Oct. 30, 1934. E. GATHMANN 1,978,996

METHOD OF AND MEANS FOR PRODUCING INGOTS

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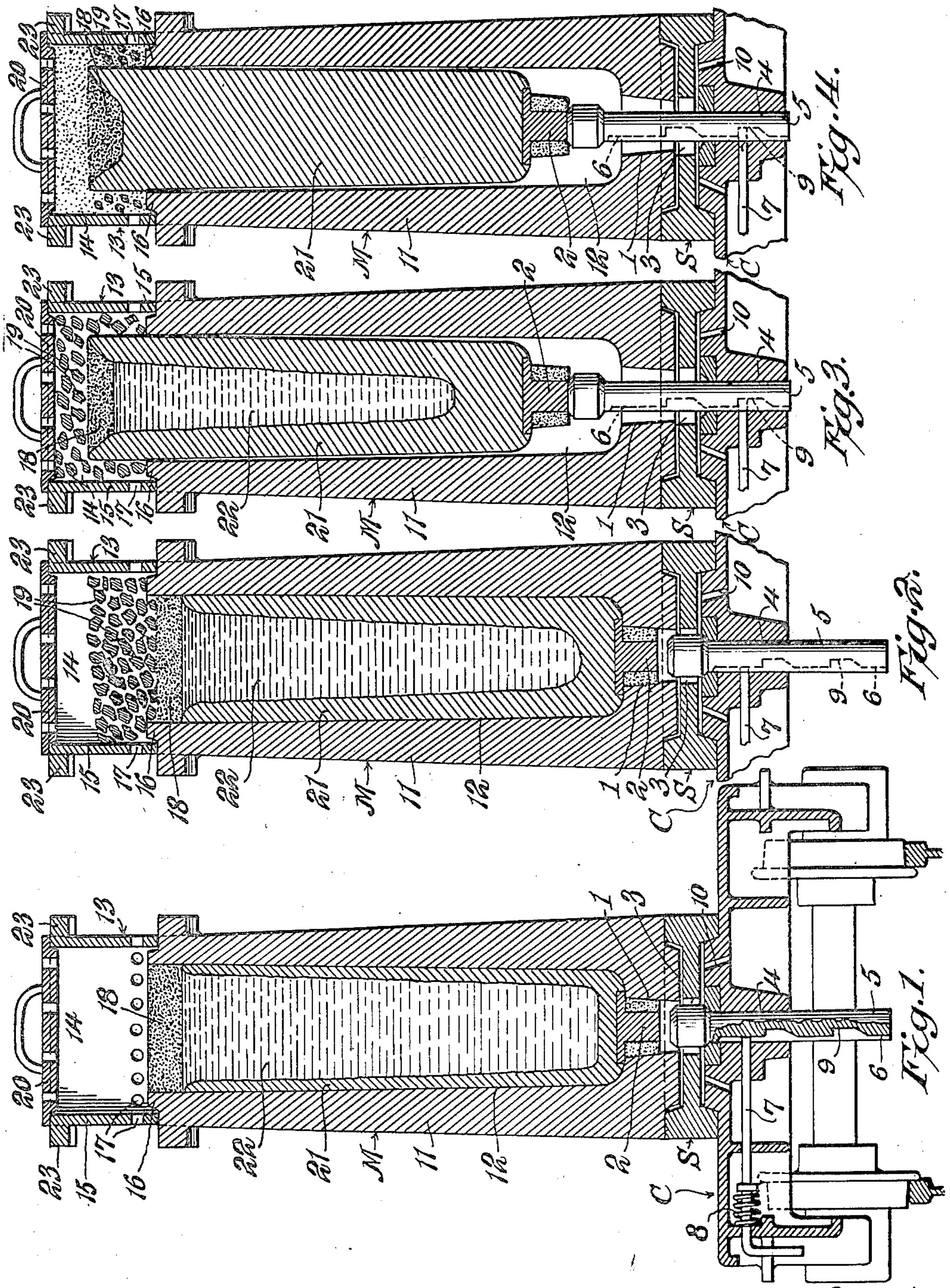

