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J. E. PERRY

INGOT, MOLD, AND METHOD OF CASTING

Filed April 21, 1921

Fig. 1.

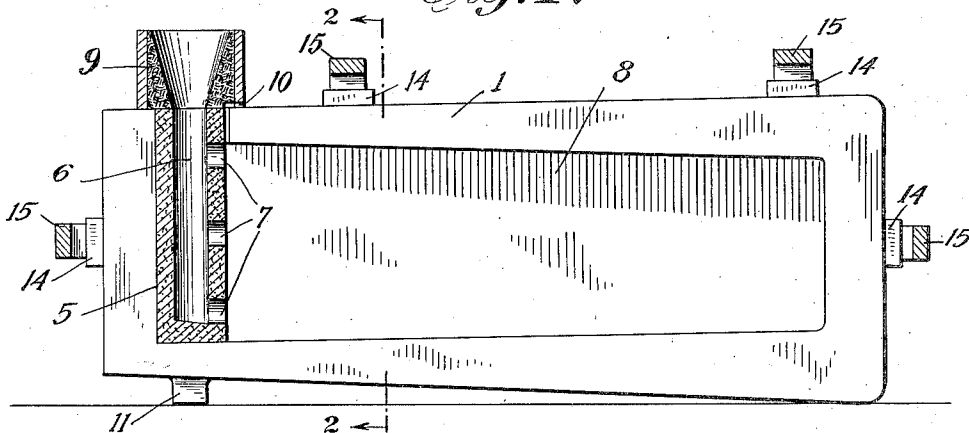


Fig. 2.

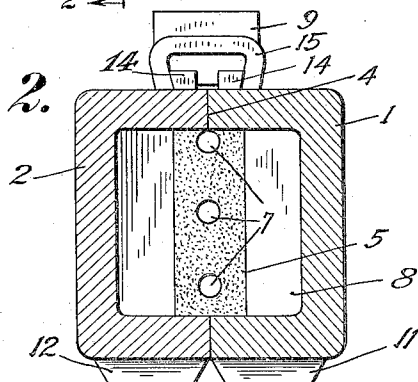
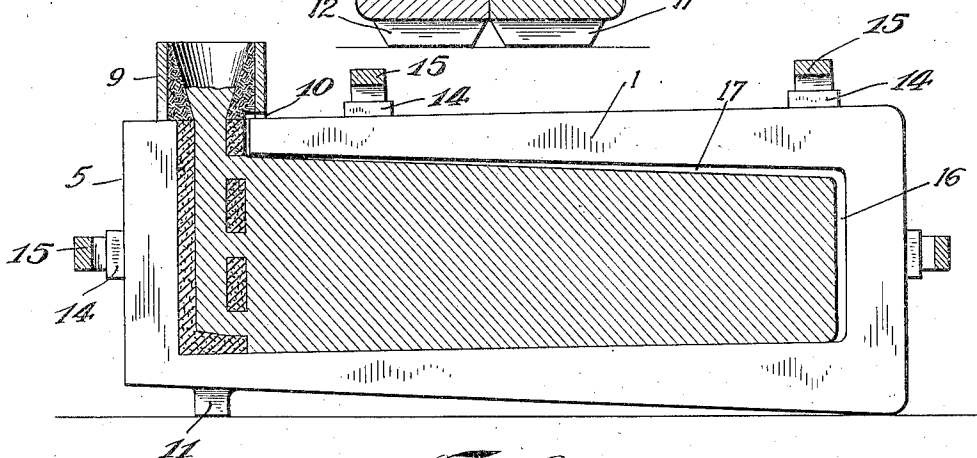


Fig. 3.

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By

UNITED STATES PATENT OFFICE.

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INGOT, MOLD, AND METHOD OF CASTING.

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To all whom it may concern:

Be it known that I, JOHN E. PERRY, a citizen of the United States, residing at Sharon, in the county of Mercer, State of Pennsylvania, have invented certain new and useful Improvements in Ingots, Molds, and Methods of Casting, of which the following is a specification.

