

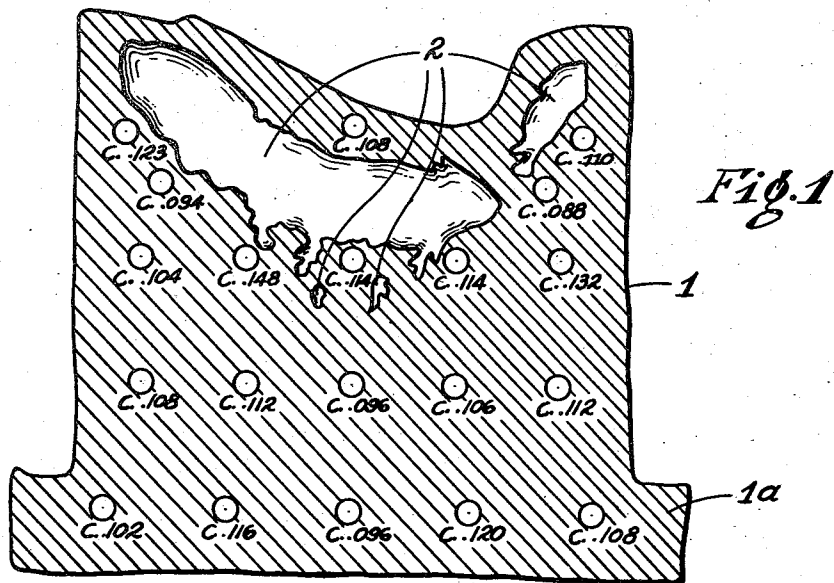
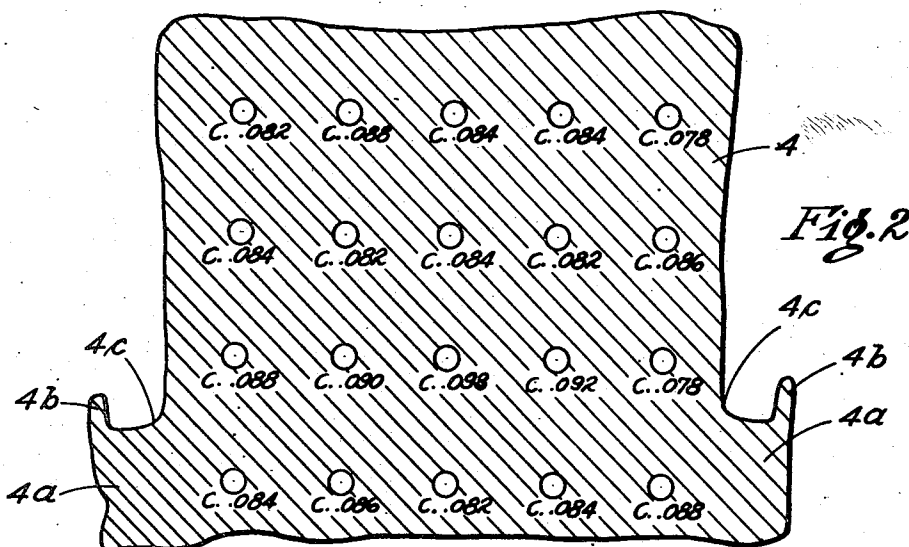
Sept. 11, 1951

