July 20, 1943. L. B. LINDEMUTH 2,324,786

INGOT MOLD

Filed Dec. 11, 1941 3 Sheets-Sheet 1

Fig. 1.

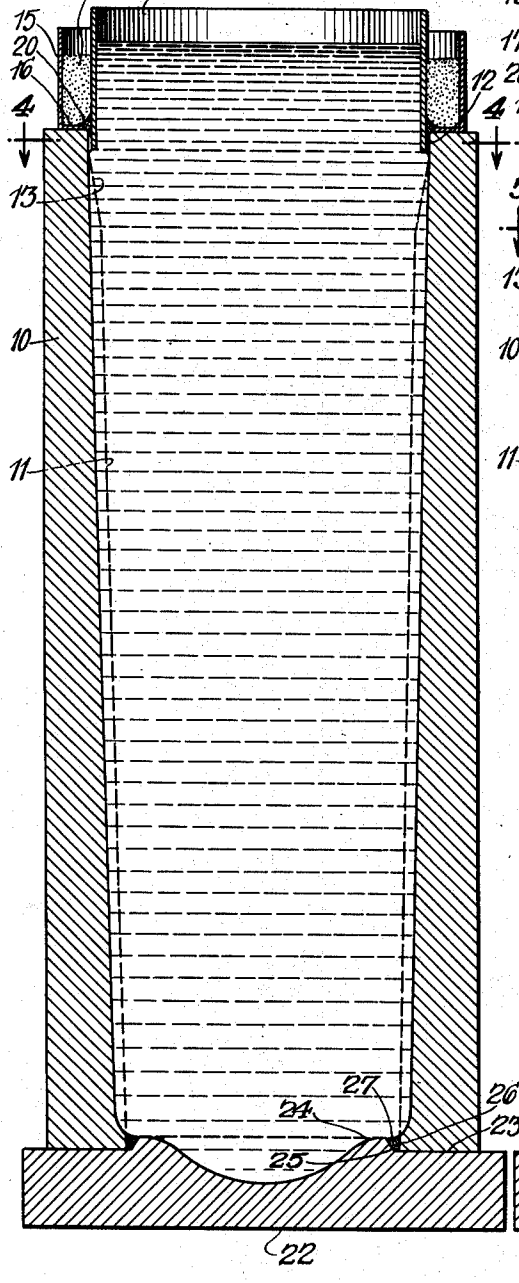
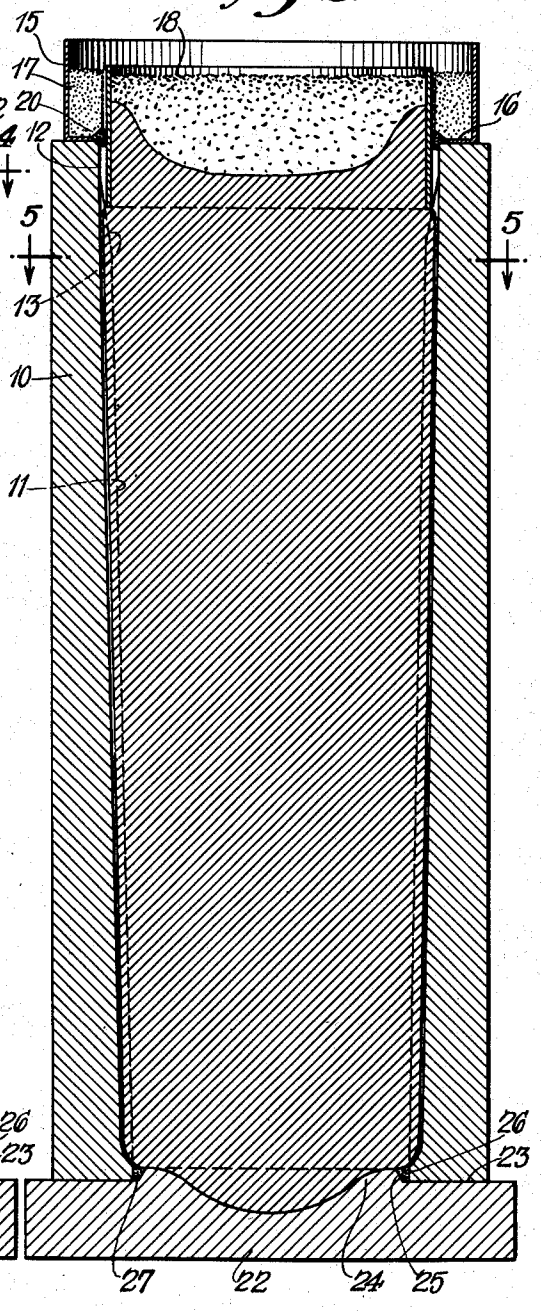


Fig. 2.



