Nov. 19, 1940. E. J. KAUFFMAN 2,221,948

INGOT POSITIONING MOLD

Filed Oct. 25, 1938 2 Sheets-Sheet 1

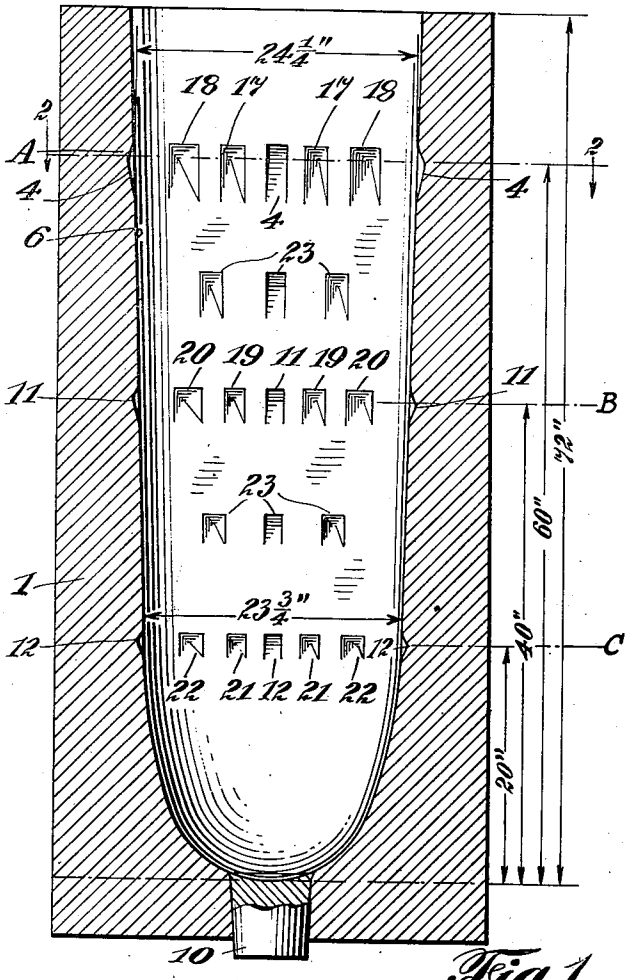


Fig. 1.

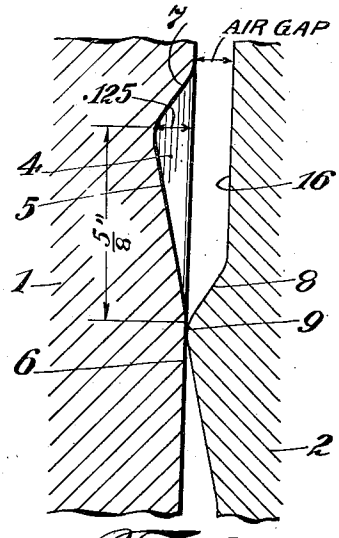


Fig. 3.

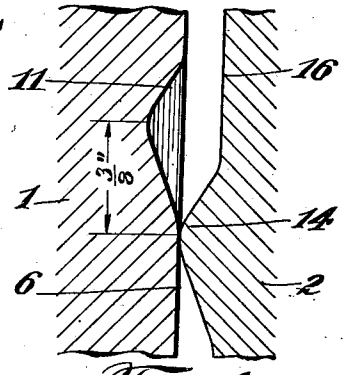


Fig. 4.

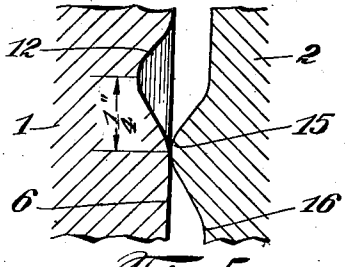


Fig. 5.