M. J. R. MORRIS
APPARATUS FOR CASTING METALS

2,567,525

Filed Nov. 2, 1945

4 Sheets-Sheet 1



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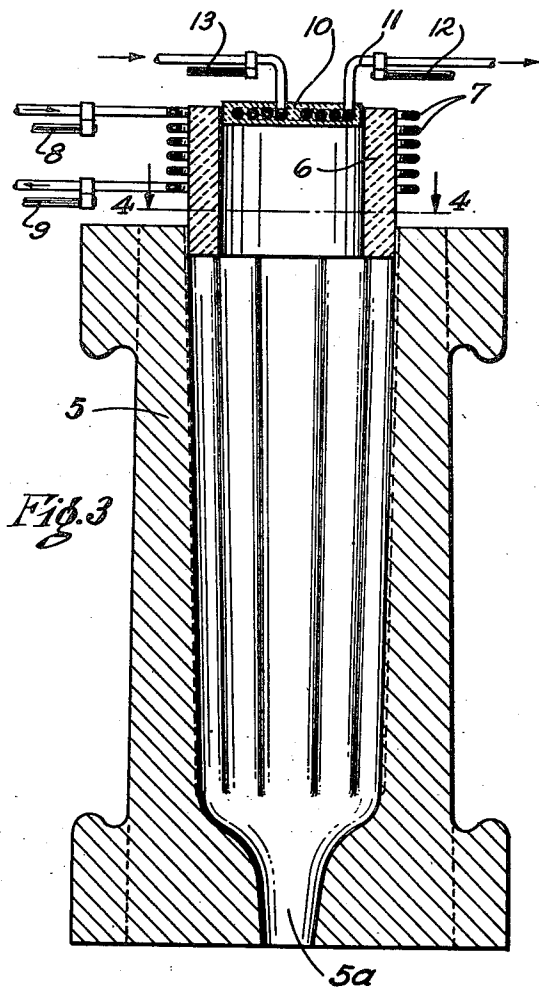
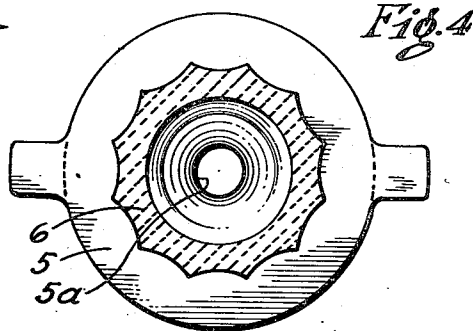
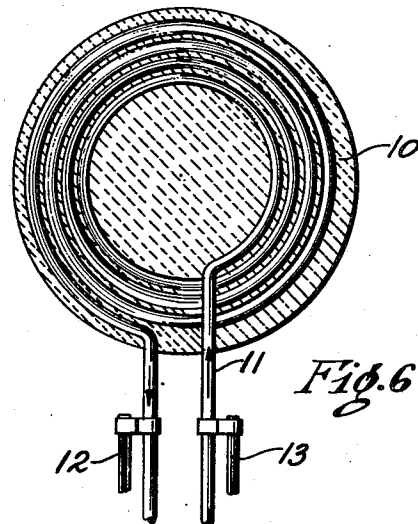
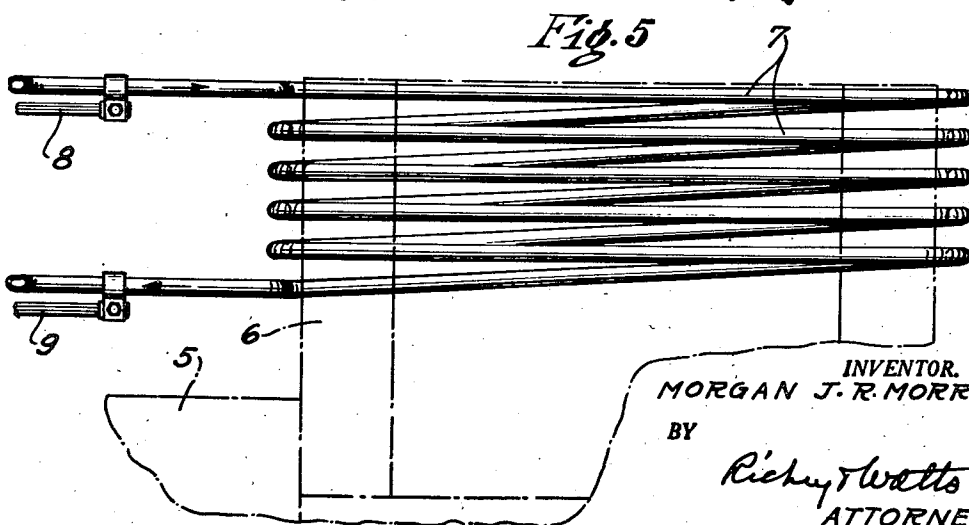
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4 Sheets-Sheet 2



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APPARATUS FOR CASTING METALS

