in the mold which is completely molten, a portion which is partially solidified, and a portion just before the exit from the mold which is fully solidified.

In one type of continuous casting process the solidified material leaving the mold is sprayed with cooling water in order to cool the same. This sudden cooling of the casting by the water sometimes causes the casting to break apart or causes other types of structural defects therein. One method of preventing such structural defects and splitting of the casting is to use cooling water whose temperature is not too low. However, with such an arrangement one of the primary advantages of water cooling of a continuous casting is lost. That is, with cooling water having a relatively high temperature, the cooling of the casting takes a substantial amount of time and the texture of the casting becomes substantially thicker instead of the desirable finer texture.

When it is desired to produce casting from metal alloys containing alloying metals which are at pouring or casting temperature partially or completely insoluble in the melt and cause liquation, it is difficult and often impossible to obtain an even distribution of these alloying metals in finely divided form throughout the entire cross-section of the casting. Accumulations or nests of such alloying metals impair the quality of ingots which are destined to be deformed to sheets, rods, profiles, forgings and the like in a chipless manner. For instance, manganese which is desired in nearly all magnesium alloys because of its anticorrosive properties, easily forms undesirable manganese streaks in sheets and profiles when, for instance, to a magnesium alloy containing about 6% aluminum and 1% zinc, manganese is added in a quantity which exceeds its solubility at pouring temperature by about 0.1%. In the case of free cutting brass or free cutting aluminum alloys, the machinability of the work piece is impaired by an uneven and coarse distribution of lead or of the equivalent metals bismuth, cadmium, tin, etc.

It has been attempted to influence the crystallization process in the direction of increasing the number and reducing the size of grains during production of continuous casting ingots by exposing the only partially solidified

casting to the effect of a rotary magnetic field in order to equalize localized differences in temperature and heat content by causing a controlled circular movement.

However, such circular movement of the casting material is connected with disadvantages such as vortex formation in the vicinity of the center axis of the poured material and there exists the danger of tearing of the ingots and also of impairment of the ingot quality due to increased liquation.

It is therefore an object of the present invention to overcome the above described disadvantages in the continuous casting of molten metal.

A second object of the present invention is to provide a new and improved continuous casting apparatus.

Another object of the present invention is to provide a continuous casting apparatus wherein the casting made from the molten material has a fine structural texture.

Still another object of the present invention is to provide a water cooled continuous casting apparatus using a magnetic field near the inlet of the mold into which the molten material is poured.

A further object of the present invention is to provide a new and improved continuous casting apparatus wherein the partially solidified material being cast is subjected to the action of a magnetic field.

Still a further object of the present invention is to provide a new and improved apparatus for the continuous casting of a molten material wherein the partially solidified material in the mold in subjected to an alternating magnetic field having its axis in a plane substantially perpendicular to the direction of flow of the molten metal in order to cause a stirring in the same for equalizing the temperature in the casting and to provide a desired structural texture.

With the above and other objects in view the present invention mainly consists of an apparatus for the continuous casting of molten material and including a mold for receiving the molten material to be cast, the mold having an inlet through which the molten material is poured, and means for establishing an alternating magnetic field having lines of flux in the region of the mold inlet, the lines of flux extending through at least a portion of the material already poured into the mold and the axis of said magnetic field being perpendicular to the direction of flow of the molten material into and through the mold.

In a preferred embodiment of the present invention the means for establishing the alternating magnetic field includes a water cooled copper tubing formed in the shape of an annular member and arranged near the inlet of the mold for establishing a magnetic flux when electrical current is passed therethrough. A secondary magnetic member is provided, substantially surrounding the copper tubing and distributing the magnetic flux into a predetermined pattern having the axis thereof arranged perpendicular to the direction of flow of the molten metal into the mold so that the magnetic flux flows through the partially solidified material in the mold.

The present invention also includes in a method for the continuous casting of molten material wherein the material is poured into a mold and continuously withdrawn therefrom, the improvement comprising subjecting partially solidified material within the mold to the action of an alternating magnetic field having its axis lying in a plane substantially perpendicular to the direction of flow of the material where the material is subjected to the alternating magnetic field.