The present invention relates broadly to metallurgy and more especially comprises a method, a mold, and ingot, all relating to the steel industry.

One of the principal objects of the present invention is the method of casting steel ingots to obtain a homogeneous compact mass of steel by arranging the mass with the major axis substantially longitudinal and then causing the steel to crystallize from one end of the mass toward the other end in such manner as to compact the steel mass as the crystallization progresses, thereby avoiding cavities in the ingot.

Another object of the present invention is the method of casting steel ingots wherein steel is arranged with the major axis thereof substantially horizontal and the heat is withdrawn differentially from all sides of the steel mass so that the heat gradient runs toward the head end of the ingot.

Another object of the present invention is the method of casting steel ingots in a tapered form with the axis thereof substantially horizontal and wherein heat is absorbed differentially from the ingot in such manner that the heat gradient runs toward the head of the ingot and in the same direction as the ingot enlarges in cross section due to tapering.

A still further object of the present invention is the casting of steel ingots by arranging the steel in a compact mass without segregation and feeding the mass at one end with molten steel while progressively cooling the mass from the other end toward the feeding end.

A still further object of the present invention is the method of producing solid homogeneous steel ingots by casting the same in full closed chill molds with the axis substantially horizontal and by causing the crystallization to progress from the foot of the ingot toward the head thereof.

Another and further object of the present invention is the method of casting steel in-

got in such manner as to obtain a substantially uniform ingot both as to physical and chemical characteristics and wherein the crystallization action is caused to take place first in the form of a shell surrounding the ingot and then to proceed as a compacting zone which moves from the foot of the ingot toward the head thereof in such manner as to cause the shell to shrink and compact the interior of metal upon itself to obviate all cavities in the metal.

Another and primary object of the present invention is a mold for casting steel ingots wherein the axis of the matrix is substantially horizontal and the mold walls are adapted to withdraw heat from the steel in the matrix in a differential manner so that the foot of the mold possesses the greatest heat withdrawing capacity and the head of the mold possesses the least heat withdrawing capacity.

Another object of the present invention is a mold for casting steel ingots and the like comprising a completely closed chill mold having tapered side walls of heat absorbing material with the thickest walls adjacent the foot of the mold and with the walls tapered from the foot to the head whereby the heat absorbing capacity of the walls diminishes from the foot toward the head of the mold.

A still further object of the present invention is an ingot mold having a tapered matrix portion with the axis thereof substantially horizontal and wherein the side walls of the mold are tapered in the opposite direction of the taper of the matrix so that the thickest portion of the side walls is adjacent the least cross section of the matrix.

Another object of the present invention is a steel ingot comprising an article of manufacture and having all sides thereof chilled and with the ingot tapered from the foot toward the runner end.

Another and further object of the present invention is an ingot of steel comprising an article of manufacture and having substantially uniform and homogeneous physical and chemical characteristics.

A third object is a steel ingot having a density which is from five to ten per cent (5% to 10%) greater than an ingot cast in an open vertical mold from the same "bath" of metal as the vertical ingot.

An article of manufacture comprising an

ingot of substantially uniform density throughout the entire ingot and wherein cavities are substantially absent.

Other and further objects of the present invention will in part be obvious and will in part be pointed out hereinafter by reference to the accompanying drawings, in which it is to be understood that the constructions illustrated are for purposes of exemplification and are not intended to represent a limited construction other than such as is one form of an embodiment of the present invention.

Figure 1 is an elevational view through a vertical split mold comprising one embodiment of the present invention and illustrating one structure by which the method comprising the present invention may be carried out to produce the ingot of the present invention.

Figure 2 is a transverse section taken on line 2—2 of Figure 1:

Figure 3 is a view illustrating a complete crystallized ingot within the mold and showing in an exaggerated manner the shrinkage of the ingot in the mold.