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4 Sheets-Sheet 3

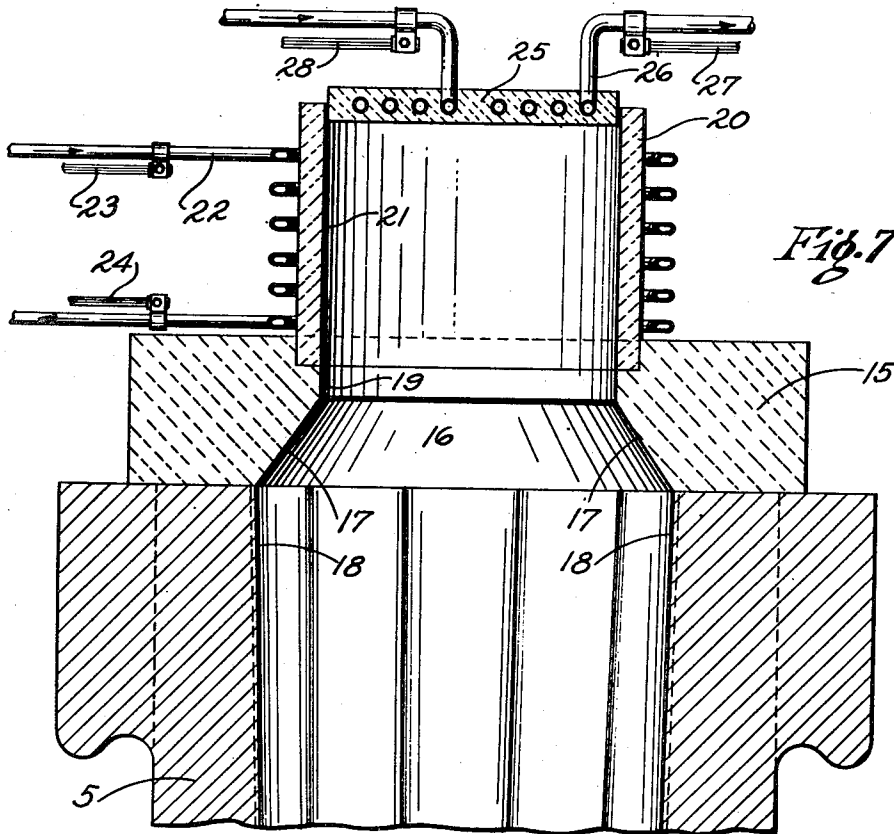


Fig. 7

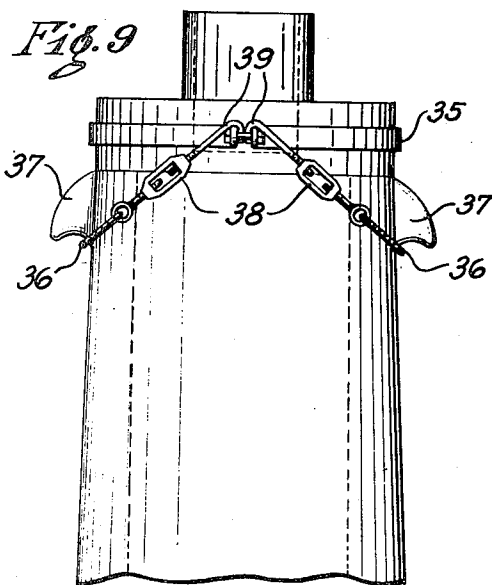


Fig. 9

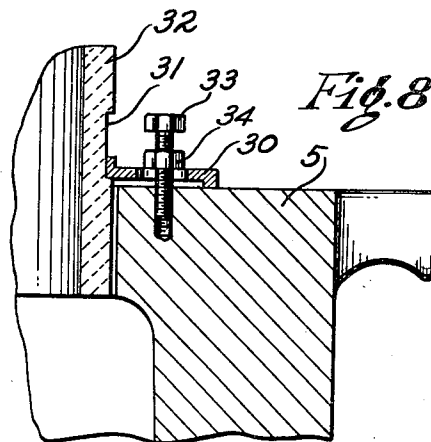


Fig. 8

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4 Sheets-Sheet 4

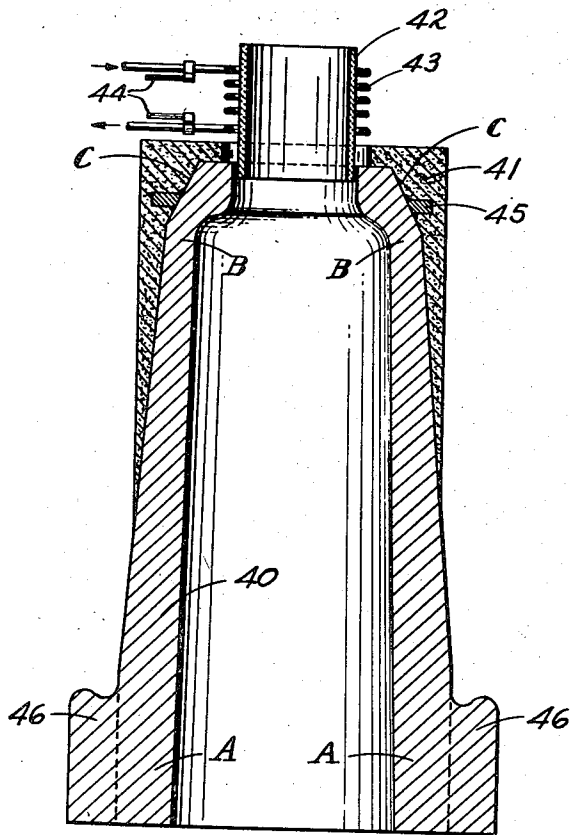


Fig. 10

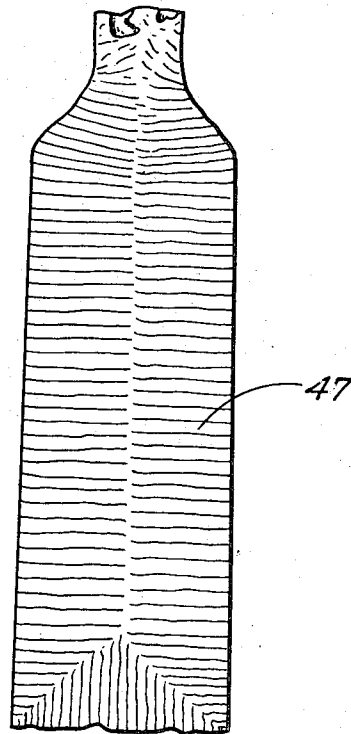


Fig. 11

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UNITED STATES PATENT OFFICE

2,567,525

APPARATUS FOR CASTING METALS

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Application November 2, 1945, Serial No. 626,255

3 Claims. (Cl. 22—147)

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The present invention relates generally to the art of casting metals. It relates more particularly to a new apparatus for casting a steel ingot which, thruout the ingot and the attached hot top metal, is sound and substantially uniform in composition.

For many years, steel ingots have been cast in molds provided with refractory hot tops. The intended purpose of these hot tops was to insure the production of sound ingots and this purpose was largely achieved. However, the metal in the hot top contained gas voids and pipes and the composition was not uniform, that is, the carbon and other elements segregated in the hot top metal. These defects made the hot top metal unsuitable for use in finished products. Also, fins of steel formed between the hot top and the mold and abrupt angles were formed by the intersecting surfaces of the metal in the hot top and mold. These fins and angles made it difficult to convert the ingot and hot top metal into satisfactory finished products. For these reasons, the hot top metal was cut off as scrap and was remelted. The resulting loss of metal was large in tonnage and in terms of the cost of finished articles. For many years those skilled in the art have known about these losses and have tried to avoid them. During all that time no proposal to avoid those losses has been commercially satisfactory or a solution of the problem, so far as I know.