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Fig. 3.

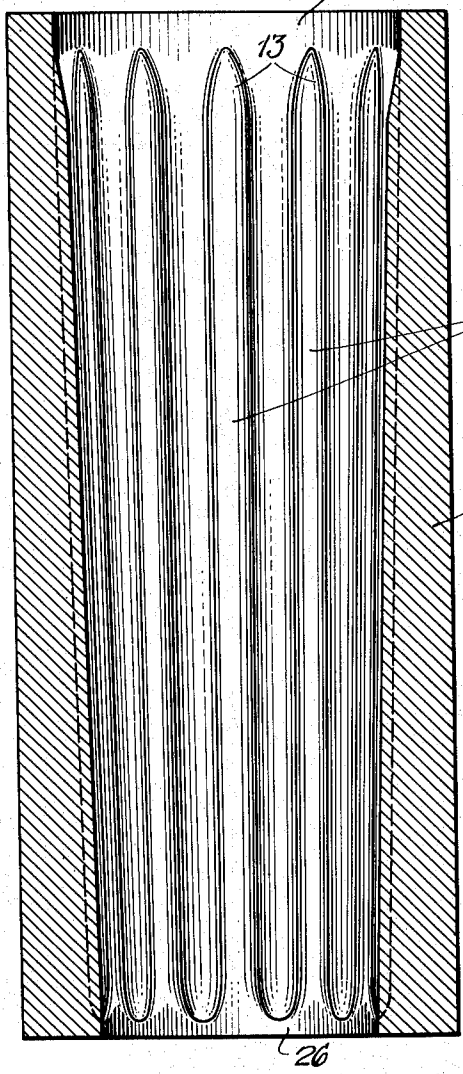


Fig. 4.

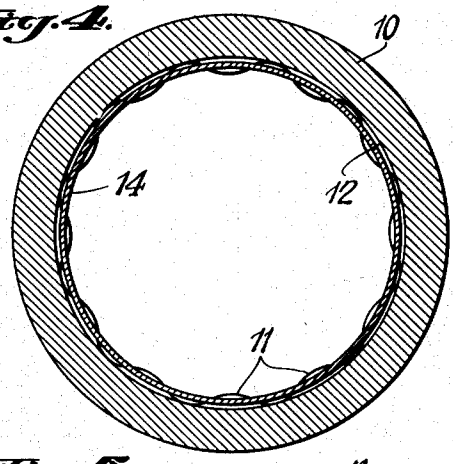


Fig. 5.

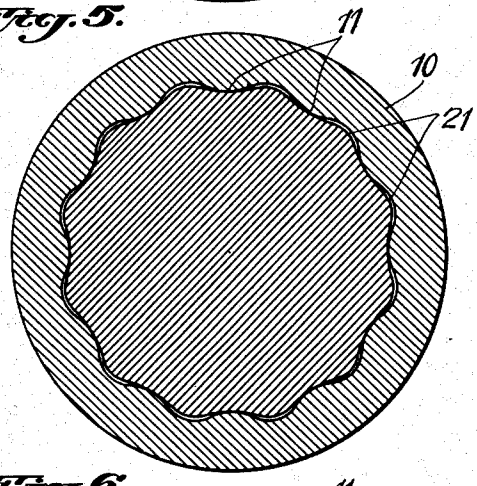


Fig. 6.

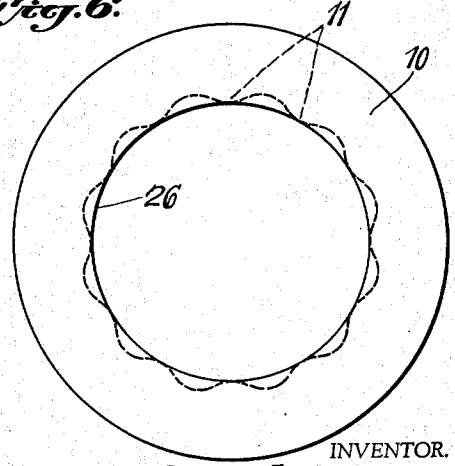
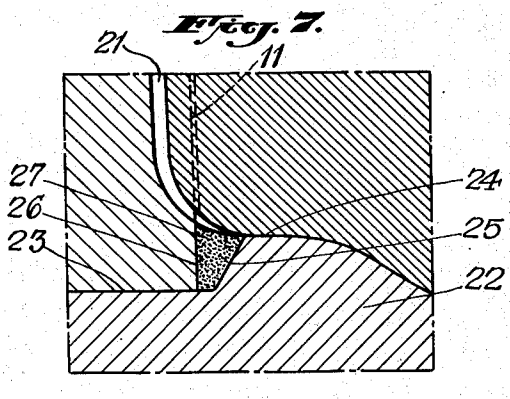