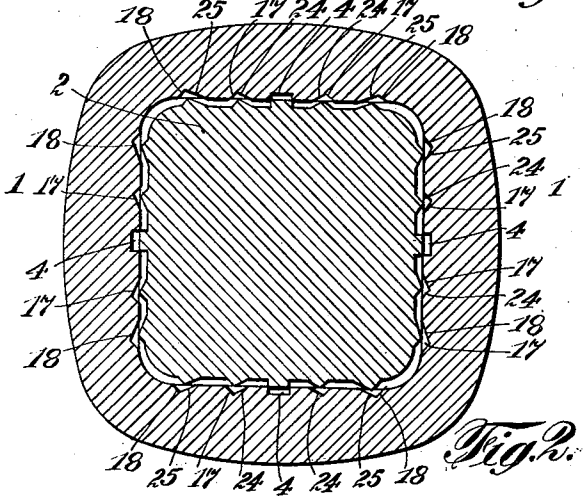


Fig. 2.

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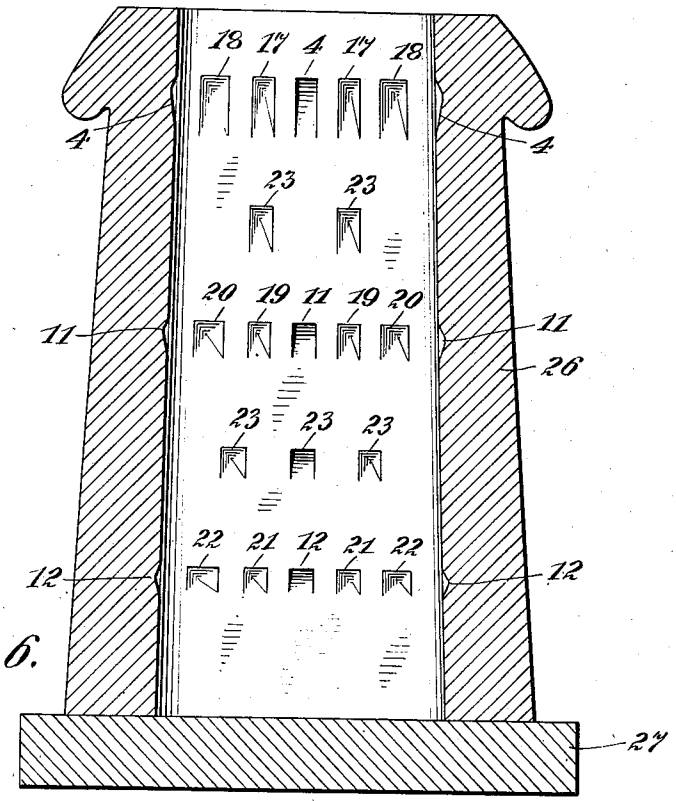


Fig. 6.

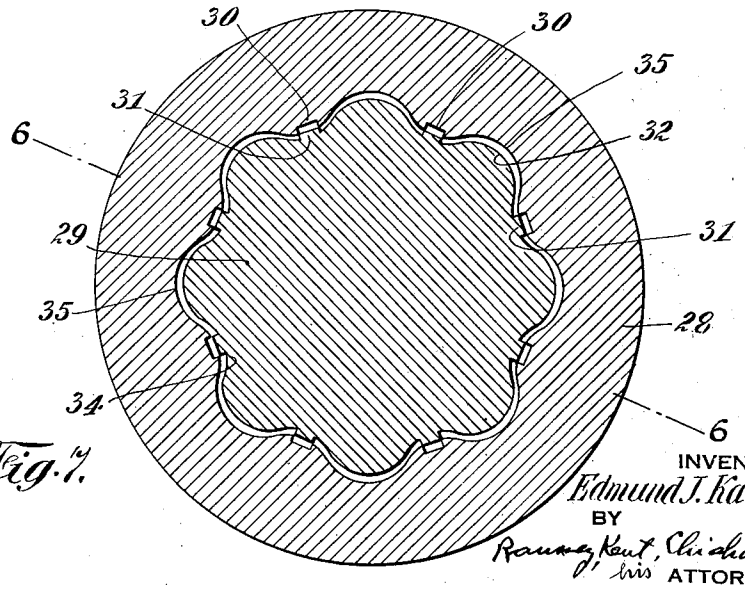


Fig. 7.