The present invention aims to provide apparatus by which substantially all segregation, voids and pipes may be eliminated from the hot top metal and substantially all that metal may be worked into satisfactory finished products. That these aims have been achieved by the present invention is indicated by the outstanding results which have been obtained. The present operating practice requires that a certain minimum amount of metal be discarded from the butt and top ends of an ingot. The minimum amount of discard at the top end is increased as much as is required to eliminate voids, pipes, segregations and the like. Ordinarily there is not much variation in the amount of metal discarded from the butt end of the ingot. Under present commercial practice the weight of rolled ingot metal remaining after the minimum discards have been taken ranges between about 70% and about 85% of the total weight of rolled ingot metal. That is, the yield ranges between 70% and 85%. Yields obtained by the present invention have exceeded 90% even tho the amount of bottom discard was substantially the same as in prior practice and the minimum top discard was made by reason of

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the established practice, altho that discarded metal was satisfactory for rolled finished products. In other words, substantially all the metal at the top end of the ingot was suitable for use in rolled finished products.

The present apparatus invention may be briefly described as including a metal mold, a reservoir opening into the mold and in which metal may be kept in molten condition, preferably by a high frequency inductor coil disposed about the reservoir and in inductive relation to the outer portions of the metal in the reservoir, and, preferably, means at the outer end of the reservoir to prevent premature chilling of the surface of the metal in the reservoir by contact with the atmosphere.