Fig. 7.



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Fig. 8.

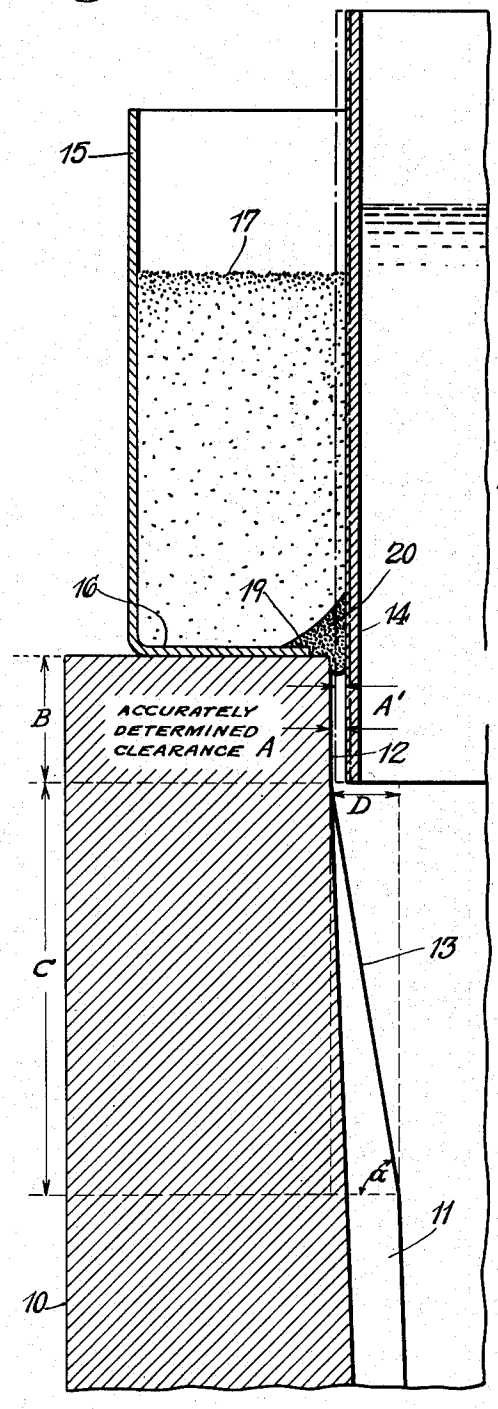
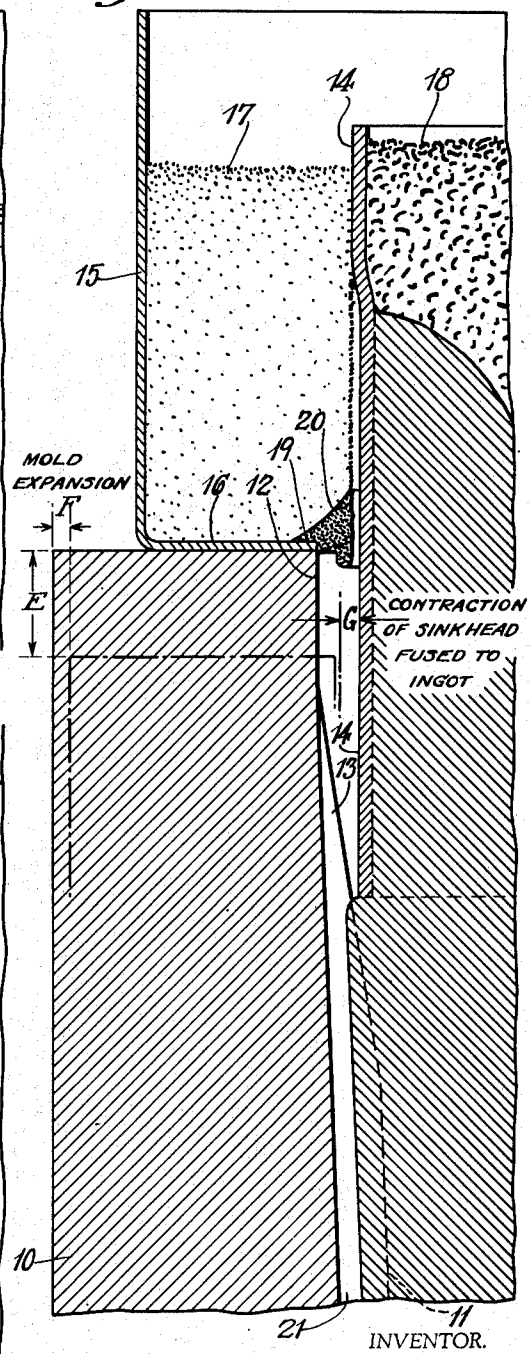


