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B. M. SHIELDS
METHOD OF PRODUCING SOUND INGOTS OF FULLY
KILLED STEEL IN BIG-END-DOWN MOLDS
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FIG. 1.

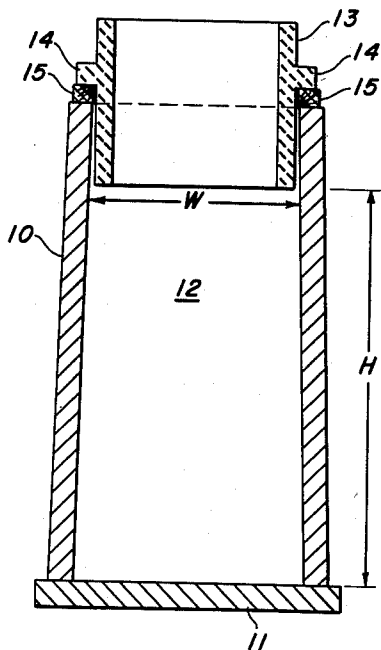


FIG. 2.

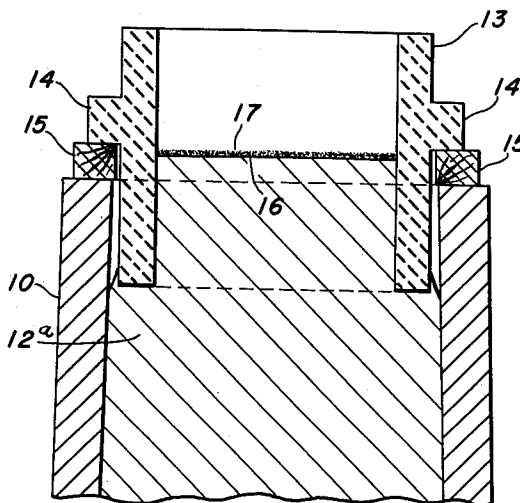


FIG. 4.

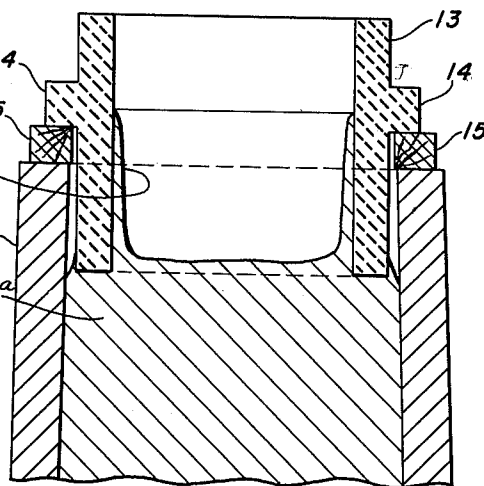
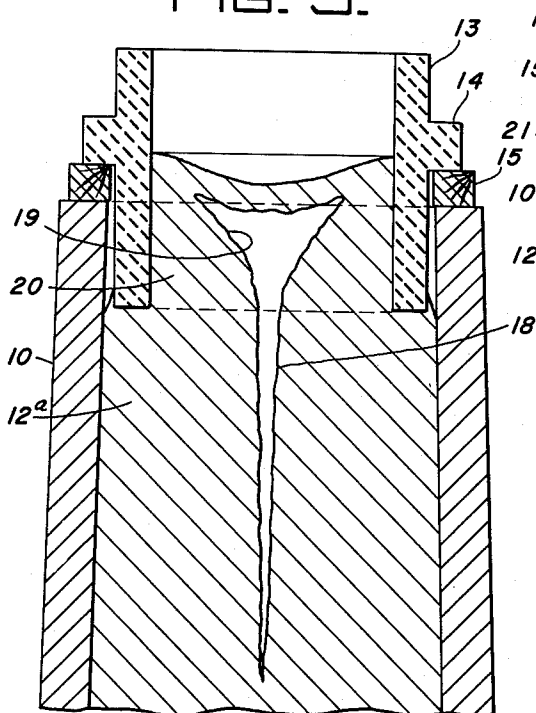


FIG. 3.



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METHOD OF PRODUCING SOUND INGOTS OF FULLY KILLED STEEL IN BIG-END-DOWN MOLDS

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2 Claims. (Cl. 22—215)

This invention relates generally to the ingot practice in steel production and, in particular, to a method of treating fully killed steel cast in big-end-down (B. E. D.) molds, so as to produce ingots which are sound throughout a great portion of their height, giving a high yield.