The present invention will be better understood by those skilled in the art from the following description and the accompanying drawings in which,

Fig. 1 is a vertical, sectional view taken thru the hot top and part of the upper end of a steel ingot representative of the prior practice and showing characteristic segregations and voids;

Fig. 2 is a view corresponding to Fig. 1 but showing results obtained by the present invention including the substantial absence of segregations, voids and pipes;

Fig. 3 is a vertical, central, sectional view taken thru a conventional big-end-up, round, fluted, ingot mold equipped with a conventional hot top provided with a high frequency inductor coil and an electrically heated plate;

Fig. 4 is a horizontal, sectional view taken on line 4—4 of Fig. 3;

Fig. 5 is an enlarged, side elevational view of the induction coil of Fig. 3;

Fig. 6 is a horizontal, sectional view taken thru the top plate of Fig. 3;

Fig. 7 is a fragmentary, central, vertical, sectional view of an ingot mold like that shown in Fig. 3 but equipped with a new hot top, an inductor coil and an electrically heated hot top plate;

Fig. 8 is a fragmentary, sectional view, showing one form of means for holding a hot top in assembled position on a mold in accordance with the present invention;

Fig. 9 is a side elevational view showing a modified form of means for holding a hot top on an ingot mold;

Fig. 10 is a central, sectional view, of a big-end-down mold and associated parts, embodying the present invention; and

Fig. 11 is a central, vertical, sectional view of

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an ingot cast in the mold of Fig. 10 by the present invention.

In Fig. 1, which is illustrative of the prior art, the steel which solidified in the hot top is indicated at 1 and part of the metal which solidified in the ingot mold proper is indicated at 1a. The voids in part 1, indicated at 2, were caused by the evolution of gas during solidification of, and by shrinkage during solidification of, the metal in the mold proper. Gases could not escape from the hot top metal because of the quick chilling of the top surface of the hot top metal and, hence, were entrapped in the metal. As the metal in the mold solidifies it shrinks and molten metal in the central part of the hot top flows down to fill the shrinkage spaces after the outer portions of the hot top metal have cooled and set to some extent. Thus, the central part of the hot top metal is drawn away and pipes are created in the hot top. After the crust freezes on the top of hot top metal the metal beneath the crust becomes relatively quiescent or comes to a state which is conducive to segregation of carbon and other elements such as manganese, silicon, chromium and the like. The resulting non-uniformity of composition is illustrated in Fig. 1 which shows, in percentage figures, the amounts of carbon at the places indicated by the circles.

In Fig. 2, which is illustrative of the results obtained by this invention, the part of the metal which solidified in the reservoir and which is designated at 4 is substantially as dense and free from gas voids and pipes as is the metal 4a which solidified in the mold proper. The uniformity of composition is illustrated by the figures showing the percentage of carbon at the points indicated by the circles. Since the top surface portion and side portions of the reservoir metal were kept molten until the metal in the mold had solidified, there are substantially no segregations, gas voids, or pipes in the reservoir metal 4, and substantially none of that metal need be discarded for those reasons.

Fig. 3 shows a conventional big-end-up, round, fluted, ingot mold 5, it being understood that a conventional plug (not shown) is employed to close opening 5a at the bottom end of the mold cavity. A reservoir for molten metal is located at the top of mold 5. The reservoir comprises a conventional, refractory, hot top 6 which serves as a reservoir and extends into the upper end of mold 5, and means are included to maintain metal in the reservoir in molten condition. The means shown is an inductor coil 7 which surrounds reservoir 6 and has terminals 8 and 9 connected to a high frequency alternating generator (not shown). The coil 7 is preferably composed of copper tubing thru which a cooling liquid, such as water, may flow to control its temperature. Copper tubing about $\frac{3}{4}$ " in diameter, with a wall thickness of about $\frac{1}{16}$ ", has been found satisfactory, altho larger diameter tubing with greater wall thickness may be employed if desired. Preferably, the turns of coil 7 are flattened so that they have an oval cross-sectional shape with the long axes disposed horizontally. As shown, the coil 7 has six turns and the bottom turn is spaced far enough from the top of mold 5 so that the majority of the lines or force or of the flux density will pass thru the metal in the reservoir. The distance between the lower turn of coil 7 and the top of mold 5 of Fig. 3 is approximately 3". In some cases it may be desirable to heat the upper end of the mold wall by induced current. In such a case, a predetermined amount

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of electrical heating of the upper end of the mold may be obtained by positioning the coil closer to the mold and thereby causing more lines of force or more flux density to pass into the mold.

The spacing between the turns of coil 7 and the metal in the reservoir is important for one purpose of using high frequency current is to heat the outer portions of that metal and prevent it from solidifying long before the central part of that metal solidifies. With frequencies of the order of 9600 to 12000 cycles good results have been had when there was a distance of about 3" from the outer surface of the reservoir metal to the coil, that is, the reservoir wall was 1" thick and the coil was 2" from the outer surface of that wall. The turns of coil 7 should extend near to the upper end of the hot top so that the upper part of the metal in the reservoir will be inductively heated.