There are many types and kinds of steel due to the ingredients making up the steel. Certain of these steels while exceedingly useful for one purpose would be useless for another purpose; for example for some uses mild soft steel well adapted to stand vibration, shock, etc., and well adapted for drawing into shapes by presses or into wire, or other operations requiring ductility, is an ideal and necessary product. In other cases, extremely hard steel of very brittle, dense, structure adapted to withstand great wear is particularly useful for railroad rails, balls or rollers for ball bearings or the like, cutting tools, and other devices requiring this character of material. It is obvious that the steel of the first type having mild characteristics would be useless for the purposes demanded of the second type having hard characteristics, and vice versa. In the steel art it is the practice to attempt to control or predetermine the characteristics, of the steel for the resultant product, by predetermining the mixture of the materials in the "bath". The characteristics of the metal in the bath may be exactly what is desired in the final product, and these characteristics may be controlled up to the moment of casting, that is, the metal in the ladle may be thoroughly homogeneous with exactly the desired constituents in exactly the right proportions to meet the requirements of the finished article. But heretofore the moment this predetermined molten steel is cast into an ingot the operator has lost control, because when the steel starts to solidify in the bottom of the mold certain of the constituents tend to crystallize out, or to be driven from the solidifying material into the liquid steel

above. As the crystallization progresses from the bottom upwardly, the molten metal is continuously enriched by these driven out elements until the molten mass is very different from the metal as it came from the ladle. One factor in this process is the fact that the materials being thrown out in substantially all cases are materials having a lower point of fusion and consequently tend to lower the point of fusion of the upper unmelted steel and thus keep this steel liquid, while the steel from which the materials has segregated tends to crystallize more quickly. The result of this action is that the materials which are thrown out rise into the upper part of the mass and are again driven back into the ingot due to the fact that as the metal crystallizes it shrinks and the liquid or molten steel in the top of the ingot tends to drop back into and partly fill shrinkage cavities. When the steel is finally solidified into an ingot it will be found that the homogeneity which existed in the bath and in the ladle has been completely lost in the final ingot and that the materials in the lower end of the ingot are different both in physical and chemical characteristics from the materials in the upper end of the ingot, and furthermore, the materials in the core of the ingot are different in physical and chemical characteristics from the materials adjacent the surface of the ingot.

From this it will be seen that the predetermined conditions which were originally imposed by the manufacturer and which he attempted to establish by controlling the molten material, have entirely gotten beyond his control and the desired conditions are lost when the material is in the form of an ingot and ready to be fabricated. From this time on he can only approximate the desired end by chopping up this ingot by what is known as cropping, and he is therefore compelled to reject a large percentage of the final material because it has departed too far from the requirements even though it all came originally from perfectly good metal.

Heretofore in the art of casting steel ingots, the vast majority of ingots have been cast vertically. Where ingots are cast vertically the pool of molten steel solidifies from the bottom of the ingot toward the top and drives upwardly into the unsolidified molten metal such materials as tend to segregate during the action of crystallization. Vertically cast ingots tend to both pipe and segregate and various expedients have been attempted to obviate these troubles. Such ingots have been cast with the big end up, and by both bottom pouring and top pouring, yet following the best practice a large percentage of such ingots must be cut away to eliminate faults and flaws. All shrinkage that takes place in vertical molds is from the top of the metal in the ingot toward the bot-

tom. In other words, the material cast in the mold is always supported against gravity by the bottom portion and as shrinkage occurs in the metal it settles down in the mold.

5 This sometimes causes trouble by what is known as "bridging", which is due to the metal in the upper end of the ingot becoming semi-solid and holding to the mold walls while the metal lower in the mold continues to cool and shrink away from upper metal, thereby producing transverse cracks and flaws. A further effort to avoid these difficulties has been the expedient of using a hot top. This is intended more especially to prevent bridging and piping, but it tends to accentuate another bad fault, namely, segregation, and this is particularly true where hot top molds are bottom poured. Because of these facts and the fact that segregation takes place from the bottom of the metal mass toward the top thereof it follows that vertical ingots have different chemical constituents in the top end from those in the bottom. This is a bad fault because the rolled finished product has ends of different physical and chemical characteristics, and therefore are of different strengths, and different reactions. Where the requirements are high, as in rails, rods, shafts, etc., segregation is responsible for a large percentage of rejects.