Fully killed steel exhibits pronounced shrinkage on solidifying, leading to the formation of a cavity or so-called "pipe," in ingots thereof cast in conventional B. E. D. molds. Attempts have been made to reduce pipe or shrinkage cavities by using some variety of an insulating hot-top to maintain a sinkhead above the mold during cooling of the ingot. This practice, however, has not proved effective. Accordingly, it has long been held that it is impossible to achieve an economically acceptable ingot-to-bloom yield by teeming fully killed steel into B. E. D. molds, because the secondary pipe which forms in the ingots even when hot-topping is practiced, necessitates excessive cropping (Gathmann, "The Ingot Phase of Steel Production," 2d ed., pp. 18, 19, 33, 34, 110; "The Making, Shaping and Treating of Steel," 6th ed., p. 574). Big-end-up (B. E. U.) molds have therefore been recommended and are universally employed for making ingots of killed steel, where freedom from pipe is required, despite the difficulty thereby introduced in respect to stripping and mold handling and the shorter mold life resulting.

I have invented a method whereby ingots of fully killed steel substantially free of pipe may be formed in B. E. D. molds with an ingot-to-bloom yield as high as 86-90% which is not only far in excess of that normally achieved in such molds (30-50%), but even higher than that obtainable using B. E. U. molds (around 77%). Generally speaking, my improved method contemplates the use of a B. E. D. mold designed to form ingots having a predetermined ratio of height to the minimum transverse dimension, with a refractory collar or hot-top inserted in the mold, and establishing a sinkhead of just sufficient metal to fill any cavity which may be formed in the ingot by shrinkage on cooling and solidification. I teem liquid metal into the mold in such quantity that it will rise only to a predetermined level in the collar so that the sinkhead has a predetermined limited volume much less than that provided heretofore. I then let the mold stand for a predetermined time to permit cooling and partial solidification of the ingot. During this time, the sinkhead freezes at least partially, after some of the metal thereof has drained into the ingot.

An essential step of my method is the application of a large amount of heat to the sinkhead after it and the main mass of the ingot have largely solidified, leaving only the central portion of the ingot liquid or in an intermediate stage of solidification. This late application of heat to the metal in the hot-top must be sufficient to fuse it so the metal will run down and fill any voids which may have formed in the central portion. Practically all the hot-top metal is thus absorbed by the ingot leaving only a thin shell lining the collar when the ingot finally becomes solidified throughout. The late application of

heat may be effected by depositing on the sinkhead a charge of a mixture of thermite-like reagents which begin to react under the temperature thereof or by means of auxiliary heat application, and by such reaction evolve the desired additional amount of heat. Thereafter, I permit the mold to stand undisturbed longer than required by conventional practice, until substantially complete solidification of the central core occurs.

A complete understanding of the invention may be obtained from the following detailed description and explanation which refer to the accompanying drawings illustrating the present preferred embodiment. In the drawings,

Figures 1-4 are vertical sections through a B. E. D. mold or the upper portion thereof, showing the several steps of my improved method.

Referring now in detail to the drawings and, for the present to Figure 1, a conventional B. E. D. ingot mold 10 rests on a stool or base 11 and has a cavity 12 therein of any desired cross-sectional shape, say rectangular, which tapers slightly toward the top. A refractory collar or hot-top 13 is placed on the upper end of the mold to hold the sinkhead. The collar may be of any known design and construction. As an example, it may be made of fire clay and of a cross-sectional shape conforming to that of the cavity in the mold 10. The collar is mounted on the mold so that it projects a substantial distance downwardly thereinto. It may have lugs 14 resting on spacer blocks 15 disposed on top of the mold.

The mold is designed to form an ingot 12a of height H, the distance between the top of the stool 11 and the bottom of collar 13, and of a minimum transverse dimension (width or thickness) W. The ratio of these dimensions, H/W, should be not less than about 2.5 and not more than about 3.4, and preferably between 2.7 and 3.2. In a specific example, the mold was designed for a 4.5 ton ingot 65" high, 25" wide and 22" thick at the top, giving a ratio of H/W of 2.96 and the collar 13 projected 8" down into the mold. If the ratio H/W is more than 3.4, there is serious risk of the formation of secondary pipe. A ratio within the limits given practically eliminates secondary pipe.

Fully killed liquid steel is teemed into the mold 10 until it rises to a predetermined height above the bottom of collar 13 as shown at 16 in Figure 2. This height should be such that the volume of metal initially present in the hot-top is from 5 to 10% and preferably about 6% of the volume of the ingot proper. A sinkhead volume less than 5% will usually not provide sufficient metal to completely fill the shrinkage cavity. More than 10% is practically never needed. The presence of a sinkhead is essential to avoid deep pipe which greatly reduces the yield obtainable.