Fig. 9.



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UNITED STATES PATENT OFFICE

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INGOT MOLD

Lewis Byron Lindemuth, Port Washington, N. Y.

Application December 11, 1941, Serial No. 422,465

5 Claims. (Cl. 22—139)

This invention pertains to the production of metal ingots, and more especially to improvements in the construction and arrangement of ingot molds and associated sinkheads, for producing sound metal ingots free from cracks, fissures or other surface flaws.

Ingot molds having a corrugated or fluted interior are preferred for casting large ingots, because they minimize the tendency of the ingot to crack on cooling and solidifying. If, for example, the mold were of circular section, the ratio of the perimeter to cross-sectional area of the ingot would be a minimum, so that there is no excess surface metal to draw upon as the outer portion of the ingot tends to cool and contract uniformly against its still molten interior. Cracks and fissures therefore develop. With the corrugated or fluted mold, on the other hand, the perimeter is greatly increased in relation to the cross-sectional area, so that as the ingot metal cools, it may contract initially at the outer vertices of the corrugations or flutings, and in this way eliminate any tendency to crack.

In the casting of sound metal ingots, it is desirable, for reasons well understood, to provide the mold with a hot top or sinkhead in which the piped portion of the ingot, containing the segregations, etc., is formed, and which is subsequently cropped off. In accordance with certain constructions, these sinkheads may comprise molded and baked forms of fire clay and the like, which are supported on the upper edge of the mold, and the molten ingot metal poured in until it rises to a level within the sinkhead. On subsequent cooling, the ingot metal contracts in the longitudinal as well as in the radial direction, and, if this type of sinkhead is employed in conjunction with the corrugated or fluted mold, fins of the ingot metal may solidify between the sinkhead and the upper edge of the mold, or over the abrupt shoulders formed by the upper surfaces of the mold corrugations or flutings, whereby uniform longitudinal contraction of the ingot on cooling is prevented and transverse cracks develop along its length. It would, of course, be entirely too expensive to attempt to conform the shape of sinkheads of this type to the flutings or corrugations in the mold, since both the sinkheads and the molds themselves are formed by molding or casting, in consequence of which slight irregularities in the corrugations or flutings will inevitably occur.

In my Patent 1,332,905, I have disclosed a sinkhead construction consisting of a strip of sheet metal which is bent into tubular form with the overlapping edges riveted or welded, and which is made of such a contour as to fit within and to initially frictionally engage the upper interior wall of the mold. With this type of sink-head so disposed, the molten ingot metal is poured until it rises to a level within the sinkhead, whereupon on cooling and solidification of the ingot, the sheet metal sinkhead becomes welded thereto and slides downwardly in the mold along with the ingot as the latter contracts longitudinally. It will be evident that the employment of this type of sinkhead in conjunction with the corrugated or fluted type of mold would eliminate the development of cracks and fissures in the ingot on cooling. It is, however, both difficult and expensive to form the sheet metal hot top with the requisite corrugations or flutings to fit those of the mold, since, as stated, the latter are subject to slight variations owing to formation by casting. Moreover, with the corrugated or fluted sheet metal sinkhead, crevices would tend to develop between the sinkhead and the mold walls during casting, as a result of uneven expansion, buckling, etc., whereby the packing of sand ordinarily employed about the sinkhead, as set forth in the aforesaid patent, would tend to fall between the mold and ingot and contaminate the ingot surface. A sheet metal sinkhead of circular section would be much cheaper and easier to fabricate and fit into the mold, without buckling during casting, provided the corrugated or fluted type of mold could be appropriately modified to employ the same.