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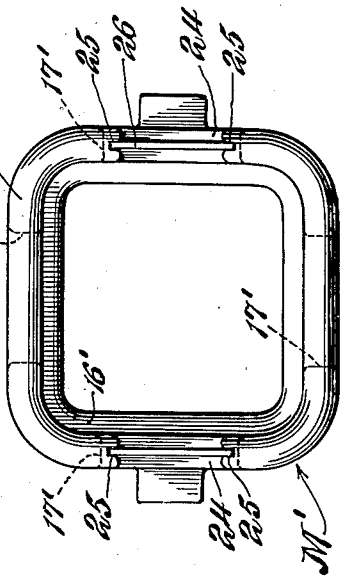
Fig. 6.



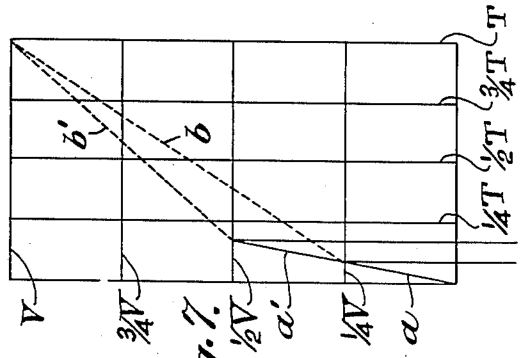


Fig. 7.

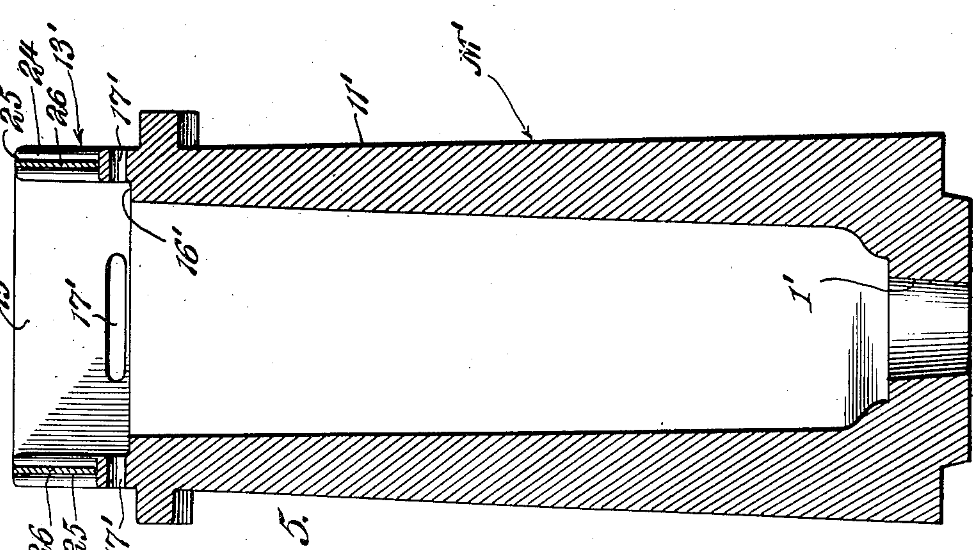


Fig. 5.

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METHOD OF AND MEANS FOR PRODUCING INGOTS

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14 Claims. (Cl. 22—200)

This invention relates to methods of and means for producing ingots, and more particularly to methods of and means for producing ingots from fully degasified or deoxidized steel, that is, ingots known to the art as "killed steel ingots". Considered in one of its aspects, the method of producing ingots in accordance with the present invention constitutes an improvement of the method of producing ingots disclosed and claimed in my prior United States Patent 1,911,228, of May 30, 1933.