The "ideal" steel ingot is one wherein the entire mass in the ingot is of substantially homogeneous physical characteristics throughout its entire length, that is, the "ideal" ingot is one having solid metal of uniform character from one end to the other and with all cavities, cracks, pipes, blow holes, and other defects, absent. Ideal ingots were heretofore so rare, in practice, that any ingot having smooth rolling surfaces and deep seated seams, secondary pipes, and other deep seated defects, and with little segregation, was known in the art as a "perfect ingot."

The present invention, overcomes the difficulties of the known prior art and comprises a method, a mold, and ingot of steel, and which method actual practice has demonstrated will produce an "ideal" ingot of solid steel of substantially uniform characteristics, physically and chemically, from one end to the other and wherein the entire ingot is adapted to be rolled into finished product from which samples of various portions of the finished product show substantially the same analysis and substantially the same strength, density, and elasticity, and these tests show substantially the same uniformity in both transverse and longitudinal samples.

The present invention may be carried out in specific molds, and apparatuses and by specific methods, other than those herein illustrated and described and the illustration

and description herewith is merely for the purposes of exemplification and is not intended to be understood as in any way limiting the breadth of the invention or inventions.

The preferred method, comprising the present invention, may be carried out in a horizontal chill mold wherein the matrix of the mold is substantially an enclosed chamber having all side walls comprising chilling walls. In horizontal molds the depth is short as compared to the length of the pool, consequently the shape of the pool does not encourage segregation, and in carrying out the present invention segregation is prevented by quick pouring, thorough mixing during pouring, and then chilling quickly the whole mass in the manner hereinafter fully explained. The method in a broad sense comprises treating the steel by obtaining an elongated horizontal mass of non-segregated molten steel of the shape and size desired and wherein the mass is fed with molten steel at one end and is chilled from the other end in such manner that the chilling progresses from the distant end toward the feeding end so that the feeding end of the ingot shall be last to solidify.

In order to prevent confusion in the specification and claims, the feeding end of the mold and also the ingot, is designated as the "head" end, and the other end of the mold and the ingot is correspondingly designated as the "foot" end.

Since the present invention is adapted to be carried out in closed chill molds, the escape of mold gases may be provided by leaving slight cracks or spaces where the mold parts join, and may be provided by a gas outlet at the head of the mold. Where ingots are cast in open vertical molds the top surface of the metal is in contact with oxidizing air which is being constantly changed due to convection currents. Some of the oxide is trapped in the steel and injures the ingot. In the present method the gas outlet opening is relatively small. The entrance of hot steel into the mold expands the air suddenly and it rushes out through the opening provided, but since the outlet is small there are no convection currents and the mold fills with gases expelled from the steel. These are non-oxidizing gases and the mold therefore fills in a non-oxidizing atmosphere so that the steel in the mold is free from oxide.

The present method may be performed by withdrawing heat from the molten mass of the ingot in such manner that the heat is withdrawn differentially in order that the foot of the ingot shall have heat taken away more rapidly than the head of the ingot and wherein the capacity of the mold for the taking away of the heat shall decrease in ratio of rapidity as the distance

from the head decreases, in other words, cooling shall progress gradually from the foot toward the head. This method may be carried out in various types of constructions, one of which, may comprise a full closed horizontal chill mold of the character above specified and wherein the heat absorbing or dissipating capacity of the mold walls, due to thickness of metal, radiating fins, cooling fluids, or other means, shall be greatest at the foot end of the mold and shall be least at the head end of the mold.