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INGOT POSITIONING MOLD

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Application October 25, 1938, Serial No. 236,833

8 Claims. (Cl. 22—139)

The present invention relates to metallurgy and more especially to ingot molds.

The primary object of the present invention is an ingot mold constructed in such manner as to cause an ingot cast therein to be automatically positioned within the ingot mold since as the ingot freezes and shrinks from the side walls of the mold an air gap is formed between the ingot and the mold.

Where an ingot is cast in a vertical metallic mold such as is customary in the art, the ingot shrinks vertically and laterally as it freezes and therefore the frozen ingot is of a lesser size than the matrix of the mold. The air gap thus formed between the ingot and matrix wall of the mold comprises a substantial heat insulation zone. The heat from the ingot in the air gap zone is transferred to the mold by radiation instead of by conduction which takes place so long as the ingot is in direct contact with the mold. The transfer of the heat by radiation is very much slower than by conduction. The solidified ingot frequently tips to one side and remains in contact with the matrix of the mold on one side thereof while increasing the air gap between the matrix of the mold and the other side of the ingot. The side of the ingot in contact with the mold loses its heat to the mold much more rapidly than the side of the ingot which is out of contact with the mold. This means unbalanced heat transfer which sets up unequal stresses both in the ingot and in the mold. The unequal stress conditions in the ingot tend to produce undesirable crystalline characteristics in the ingot and often results in surface cracks which may constitute substantial defects in the ingot. The unequal heating of the mold sets up unbalanced stresses which seriously affect the mold lift.

The present invention utilizes the shrinkage of the ingot in the mold to maintain the ingot positioned within the matrix so that an air gap is maintained around the ingot so long as the ingot remains in the mold.

All points on the molten ingot surfaces are initially common with all like points on the mold matrix surfaces. On the other hand, as the metal cools and progressively solidifies, consequent lateral and vertical shrinkages take place and all points of the ingot skin, from the plastic to rigid, move relatively with respect to like points in the mold matrix surfaces while at the same time these mold matrix points, because of the expansion of the mold matrix walls, are shifting their positions relative to those which they originally occupied at the initial instant of contact with the molten or liquid ingot metal.

The invention is embodied in an ingot mold more especially by providing cam surfaces on the mold which will form cooperating cam surfaces on the ingot, so that as the ingot shrinks in cooling, these cam surfaces move relative to each other and may be maintained substantially in contact. These cam surfaces may comprise either control protuberances on the side wall of the matrix of the mold or control recesses in the side wall of the matrix of the mold. Recesses are the preferred form of the invention for the reason that the molten steel extending into the control recesses chills more quickly than does the body of the ingot and, therefore, comprises protuberances of metal having a density greater than the metal in the body of the ingot and thereby capable of sustaining pressure which is transmitted to the body of the ingot. The cam surfaces are preferably shaped with regard to the shrinkage of the ingot relative to the location of the positioning control members in the matrix of the mold. The shrinkage of a steel ingot, while freezing from a liquid to a solid in the mold in which it is cast, is dependent upon several factors, such as the character of the steel, the temperature at which the steel is poured, the state of solidification of the ingot, and other factors, but may be stated roughly to theoretically be approximately one-eighth of an inch per linear foot at such time as the average ingot is ready to be stripped from the mold, therefore, a zone on a vertical ingot sixty inches from the bottom of the mold will shrink downwardly approximately five-eighths of an inch during this time. Assuming the transverse measure of the matrix of this illustrative mold, at this sixty-inch zone, to be substantially twenty-four inches and following the same rate of shrinkage, the transverse shrinkage of the ingot will, therefore, be one-quarter of an inch or one-eighth of an inch on each side of the ingot. If a control recess be provided in the mold wall at this sixty-inch zone and having a depth of substantially one-eighth of an inch, at its upper portion, and being wedge-shaped downwardly for a distance of substantially five-eighths of an inch, a protuberance cast on the ingot, by the metal flowing into the said recess, will slide downwardly and inwardly as the ingot shrinks and when the shrinkage has reached the total of one-eighth of an inch per foot, the protuberance or projection will substantially be resting on the matrix side wall of the mold.