Prior to my invention of the method disclosed in the prior patent referred to, the greater tonnage of "killed steel ingots" has been produced in big-end-up cast iron molds adapted to retard the solidification of the upper portion of the ingot relative to that of the lower portion and fitted with fire clay shrinkhead casings so as to confine the pipe or cavity incident to the shrinkage of the ingot metal from the liquid to the solid state to the extreme upper portion of the ingot. The shrinkhead portion of the ingot also provided a projection above the mold proper, making it possible to lift or strip the ingot with the soaking pit tongs, whereas without such a projecting portion the molds had to be upended and the ingots dumped.

The primary function of a shrinkhead casing is to retard the solidification of the upper portion of an ingot until the lower and intermediate portions have cooled and solidified through the absorption of the heat of the forming ingot by the mold walls. While, prior to the invention disclosed in my Patent 1,911,228, no satisfactory substitute had been found, the use of fire brick shrinkhead casings has a number of disadvantages. Being made of brick or loam, small particles of the shrinkhead casing at times break off and drop into the mold when the casing is being positioned on the mold, and it sometimes happens that the pouring ladle is not centered accurately over the mold and the stream of molten metal washes away a portion of the casing during teeming. In this way particles of the brick or loam are carried into the ultimate product. The surface of that part of the ingot cast within the shrinkhead casing invariably is very rough and is pitted with minute blow holes, and it cannot be rolled satisfactorily into usable or salable products. Furthermore, shrinkhead casings are expensive and increase materially the cost of sound ingot production.

In accordance with the method disclosed in my Patent 1,911,228 before referred to, molten metal is poured into a big-end-up mold and allowed to solidify throughout only a predetermined part of its volume, at which time the ingot is raised partially through the mold until the top part only of the ingot protrudes from the top of the mold. Air then is admitted through the mold bottom into the annular space between the mold walls and the partially stripped ingot, whereby cool air flows up through the annular space, cooling the lower and intermediate parts of the ingot relatively rapidly. The protruding upper portion of the ingot, being surrounded by more or less dead air, is not cooled so quickly, the metal at the top thereby remaining molten longer than at other parts of the ingot and thereby serving to "feed" the shrinking ingot so as to confine the shrinkage cavity to the upper portion of the ingot. Due to the rapid cooling effected by the draft of air flowing up around the ingot, the total time required for solidification of the ingot is reduced materially and a relatively sound homogeneous ingot is produced.

An object of the present invention is to provide a method for producing metallic ingots of at least as large cross section at the top as at the bottom thereof in such manner that the ingot sides are skin-chilled initially throughout their entire lengths by metallic mold walls so as to form a smooth surface; and in which chilling of the intermediate and lower portions of the ingot is continued after the initial chill skin has been formed while the upper portion of the ingot is insulated efficiently against escape of heat so as to retard solidification at the top and to feed the shrinking ingot, thereby producing a smooth surfaced, sound, homogeneous ingot, the shrinkage cavity of which is confined to the extreme upper portion of the ingot itself. Another object is to provide a method in which the intermediate and bottom portions of an ingot are cooled rapidly by air moving in contact therewith and in which the top surface and upper side surfaces are insulated efficiently against loss of heat and preferably are heated during the solidification of the ingot.

Generally stated, in practicing the method of the present invention, I pour molten metal into a chill mold and immediately thereafter place on the top surface of the ingot metal a measured quantity of loose heat-conserving material. After the ingot metal has solidified sufficiently to form a shell capable of sustaining the weight or ferro-static pressure of the molten metal inside of the shell, the ingot preferably is raised partially through the mold until the top portion of the ingot is projected into and encompassed by the heat-conserving material. Relatively cool air enters the mold at its bottom and passes up through the annular space between the mold and the partially stripped ingot, cooling the lower and intermediate portions thereof. Preferably the heat-conserving material referred to comprises both heat-insulating material, which is placed on top of and directly in contact with the ingot metal, and loose combustible material, preferably in lump form, which is placed on top of the heat-insulating material. Since the combustible material acts to prevent escape of heat from the molten ingot metal, the combustible material as well as the insulating material is a "heat-conserving material", and throughout the description and claims this term will be understood as including either heat-insulating material or combustible material or both.