One specific apparatus for carrying out the present invention may comprise a chill mold of the character specified and wherein the end wall at the foot of the mold shall be relatively thick and wherein the side walls shall be gradually reduced in thickness toward the head. Another and effective apparatus for carrying out the invention comprises a double tapered effect in the mold, namely, by arranging the matrix of the mold tapered longitudinally in such manner that the cross-section of the matrix at the foot shall be smaller than the cross-section at the head of the mold, so that the ingot cast therein will be a tapered ingot having a larger end or head thereof adjacent the runner, and wherein the side walls of the mold are tapered oppositely to the matrix so that the thickest part of the mold walls shall be adjacent the smallest cross-section of the matrix. Under these conditions the cross-section of the molten metal at the foot is relatively small and the cross-section of the chill walls adjacent thereto is relatively large, whereas conditions are reversed as to the cross-section at the head or runner end of the mold and ingot. This places a relatively large heat absorbing wall adjacent a small mass of hot metal, thus the effect desired is accentuated. The filling of the matrix of the mold with molten steel should be done as quickly as possible preferably, through a vertical runner set in one end of the mold with the runner opening or openings so arranged as to provide thorough vertical mixing of the steel during the pouring operation to cause homogeneity of the molten mass. As soon as the matrix is filled with molten steel the predetermined condition causes a chilled shell to quickly form around the entire steel mass, with the exception of a small part of the molten steel which extends from the runner root into the mass of steel adjacent the runner at the head end of the mold. The freezing or chilling action is caused to begin quickly at the foot end of the mold and the side walls of the mold are so proportioned to the molten metal mass forming the ingot that the crystallizing action progresses gradually from the foot end toward the head or runner end in order that the head end is last to solidify. The mold is set with a proper incline to the

upper matrix surface so that all air and gases are driven out ahead of the molten steel and there are no entrapped gases in the steel. The formation of the chilled steel shell at the foot and the movement of the crystallizing action from the foot toward the head produces a compacting effect that leaves back of this forwardly moving compacting zone a mass of solid non-segregated steel from which defects are absent, since the entire mass is solidified or frozen before any segregation has occurred. In this action the center of the ingot crystallizes substantially as fast as the side walls and there is no driving out of or segregation of the materials of lower fusion. The ingot rests solidly on the long bottom side which provides a base having a large area and the shrinkage of the ingot is away from the lateral sides, top side, and foot of the mold, and is substantially all toward the head or runner end. In other words, when the ingot has completely solidified and is ready to be stripped it appears that there is space between the mold and the sides and foot of the ingot, with the major space between the foot of the ingot and the foot of the mold, whereas the ingot will lie substantially in contact with the head end wall of the mold adjacent the runner.

In vertical ingots the ferro static head is large and the pressure at the bottom of the mold is great. When the first skin or chilled shell forms this shell tends to contract, but the pressure is so great that contraction is prevented. This prevention of the chill shell from contracting continues as the chill shell thickens until the shell is sufficiently strong to overcome this ferro static pressure, and by that time the remaining ability of the crystallized steel to contract is small and the valuable compacting effect is lost. In the present method the ferro static head is very low and the pressure is light, so that a very thin shell will support this pressure and as the shell thickens and shrinks it exerts the important compacting action so much to be desired at this time. This is one explanation as to why the ingot in the present case draws away from the side walls of the mold and since the foot of the ingot is farthest from the foot of the mold it follows that the compacting action has taken place not only in a lateral or radial direction toward the axis of the ingot, but also axially or longitudinally of the ingot. Furthermore, the mold acts primarily as a medium for measuring and shaping mass of steel as desired and holding the steel in this shape until the supporting enclosing shell forms, from that time on the steel is really out of contact with the mold except on the bottom and head end, and the steel supports itself and crystallizes under ideal and normal conditions while the mold acts merely

as an absorbent or dissipating means for taking away the heat in a predetermined manner.

Where ingots are cast in accordance with the invention above described such ingots have been found to comprise solid masses of steel without any pipes, cavities, or defects whatever, and wherein the chemical constituents are uniformly distributed from end to end of the mass and wherein the metal when rolled into finished product is substantially uniform in chemical and physical characteristics throughout the entire mass, in other words, the method produces not a "perfect" ingot as is known in the art, but a true "ideal" ingot.