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 longitudinal cross sectional view of one embodiment capable of carrying out the principles of the present invention;

Fig. 2 is a top plan view of the embodiment shown in Fig. 1;

Fig. 3 is a longitudinal cross sectional view of a second embodiment incorporating the principles of the present invention; and

Fig. 4 is a plan view of the apparatus illustrated in Fig. 3.

Referring to the drawings and more particularly to Figs. 1 and 2, it can be seen that the molten material to be cast is poured into the cylindrical mold 3 from a spout 6. The mold 3 has an inlet 11 and an outlet 12.

Emerging from the outlet 12 of the cylindrical mold 3 is shown the solidified portion 4 of the casting which has a partially molten and partially solidified portion 5 near the upper edge thereof adjacent the inlet 11 of the mold. As the solidified portion of the casting emerges from the outlet 12 of the mold 3 it is cooled by cooling water supplied from an annular channel 13 connected to an annular reservoir 14 within the mold. An inlet channel 16 for the reservoir 14 is adapted to be connected to a source of cooling water for replenishing the water in the reservoir 14 as it is used in cooling the casting.

Adjacent the inlet 11 of the mold 3 is mounted a copper tubing 1 which is formed in the shape of an annular member having an annular diameter substantially equal to the diameter of the circular inlet 11 of the mold. Partially surrounding the copper tubing 1 is a secondary magnetic member 2. The secondary magnetic member 2 is also shaped as an annular member and is made up of a plurality of transformer laminations. This can best be seen in the plan view of Fig. 2. Each of the transformer laminations used in the secondary magnetic member 2 has a horseshoe-shaped cross section when taken in a direction parallel to the annular axis of the annular member 2.

That is, the secondary annular magnetic member 2 is formed of a plurality of horseshoe-shaped transformer laminations. In Fig. 1 it can be seen that the open end of the horseshoe faces the inlet 11 of the mold 3.

In operation, the copper tubing 1 is connected to a source of alternating electrical current so that a magnetic field is established thereabout. Since the transformer laminations are made of a magnetic material, substantially all of the lines of flux of the magnetic field established by the current flowing through the copper tubing 1 flows through the horseshoe-shaped elements of the secondary magnetic member 2. However, there is an air gap between the open ends of the horseshoe so that a substantial amount of the flux passes from one end of the horseshoe through the partially solidified portion 5 of the casting back into the other leg of the horseshoe.

Accordingly, the secondary magnetic member 2 which is mounted in the region of the magnetic lines of flux distributes the lines of flux into a pattern extending through the partially solidified portion 5 of the material in the mold. As can be seen from the arrangement of the tubing 1 and the secondary magnetic member 2 in Fig. 1, the pattern of the alternating magnetic field so established is arranged with a substantially annular axis lying in a plane perpendicular to the direction of flow of the molten metal into the mold. That is, each of the horseshoe-shaped laminations of the secondary magnetic member 2 provides a substantially circular or annular magnetic field having an axis which is perpendicular to the direction of flow of the molten material. The total of these magnetic fields is a substantially annular magnetic field having an annular axis lying in a plane perpendicular to the direction of flow of the molten material where such material is subjected to the magnetic field. When this partially solidified portion 5 is subjected to the alternating magnetic field, a gentle stirring of this portion occurs which tends to eliminate any local variations of temperature within the solidified portion. Therefore, a uniform heating and cooling of the casting is provided since, by the time the partially solidified portion 5 becomes solidified as shown in the portion 4, any initial temperature variations within the molten material are dissipated due to the action of the lines of flux established by the magnetic field.

It has been found that subjecting the partially solidified material of the casting to such an alternating magnetic field results in a casting which has a desirable texture and which is free from any structural defects.