Since the coil is not shielded from the metal in the reservoir and the coil and the outer portions of the metal in the reservoir are in inductive relation, current flow in the coil will induce flow of current in the outer portions of that metal and will result in heating that metal by reason of resistance, eddy effects and hysteresis and will also agitate the metal sufficiently to prevent segregation of carbon and other elements.

It will be understood that the number of turns of coil 7 will depend on several factors, including the axial length of the reservoir, the inside diameter of the reservoir, the capacity of the generator, and the amount of metal in the reservoir. There should be enough turns and enough electrical energy applied thereto to supply sufficient heat to the metal in the reservoir to maintain it in fluid-like condition until substantially all gases have escaped therefrom and until the mold metal has solidified. By way of illustration, the mold of Fig. 3 was 20" in diameter at its top, the reservoir projected about 10" above the mold, there were six turns of coil 7 and a current of about 9000 cycles and 50 kw. from a 100 kw. generator was applied to the terminals of the coil for 90 minutes after the metal was poured and was then gradually reduced to zero over a period of 20 minutes. It will be understood that more or less turns of coil 7 may be used with different sets of the foregoing conditions and that currents of other frequencies and values may be used.

Fig. 3 shows means for preventing premature chilling of the top surface of the metal in the reservoir. This means is plate 10 which is composed of refractory material and has a pancake coil of copper tube 11 embedded therein. This tube 11 is connected at its ends to terminals 12 and 13 of a suitable source of current, such as an alternating current generator, and the turns of the tube 11 are spiral and lie in a horizontal plane. Tube 11 may be connected to a source of supply of cooling liquid, such as water, so that its temperature may be controlled. After the metal is poured into the mold, plate 10 is placed on the top surface of the metal in the reservoir, thereby protecting the metal against contact with the atmosphere and retarding chilling of the top surface of the metal. When current flows thru coil 11 heat is generated and transmitted to the metal thereby prolonging the time during which the top part of the metal remains molten.

Fig. 7 shows the upper part of a conventional fluted mold for a round ingot, similar to mold 5 of Fig. 3. The reservoir of Fig. 7 comprises a refractory base 15 having a central opening 16 defined by a lower conical surface 17 which ex-

tends from the inner surface 18 of the mold 5 to an upper cylindrical surface 19. A refractory cylinder 20 is secured in an annular recess in base 15 and has its inner surface 21 substantially flush with surface 19. While various refractories may be used for base 15 and cylinder 20, satisfactory results have been obtained with a base consisting largely of aluminum disilicate and containing about 40% of Al_2O_3 , about 1½% of TiO_2 , about 57% of SiO_2 and about 2% of oxides of alkalis and alkali earths; and with a cylinder consisting of approximately 82% of Al_2O_3 , about 16% of SiO_2 and about 20% of impurities. Any other suitable compositions may be used in the base and cylinder; and the base and cylinder may be made integral or may be made separately and joined together by any suitable means.

One advantage of the reservoir of Fig. 7 is that it does not form fins or square shoulders at the junction of the metal in the mold and reservoir, as is illustrated in Figs. 1 and 2, and consequently when the metal cast in the mold and reservoir is rolled none of it need be discarded because of laps and the like traceable to fins or abrupt angularity of intersecting surfaces.

Several turns of an electrically conductive coil 22 surround cylinder 20 and are attached by leads 23 and 24 to a suitable source of current, such as an alternating current generator (not shown). Coil 22 corresponds to coil 7 of Fig. 3. Plate 25 is of a size to fit into the upper end of cylinder 20, where it may rest on metal in the reservoir, and has embedded in it tube 26 corresponding generally to tube 11 of Fig. 3. This tube is connected by leads 27 and 28 to a suitable source of electric heating current.

It will be understood that, in connection with the apparatus of Figs. 3 and 7, any suitable means may be employed to hold the reservoir in proper assembled position relative to the top of the mold against the lifting forces applied thereto by molten metal rising in the mold. When the conventional hot top is used ingot metal runs in between the hot top and mold and solidifies almost immediately. This metal forms fins, as indicated at 4a in Fig. 2, which anchor the hot top in place against lifting forces of the metal in the ingot. However, when the heated reservoir of this invention is used this fin metal does not solidify with sufficient rapidity to anchor the reservoir and, unless restrained, the reservoir is lifted by the metal in the mold. Accordingly, means are provided for holding down the reservoir.