Since there are no cavities in the ingot, an ingot cast in accordance with the present invention has greater unit density than an ingot cast in any other known way, and when it is rolled or drawn into finished product, this product has far greater tensile strength and elasticity than identically the same product made from ingots cast vertically in the ordinary way from identically the same bath of molten metal.

Referring now to the drawings, which illustrate diagrammatic constructions, the mold may comprise a pair of body members 1 and 2 which may be joined together by a vertical joint 4. Preferably a runner tile 5 which may comprise a suitable fire brick member having a vertical conduit 6, with a pouring opening or openings 7 that enter into the matrix portion 8 of the mold, is adapted to set in a suitable channel provided in the body members. This matrix portion in the preferred form is tapered, with the small end of the matrix at the foot of the mold and with the large end adjacent the head or runner tile. A suitable fountain 9 is provided over the runner tile and preferably sufficient space is allowed between the runner tile and the fountain to provide a gas outlet 10. Where dead melted steel is used very little gas will escape other than the air in the mold which is heated and driven out as the steel enters the mold matrix. In order to further facilitate the escape of gas from the mold the runner end may be slightly raised by means of feet 11 and 12 which may be either separate or integral with the mold sections. In order to prevent the mold from spreading, suitable clamp lugs 14 are provided where desired and C clamps 15 are adapted to cooperate with the lugs in order to lock the sections together. The number of openings 7 in the runner tile 5 depends upon the size of the cross section of the matrix and under certain conditions one opening may be sufficient and under other conditions a plurality of openings may be utilized, so long as the matrix may be quickly filled with non-segregated steel.

Figure 3 illustrates the cross section of the mold and ingot after the ingot has been poured and has solidified. This cross section indicates a condition demonstrated in practice and shows that the crystallization has progressed from the foot of the mold toward the runner end thereof in view of the fact that a relatively large shrinkage space 16 exists between the foot of the mold and the ingot, whereas a relatively small space 17 exists around the sides of the ingot. The shape of the ingot is not material so long as the present invention is carried out in producing the same and the particular apparatus for carrying out the invention is not material so long as the result stated is obtained and the withdrawing of the heat from the ingot may be brought about by absorption or conduction or radiation or may be carried away by suitable fluids and therefore may be carried on by convection and it is to be understood that the withdrawal of heat may be brought about by any one of many ways of carrying on the phenomena of heat transfer.

Having thus described my invention, what I claim is:

1. The method of casting steel ingots which comprises providing a horizontal pool of molten steel having a wide head and a narrow foot with tapering sides between the head and foot; chilling all surfaces of the pool excepting a small portion at the head end; and withdrawing heat from the foot end of the ingot whereby the heat gradient runs toward the head end of the ingot until after the mass of steel has all been cooled to a temperature lower than crystallization temperature of the mass.

2. The method of casting steel ingots which comprises providing an inclosed horizontal pool of molten steel of the shape and size of the ingot desired, chilling all surfaces of the pool excepting a small portion at the head end; withdrawing heat from the foot end of the ingot to cause the heat gradient to run toward the head end of the ingot until after the mass of steel has all been cooled to a temperature lower than crystallization temperature of the mass to cause solidification to progress from the foot toward the head of the ingot; and supplying molten steel to the head end of the ingot during cooling.

3. The method of casting steel ingots which comprises providing a nonsegregated pool of molten steel having a wide head end and a narrow foot end and with the greatest length of the mass substantially horizontal; chilling all surfaces of the pool excepting a small portion at the head end; withdrawing heat from the other end of the ingot whereby the heat gradient runs toward the head end of the ingot until after the mass of steel has all been cooled to a tem-

perature lower than crystallization temperature of the mass, and supplying molten steel in a horizontal direction to the head end of of the ingot during cooling.