A further object is to provide an ingot mold especially adapted for use in producing ingots in accordance with my improved method. Other objects and the more detailed nature of the method and mold of the invention will be understood from a reading of the following description, the appended claims, and the accompanying drawings, in which:

Figure 1 is a transverse vertical sectional view of apparatus for practicing my improved method, the illustrative embodiment comprising a mold support or car and an ingot mold supported thereon, the ingot metal within the mold being shown graphically as in the initial stage of solidification, and heat-insulating material being shown on top of the ingot metal;

Figure 2 is a view similar to Figure 1 but omitting the car and showing the ingot at a subsequent stage of solidification and showing combustible heat-producing material on top of the ingot metal and insulating material;

Figure 3 is a view similar to Figure 2 but showing the ingot partially stripped and the metal at a subsequent stage of solidification;

Figure 4 is a view similar to Figure 3 but showing the ingot completely solidified;

Figure 5 is a vertical sectional view of a modified form of mold constructed in accordance with the invention;

Figure 6 is a top plan view of the mold shown in Figure 5; and

Figure 7 is a chart illustrating graphically the comparative time phases of solidification of ingots produced in accordance with the invention.

Referring to the apparatus shown by way of illustration as being suitable for use in practicing the method in accordance with the invention, a mold generally designated M of the big-end-up type is supported on a stool S, which in turn is carried by a car C. The mold is provided with a tapered bottom opening 1 which is closed by means of a closure 2 which may be of any suitable kind but which preferably is of the kind disclosed in my copending application Serial No. 638,208, filed October 17, 1932 which matured into Patent 1,915,729, of June 27, 1933. The stool is provided with an opening 3 in alignment with the opening 1 in the bottom of the mold, and the car is provided with an opening 4 in alignment with the openings 1 and 3.

A stripper rod 5 is mounted for sliding movements within the opening 4 in the car, and is adapted to be moved upwardly through the openings 4, 3, and 1 into engagement with the closure for moving the ingot relatively upward through the mold. The stripper rod is provided with a longitudinally extending groove 6, which receives for sliding movements the inner end of a latch rod 7, the latter being urged inwardly into engagement with the root of the groove 6 by a spring 8. The stripper rod is formed with notches 9 near the bottom of the groove 6 which are adapted to receive the inner end of the latch rod 7 when the stripper rod 5 has been raised and the ingot partially lifted or stripped from the mold to the desired extent.

The openings 1 in the mold and 3 in the stool preferably are considerably larger than the head of the stripper rod so as to provide for the passage of air up into the mold when the stripper rod and ingot are raised. In order to provide for the entrance of air into the openings referred to, the car is formed with a plurality of openings 10 directly under the stool. Stripping apparatus of the general nature referred to above is described more in detail in my copending application Serial No. 619,807, filed June 28, 1932, and my Patent 1,897,696, issued February 14, 1933.

In accordance with one feature of the present invention, I employ a mold or mold assembly comprising a lower or ingot-forming section 11 having vertically extending walls defining a big-end-up mold matrix or ingot-forming chamber 12, and a separable upper section 13 positioned on top of the ingot-forming section and defining an open space 14 larger in horizontal cross section than the ingot-forming section. The cross sectional contour of the ingot-forming chamber may be square with rounded corners, but other cross sectional contours may obviously be used. The lower section or mold proper 11 is made of cast iron or other suitable material having high heat-conducting capacity, so that the body of an ingot I cast therein will be chilled rapidly.