Figs. 8 and 9 show two simple "hold-down" means. In Fig. 8 a plurality of clips 30 bear at their inner ends in notches 31 in the reservoir wall 32 and at their outer ends on mold 5. Bolts 33 and nuts 34 hold the clips in place. In Fig. 9 a band 35 is clamped around the reservoir and two connectors engage this band and the mold. Each connector includes a flexible cable 36 to engage under the mold lugs 37 and turnbuckles 38 with hooks 39 at each end of the cable. The hooks 39 engage with band 35.

It will be understood that, if desired, the plates 10 or 25 of Fig. 3 or 7 may rest on the top end of the reservoir instead of resting on the top of the metal in the reservoir and that, when desired, the tubes 11 or 26 may be separate from and simply rest on the top of plates 10 or 25 or may be omitted altogether.

The operation of the apparatus hereinabove described is believed to be substantially as fol-

lows: When molten metal is poured into the mold until its top surface is near to the upper end of the reservoir, solidification of the metal in the mold progresses inwardly from the outer surfaces of the metal and, as the metal solidifies, it contracts. The flow of high frequency alternating current in the coil 7 or 22 creates lines of force or flux as well as eddy currents in the outer portions of the metal in the reservoir and, as a result, heat is generated in those portions of the reservoir and that metal is agitated and mixed with resulting prevention of segregations. This generation of heat in the reservoir metal retards its rate of cooling and tends to maintain the outer portions of that metal in molten or fluid-like condition so that it can flow into the mold and compensate for shrinkage which takes place during the solidification of the metal in the mold and thereby render the mold metal dense and sound, and gases which are expelled during solidification of the metal can readily escape thru the reservoir metal. The generation of heat by coils 11 or 26 in or on plates 10 or 25, respectively, in the upper portion of the metal in the reservoir and the protection of the top surface of that metal against contact with the surrounding atmosphere, which is offered by plates 10 or 25, insures maintenance of the top surface portions of the metal in the reservoir in a fluid-like state suitable for escape of gases therethru until substantially all gases have escaped from the reservoir metal and thereby prevents the formation of gas voids. The slow substantially uniform cooling of the reservoir metal avoids the formation of pipes therein.

It is important that the electrical energy applied to coils 7 or 22 should be sufficient to supply enough heat to the metal in the reservoir to accomplish the foregoing desired results. While this amount of energy will naturally vary depending upon a number of factors, including the size of the mold and the amount of metal in the reservoir, it may be said, for illustrative purposes, that satisfactory results have been obtained on a 20" round ingot top with the apparatus shown in Fig. 3 when 50 kw. of 9600 cycle current was applied to coil 7 for 90 minutes, following which the power was gradually reduced to zero over a period of 20 minutes. In another instance in which a rectangular reservoir was used with a 25 x 25" square ingot mold, 35 kw. of 9600 cycle current was applied to the coil for about 45 minutes and was then gradually reduced to zero over a period of about 35 minutes.

The savings attributable to the present invention are outstanding in importance. In one instance metal of the same composition was poured into two standard big-end-up molds equipped with standard hot tops, one of which was provided with the inductor coil and electrically heated plate of the present invention. Only 80% of the metal poured into the standard mold, not equipped with the apparatus of this invention, was sound and acceptable, while 93.3% of the metal poured in the mold embodying this invention was sound and acceptable. This test showed a saving of over 13%, that is, 13% more of the metal cast met the customers' tests after being rolled into finished product. In another similar instance 74% of the metal poured into a standard mold, equipped with a standard hot top, was sound and acceptable, while over 92% of the metal poured in a similar standard mold and hot top, equipped with the apparatus of this invention, was sound and acceptable. Even higher

yields are obtainable with modified reservoirs of the type shown in Fig. 7.

The present invention has been found to be commercially satisfactory on killed steels, on low carbon and supersaturated carbon steels and on stainless steels. It is believed to be applicable to rimmed steels.

The present invention has also been used satisfactorily on big-end-down ingot molds.

Fig. 10 shows a round, big-end-down mold embodying the present invention which was used to produce the ingot shown in Fig. 11.

Fig. 10 shows a big-end-down mold 40, the buggy on which the mold rests during casting of the ingot being omitted. The thickness of the wall of mold 40 varies progressively from the lower end where the wall is of conventional thickness, that is, about 5" thick at the points marked A, to the upper end where, at points B just below the neck, the wall is about 3" thick. Around the neck of the mold the outer surface of the wall is beveled, that is, inclines inwardly as at C. A sand blanket covering indicated at 41 surrounds the mold for about the upper half of its length. A reservoir 42 extends thru the top end of the blanket 41 and into the upper end of the mold 40, and an inductor coil 43 surrounds the reservoir and is connected by leads 44 to a source of high frequency current of the values and after the manner described in connection with Figs. 3 and 7. Means (not shown) are employed to retain the reservoir in its thus assembled position relative to the mold.