5 4. The method of casting steel ingots which comprises forming a mass of molten steel into the shape and size of the ingot desired by arranging the axis of the ingot substantially horizontal and supplying 10 molten steel in such manner as to cause a mixing action during the pouring and wherein molten steel forming the mass is supplied at one end of the mass; and withdrawing heat from the mass by taking away 15 the heat more rapidly from the foot end than from the pouring end so that the heat gradient is caused to run toward the pouring end until after the ingot has solidified.

5 5. The method of casting steel ingots which comprises forming a mass of molten steel into the shape and size of the ingot desired by arranging the axis of the ingot substantially horizontal and with the bottom of the mass under a low ferro static 20 pressure; supplying molten steel in such manner as to cause a mixing action during the pouring and wherein the molten steel forming the mass is supplied at one end of the mass; completely chilling the top, bottom, and sides and withdrawing heat from 30 the mass by taking away the heat more rapidly from the foot end than from the pouring end so that the heat gradient is caused to run toward the pouring end until 35 after the ingot has solidified.

6. The method of casting steel ingots which comprises forming a mass of molten steel into the shape and size of the ingot desired by arranging the axis of the ingot 40 substantially horizontal and supplying non-segregated molten steel in such manner as to cause a mixing action during the pouring to prevent segregation and wherein molten steel forming the mass is supplied at one 45 end of the mass; and withdrawing heat quickly from the mass by taking away the heat more rapidly from the foot end than from the pouring end to cause a crystallizing and compacting shrinkage zone to move 50 from the foot to the head of the mass with solidified steel back of the zone and molten steel in front of the zone.

7. The method of casting steel ingots which comprises forming a mass of molten 55 steel into the shape and size of the ingot desired by arranging the axis of the ingot substantially horizontal and with the bottom of the mass under a low ferro static pressure; supplying molten steel in such 60 manner as to cause a mixing action during the pouring to prevent segregation and wherein molten steel forming the mass is supplied at one end of the mass completely chilling the top, bottom, and one end of the 65 mass; and withdrawing heat quickly from

the mass by taking away the heat more rapidly from the foot end than from the pouring end to cause a crystallizing and compacting shrinkage zone to move from the foot to the head of the mass. 70

8. The method of casting steel ingots which comprises casting the ingot substantially horizontally by introducing the metal adjacent the head end of the mold and causing the crystallization of the metal 75 to proceed substantially throughout the cross-section of the ingot as a cupped zone open toward the head end of the ingot and to move from the foot of the mold toward the head of the mold. 80

9. The method of casting steel ingots which comprises casting the ingot substantially horizontally by quickly introducing the metal adjacent the head end of a covered mold to completely fill the mold 85 so that the only molten metal surface in contact with air is the surface in the fountain and causing the crystallization of the metal to proceed substantially throughout the cross-section of the ingot and to move 90 from the foot of the mold toward the head of the mold.

10. The method of casting steel ingots which comprises casting the ingot substantially horizontally by introducing the metal 95 adjacent the head end of the mold and controlling the chilling of the metal to cause the crystallization of the metal to proceed substantially throughout the cross-section of the ingot beginning at the foot end of 100 the ingot and with crystallization producing a shrinkage compacting zone moving from the foot of the mold toward the head of the mold.

11. The method of casting steel ingots 105 and the like in a substantially horizontal chill mold, which comprises introducing the steel at the head end of the mold through a runner leading from outside the mold, expelling the air from the mold by hot steel 110 and maintaining a substantially non-oxidizing atmosphere in the mold as the mold is filled and differentially withdrawing heat throughout the entire length of steel in the mold whereby the crystallization action 115 progresses from the foot of the ingot toward the head of the ingot throughout substantially the cross section of the ingot and forms a moving compacting zone tending to compress the metal radially inwardly and 120 toward the head end whereby shrinkage occurs from the foot of the ingot toward the head thereof.

12. The method of casting steel ingots or the like in horizontal closed chill molds 125 which comprises pouring the metal in a non-oxidizing atmosphere after the air in the mold has been expelled, supporting the metal forming the ingot on one long side thereof, withdrawing heat from the mass 130

differentially from the foot to the head of the ingot to form a supporting shell adapted to sustain the metal in the ingot independently of the side walls of the mold and causing a crystallizing zone within the shell to move from the foot of the ingot toward the head.