The upper section 13, in the form shown, includes vertically extending walls 15 spaced laterally beyond the inner surfaces of the walls of the ingot-forming section and adapted to seat upon the top of the mold proper. Preferably the walls 15 embrace a reduced portion 16 at the top of the mold thereby to maintain the upper section 13 against accidental displacement. The mold or mold assembly is so arranged as to provide openings or air passages leading from the top of the ingot-forming chamber, or from a point just above the top of the chamber, to the outside of the mold. In the form shown in Figures 1, 2, 3, and 4, a plurality of air passages 17 is formed in the upper section, several such passages extending through each wall 15.

In producing ingots in accordance with my improved method and by the use of a mold or mold assembly such as has been described above, I prefer first to preheat the mold to between two hundred to three hundred degrees Fahrenheit. Molten metal which has been deoxidized or degasified in the furnace, and preferably also in the ladle, is poured into the mold so that the stream of metal enters the mold substantially along the vertical axis thereof, or as nearly so as practicable. This centering of the stream of metal is advisable in order to prevent undue splashing and sticking of the steel to the mold matrix walls. When the level of molten metal has reached a predetermined height in the mold somewhat below the upper end of the mold chamber 12, pouring is stopped. As quickly thereafter as practical, a predetermined quantity of heat-insulating material is placed directly on top of the ingot metal as indicated at 18. I prefer to employ diatomite, a loose, finely divided material having very high heat-insulating qualities, as the heat-insulating material, because, in addition to having excellent heat-insulating characteristics, this material is non-fusible and neutral, having no tendency to alter the analysis of the ingot metal. The insulating material 18 maintains the upper portion of the ingot fluid during the initial solidification of the metal caused by absorption of heat from the outer surface of the ingot by the chill mold walls, which contact with the ingot side surface throughout the vertical length thereof. Sufficient insulating material should be placed on the ingot to cover the top of the latter to a depth equal to about one fourth its minimum cross section.

Immediately after the insulating material 18 is put on the ingot metal, I place a quantity of combustible material 19—such for example as charcoal, preferably in lump form—on top of the insulating material 18, and within the non-ingot-forming section 13.

In some cases, for example in rainy weather, it is preferable to place a vented cover, such as that designated 20, on top of the upper section 13 in order to prevent the material 18—19 from becoming wet when the mold or mold assembly is moved through the yards from one building to another.

When there has been formed a surface skin or shell 21 sufficiently thick to sustain the pressure of the molten metal 22 at the inside of the ingot, a shell of such thickness being shown in Figure 2, the stripper rod 5 is raised so as to engage the closure 2 and to lift the ingot partially upwardly through the mold chamber so as to project the top portion of the ingot and the insulating material 18 into the combustible material 19 so as to be encompassed thereby, as shown in Figure 3, it being noted that at this stage the ingot metal at the central portion of the ingot is still molten. The exact degree to which the ingot is lifted through the mold will vary somewhat with practical considerations such, for example, as the analysis of the steel, the length and cross section of the ingot, and the pouring temperature. Generally stated, however, the ingot should be lifted a sufficient distance to locate between five per cent to twenty per cent by volume of the ingot metal within the upper mold section and encompass it by the material 19.

The time during which the ingot should be left in its initial position, as shown in Figure 1, will also vary somewhat, depending upon practical considerations such as the pouring temperature, the temperature of the molds when teeming is started, and the chemical composition of the steel. The diagram shown in Figure 7 illustrates graphically the approximate values V of ingot volume solidified in time T when metal of average analysis is poured into cast iron ingot molds under the usual conditions of temperature. The abscissæ represent elapsed time, and the ordinates percentage of volume solidified. The lines *a* and *a'* represent the amount of solidification which has taken place during corresponding periods of elapsed time while the ingot metal is in its lower or Figure 1 position, in which the surface of the ingot contacts with the mold walls throughout its length. The lines *b* and *b'* represent the progressive solidification of the ingot metal after the ingot has been raised to its Figure 3 position. In some cases it will be satisfactory to raise the ingot partially when substantially one-fourth of its total volume has been solidified, which usually will occur when substantially one-twelfth of the total time required for complete solidification has elapsed, after which the ingot is raised partially through the mold, the ingot then becoming solidified as indicated by the lines *a*—*b*. In other cases it is advisable to allow substantially one-half of the ingot metal to solidify, which will occur when about one-sixth of the total time required for complete solidification has elapsed, after which the ingot is partially raised through the mold in the manner described above. The solidification in this case will occur as indicated at *a'*—*b'*. When the ingot is about twenty inches square in cross section and requires approximately one hundred and twenty minutes for complete solidification of the lower and intermediate portions, partial stripping of the ingot can be performed safely about ten minutes after teeming, and should be performed not later than about fifteen minutes after teeming.