In accordance with a feature of the present invention, I propose to accomplish this result by making the interior wall of a corrugated or fluted mold of circular section at its upper edge, as for example by machining in the upper edge an annulus to a depth of an inch or so and of a diameter corresponding to the outer vertices of the mold corrugations or flutings. This modification alone, however, would terminate the corrugations or flutings in abrupt shoulders on which the sheet metal sinkhead would rest, and over which the molten ingot metal would flow and solidify to prevent longitudinal contraction of the ingot on cooling, with consequent cracking. To prevent this, I propose further modifying the mold by terminating the corrugations or flutings in a gradual taper as they approach the aforesaid annular portion. That is to say, commencing at a height somewhat below the annulus, the inner vertices of the corrugations or flutings are gradually reduced in size toward the top of the mold, or are gradually tapered upwardly and

outwardly until they substantially merge in the smooth annulus which receives the sinkhead. This taper is so proportioned, as explained below, that, as the ingot contracts both radially and longitudinally on cooling, its upper end, having the annular sinkhead welded thereto, may pass easily downward over the tapered portion of the flutings without any binding or jamming.

The sheet metal annular sinkhead employed is preferably made of slightly smaller diameter than the annular portion of the mold to provide a clearance at room temperature such that during pouring of the ingot, the sinkhead will expand initially against the mold, but will not bind the same too tightly although slight binding is inconsequential since no buckling can occur in view of the circular section employed. On subsequent cooling and solidification of the ingot, the sheet metal sinkhead will, as stated, become welded thereto and will contract radially and be drawn down into the mold along with the ingot as the latter contracts both radially and longitudinally, but in such manner that neither the ingot nor the sinkhead will bind or jam against the mold. The sinkhead may be surrounded with a sand box, such as that disclosed in my patent aforesaid, and a packing material of sand, etc., may be employed for filling the space between the sand box flange and the sinkhead, together with a luting of asbestos rope, clay, etc., for closing off the clearance space between the sinkhead and mold, and to retain the sinkhead in proper position in the mold during pouring.

The molds employed for casting large ingots are usually open at both ends, and the casting effected by standing the mold on a cast iron base or "stool." If, however, any of the molten metal seeps between the base of the mold and the stool, it forms a fin on solidifying, which prevents the ingot from being lifted out of the mold without injury. In accordance with a further feature of my invention, I propose to overcome this defect by providing the stool with a raised or elevated portion adapted to fit loosely within the base of the mold, and by filling in the intervening space or crevice with some powdered material which does not contaminate the ingot metal, such as ferro-silicon, ferro-chrome, ferro-manganese, etc., in the casting of steel ingots. However, in the case of a corrugated or longitudinally fluted ingot, it is difficult and expensive to form this raised portion of the stool with corresponding corrugations or flutings in such manner as to eliminate binding, because both the mold and the stool are formed by casting, so that slight irregularities in the corrugations, etc., inevitably occur. Also it is difficult in placing the mold on the stool to properly line up the corrugations or flutings in the mold proper with those in the stool.

I overcome this difficulty by making the mold of circular section at its base, which is accomplished by gradually tapering the outer vertices of the mold corrugations or flutings, inwardly to the diameter of the inner vertices thereof at a point somewhat above the lower edge of the mold, and by imparting a circular section to the mold between this point and the lower edge. The raised portion of the stool may now likewise be made of circular section and of such diameter as to fit loosely within the circular base of the mold, so that the mold may be easily placed in position over the raised portion of the stool. To further facilitate this, I impart slight, opposite, conical tapers to the circular base of the mold and the raised portion of the stool, the mold being tapered downwardly and inwardly, and the stool upwardly and inwardly. The taper on the elevated portion of the stool is made sufficiently great, as explained below, that as the ingot shrinks, it can not bind or tear. There is nothing critical as regards the taper employed at the base of the mold for tapering the outer vertices of the corrugations or flutings to the inner vertices thereof, such as is encountered in connection with the above-mentioned taper at the top, because no binding can occur in the corrugations or flutings at the base of the mold as a result of shrinkage and contraction of the ingot. The circular tapered portions at the base of the mold and in the elevated portion of the stool need not be machined. Sufficient clearance can be provided so that ordinary casting suffices, owing to the tolerance available. As before, the crevice occurring between these tapered circular portions of the mold and stool is filled in with some powdered material which does not contaminate the ingot, such as ferro-silicon, etc., in the casting of steel ingots. With this construction and arrangement of the mold and stool, no fins of ingot metal can form and solidify therebetween to bind the ingot to the mold. Accordingly, the ingot may be easily removed from the mold when sufficiently solidified.