13. The method of casting steel ingots or the like in closed chill molds which comprises pouring the metal in a non-oxidizing atmosphere after the air has been expelled, supporting the metal forming the ingot on one long side thereof, withdrawing heat from the mass differentially from the foot to the head of the ingot to form a supporting shell sustaining the metal in the ingot independently of the side walls of the mold and causing a crystallizing zone within the shell to move from the foot of the ingot toward the head, and supplying the interior of the shell with molten steel during the cooling.

14. The method of casting steel ingots or the like which comprises arranging the molten metal for the ingot in the form of a substantially horizontal mass tapered toward the foot of the ingot and being supported on a long side of the ingot, then withdrawing heat from the foot of the ingot more rapidly than the heat is withdrawn from the head of the ingot.

15. The method of casting steel ingots or the like which comprises pouring the molten metal for the ingot into a closed chill mold in the form of a substantially horizontal ingot supported on a long side of the ingot, expelling the air from the matrix of the mold when the steel first enters, maintaining a non-oxidizing atmosphere in the matrix during pouring, and differentially withdrawing heat quickly from the ingot.

16. A mold for casting steel ingots comprising a full closed horizontal chill mold having walls of greatest thickness adjacent the foot of the mold and with the walls of lesser thickness adjacent the head of the mold, and means for introducing molten steel into the mold in a substantially horizontal direction and adjacent the head thereof.

17. An article of manufacture comprising a horizontal covered chill mold for casting steel ingots and having walls of greatest heat withdrawing capacity adjacent the foot of the mold, and with the walls constructed in such manner that the heat withdrawing capacity decreases toward the head of the mold, and means supported by the mold for introducing molten steel adjacent the head of the mold.

18. An article of manufacture comprising a chill mold for casting steel ingots said mold being formed in sections and having walls of greatest heat withdrawing capacity

adjacent the foot of the mold, and with the walls constructed in such manner that the heat withdrawing capacity decreases toward the head of the mold, said matrix having the top wall inclined slightly to the horizontal and toward the head end, a runner tile for introducing molten steel adjacent the head of the mold, and a channel in the mold to support the runner tile.

19. An article of manufacture comprising a closed chill mold for casting steel ingots with the matrix of the mold substantially horizontal and having walls of greatest heat withdrawing capacity adjacent the foot of the mold, and with the walls constructed in such manner that the heat withdrawing capacity decreases toward the head of the mold, said matrix having the top wall inclined slightly to the horizontal, and means being provided for introducing molten steel adjacent the head of the mold in such manner that the steel enters substantially parallel to the axis of the matrix.

20. An article of manufacture comprising a horizontal chill mold for casting horizontal ingots or the like having a body portion with a tapered matrix to cause the axis of the steel crystals to incline slightly toward the head end of the mold, and with the heat withdrawing capacity of the side walls of the mold being substantially inversely proportionate with the cross section of the matrix adjacent thereto.

21. An article of manufacture comprising a closed chill mold for casting horizontal ingots or the like having a body portion provided with a matrix having the smallest cross section at the foot of the mold, and with the heat withdrawing capacity of the side walls of the mold being substantially inversely proportionate with the cross section of the matrix adjacent thereto, and a runner tile located at the head of the mold, and leading from the outside of the mold to the interior thereof.

22. An article of manufacture comprising an ingot of steel of symmetric cross section both as to physical and chemical characteristics and as to transverse and lateral cross sections.

23. An article of manufacture comprising a cast steel ingot of substantial homogeneity from end to end having its chemical constituents uniformly distributed throughout the mass.

24. A horizontal ingot mold comprising a body portion having a matrix tapered inwardly toward the foot with sidewalls having heat withdrawing capacity substantially inversely proportionate with the cross section of the matrix adjacent thereto, and a runner tile set within a channel formed in the head end of the mold.

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