An experiment was carried out during the casting of a high-strength aluminum alloy of the type using aluminum, copper and magnesium. Castings having a diameter of 300 mm. were cast with a pouring velocity of 45 mm. per minute. In order to prove the effectiveness of the method and apparatus incorporating the principles of the present invention, two simultaneous castings were poured. One casting was made with the conventional distributing means and the second casting was made with the induction apparatus made up of the copper tubing 1 and the transformer laminations 2 as illustrated in Figs. 1 and 2. During this experiment all other factors, such as the casting temperature, the shape of the mold and the length thereof, the amount and temperature of the cooling water were all maintained exactly the same. That casting which was formed without the alternating magnetic field provided by the present invention was full of structural cracks and fissures as well as other structural defects. On the other hand, the casting formed by the apparatus incorporating the principles of the present invention was completely uniform and homogeneous and had not structural defects at all.

A corresponding experiment was carried out in the same manner with an aluminum alloy formed of aluminum and manganese. That casting which was made without the alternating magnetic field was found to be full of voids and other structural defects while the casting made by the principles of the present invention were free of such defects.

Further experiments have also been carried out using aluminum alloys made from aluminum, zinc, magnesium and copper and showing the same results. In these latter experiments it was also found that in the castings made by the principles of the present invention, there was no segregation or liquation of chromium.

In further experiments aluminum alloy castings of the type including aluminum, magnesium and silicon were produced having diameters in the order of 170 mm. without having any structural defects.

Referring now to Figs. 3 and 4 a second embodiment of the present invention is shown. The elements in Figs. 3 and 4 which carry out the same functions as in Figs. 1 and 2 are numbered with the same numerals. However, in this second embodiment the copper tubing 1' forms an annular member which has a substantially smaller annular diameter than the diameter of the circular inlet 11 of the mold 3

Also, in this embodiment the secondary magnetic member 2', which surrounds the copper tubing 1', also is shaped as an annular member having an annular diameter substantially smaller than the diameter of the circular inlet 11 of the mold 3.

In this second embodiment the members 1' and 2' are supported on the upper surface of the mold 3 by a supporting member 17.

In operation this second embodiment operates substantially in the same manner as in the first embodiment. However it can be seen in Fig. 4 that the spout 7 may be shaped with a bifurcated end having channels 8 and 9 in respective end portions thereof so that the molten material poured into the mold is poured outside of the

secondary magnetic member 2' closer to the sides of the mold 3 so that an even distribution of the molten material poured into the mold is provided.

In both of the embodiments described hereinabove it is possible to provide water-cooling for the copper tubing 1 and 1' since these tubings are hollow and permit the passage of cooling water therethrough.

According to the method of the present invention it is possible to produce continuous casting ingots, billets or the like from alloys which include alloy forming metals which at casting temperature are partially or completely insoluble in the melt and tend to cause liquation, in such a manner that these alloy forming metals are finely and evenly distributed throughout the entire ingot. This is achieved by subjecting the partially solidified melt to the action of an alternating magnetic field, such as can be produced with the apparatus of the present invention.

It has now further been found that an optimum of even and finely divided distribution of the liquating alloying metal can be achieved by super-heating the melt prior to casting to a sufficiently high temperature above the casting temperature so as to substantially dissolve the liquation-causing alloying metals, and by subsequently cooling to casting temperature. For instance, continuous casting ingots produced according to the methods of the present invention from an aluminum alloy containing aluminum, copper, magnesium and lead have shown greatly improved machining properties. X-ray photographs of slices taken from such ingots show the completely even and very fine distribution of the lead.

The degree of super-heating of the melt above pouring temperature depends on the degree of solubility of the alloying metals in the melt at the respective temperatures. For instance, the solubility of lead in liquid aluminum, or of manganese in liquid magnesium is greater at temperatures which are above the normal casting temperatures for aluminum or magnesium alloys. The degree of superheating will have to be increased, according to the present invention, in accordance with increase in the relative quantity of, for instance, lead or manganese in the melt which would not be dissolved at casting temperature.

The percentage amount of liquating-causing alloy components which are dissolved at casting temperature depends on the type and relative quantity of the other alloying components. For instance, the solubility of manganese in magnesium (in binary alloys) is considerably reduced by the addition of aluminum. It follows that the desirable degree of super-heating above the casting temperature of the respective alloy will have to be determined in each case, so as to achieve substantially complete dissolution of the alloy components which would not be dissolved at regular casting temperature.