The recesses in the matrix wall of the mold

may be positioned in such manner as to control the air gap relative to various portions of the ingot as described. If for example it is desired to cause a portion of the ingot to move away from the matrix mold wall prior to another portion, a recess is so located as to provide the desired effect. If on the other hand a uniform air gap around the ingot is desired the recesses may be diametrically opposed.

Usually the corners of a rectangular ingot cool first and tend to shrink away from the matrix of the mold before the side walls of the ingot leave the side walls of the matrix. Therefore, if the control recesses are located in the mid side walls of a substantially rectangular mold, the lateral shrinkage which occurs on each side will be toward the mid section thereof. Consequently, the bottom of such a mid recess need not be inclined or curved laterally. As to recesses which are provided near the corners, however, where shrinkage is substantial in a lateral direction, it is preferable that the bottoms of such recesses be inclined laterally as well as vertically in order to form cam surfaces against which protuberances or projections cast on the ingot may slide toward the mid portion of the side wall of the mold. The same result may be attained by a downwardly inclined direction to the corner recesses, so as to take care of both vertical and lateral movement of the ingot skin relative to the mold matrix.

Other and further objects of the present invention will in part be obvious and will in part be pointed out hereinafter in the specification following by reference to the accompanying drawings forming a part of this specification.

The disclosure herewith is to be understood as being illustrative and is not intended to be considered in a limiting sense in that the invention may be embodied in constructions which are specifically different but mechanically equivalent to those disclosed herewith.

Fig. 1 is a sectional view through a big-end-up ingot mold taken on line 1—1 of Fig. 2 with the ingot removed from the mold.

Fig. 2 is a cross-sectional view taken on line 2—2 of Fig. 1 and showing a cross-section through the mold and an ingot in the mold.

Fig. 3 is a detail view illustrating a cross-section, of a fragment of the mold and the fragment of an ingot, taken adjacent the recesses A (Fig. 1) after shrinkage to the ingot has occurred.

Fig. 4 is a detail view illustrating a cross-section of a fragment of the mold and the fragment of an ingot, taken adjacent the recesses B (Fig. 1) after shrinkage to the ingot has occurred.

Fig. 5 is a detail view illustrating a cross-section of a fragment of the mold and the fragment of an ingot taken adjacent the recesses C (Fig. 1) after shrinkage to the ingot has occurred.

Fig. 6 is a cross-section through a big-end-down ingot mold on line 6—6 of Fig. 7 with the ingot removed.

Fig. 7 is a cross-section through a substantially circular corrugated ingot mold and ingot in accordance with the present invention.

Referring now to the drawings and more especially to Figs. 1 and 2 which illustrate a big-end-up ingot mold 1 in which is shown in Fig. 2 an ingot of steel 2. The mold chosen for illustration is one wherein vertical dimensions are substantially those shown on Fig. 1 of the drawings and the matrix of the mold is substantially rectangular with lateral dimensions such as is indicated on Fig. 1 of the mold. The purpose and the use of dimensions in connection with this disclosure is to facilitate an explanation of the present invention.