As soon as the mold has been filled, I spread on the surface of the sinkhead a small amount of a known insulating material so as to permit the initial formation of only a thin crust of solid metal at such surface, thereby keeping the interior molten for a substantial period. The amount of this covering, indicated at 17, should not be such as to insulate the sinkhead from the additional heat to be supplied as described hereinafter, but should be sufficient to prevent the sinkhead from freezing rapidly throughout and thus interfering with proper feeding of metal therefrom to the shrinkage cavities.

When the sinkhead has been covered, the ingot is allowed to cool until it has solidified except for the central portion. As solidification of the latter proceeds and pipe or voids tend to form along the axis of the ingot in the lower portion thereof, they are filled by liquid metal flowing downwardly from the upper portion of the ingot which is replaced by metal from the sinkhead, leaving a void 19 therein. When freezing of the ingot reaches the

stage shown in Figure 3, which takes about 40 minutes for the ingot specified as an example, I apply additional heat to the sinkhead sufficient to remelt the portion 20 thereof which has solidified. The time required for such partial solidification will generally vary from 15 to 60 minutes, depending on the cooling rate which varies with the size and shape of the ingot and the pouring temperature.

The added heat necessary for remelting the sinkhead may be supplied by any convenient means. One simple method is to deposit thereon a charge of a thermite-like mixture of powdered aluminum and metal oxides the reaction of which is exothermic and is initiated by the heat of the solidified top crust of the sinkhead. An example of such a mixture of reagents is that sold under the brand "Ingotherm" by Exomet, Inc. The amount added of this mixture, for example, should be from 25 to 40 lb. per ton of ingot weight and preferably about 33 lb. The addition of less than 25 lb. per ton is insufficient to avoid the formation of pipe and the use of more than 40 lb. is unnecessary and undesirable economically. The amounts of other mixtures would, of course, be different.

The exothermic reagent mixture should be of such composition that it will not seriously disturb the desired composition in the core of the ingot which freezes last. That is to say, the product of the reaction of the reagent mixture should be compatible with the composition of the particular steel being produced, plain-carbon, stainless or whatever.

When the remelting of the sinkhead has been effected, the greater portion thereof will be absorbed into the ingot proper as shown in Figure 4, leaving only a thin shell 21 of solidified metal lining the collar 13. After remelting the sinkhead, I permit the mold to stand long enough to permit complete solidification of the core. This usually involves a wait of about one half-hour longer than conventional practice before stripping, after which stripping may be done in the usual manner.

The yields of sound product obtained from a substantial number of ingots of fully killed steel, for various sizes, produced by the method of my invention, fell between 86 and 89.6% with an average of 88%. The final product made from these ingots proved satisfactory under the macro-etch test and upon analysis for segregation. It was free from pipe and porosity and equivalent in quality to the product made from B. E. U. ingots. The blooms themselves exhibited no secondary pipe or other internal defects when examined by the Sperry "Reflectoscope."

Instead of using an exothermic-reaction mixture to supply the heat for remelting the sinkhead, I may employ other methods and means such as the electric arc, the oxy-hydrogen flame or radiant gas burners.

It will be readily appreciated that the method of my in-

vention has many important advantages, the principal one, of course, being the production of ingots of fully killed steel of good quality giving a higher ingot-to-bloom yield than has been attainable heretofore. The use of B. E. D. molds means easier stripping and facilitates mold handling. It also permits a reduction in mold inventory since special molds need no longer be stocked for casting fully killed ingots. The life of B. E. D. molds, furthermore, is greater than that of B. E. U. molds. The method disclosed herein adds little trouble or expense to conventional practice and does not involve changes in the teeming or stripping operations. The amount of metal needed in the sinkhead is considerably reduced without affecting the soundness of the ingot, since it is practically all absorbed by the ingot leaving little or no sinkhead when the ingot is stripped.

Although I have disclosed herein the preferred embodiment of my invention, I intend to cover as well any change or modification therein which may be made without departing from the spirit and scope of the invention.

I claim:

1. In a method of producing ingots of fully killed steel, the steps including providing a big-end-down ingot mold, placing on the mold a refractory collar extending downwardly thereinto a distance such that the ratio of the distance from the bottom of the collar to the bottom of the mold and the minimum transverse dimension of the ingot is between 2.5 and 3.4, teeming fully killed steel into the mold through the collar, until it rises in the latter to a level above the bottom thereof forming a sinkhead above the steel confined by the mold, permitting the mold to stand for from 15 to 60 minutes to cause partial freezing of the steel in the mold and collar, and then depositing on top of the sinkhead from 25 to 40 pounds per ton of ingot weight of an exothermic reaction material, thereby causing the metal of the sinkhead to remelt and run down into any voids tending to form in the ingot as a result of shrinkage.

2. The method defined by claim 1 characterized by discontinuing the teeming when said sinkhead has a volume of from 5 to 10% of that of the ingot proper.

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