Preferably, the difficultly soluble alloy component is added last to the remainder of the alloy composition. The other alloying metals may be combined at lower temperature, and the liquating alloy component is then added last at the desired super-heating temperature. Immediately after dissolution of the liquating alloy component, the melt may be cooled to casting temperature and cast. This feature of the present invention is described in detail further below in Examples 1, 2, 4 and 8.

The following examples are given as illustrative only, the present invention however not being limited to the specific details of the examples.

All of the examples of continuous casting of alloys according to the method of the present invention were carried out in low frequency induction furnaces. It must be emphasized, however, that other types of furnaces such as gas or oil heated furnaces could also be employed for carrying out the method of the present invention.

In all examples, an induction device as herein described having a frequency of 50 cycles was used.

EXAMPLE I

Magnesium alloy containing 7.5% aluminum, 1.2% zinc, 0.21% manganese, balance magnesium

Magnesium pig is melted at 720° C. At this temperature the aluminum and zinc are alloyed with the magnesium, and the melt is then heated to 780° C. Upon reaching a temperature of 780° C. the manganese is added to the alloy. Thereafter, the melt is quickly cooled to 700° C. and cast. In a casting device, four continuous castings are made simultaneously with a casting speed of 60 mm. per minute. Each continuous casting has a diameter of 170 mm. The series-connected induction devices have a total power of 4 kilowatts and a total voltage of 6 volts.

The thus-obtained individual ingots of about 4 mm. lengths possess throughout their entire length and cross-section a fine-grained, even structure, completely free of manganese-nests, as shown by X-ray inspection.

EXAMPLE II

Binary magnesium alloy containing 0.75% zirconium

Magnesium pig is melted (the melting point of the magnesium is about 650° C.), the melt is super-heated to 800° C. and zirconium is added in the form of a 50% magnesium-zirconium key alloy. Thereafter, the melt is quickly cooled to 700° C. and cast. In a casting device two continuous castings are made simultaneously with a casting speed of 65 mm. per minute. Each continuous casting has a diameter of 180 mm. The series-connected induction devices have a total power of 2 kw. and a total voltage of 2.8 v.

The thus-obtained ingots possess throughout their entire length and cross-section a fine-grained, even structure. The grain size is below 0.1 mm. X-ray examination shows complete absence of zirconium inclusions.

EXAMPLE III

Binary magnesium alloy containing 1.9% manganese

Magnesium pig is melted and super-heated to 740° C. At this temperature, the manganese is added in the form of water-free $MnCl_2$, whereby the manganous chloride reacts with the molten magnesium under formation of manganese and magnesium chloride. The melt is quickly cooled at 700° C. and cast. A continuous casting of 300 mm. diameter is formed at a casting speed of 40 mm. per minute. The induction device has a power of 4 kw. and a voltage of 5 v.

The thus-obtained ingots possess a fine-grained structure and are free of so-called columnar-structures and manganese nests, while similarly produced ingots which, however, were not exposed to the alternating magnetic field show both columnar-structures and manganese nests.

EXAMPLE IV

Aluminum alloy containing 4.0% copper, 0.8% magnesium, 1.0% manganese, 0.2% silicon, 0.3% iron, 2.0% lead, balance aluminum

The aluminum is molten and alloyed at 720° C. with all alloying elements except lead. The melt is then heated to 800° C. at which temperature the lead is added. Thereafter, the melt is cooled to 700° C. and cast. In a casting device four continuous castings of 170 mm. diameter each are made simultaneously with a casting speed of 60 mm. per minute. The induction device operates as described in Example I.

The thus-obtained ingots possess an extraordinarily fine-grain structure. Lead is present in finest distribution throughout the entire cross-section and can hardly be recognized by X-ray examination. X-ray examination of similarly produced ingots which, however, have not been exposed to the alternating magnetic field show ball-like agglomerations of lead.