Various further and more specific objects, features and advantages will appear from the detailed description given below taken in connection with the accompanying drawings which form a part of this specification and illustrate merely by way of example, a preferred form of the invention. The invention consists in such novel features, arrangements and combinations of parts as may be shown and described in connection with the constructions herein disclosed.

In the drawings, I have shown the ingot mold as of the inverted or "big end up" corrugated cylindrical type, but various features of invention may be used in connection with other types of molds with either the large, or the small end uppermost, and of various cross-sectional shapes such as square, octagonal, etc.

In the drawings—

Fig. 1 is a vertical sectional view of an ingot mold and accompanying parts embodying the invention, the mold being shown as filled with molten metal;

Fig. 2 is a view similar to Fig. 1, but with the parts in the position which they will assume upon cooling and contraction of the ingot;

Fig. 3 is a vertical sectional view of the upstanding tubular portion of a corrugated type ingot mold embodying features of the invention;

Figs. 4 and 5 are sectional views taken respectively along lines 4—4 and 5—5 of Figs. 1 and 2;

Fig. 6 is a bottom view of the mold portion of Fig. 3;

Fig. 7 is an enlarged sectional view of a portion shown at the bottom of Fig. 2;

Fig. 8 is an enlarged view of a portion at the top of Fig. 1; and

Fig. 9 is an enlarged view of portions at the top of Fig. 2.

Referring to the drawings in further detail, a tubular upstanding portion 10 of the mold is made, for example, of cast iron, and has interior walls formed with corrugations as at 11. (The term "corrugations" herein is intended to include flutes of various types.) Except at the top and bottom portions of the molds, the corrugations may be of suitable well-known dimen-

sions and shapes. At the top, the wall area, to a depth B (Fig. 8) is formed into a smooth annulus, as at 12, this portion of the mold cavity preferably being of a diameter about equal to the diameter of the adjacent corrugated areas as measured at the deepest parts or outer vertices of the corrugations. Also this area is preferably finished to accurate dimensions as by machining. Starting at a region substantially below the lower edge of the area 12, the corrugations as shown are gradually reduced in size toward the top, as by a gradual taper 13 upwardly and outwardly of the mold, until they merge smoothly into the annular area.

A sheet metal sinkhead 14 is adapted to have its lower portion inserted to the depth B within the upper end of the mold. Such sinkheads may be made by bending relatively thin sheet metal into a tubular shape and finishing same for accurately corresponding as to shape, to the smoothly finished area 12. For a relatively large ingot mold, 18-gauge sheet steel for example, will be satisfactory for such sinkheads. As distinguished from the sinkheads of the above mentioned patent, according to the present invention the sinkheads are preferably made of a size to normally provide, when the parts are cool, a predetermined clearance space A (Fig. 8) between the non-corrugated mold wall area and the external surface of the inserted portion of the sinkhead. This clearance space should be rather accurately determined so that when the sinkhead first reaches about its maximum temperature during pouring, it will substantially fit within the non-corrugated top of the mold. That is, the sinkhead being of relatively thin sheet metal, will quickly become heated and thus will expand more rapidly than will the mold which has a much larger mass. Hence the clearance space should be so determined that the sinkhead will at no time expand enough to more than slightly bind temporarily within the top of the mold. Thus not only will danger of buckling be avoided, but at the time when the mold is at first filled with molten metal, the clearance space will either be at a minimum or disappear entirely. Ordinarily a clearance of about ⅛ inch all around, when the parts are at room temperatures, will be sufficient for this purpose. But it will be appreciated that accurate determination of the proper clearance will depend upon the dimensions of the sinkhead and mold parts, as well as the temperature of the metal being poured into the mold.

The portion of the sinkhead protruding from the mold may be surrounded by a box-like structure including for example a cylindrical sheet metal wall 15 formed with an inturned bottom flange 16 resting on the top of the mold. This structure provides a receptacle surrounding the sinkhead for containing fine sand or other suitable heat insulating material as at 17 for preventing too rapid cooling of the sinkhead portion of the casting. For the same purpose the upper open end of the sinkhead after pouring may be filled with a suitable known granulated cork material, as at 18. The inner edge 19 of the flange 16 is preferably cut to a diameter so that it will be spaced substantially from the sinkhead and the intervening space will be filled with a suitable packing 20 formed for example of clay or asbestos rope. It will be noted that this packing will further serve to close off the top of the clearance space A.