The side walls of the matrix of the mold 1 are shown as being provided with control recesses which are well distributed over the side walls but in order to more clearly explain the present invention, three groups of recesses are prominently illustrated, with other recesses between these groups. The reason for selecting groups located at definite intervals within the mold is to be able to refer to definite dimensions and thereby clearly explain the present invention. The group A of recesses are illustrated as located at substantially sixty inches from the bottom of the matrix of the mold; the group of recesses B are located in a zone substantially forty inches from the bottom of the matrix; and the group of recesses C are located in a zone substantially twenty inches from the bottom of the matrix. The matrix of the mold is substantially square, on a horizontal cross-section, with its dimensions being substantially twenty-four and one-quarter inches adjacent the zone A of recesses; substantially twenty-four inches adjacent zone B and substantially twenty-three and three-quarter inches adjacent zone C. It is assumed for the purpose of illustrating the present invention that the type of steel to be cast in this mold 1 will be steel which shrinks substantially one-eighth of one inch for each linear foot when it freezes from a liquid state into a plastic solid and at the temperature at which ingots are usually stripped from the mold. It is recognized that the ferrostatic head of the molten steel causes the vertical shrinkage to be slightly greater than the lateral shrinkage so that the vertical shrinkage at the top of the ingot is slightly greater than one-eighth of an inch per foot, while the lateral shrinkage at the mid portion of the ingot is slightly less than one-eighth of an inch per foot and that this varies for different vertical portions of the ingot. For example, zones intermediate the top and bottom of the ingot may have less shrinkage than that at the top or bottom of the ingot. The present invention to be carried out on an enirely theoretical basis should include corrections for the conditions above specified. However, the invention may be efficiently carried out in practice without accurate adherence to theoretical conditions.

Considering for the moment the mid sections of each side of the mold, control recesses may be formed at these sections in accordance with the downward travel of a short line on the side of an ingot cast in the mold, for example, in the sixty-inch zone A, the mid control recess 4 may have a maximum depth of one-eighth of an inch which is one-half of the total lateral theoretical shrinkage of an ingot twenty-four and one-quarter inches square and the bottom of this recess shall slope as at 5 for a distance of five-eighths of an inch until it merges with the matrix side wall 6. The width of the control recesses 4 need not be of any definite fixed dimension although they should be sufficiently wide for the purpose intended but preferably not be so wide as to extend entirely around the mold since it is desirable to provide an open air gap into which air may flow as the ingot shrinks from the mold. Preferably, in the mold specified, the control recesses 4 are approximately from one-quarter of an inch to an inch in width. The upper end of

the recesses are inclined as at 7, at an amount of substantially less than 90° to the vertical, in order to produce an inclined surface 8 on the protuberance 9 formed on the ingot so that when the ingot is stripped from the mold by pressure on the plug 10 or otherwise, the protuberances 9 do not catch on abrupt shoulders or surfaces provided on the mold.

The control recesses 11, also located in the mid portion of the side wall, in the zone B may have a depth of one-eighth of an inch for the mold specified and a downward length of substantially three-eighths of an inch. The recesses 12 in the zone C may also have a depth of substantially one-eighth of an inch and a length in a downward direction of slightly less than one-quarter of an inch.

From the foregoing and from Figs. 3, 4, and 5, it will be observed that while the ingot has shrunk, the protuberances 9 have moved downwardly and inwardly from the maximum depth of the slots 4 to a position on the matrix side wall 6; that the protuberances 14 have moved from the recesses 11 downwardly and inwardly to a position adjacent the lower end of the control recess and on the side wall of the matrix 6; and that the protuberances 15 have moved downwardly and inwardly out of the recesses 12 to a position on the matrix side wall 6. As the protuberances have moved out of the control recesses, it will be observed that the space maintained entirely around and between the side wall 16 of the ingot 2 and the matrix side wall 6 is substantially one-eighth of an inch. The ingot is now definitely positioned in the matrix due to the shrinkage of the ingot in the matrix and the camming of the protuberances 9, 14, and 15 from the recesses 4, 11, and 12 as the ingot has shrunk.