The insulating material 18 serves both to insulate the molten metal during the interval between completion of teeming of the mold and placing of the combustible material 19 in the upper section 13, and to form a neutral protective layer between the molten metal at the upper central portion of the ingot and the combustible material 19. As is well known, molten steel has a decided tendency to absorb carbon from any carbon-bearing material with which it comes in contact, the absorbed carbon diffusing rapidly throughout the molten metal and the chemical analysis of the latter thereby being changed. For this reason it is desirable to interpose the layer of material 18 between the molten metal 22 and the carbon-bearing combustible material 19. The material 18, as stated above, preferably is infusorial earth or diatomite, which has no tendency to alter the analysis of molten metal with which it comes in contact.

By the time that the combustible material is placed within the upper section 13, the upper inner edges of the walls of the lower section 11 will have become heated to a red heat, so that, as soon as the combustible material comes in contact with the upper portions of the walls, it will become ignited, combustion of the material 19 being supported by air entering through the openings 17, the burning of the material 19 creating a region of high temperature within the upper section 13.

When the ingot is raised partially through the mold in the manner previously described, the extreme upper portion of the ingot and the heat-insulating material 18 thereon will become encompassed by the burning combustible material 19, as indicated in Figures 3 and 4, and will be heated to and maintained at a high temperature. With the ingot in its raised position, the sides of the top portion thereof will be in direct contact with the combustible material 19, but, inasmuch as the sides of the ingot at this time will have been solidified, there is no danger of the metal absorbing carbon from the material 19, and, as stated above, the blanket of neutral insulating material 18 will prevent the molten metal 22 from absorbing carbon from the material 19 directly above the ingot metal. When the ingot is held in its partially stripped position, the top portion thereof, being located in a region of high temperature, will be maintained molten, while relatively cool air will enter through the openings 10, 3, and 1 into the mold and will pass upwardly through the annular space between the mold chamber walls and the ingot so as to cool the lower and intermediate portions of the ingot. Air passing up through the annular space will pass through and contact with the combustible material 19, thereby effecting rapid combustion of the latter and maintaining a high temperature within the section 13 so as to keep the metal in the upper portion of the ingot in a molten state for a relatively long time.

The air entering the mold bottom opening and contacting with the bottom portion of the ingot will be relatively cool as compared to the air which has been in contact with the bottom of the ingot and which has passed along the ingot, the result being that the air has a cooling effect on the ingot which is progressively less from the bottom upwardly to the portion thereof which is encompassed and insulated by the material 18. Thus, while the lower and intermediate portions of the ingot are cooled at a rate which gradually diminishes from the bottom upwardly, the extreme upper portion is heat-insulated effectively, thereby being maintained molten long after the bottom and intermediate portions have solidified. By discontinuing chilling of the upper five per cent to twenty per cent of the ingot while continuing to air-chill the lower ninety-five per cent to eighty per cent thereof, the metal in the upper portion of the ingot is kept molten and thereby is able to feed the shrinking ingot very effectively so as to produce a sound homogeneous ingot structure.