When the parts are initially put in place, they will assume the position shown in Figs. 1 and 8, with the packing 20 retaining the sinkhead at the proper elevation. Thereupon when the molten metal is poured into the mold, the sinkhead will quickly expand in diameter by an amount at least as much as indicated at A' (Fig. 8) before the mold expands substantially. Then the mold will ultimately expand in height and radially, by amounts such as indicated at E and F respectively (Fig. 9). Subsequently as the external shell of the sinkhead portion of the ingot solidifies, it will fuse or weld to the sinkhead and cause contraction of the latter by an amount such as indicated at G (Fig. 9). Meanwhile and subsequently, as the ingot becomes cooler, it will contract in height as well as in cross section, so that its upper end portions will assume positions such as shown in Fig. 9. That is, at least the more protruding portions of the corrugated side walls of the ingot will become spaced as at 21 from the more deeply recessed portions of the corrugations on the mold walls, and also the upper portion of the ingot and the sinkhead welded thereon will have slid down with respect to the upper end of the mold to positions as shown.

If the upper ends of the corrugations 13 terminated abruptly, it will be apparent that opportunity would be afforded for a fin to form on the ingot extending out over the tops of the corrugations at the lower edge of the sinkhead. And in that event the ingot could not shrink down to the position shown in Fig. 8 without fracture, etc. However, with the gradually tapered upper end portions 13 of the corrugations, the ingot is free to contract vertically and in width without jamming at any point. To achieve this result, the slope or angle of the tapered portions 13 should at least exceed a predetermined degree, dependent upon the height and diameter or width of the mold. That is, with the depth of corrugations D as indicated, and with the taper extending down for a distance C as indicated, the angle of the slope with respect to the horizontal as indicated at a, should be such that its tangent

$$\frac{C}{D}$$

is at least equal to the ratio of the height of the main body of the ingot to its width. If the angle of the taper is less than this amount, then there will be danger when the ingot shrinks in height, that the lower edge of the sinkhead may at some points jam against the tapered portions of the corrugations. For example, if the mold is five times as hight as its width, then the slope should have a maximum ratio of about 5:1. In that case, a slope ratio of 4:1 would not be sufficient, although a smaller ratio of, say, 6:1 would be satisfactory. The dimension C will of course depend upon the depth of the corrugations.

After the ingot is solidified, it may be removed from the mold by grasping the projecting portion of the sinkhead with lifting dogs or tongs.

The molding portion 10 is adapted to rest upon a cast iron stool as at 22. As shown, this stool is formed with a flat annular peripheral area 23 upon which the lower edges of the portion 10 are adapted to rest. Inside this peripheral area, the stool may be formed with a raised area 24 which preferably joins the peripheral area by a tapered annular area 25 inclined upwardly and

inwardly from the vertical by about 15° for example. Within the lower end of the portion 10, the deepest portions of the corrugations are preferably tapered downwardly and inwardly of the mold until they merge to form an annular non-corrugated surface as at 26 around within the bottom edge of the mold, i. e., a surface from which the corrugations have disappeared. The diameter of this non-corrugated annular surface is preferably about the same as the minimum diameter of the mold cavity as measured at the inner vertices of the mold corrugations, and the annular portion is slightly tapered downwardly and inwardly, as will be apparent in Fig. 6. Also this diameter is preferably such as to provide a substantial clearance space 27, of for example about ¼ inch, around the raised area 24 on the stool, in order to enable the mold to be easily placed on the stool.

This clearance space 27 is adapted to be filled with a suitable luting material which will not contaminate the molten metal. For example, in the casting of steel ingots, powdered ferro-silicon or the like may be used for this purpose, since it will not injure the steel if some of it should get into the molten metal in view of the fact that all steel contains a certain amount of silicon. Finely divided ferro-manganese, ferro-chrome, etc., may also be used, as well as other materials, provided the ingredients thereof are selected from among the materials present in the molten metal for which the mold is intended to be used.