The ingot shrinks laterally as well as vertically. The recesses 17 and 18 in the zone A and on each side of the recesses 4, and the recesses 19 and 20 in zone B and on each side of the recesses 11, and the recesses 21 and 22 in the zone C on each side of recesses 12, are preferably provided with inclined sides as is illustrated at 24 and 25 in Fig. 2. The slope of the sides 24 and 25 toward the mid-control recesses 4, 11, and 12 is preferably proportioned to the shrinkage values so that the ingot protuberances from these recesses move both downwardly and laterally in contact with the control recesses until the ingot protuberances have substantially left the recesses and rest against the matrix side walls. The other side of these recesses may also be sloped if desired.

It may be remarked also that in Fig. 1 and also in Fig. 6, intermediate recesses 23 are illustrated and are formed on the same basis principle as are the recesses previously described. These intermediate recesses act the same as the control recess specifically described above.

The usual stripping temperature for steel ingots is generally in the neighborhood of 1400° F., however, ingots are often stripped in practice at temperatures varying from 1000° to 1800° F., and ingots are also stripped at room temperature. At these varying temperatures, the shrinkage of the ingot relative to the mold matrix varies. The present invention has such limits of tolerance that it may readily be adapted to suit limit conditions as above suggested.

The depth of the control recesses may be varied between one-one hundred and twenty-five thousandths (.125") of an inch to six hundredths (.06") of an inch and still obtain satisfactory results on ingots of the dimensions of the illustrative ingot herein specified. It is to be understood that larger or smaller ingots require proportional corrections in accordance with this invention. While the drawings, as a matter of illustration, exaggerate the size and depth of the recesses and indicate sharp corners and angles to these recesses, it is to be understood in practice that the recesses are relatively shallow and that sharp corners and sharp angles are to be avoided.

In practice, this invention may be carried out without closely following the theoretical specific dimensions herein set forth and it is possible to obtain a substantial benefit even where the control recesses are all the same shape and size. The depth of the recesses need not approximate the full shrinkage of the metal adjacent thereto, however, in all cases the recesses are to be less than the shrinkage. The object to be attained is that there will always be some air gap formed at the zone or place where an air gap is desired. An air gap of any appreciable amount is a substantial heat insulator and accordingly the present invention may be carried out with a non-uniform air gap around the ingot.

Fig. 6 illustrates a big-end-down mold 26 adapted to set on a stool 27 and equipped with control recesses according to the present invention. Since the recesses are substantially the same as those shown in Fig. 1, the same designating characters are used. The stripping taper in a big-end-up mold is upward and outward, while in a big-end-down mold, the taper is upward and inward, therefore, slight corrections may be made in the length of the control recesses when used in a big-end-down mold, however, the amount of taper is so small in the length of a control recess that the present invention may be practiced successfully by substantially ignoring this factor.

Fig. 7 illustrates a substantially cylindrical corrugated ingot mold 28 showing a cross-section of an ingot 29 therein. In this type of mold, the recesses 30 may be placed so as to produce protuberances 31 on the ingot 29 on either the tops 32 of the corrugations or in the valleys 34. Preferably, however, the recesses 30 are located in the valleys 34 for the reason that the tops 32 of the corrugations tend to cool before the valleys and tend to shrink away from the matrix side wall 35 before the valleys leave the matrix side walls. Therefore, as the ingot shrinks vertically, the protuberances 31 on the ingot tend to move out of the recesses 30 and to push the valleys away from the matrix side walls. This positions the ingot 29 within the mold 28 and establishes the desired air gap around the ingot. In view of the fact that the ingot is substantially circular, the side walls of the control recesses 30 do not necessarily need to be wedge-shaped in two directions as is the case of certain of the recesses in Figs. 1 and 6.

Where substantially rectangular cross-section matrix molds are provided with corrugations, the recesses may be located in the mold so as to place the protuberances on the tops of the corrugations on the ingot or in the valleys. Preferably, however, as is shown in Fig. 7, the recesses are located so as to produce the protuberances in the valleys of the ingot.