After the ingot has solidified completely, the material 18 may be recovered by suitable apparatus, such for example as that shown in my prior Patent No. 1,719,542, of July 2, 1929, and the upper section 13 lifted off the lower section 11, lugs 23 on the upper section serving to facilitate its removal. The protruding upper end of the ingot will then be grasped by the usual lifting tongs and the ingot removed completely from the mold.

In the modification shown in Figures 5 and 6, the lower ingot-forming section 11′ and the upper non-ingot-forming section 13′ are formed integrally, the walls 15′ of the non-ingot-forming section being spaced laterally beyond the inner surfaces of the ingot-forming section to provide a ledge or shoulder 16′. Air passages 17′ are formed in the walls 15′. Two opposed walls 15′ are provided with cut-out openings 24—24, the vertically extending side edges of which are grooved as at 25—25 for the reception of separable closure plates 26—26. When using this form of mold, the plates 26—26 can be removed after the ingot has solidified completely, thereby providing ample space for the lifting tongs to be moved in laterally to grasp the ingot for lifting the latter completely from the mold for removal to the soaking pit. In most instances the plates 26—26, which are relatively thin, may be left in the mold and removed by the tongs with the ingot.

Theoretically, it should be possible to produce ingots by my improved method having a pipe section amounting to only slightly more than three per cent to four per cent of the volume of the ingot, three per cent to four per cent being the actual shrinkage in the ingot metal from the molten to the solid state. Practically, however, there is always some escape of heat from the upper portion of the ingot during the time interval between the completion of teeming of the metal and the placing of the heat-conserving material on top of the ingot, so that the actual depth of the pipe is slightly greater than the minimum theoretical depth. In my Patent No. 1,711,052, of April 30, 1929, I have disclosed and claimed a method for producing ingots containing a minimum pipe section. By the method of the present invention, it is possible to produce ingots of such minimum piped section more efficiently and at considerably less cost.

In addition to the advantage of producing sound ingots comprising a minimum pipe section, the method of the present invention also makes possible the production of ingots which are smooth along the entire length of their side surfaces, this being due to the fact that the side surfaces are initially chilled throughout their entire length by contact with the metallic mold walls as distinguished from the usual prior practice in which the upper portion of the ingot was cast within a shrinkhead casing and subjected to the formation of blow holes and adhesion of the material of which the shrinkhead casing was formed, such adhesion invariably having resulted in a rough surface rendering the upper portion of the ingot unsatisfactory for rolling into usable or salable products. A still further advantage results from the fact that there is no danger of particles of heat-conserving materials or the like falling into the mold prior to teeming, or falling off during teeming, and thus being incorporated in the ingot structure.

I claim:

1. The method of producing metal ingots which comprises pouring molten metal into a chill mold, placing on the top surface of the ingot metal a quantity of loose heat-conserving material greater in horizontal area than the top part of the ingot, and then partially raising the ingot through the mold and thereby projecting the top portion of the ingot into said heat-conserving material to be encompassed thereby when the outer ingot metal has solidified sufficiently to form a shell capable of sustaining the molten ingot metal inside of said shell.

2. The method of producing metal ingots which comprises pouring molten metal into a chill mold, placing on the top surface of the ingot metal a quantity of heat-conserving material greater in horizontal area than the top part of the ingot, and then raising the ingot through the mold until from five per cent to twenty per cent of the volume of the ingot metal has been projected into and encompassed by said material.

3. The method of producing metal ingots which comprises pouring molten metal into a chill mold, placing on the top surface of the ingot metal a quantity of heat-conserving material greater in horizontal area than the top part of the ingot, and partially raising the ingot through the mold and thereby projecting the top portion of the ingot into said material to be encompassed thereby when from one-twelfth to one-sixth of the time required for total solidification of the ingot metal has expired since pouring the ingot metal.

4. The method of producing metal ingots which comprises confining a mass of molten metal within chill walls defining a vertically extending matrix adapted to produce an ingot of at least as large cross sectional area at the top as at the bottom, thereby to chill the outer vertically extending surface of said mass of metal, and discontinuing chilling of the upper portion of said side surfaces and encompassing said upper portion side surfaces with heat-conserving material in direct contact with the ingot metal when from sixty to ninety per cent of the ingot metal has solidified.