The constructional features as above described at the bottom of the mold are such as to prevent any danger of formation of a radially-extending fin between the stool and the body portion of the mold. Any such fin would of course prevent the ingot from being removed upwardly from the mold without breakage. The corrugated wall surfaces within the lower end of the mold as tapered downwardly and inwardly (as contrasted with an opposite form of taper at the upper end) make it possible for the lower end of the mold cavity to be non-corrugated while enabling the ingot to be removed upwardly. This non-corrugated area enables the mold to be lowered into proper position on the stool without danger of jamming or breaking any protruding portions of corrugations, and also makes it possible to more easily apply the luting material without danger of leaving irregular gaps which would afford space for fins or protruding portions on the ingot. The inclined position of the surface 25 on the stool insures against any danger of binding or tearing of the ingot when it is removed in the event some of the molten metal should extend down into the clearance space 27.

It will be apparent that if a mold is to be used of the type having its smaller end uppermost, then the corrugations should be tapered downwardly and outwardly at the bottom, and the wall surfaces between corrugations should be tapered upwardly and inwardly at the top, i. e., the construction would then be substantially that of Fig. 3 as viewed upside down.

While the invention has been described in detail with respect to particular preferred examples, it will be understood by those skilled in the art after understanding the invention, that various changes and further modifications may be made without departing from the spirit and scope of the invention, and it is intended therefore in the appended claims to cover all such changes and modifications.

Features relating to the lower portion of the mold and stool are disclosed and claimed in my divisional copending application Ser. No. 489,365, filed June 2, 1943.

What is claimed as new and desired to be secured by Letters Patent is:

1. In combination, a corrugated ingot mold formed with a non-corrugated area around within its top, a sheet-metal sinkhead having a portion of a size and shape to substantially fit within said area during the pouring, but normally separated therefrom by a clearance space, the mold corrugations, starting at a region substantially below said area, being so formed as to gradually taper in an upward and outward direction until they substantially disappear at the lower edge of said area, the angle of the taper being such that upon cooling of the ingot, the sinkhead and adjacent tapered corrugated portions of the ingot are free to move downward in the mold to the extent occasioned by shrinkage, without substantial jamming against the tapered corrugated portion of the mold.

2. An ingot mold having interior walls formed with corrugations extending from the lower portion of the mold up to a non-corrugated area extending around within the top of the mold for conforming to a sheet metal sinkhead, said non-corrugated area extending down only to about the normal depth of initial insertion of such sinkhead, the corrugations, starting at a region somewhat below said area, being so formed as to gradually taper in an upward and outward direction until they substantially merge into said area, the angle of the taper with respect to the horizontal, being such that its tangent substantially equals or somewhat exceeds the ratio of the height to the width of the mold cavity, whereby upon cooling and shrinkage of the mold, and of an ingot and such a sinkhead therein, the sinkhead may be drawn down within the region of the tapered corrugations without substantial jamming.

3. An ingot mold having interior walls formed with corrugations extending from the lower portion of the mold up to the sinkhead portion at the top of the mold, the wall area around within said latter portion being non-corrugated for conforming to a sheet metal sinkhead, the upper ends of said corrugations, at the region adapted to receive the lower edges of the sinkhead during cooling and shrinkage of the ingot, being gradually tapered upwardly and outwardly until such upper ends substantially merge into the non-corrugated area, to avoid jamming against the sinkhead when the latter is drawn down into said region during such cooling.

4. In combination, an ingot mold having interior walls formed with corrugations extending from the lower portion of the mold up to the sinkhead portion at the top of the mold, the wall area around within said latter portion being non-corrugated, a sheet metal sinkhead having a portion of a size and shape to substantially conform to and fit within said area during the pouring, but normally separated therefrom by a clearance space, the upper ends of said corrugations, at the region adapted to receive the lower edges of the sinkhead during cooling and shrinkage of the ingot, being gradually tapered upwardly and outwardly until such upper ends substantially merge into the non-corrugated area, to avoid jamming against the sinkhead when the latter is drawn down into said region during such cooling.

5. A corrugated ingot mold member within the upper end of which, the corrugations gradually

taper in an upward and outward direction until they merge into a smooth wall area around within the top of the mold cavity, the wall surface portions between corrugations within the bottom end of the mold, being tapered in a downward and inward direction until they merge into a smooth wall area around within the bottom of the mold cavity, the latter smooth wall area defining a bottom opening for the mold member, said opening having a cross section approximately the same as the cross section of the lower corrugated portion of the mold cavity exclusive of the channel spaces between corrugations.

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