EXAMPLE V

Aluminum alloy containing 3.8% copper, 0.9% magnesium, 0.9% manganese, 0.2% silicon, 0.3% iron, 0.5% bismuth, 0.5% lead, balance aluminum

The aluminum is molten and all alloying elements are added at a temperature of 720° C., however, preferably lead and bismuth are added last. Thereafter, the melt is cooled to 700° C., and cast as described in Example IV. The thus-obtained ingot structure is comparable to the structure obtained according to Example IV.

EXAMPLE VI

Aluminum alloy containing 4.5% zinc, 3.0% magnesium, 0.7% copper, 0.25% manganese, 0.3% iron, 0.2% silicon, 0.25% chromium, balance aluminum

After melting the aluminum, all of the alloying elements are added at a temperature of 740° C. Chromium in the form of an aluminum-chromium key alloy containing 10% chromium is added last. Casting takes place at 720° C. An ingot of 450 mm. diameter is cast at a speed of 28 mm. per minute. The induction device has a power of 4.5 kw. and a voltage of 6.3 v.

The thus-obtained ingot is of highly fine-grained structure and, as can be shown by X-ray tests, the structure is free of coarse chromium aluminides (intermetallic compounds of chromium and aluminum).

EXAMPLE VII

Aluminum alloy containing 8.1% zinc, 2.0% magnesium, 0.4% manganese, 0.1% silicon, 0.25% iron, 0.27% chromium, 0.07% vanadium, balance aluminum

Alloying and casting temperatures are the same as described in Example VI. Two ingots of 300 mm. diameter are cast with a speed of 37 mm. per minute. The series-connected induction devices have a total power of 4 kw. and a total voltage of 6 v.

The thus-obtained structure is similar to the one described in Example VI and completely free of chromium aluminides and vanadium aluminides.

EXAMPLE VIII

Aluminum alloy containing 0.82% magnesium, 1.0% silicon, 0.21% iron, 0.91% manganese, 0.2% chromium, 1.0% lead, 1.0% tin, balance aluminum

After melting the aluminum, the alloying elements magnesium, silicon, manganese and chromium (the latter in the form of a 10% key alloy) are added at a temperature of 720° C. The melt is heated to 800° C., and at this temperature lead and tin are added. The melt is now cooled to 710° C., and four ingots of 170 mm. diameter are cast at a casting speed of 57 mm. per minute. The induction device is operated as described in Example I.

Inspection of the ingot structure including X-ray examination shows a fine-grained structure, absence of coarse chromium aluminides, and lead and tin in an extraordinarily fine distribution.

EXAMPLE IX

Brass containing 58.0% copper, 2.8% lead, 39.2% zinc

The copper is molten at 1050° C. and alloyed at the same temperature with zinc and lead. A casting temperature of 1000° C. is maintained. An ingot of 165 mm. diameter is cast at a speed of 70 mm. per minute. The induction device has a power of 3 kw. and operates at a voltage of 3.2 v.

In contrast to an ingot cast in similar manner but without exposure to an alternating magnetic field, the ingot obtained as described above is of even fine-grained structure with the lead very finely distributed throughout the entire cross-section, as can be seen by X-ray examination.

EXAMPLE X

Aluminum brass containing 58.0% copper, 1.0% aluminum, 0.8% manganese, 1.5% lead, 0.3% iron, 38.4% zinc

The copper is molten at 1050° C. and heated to 1200° C. At this temperature manganese and iron are added in the form of 30% key alloys. The melt is cooled to 1050° C. and zine, lead and aluminum are added. After further cooling to 1000° C., an ingot of 165 mm. diameter is cast at a speed of 65 mm. per minute. The induction device operates as described in Example IX.

The result of structural examination of the thus-obtained ingot are similar to those described in Example IX.

It is therefore seen that by the improved method and apparatus incorporating the principles of the present invention it is possible to obtain in a continuous casting process a solid casting of wide diameter containing substantially no structural defects while permitting a high rate of production.

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 casting operations differing from the types described above.