Ring 45 is welded to the beveled surfaces C and serves to assist in retaining the sand blanket 41 in position on the mold and, when the blanket is removed, serves as book-engaging means by which the mold may be stripped from the ingot.

In this particular instance the mold had an overall height of 58". The mold wall was of conventional thickness, that is about 5" thick, from the bottom end of the mold to a point about 1/2" above the hold-down lugs 46. From that point upwardly for about 39 1/2" the walls tapered gradually in thickness to a thickness of about 3". The top six inches of the mold were beveled as indicated at C. Ring 45 was about 1/2" thick and its top surface was about 3" below the top surface of the mold. The hot top was about 12" in outside diameter and 10 1/2" in inside diameter and was about 12" long with about 1 1/2" thereof projecting into the mold below the top surface of the latter. The coil 43 consisted of six turns in a vertical space of about 5 3/4", the lower turn being about 2 1/2" from the top of the mold. The ends of conductors 44 were connected to a 100 kw. generator and 50 kw. of alternating current of about 9600 cycles was applied to coil 43 for a period of about 90 minutes and then was reduced to zero in a period of about 20 minutes.

The ingot 47 produced in the mold of Fig. 10 by this method is shown in central vertical section in Fig. 11. This figure shows that the metal of ingot 47 was sound thruout not only the full length of the metal in the mold but also thruout substantially all the metal in the reservoir. It also shows that the metal at the lower end of the reservoir did not freeze and thereby plug the hot top but, on the contrary, remained molten until after the metal in the mold had solidified.

In other instances in which the present invention has been applied to big-end-down molds but in which the sand blanket 41 was not employed, the resulting ingots were sound and were

successfully rolled into articles of various thickness down to thin sheets which were satisfactory and acceptable. Photographs of vertical central sections of such ingots indicated structures along the vertical center lines of the ingots which were somewhat different in appearance from the surrounding crystalline metal. However, whether these differences in appearance were due to a difference in crystallization shape or form of the metal, or to crystallization shrinkage voids, or to some other reason, it had no observable effect on the rolled products for no tendency to separation of the metal at places corresponding with the axial center line of the ingot was observed even when the metal was reduced to thin sheets. Thus the sand blanket of Fig. 10 or other means of retarding the rate of cooling of the metal in the upper part of a big-end-down mold is not essential to the making of sound big-end-down ingots by means of the present invention.

In casting big-end-down ingots, it is preferable so to position the inductor coil relative to the top of the mold that enough lines of force or enough flux will pass thru the mold walls about the top opening as to prevent premature chilling of the metal in the opening for free feeding of molten metal thru the opening is important to complete filling of the mold with a sound dense casting. This object may also be accomplished by the heat retarding blanket above mentioned or by the blanket together with this heating of the mold walls or by so proportioning the thickness of the mold walls that cooling at the bottom of the mold is expedited and at the top is retarded. I prefer to use all these means together. Altho I have specifically mentioned only steel ingots hereinabove, it is to be understood that any metal, including non-ferrous metals, which affords substantial resistance to the flow of current or the passage of lines of force therethru may be cast in this apparatus; and that castings of shapes and sizes different from the ingots shown may be made by this invention.

Having thus described my invention so that others skilled in the art may be able to understand and practice the same, I state that what I desire to secure by Letters Patent is defined in what is claimed.

What is claimed is:

1. Metal casting apparatus comprising a refractory reservoir for molten metal at the upper end of an ingot mold, said reservoir having a bottom surface to rest on the top of an ingot mold and having a passage therethru for molten metal defined by an upper cylindrical surface and a lower, frustro-conical surface extending outwardly to substantially the inner surface of the mold.

2. Metal casting apparatus comprising a refractory reservoir for molten metal at the upper end of an ingot mold, said reservoir having a bottom surface to rest on the top of an ingot mold and having a passage therethru for molten metal defined by an upper cylindrical surface and a lower, frustro-conical surface extending substantially to the inner surface of the mold, and means connecting the reservoir to the mold to prevent metal in the mold from lifting the reservoir.

3. A refractory hot top for an ingot mold comprising a base having a bottom surface to rest on the top of an ingot mold and having a passage therethru defined by a frustro-conical surface

extending from substantially the mold top and merging into a cylindrical surface, and a cylinder resting its lower end on said base and having a passage therethru defined by a cylindrical surface constituting a continuation of the said cylindrical surface of said base.

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