5. The method of producing metal ingots which comprises pouring molten metal into a chill mold, placing on the top surface of the ingot metal a quantity of loose combustible heat-producing material greater in horizontal area than the top part of the ingot, and then partially raising the ingot through the mold and thereby projecting the top portion of the ingot into said heat-producing material to be encompassed thereby.

6. The method of producing metal ingots which comprises pouring molten metal into a chill mold, placing on the top surface of the ingot metal a quantity of loose material greater in horizontal area than the top part of the ingot and including heat-insulating and heat-producing material, and then partially raising the ingot through the mold and thereby projecting the top portion of the ingot into said material to be encompassed thereby.

7. The method of producing metal ingots which comprises skin-chilling a body of molten metal throughout its length until a shell of solidified metal has formed, and then moving the ingot bodily and projecting the upper end portion into heat-conserving material.

8. The method of producing metal ingots which comprises pouring molten metal into a chill mold, placing heat-insulating material on the top surface of the molten metal, placing on top of said heat-insulating material a quantity of loose combustible material greater in horizontal area than the top part of the ingot, then raising the ingot only partially through the mold and projecting the upper end portion of the ingot and the insulating material thereon into said combustible material, and admitting air from outside the mold to the annular space between the mold and ingot whereby air will rise through said space along and in contact with the lower and intermediate portions of the ingot.

9. The method of producing metal ingots which comprises pouring molten metal into a chill mold, placing finely divided heat-insulating material on the top surface of the molten metal, placing on top of said heat-insulating material a quantity of loose combustible material greater in horizontal area than the top part of the ingot, then raising the ingot only partially through the mold and projecting the upper end portion of the ingot and the insulating material thereon into said combustible material, and admitting air from outside the mold to the annular space between the mold and ingot whereby air will rise through said space along and in contact with the lower and intermediate portions of the ingot.

10. An ingot mold comprising walls defining a vertically extending ingot-forming chamber of big-end-up contour and a non-ingot-forming chamber above and of larger horizontal cross sectional area than said ingot-forming chamber, said non-ingot-forming chamber having opposed openings in its side walls extending downwardly from the top thereof, and closures removably positioned in said openings.

11. A big-end-up ingot mold comprising side walls defining a vertically extending big-end-up ingot-forming chamber and a non-ingot-forming chamber above the ingot-forming chamber, there being provided an opening in the bottom of the mold and an opening extending from the ingot-forming chamber to the outside of the mold at a level between said ingot-forming chamber and said non-ingot-forming chamber.

12. A big-end-up ingot mold comprising unitary side walls defining a vertically extending big-end-up ingot-forming chamber and a non-ingot-forming chamber above the ingot-forming chamber, there being provided an opening in the bottom of the mold and an opening extending from said non-ingot-forming chamber completely through one of said side walls.

13. The method of producing metal ingots which comprises pouring molten metal into a chill mold, placing on the top surface of the ingot metal a quantity of loose combustible material greater in horizontal area than the top part of the ingot, then raising the ingot through the mold until the top portion of the ingot metal is removed from contact with the chill mold walls and projected into and encompassed by said material, and admitting air from outside the mold to the space occupied by said combustible material at a level adjacent to the top of the raised ingot.

14. The method of producing metal ingots which comprises pouring molten metal into a chill mold, placing on the top surface of the ingot metal a quantity of loose combustible material greater in horizontal area than the top part of the ingot, then raising the ingot through the mold until the top portion of the ingot metal is removed from contact with the chill mold walls and projected into and encompassed by said material, admitting air from outside the mold to the space occupied by said combustible material at a level adjacent to the top of the raised ingot, and admitting air from outside the mold to the space between the mold and ingot at a level below the bottom of the raised ingot.

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