While the invention has been illustrated and described as embodied in a continuous casting 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 an apparatus for the continuous casting of molten material, in combination, a mold for receiving the molten material to be cast, said mold having an inlet through which the molten material is poured to be solidified in the mold and an outlet from which the solidified material is continuously withdrawn; an annular current conducting member consisting essentially of a metal tubing disposed directly above and adjacent said mold inlet for establishing alternating magnetic lines of flux in the region of said mold inlet when alternating current flows therethrough; and an annular magnetic member made up from a plurality of transformer laminations, each of said transformer laminations having a horseshoe-shaped cross section in a direction perpendicular to the axis of said annular magnetic member with the open end of the horseshoe-shaped cross section facing the mold inlet, said annular magnetic member being disposed in the region of said magnetic lines of flux for distributing said lines of flux into a pattern extending through the solidification zone of the material poured into the mold wherein solidification of said material occurs.

2. In an apparatus for the continuous casting of molten material, in combination, a water-cooled mold for receiving the molten material to be cast, said mold having an inlet through which the molten material is poured to be solidified in the mold and an outlet from which the solidified material is continuously withdrawn; an annular current conducting member consisting essentially of a water-cooled metal tubing disposed directly above and adjacent said mold inlet for establishing alternating magnetic lines of flux in the region of said mold inlet when alternating current flows therethrough; and an annular magnetic member made up from a plurality of trans-

former laminations, each of said transformer laminations having a horseshoe-shaped cross section in a direction perpendicular to the axis of said annular magnetic member with the open end of the horseshoe-shaped cross section facing the mold inlet, said annular magnetic member being disposed in the region of said magnetic lines of flux for distributing said lines of flux into a pattern extending through the solidification zone of the material poured into the mold wherein solidification of said material occurs.

3. In an apparatus for the continuous casting of molten material, in combination, a mold for receiving the molten material to be cast, said mold having a substantially circular inlet through which the molten material is poured to be solidified in the mold; an annular current conducting metallic member having a diameter substantially equal to the diameter of said circular inlet disposed directly above and adjacent said mold inlet for establishing alternating magnetic lines of flux in the region of said mold inlet when alternating current flows therethrough; and an annular magnetic member made up from a plurality of transformer laminations, each of said transformer laminations having a horseshoe-shaped cross section in a direction perpendicular to the axis of said annular magnetic member with the other end of the horse shoe-shaped cross section facing the mold inlet, said annular magnetic member being disposed in the region of said magnetic lines of flux for distributing said lines of flux into a pattern extending through the solidification zone of the material poured into the mold wherein solidification of said material occurs.

4. In an apparatus for the continuous casting of molten material, in combination, a mold for receiving the molten material to be cast, said mold having a substantially circular inlet through which the molten material is poured; an annular current-conducting metallic member having a diameter substantially smaller than the diameter of said circular inlet disposed directly above and adjacent said mold inlet for establishing alternating magnetic lines of flux in the region of said mold inlet when alternating current flows therethrough; and an annular magnetic member made up from a plurality of transformer laminations, each of said transformer laminations having a horseshoe-shaped cross section in a

direction perpendicular to the axis of said annular magnetic member with the open end of the horseshoe-shaped cross section facing the mold inlet, said annular magnetic member being disposed in the region of said magnetic lines of flux for distributing said lines of flux into a pattern extending through the solidification zone of the material poured into the mold wherein solidification of said material occurs.

5. In an apparatus for the continuous casting of molten material, in combination, a mold for receiving the molten material to be cast, said mold having an inlet through which the molten material is poured to be solidified in the mold; an annular current conducting member disposed directly above and adjacent said mold inlet for establishing alternating magnetic lines of flux in the region of said mold inlet when alternating current flows therethrough; and an annular magnetic member made up from a plurality of transformer laminations, each of said transformer laminations having a horseshoe-shaped cross section in a direction perpendicular to the axis of said annular magnetic member with the open end of the horseshoe-shaped cross section facing said mold inlet, said annular magnetic member being disposed in the region of said magnetic lines of flux for distributing said lines of flux into a pattern extending through the solidification zone of the material poured into the mold wherein solidification of said material occurs.

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