The disclosure herewith shows the recesses in the mold as being located more or less in definite zones in the matrix. This is the preferred form of the invention and such a disclosure is help-

ful in explaining the invention. It is to be understood, however, that these recesses may be located in the matrix without regard to a definite geometric arrangement and without reference to definite zones, the location of the recesses being in accordance with that portion of the ingot adjacent which an air gap is desired.

What I claim is:

1. A vertical ingot mold adapted to be predeterminedly position an ingot cast in said mold comprising: a body portion having a mold matrix, a plurality of cam surfaces on the mold and within the matrix to form complemental cam surfaces on an ingot cast in said mold, said cam surfaces on the mold consisting of the bottoms of recesses in the matrix wall and being generated in accordance with the movement of short lines on an ingot as said ingot is solidifying in said mold, the cam surfaces in the upper portion of the matrix being longer in a vertical direction than the cam surfaces in the lower portion of the matrix.

2. A vertical ingot mold for predeterminedly positioning ingots cast in the mold comprising: a body portion having a mold matrix wall, the major portion of said wall being provided with diametrically located recesses adapted to form and chill protuberances on ingots cast in said mold, the bottoms of said recesses comprising cam surfaces generated in accordance with the movement of the protuberances on the ingot relatively to the mold matrix as the ingot is solidifying in the mold and whereby the protuberances and the cam surfaces remaining substantially in contact and the vertical axis of the ingot is maintained substantially coincident with the vertical axis of the mold while the ingot is solidifying.

3. A vertical ingot mold for predeterminedly positioning portions of ingots cast in the mold comprising a body portion having a mold matrix wall, said wall being provided with recesses having a maximum depth slightly less than one-half the lateral shrinkage of an ingot at the zone of location of the corresponding recess and having a length substantially equal to the vertical shrinkage of the ingot at the zone of location of the corresponding recess, the bottom of each recess tapering from said maximum depth to the face of the matrix wall.

4. An ingot mold for predeterminedly positioning steel ingots cast in the mold comprising a body portion having a matrix therein, control recesses provided in said matrix, the combined depth of said control recesses on opposite sides of a mold being between the limits of .125 of an inch to .06 of an inch for each foot of ingot cross-section substantially directly in front of said recesses.

5. An ingot mold for predeterminedly positioning steel ingots cast in the mold comprising a body portion having a matrix therein, control means on the side walls of said matrix, said control means being adapted to establish an air gap adjacent said control means as the ingot freezes in the mold, said air gap being slightly less than one-half the total shrinkage of the mass of metal directly in front of said control means.

6. An ingot mold for predeterminedly positioning a steel ingot cast in the mold comprising a body portion having a matrix therein, control means on the side walls of said matrix to form complemental control means on the ingot to establish an air gap adjacent said complemental control means as that portion of the ingot moves relative to the matrix as the ingot shrinks in the mold, the depth of control means being from .0625 of an inch to .03 of an inch for each foot of steel directly in front of said control means.

7. In a vertical ingot mold for predeterminedly positioning a portion of an ingot cast in the mold relatively to the mold matrix, said mold comprising a body portion within which is provided a matrix having vertically undulated side walls, control means on the side walls of said matrix to establish a predetermined air gap adjacent said control means as the ingot freezes in the mold, said control means being located on the crests of the undulation in the mold to form complemental control means in the valleys of the undulations on the ingot.

8. In a vertical ingot mold for predeterminedly positioning a portion of a steel ingot cast in the mold relatively to the mold matrix, said mold comprising a body provided with a matrix having vertical undulations on the side wall thereof to produce complemental undulations on an ingot cast in said mold, and control means in the mold matrix to produce complemental control means on the ingot to cause the valleys on the ingot surface to move away from the crests on the matrix wall of the mold as the ingot freezes.

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